FINAL TECHNICAL REPORT

DEVELOPING THE BALD EAGLE AS A LAKE ERIE BIOSENTINEL:

Contaminant Trends in Nestling Bald Eagles in Ohio

Lake Erie Protection Fund Project: 00-05

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ABSTRACT. *Organochlorine contaminants, including PCBs and DDT, have previously been documented in plasma of nestling bald eagles from around the Great Lakes and in North America. This research examines spatial and temporal trends of these toxic substances in Ohio bald eagles. Blood samples were collected from 5 to 7-week nestlings and plasma samples were* *analyzed for organochlorine pesticides and PCB congeners. Data were grouped by regions: Lake Erie and Inland regions were compared, and then the 2 regions were further divided into 5 sub-regions. Total PCBs, p,p'-DDE, α-chlordane, and dieldrin were detected in 99, 98, 73, and 81% of the plasma samples, respectively. Concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin varied among regions. The Lake Erie region was significantly greater than the Inland for total PCBs, p,p'-DDE, α-chlordane, and dieldrin ($p < 0.0062$). Significant differences in total PCBs, p,p'-DDE, α-chlordane, and dieldrin were noted among the Lake Erie, Sandusky Bay, and the 3 Inland sub-regions ($p < 0.0001$). Most notably, geometric mean concentrations of total PCBs from the Lake Erie (50.28 μg/kg) and SE/SCO (69.00 μg/kg) sub-regions were significantly greater ($p < 0.0019$) than the Sandusky Bay (33.27 μg/kg), NEO (12.70 μg/kg), and IWO (6.77 μg/kg) sub-regions. There were no significant differences in total PCBs, p,p'-DDE, and dieldrin among the years 1994-1997 ($p < 0.3352$). However, there were significant differences among the sub-regions areas within years. Significantly greater concentrations of α-chlordane in nestling bald eagle plasma were detected in mild winter years (1995 and 1997) than in severe winter years (1994 and 1996). Reproductive productivity and success did not vary significantly among regions and sub-regions and were not correlated with concentrations of OCs. Concentrations reported in this study were generally higher than studies that were conducted in the late 1980's and early 1990's. Concentrations reported in 1999-2000 from Michigan were found to be similar to total PCBs reported for this study in Ohio. Bald eagles are indigenous to the Great Lakes Basin and as a tertiary predator at the top of the Great Lakes food web, are good indicators of the effects of persistent toxic substances.*

INDEX WORDS: *bald eagle; Lake Erie; persistent toxic substances; PCBs; DDT; biosentinel*

INTRODUCTION

The overall objective of this research was to evaluate the exposure of persistent toxic substances to the population of bald eagles nesting along the Ohio portion of Lake Erie. This objective was fulfilled by evaluating trends of concentrations of persistent toxic substances over time, and differences in exposure to persistent toxic substances between eagles nesting along Sandusky Bay versus eagles nesting along the shoreline of Lake Erie and Inland Ohio. The data from this study was also compared to plasma contaminant data from other published and unpublished bald eagle studies in North America (Frenzel and Anthony 1989, Dykstra *et al*. 1998, Donaldson *et al.* 1999, Roe 2001, Bowerman *et al.* 2003).

Previous analysis of nestling blood from Ohio from the late 1980s found great concentrations of polychlorinated biphenyls (PCBs) and p,p'-dichlorodiphenyltrichloroethylene (p,p'-DDE); however, the nestlings sampled were significantly different from that of other areas of the Great Lakes due to their advanced age (greater than 9 weeks). This sampling occurred later in Ohio due to the placement of radio transmitters on the birds (Bowerman 1993). Analysis of unhatched bald eagle eggs from the Ohio shoreline of Lake Erie indicated that concentrations of persistent toxic substances within unhatched eggs were consistent with reproductive impairment observed in a continental bald eagle project (Wiemeyer *et al.* 1984; Wiemeyer *et al.* 1993). Bald eagles nesting within 8 km of Lake Erie on the Ohio shoreline have impaired reproduction, which is impacting the recovery of the Lake Erie sub-population (Grasman *et al.* 2000).

Bald eagles are indigenous to the Great Lakes Basin and as a tertiary predator at the top of the Great Lakes food web, are good indicators of the effects of persistent toxic substances. The bald eagle is one of the most studied species in North America and a great amount of natural life history information is known, including the response of various stressors on its ability to reproduce.

Our primary objective was to provide data to the Lake Erie LaMP and Lake Erie Quality Index in support of their basic research needs related to exposure to persistent toxic substances to the population of bald eagles nesting along the Ohio portion of Lake Erie. These data can be used to complete the development of the bald eagle as a biosentinel species for Great Lakes Water Quality for Lake Erie. These data address the following questions raised within the LaMP and Lake Erie Quality Index: 1. Does exposure to persistent toxic substances differ between eagles nesting along Sandusky Bay (bay feeders) versus eagles nesting along the shoreline of Lake Erie (lake feeders)? 2. For nest sites sampled every year during the mid 1990s, have concentrations of persistent toxic substances changed among years? Are there any trends in concentrations over time? 3. Does exposure to persistent toxic substances in nestlings differ among years with severe and mild winters? 4. How do concentrations of persistent toxic substances relate to reproduction and nest success of these eagle nests?

METHODS

Study Area

Plasma samples of nestling bald eagles were collected along the Ohio shores of Lake Erie and in the Inland breeding areas within Ohio. The Lake Erie breeding region was within 8.0 km of the shorelines of Lake Erie and/or was along tributaries open to Lake Erie fish runs. The Inland breeding region was greater than 8.0 km from the shorelines of Lake Erie and was not along tributaries open to Great Lakes fish runs.

Field Methods

The methods used to collect blood samples from nestling bald eagles are designed to avoid injury and undue stress to the birds. Sample collection and morphometric methods are adapted from Bortolotti (1984a, 1984b, 1984c), Henny and Meeker (1981), Henny *et al*. (1981) and Morizot *et al*. (1985). The methods are summarized below, but details of the procedures are published in Bowerman *et al.* (2003).

Blood samples were collected from five to seven-week old nestling bald eagles from 15 May through 4 July. An aerial survey was conducted to verify nest occupancy each March. Nest monitoring is conducted by a volunteer work force and ensures hatch date knowledge within 3 days on most nests. Adult behavior is documented for incubation, brooding, and feeding activities. Young were counted as their age permitted viewing from observation points. Banding operations were timed for each nest to occur between 5 and 7 weeks of age.

Once at the nest, a trained crewmember climbed the nest tree and secured a nestling. The nestling was placed in a restraining bag, lowered to the ground, weighed by spring scale, and prepared for sampling. Morphological measurements of the culmen, hallux claw, and bill depth were derived by using calipers. The eighth primary feather and the footpad were measured by using a ruler. Procedures developed by Bortolotti (1984b) were used to determine the age and sex of the nestlings. Sex was determined by the relationship of hallux claw length, footpad length and bill depth. Once sex was determined, the length of the eighth primary feather was used to make a sex-specific estimation of age.

Sterile techniques were used to collect blood from the brachial vein of nestling bald eagles. Syringes fitted with 22 gauge needles were used for the venipuncture. Up to 12 cc of blood were drawn from the brachial vein and then transferred to heparinized vacuum tubes and placed on ice in coolers for transfer out of the field. After sampling was completed, the nestlings were banded with a size 9 United States Fish and Wildlife Service (USFWS) rivet band and an appropriate color band. The nestling was then placed back in the restraining bag, raised, and released to the nest. Samples of whole blood were centrifuged within 48 hours of collection and the plasma was decanted and transferred to another vacuum tube and frozen at approximately -20^{o} C for storage.

At the end of the sampling effort, all samples were collected and transferred to the Crane Creek Wildlife Research Center, entered into sample storage through a chain-of-custody tracking system, and stored frozen at approximately -20^{o} C. Upon request to the Research Center Chain-of-Custody officer, samples were transferred to the Clemson Institute of Environmental Toxicology (CIET) for analysis. Upon receipt at CIET, SOPs directed that samples be logged in, checked for sample integrity and again stored frozen at approximately -20^{o} C until prepared for instrumental analysis (CIET 1996, 1999).

Laboratory Methods

In 2002, 147 plasma samples were received at the CIET laboratory under chain-of-custody by 2 May 02. All extractions and analyses were conducted according to procedures detailed in CIET SOPs. Plasma samples were extracted in eight batches. Chicken plasma was used for laboratory control samples in all analytical batches. In addition to the eagle plasma samples, each analytical batch contained a reagent blank, a chicken plasma matrix blank, a chicken plasma matrix spike, and a chicken plasma matrix spike duplicate.

The target list of analytes included historical organochlorine pesticides such as chlordane, dieldrin, and dichlorodiphenyltrichloroethane (DDT) and its metabolic products, and 20 PCB congeners. Organochlorine pesticides and PCB concentrations were quantified by capillary gas chromatography with an electron capture detector using the United States Environmental Protection Agency approved methods. All reported results were confirmed by dual column analysis. The Quantification Level (QL) for the organic compounds was 2 ng/g with the exception of toxaphene, which had a QL of 125 ng/g. Method validation studies were conducted on chicken plasma as a surrogate matrix to ensure that the data quality objectives of the Quality Assurance Project Plan (CIET 1996, 1999) were met. Average recoveries of 70% - 130% for matrix spikes were required under the Quality Assurance Project Plan (CIET 1996, 1999). Correlation coefficients (r^2) for calibration curves consisting of five concentrations of standards were at least > 0.99 for all target analytes in all batches. The average detector response for the instrumental calibration checks was within 20% of the initial calibration for each batch. The average Relative Percent Difference (% RPD) for the spiked analytes in the chicken plasma matrix spike and chicken plasma matrix spike duplicate were less than 30% for all batches.

Severe and Mild Winter Data

Ohio winter weather data was assessed over the years 1994 through 1997. Seasonal mean temperature and precipitation data determined the type of winter weather, severe or mild. A winter was classified as severe when there was substantial snow cover and persistent cold temperatures in the Lake Erie Marsh region.

Reproductive Productivity and Success

Reproductive productivity and reproductive success were calculated for the Lake Erie, Sandusky Bay, and the 3 Inland breeding sub-regions from 1990 through 1997 by use of the method of

Postupalsky (1974). Productivity within each of the 5 breeding sub-regions was determined by dividing the total number of young by the number of occupied nests. Success was determined by dividing the number of nests producing fledged young by the number of occupied nests.

Statistical Analyses

For the purposes of reporting and statistical analysis of the Ohio data, and in keeping with reporting conventions in the scientific literature, the data were broadly grouped by breeding area location. At the broadest level, Lake Erie and the Inland breeding regions were compared. The Lake Erie-associated nests were evaluated further by location. The breeding areas located near Sandusky Bay were examined separately from the Lake Erie breeding region for organic contaminants to better assess the concentrations which may be affecting bald eagle productivity along the Great Lake. The Inland nests were also evaluated further by location. The Inland breeding region was broken down into Interior Western Ohio (IWO), North East Ohio (NEO), and South East/South Central Ohio (SE/SCO) breeding sub-regions for organic contaminant analysis to better assess affects on bald eagle productivity. Of the 147 samples analyzed, 82 were from breeding region along Lake Erie. The following samples represented the breeding sub-regions in Ohio: 29 Lake Erie, 53 Sandusky Bay, 25 IWO, 35 NEO, and 5 SE/SCO.

Statistical analyses of the Ohio plasma data were performed using the nonparametric Wilcoxon Rank Sum test and the Kruskal-Wallis test, as neither the assumptions of normality nor of linear regressions were met. All Wilcoxon Rank Sum and Kruskal-Wallis tests were performed using SAS Institute Inc. (1999) statistical package. Wilcoxon Rank Sum tests were performed to determine if there were differences in concentrations between Lake Erie and Inland breeding regions and differences between Lake Erie and Sandusky Bay breeding sub-regions. Kruskal-Wallis tests were preformed to determine if there were differences among the 5 breeding sub-regions (Lake Erie, Sandusky Bay, IWO, NEO, and SE/SCO) and among the years 1994-1997. Nonparametric multiple comparisons were used to determine where significant differences occurred within breeding sub-regions (SAS Institute Inc. 1999). Fourteen individual territories, within the 5 breeding sub-regions were analyzed by Kruskal-Wallis tests to detect any temporal changes in contaminant concentrations. To determine differences in contaminant data between years of severe or mild winters, Wilcoxon Rank Sum tests were performed.

Of the organochlorine contaminants detected, the following were included in the statistical analyses: the sum of the 20 PCB congeners (Total PCBs), p,p'-DDE, α-chlordane, and dieldrin. For statistical analysis, concentrations less than the MDL were reported as non-detects and were set at zero. A probability level = 95% ($\alpha = 0.05$) was used to determine statistical significance.

Differences between reproductive productivity and success were compared between Lake Erie and Inland regions, Lake Erie and Sandusky Bay sub-regions, and among the Lake Erie, Sandusky Bay, and the 3 Inland breeding sub-regions using Wilcoxon Rank Sum and Kruskal-Wallis tests (SAS Institute Inc. 1999). Relationships between concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin in blood plasma and productivity and success were determined by general linear models for regression (SAS Institute Inc. 1999). When contaminant data within an individual breeding area spanned more than one year, the contaminant data was averaged for that breeding area. Individual breeding areas with fewer than 2 years of productivity and success data were not used in the analyses.

RESULTS

Organic Contaminants in Nestling Bald Eagle Plasma

Total PCBs, p,p'-DDE, α-chlordane, and dieldrin were detected in 99, 98, 73, and 81% of the plasma samples, respectively. The metabolite that predominately attributed to the concentration for Total DDT was p,p'-DDE. Plasma contaminant concentrations were highest for Total PCBs, followed by p,p'-DDE, dieldrin, and α-chlordane (Table 1). Heptachlorobenzene and heptachlor epoxide were each detected in 7 samples, while lindane was detected in only 2 plasma samples. Heptachlor, α-hexachlorocyclohexane, γ-chlordane, and toxaphene were not detected in any of the Ohio plasma samples.

Spatial Trends

Concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin varied among breeding regions (Table 1). The Lake Erie breeding region was significantly greater than the Inland for total PCBs, p,p'-DDE, α-chlordane, and dieldrin ($p < 0.0062$). Upon examination of the Sandusky Bay sub-region, separate from the Lake Erie breeding region, Lake Erie was significantly different from the Sandusky Bay breeding sub-region for total PCBs, α-chlordane, and dieldrin ($p < 0.0473$).

Significant differences in total PCBs, p,p'-DDE, α-chlordane, and dieldrin were noted among the Lake Erie, Sandusky Bay, and the 3 Inland breeding sub-regions ($p < 0.0001$). Concentrations of total PCBs from the Lake Erie and SE/SCO breeding area sub-regions were significantly greater ($p < 0.0019$) than the Sandusky Bay, IWO, and NEO sub-regions. Total PCB concentrations from the IWO and NEO breeding areas sub-regions were significantly lower than the Sandusky Bay sub-region ($p < 0.0001$). Concentrations of α-chlordane from the IWO and NEO breeding areas sub-regions were also significantly lower than the SE/SCO, Lake Erie, and Sandusky Bay sub-regions ($p < 0.0001$). Concentrations of p,p'-DDE from the IWO breeding sub-region were significantly lower than the NEO, Sandusky Bay, Lake Erie and sub-regions ($p < 0.0001$). Dieldrin concentrations from the Lake Erie sub-region were significantly lower than the SE/SCO, IWO, and Sandusky Bay breeding sub-regions ($p < 0.0119$). Concentrations of dieldrin from the NEO breeding sub-region were also significantly lower than the other 4 sub-regions ($p < 0.0001$).

Temporal Trends

There were no significant differences in total PCBs, p,p'-DDE, and dieldrin among the years 1994-1997 (Table 2). Concentrations of α-chlordane did have significant differences among years ($p < 0.0434$) (Table 2). However, no clear trends could be discerned within the four years.

There were significant differences among the five breeding sub-regions within years. Breeding sub-region dieldrin concentrations differed significantly among all four years ($p < 0.0046$). Total PCB breeding sub-region concentrations differed significantly among the years 1994, 1995, and 1996 ($p < 0.0309$). Breeding sub-region α-chlordane concentrations varied significantly among the years 1995, 1996, and 1997 ($p < 0.0229$). Breeding sub-region p,p'-DDE concentrations only varied significantly among the years 1996 and 1997 ($p < 0.0077$). However, no clear trends could be discerned, for any of the contaminants, among the breeding sub-regions within the four years.

No significant differences in total PCBs, p,p'-DDE, α-chlordane, and dieldrin were detected in any of the 14 individual territories that were sampled over the time period 1994 to 1997. The 14 territories had been sampled at least 3 of the 4 years and represented 4 territories from the Lake Erie breeding sub-region, 4 from Sandusky Bay, 2 from IWO, and 4 territories from the NEO breeding sub-region. The SE/SCO breeding sub-region only had a total of 5 samples analyzed and only covered 2 years; therefore SE/SCO was not included in the analyses.

Severe and Mild Winter Trends

The winters of 1994 and 1996 were classified as severe winters due to the substantial amount of snow cover and persistent cold temperatures in the Lake Erie Marsh region. No significant differences in total PCBs, p,p'-DDE, or dieldrin were detected between years of severe and mild winters ($p < 0.6667$). However, mild winter α-chlordane concentrations were significantly greater than severe winter concentrations ($p < 0.0082$).

Reproductive Productivity and Success

Reproductive productivity and success did not vary significantly among breeding sub-regions (Table 3). No significant differences were found between Lake Erie and Inland breeding region productivity and success ($p < 0.3465$) or between Lake Erie and Sandusky Bay sub-region productivity and success ($p < 0.2351$). No significant differences in productivity and success were noted among the Lake Erie, Sandusky Bay, and the 3 Inland sub-regions ($p < 0.3652$). All reproductive productivity and success measurements were not significantly correlated to concentrations of total PCBs, p,p'-DDE, α-chlordane, or dieldrin in nestling blood plasma. Productivity and success within the Lake Erie, Sandusky Bay, and the 3 Inland breeding sub-regions were not significantly correlated with concentrations of total PCBs ($p = 0.854$, $r^2 = 0.013$), p,p'-DDE ($p = 0.449$, $r^2 = 0.191$), α-chlordane ($p = 0.490$, $r^2 = 0.154$), or dieldrin ($p = 0.618$, $r^2 = 0.087$). Productivity and success at the individual breeding areas were not significantly correlated with concentrations of total PCBs ($p = 0.472$, $r^2 = 0.022$), p,p'-DDE ($p = 0.244$, $r^2 = 0.056$), α-chlordane ($p = 0.269$, $r^2 = 0.051$), or dieldrin ($p = 0.789$, $r^2 = 0.003$).

DISCUSSION

Organic Contaminants in Ohio Nestling Bald Eagle Plasma

Organochlorine contaminant (OC) concentrations in plasma of nestling bald eagles constitute an efficient way of measuring local environmental contamination since these birds are fed prey items that have been caught from within the breeding territory of the adult birds. The Great Lakes eagles forage primarily on fish and piscivorous wildlife associated with coastal Great Lakes, riverine, and interior aquatic systems (Bowerman 1993, Bowerman *et al*. 2000). The tendency for many of the persistent organochlorine contaminants to biomagnify through trophic transfer makes the eagle an appropriate indicator species in which to monitor trends of OCs in the Great Lakes Basin.

Spatial and Temporal Trends

Eagles nesting along the shoreline of Lake Erie are being exposed to higher levels of persistent OCs, through their prey, mainly due to environmental cycling of earlier industrial point source contamination. They are foraging heavily on the Lake Erie aquatic food web, whereas, Inland region nesting eagles are relying on relatively less contaminated inland aquatic and terrestrial food webs. Significantly greater concentrations of total PCBs, α-chlordane, and dieldrin in Lake Erie sub-region than in Sandusky Bay sub-region may indicate that environmental cycling is redistributing the contaminants away from the pollution source. Differences among breeding regions in nestling plasma contaminant concentrations could be the result of differing foraging behaviors of the adults. The differences could also indicate potential “hot spots” of OCs, such as the high levels of total PCBs for the SE/SCO breeding sub-region.

Temporal monitoring of nestling eagle plasma OC concentrations can be used to track trends of persistent OCs in the Lake Erie and Inland Ohio ecosystem. For this study, no significant changes in total PCBs, p,p'-DDE, and dieldrin concentrations over time could indicate a stabilization of contaminant levels within the ecosystem. A variety of other Great Lakes studies, examining OC concentrations at different trophic levels, have reported a leveling off or a stabilization of the downward trends of contaminants (Hesselberg and Gannon 1995, Tillitt *et al*. 1992, Grasman *et al*. 1998). Continued nestling eagle sampling during annual banding activities could monitor for any potential new increases in plasma OC concentrations.

Severe and Mild Winter Trends

No significant differences in total PCBs, p,p'-DDE, and dieldrin in nestling bald eagle plasma between mild winter years and severe winter years may suggest that prey the Ohio adult eagle population forage on during the different seasons does not differ significantly in its contaminant loads.

Reproductive Productivity and Success

The recovery goal for the Ohio Lake Erie bald eagle population is 1.0 young fledged/occupied nest. Although productivity has increased since 1980s in the other breeding areas, the Lake Erie bald eagle sub-region population is still less than 1. Introduced bald eagle nestlings influenced and potentially confounded direct linkages between exposure to persistent toxic substances in Lake Erie and biological effects (Grasman *et al.* 2000). A large number of uncontaminated nestlings were introduced to the sub-population via hacking and fostering initiatives during the mid-1980s along the Ontario and Ohio shorelines. The sexual maturation of these introduced birds translated to an increase in nesting success (Grasman *et al.* 2000). The recovery of the bald eagle both in Inland Ohio regions and throughout North America produced a group of young eagles that dispersed in search of habitable and unclaimed breeding territories. The turnover of adults along the Ohio and Michigan shorelines of Lake Erie is high; this implies the colonization of these territories by eagles reared outside of these areas (Grasman *et al.* 2000).

Plasma Contaminant Comparisons of Ohio Nestlings to Other Great Lakes Nestlings

Organochlorine contaminants in plasma of nestling bald eagles from around the Great Lakes and in eagles in North America have previously been documented (Frenzel and Anthony 1989, Dykstra *et al*. 1998, Donaldson *et al.* 1999, Roe 2001, Bowerman *et al.* 2003). Generally, OC concentrations in plasma from nestling bald eagles, collected around the same time period, along the Canadian portion of Lake Erie (Donaldson *et al.* 1999) were higher than what was reported in this study. Geometric mean ΣPCB, p,p'-DDE, ΣChlordane, and dieldrin plasma levels from the Canadian portion of Lake Erie were reported as ΣPCB = 129.5 μg/kg, p,p'-DDE = 22.4 μg/kg, ΣChlordane = 8.2 μg/kg, Dieldrin = 3.0 μg/kg. Total PCB and p,p'-DDE levels from the Michigan shores of Lake Erie and Lake Huron (Bowerman *et al.* 2003), and the Wisconsin shores of Lake Superior, (Dykstra *et al*. 1998) collected from the late 1980's to early 1990's, were also generally higher than the Total PCB and p,p'-DDE levels reported in this study for the Ohio shores of Lake Erie. Bowerman *et al.* (2003) and Dykstra *et al*. (1998) reported total PCB geometric means of 199 μg/kg for Lake Erie, 105 μg/kg for Lake Huron, and 109 μg/kg for Lake Superior. Geometric mean p,p'-DDE concentrations were reported as 22 μg/kg for Lake Erie, 25 μg/kg for Lake Huron, and 19 μg/kg for Lake Superior.

Concentrations of total PCBs in plasma, collected from nestling bald eagles in 1999-2000 along the Michigan shorelines of the Great Lakes (Roe 2001) and from adults and sub-adult bald eagles in 1979-1982 from the Klamath Basin of northern California and Southern Oregon (Frenzel and Anthony 1989), were generally similar to what was reported in this study. Geometric mean total PCBs were reported around 4 μg/kg for Inland Michigan, 16 and 48 μg/kg for Lake Superior and the combined Lakes Michigan and Huron, respectively. Geometric means for total PCBs in adults and sub-adults from the Klamath Basin were reported as 18 and 14 μg/kg, respectively. The concentrations of p,p'-DDE from the Michigan shorelines of the Great Lakes and from the Klamath Basin were generally higher than the p,p'-DDE levels presented in this study for Lake Erie.

CONCLUSIONS

This study evaluated spatial and temporal trends of total PCBs, p,p'-DDE, α-chlordane, and dieldrin in plasma from nestling bald eagles along the Ohio shoreline of Lake Erie and Inland Ohio from 1994-1997. Plasma concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin from Lake Erie region nestlings were found to be greater than concentrations from Inland Ohio region nestlings. The Lake Erie sub-region breeding area was also significantly greater than the Sandusky Bay sub-region for plasma concentrations of total PCBs, α-chlordane, and dieldrin. Significant differences in plasma total PCBs, p,p'-DDE, α-chlordane, and dieldrin concentrations were also noted among the Lake Erie, Sandusky Bay, and the 3 Inland breeding sub-regions. However, there were no overall significant differences in plasma OC concentrations over the time period of 1994 to 1997 or at 14 individual breeding areas. Significantly greater concentrations of α-chlordane in nestling bald eagle plasma from mild winter years than in severe winter years were detected. Although productivity has increased since 1980s in the other Ohio breeding sub-regions, the Lake Erie bald eagle breeding sub-region population is still less than 1.0 and can be considered stable, but not healthy. The turnover of adults along the Ohio and Michigan shorelines of Lake Erie is high; this can only be explained by immigration of adults from the interior regions of Ohio, Michigan, and other states with healthy eagle populations. Concentrations reported in this study were generally higher than studies that were conducted in the late 1980's and early 1990's. Concentrations reported in 1999-2000 from Michigan were found to be similar to total PCBs reported in this study in Ohio.

Analysis of organochlorine contaminants in plasma has been demonstrated to be an effective tool to monitor contaminant residue levels in avian species and to monitor contaminant levels in the areas in which they forage. Therefore, nestling bald eagles are an appropriate biosentinel species in which to monitor ecosystem quality. This study matched the Lake Erie Commission priorities of protecting Lake Erie's natural resources, restoring degraded elements of the Lake Erie ecosystem, and in supporting monitoring for the Lake Erie Quality Index. This study further develops and refines the bald eagle as an indicator for the obligations undertaken by Ohio EPA, and Ohio DNR related to Federal and International obligations for Lake Erie monitoring, and State Agency Obligations for the Lake Erie Quality Index.

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Table 1. Concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin in plasma of nestling bald eagles in Ohio from 1994-1997. Contaminants reported as μg/kg in plasma, wet weight. Samples were grouped broadly as Lake Erie or Inland regions and then they were broken down into the 5 breeding sub-regions within Ohio.

		Geometric Mean Range			
Breeding Region	n	Total PCBs (μg/kg)	p,p'-DDE (μg/kg)	α-chlordane (μg/kg)	Dieldrin (μg/kg)
Lake Erie	82	38.50 < 0.38-122.56	5.34 < 0.61-17.41	0.79 < 0.75-4.09	1.54 < 0.97-9.25
Inland	65	11.36 < 0.38-102.16	4.32 < 0.61-53.10	0.05 < 0.75-5.45	0.26 < 0.97-10.23
Breeding Sub-Region					
Lake Erie	29	50.28 < 0.38-122.56	4.67 < 0.61-11.57	0.99 < 0.75-3.88	0.76 < 0.97-4.92
Sandusky Bay	53	33.27 < 0.38-98.68	5.74 < 0.61-17.41	0.69 < 0.75-4.09	2.25 < 0.97-9.25
IWO	25	6.77 < 0.38-77.99	2.59 < 0.61-7.72	0.03 < 0.75-2.19	3.20 < 0.97-10.23
NEO	35	12.70 < 0.38-53.85	6.20 < 0.61-53.10	0.04 < 0.75-2.70	0.03 < 0.97-3.08
SE/SCO	5	69.00 < 0.38-102.16	4.46 < 0.61-6.59	3.43 < 0.75-5.45	4.12 < 0.97-5.86

Table 2. Concentrations of total PCBs, p,p'-DDE, α-chlordane, and dieldrin in plasma of nestling bald eagles in Ohio by year from 1994-1997. Contaminants reported as μg/kg in plasma, wet weight. Samples were grouped broadly as Lake Erie or Inland breeding regions and then they were broken down into the 5 breeding sub-regions within Ohio.

		Geometric Mean			
Breeding Region	Year	Total PCBs (μg/kg)	p,p'-DDE (μg/kg)	α-chlordane (μg/kg)	Dieldrin (μg/kg)
Lake Erie	1994	38.21	6.26	0.34	2.24
	1995	43.34	6.52	1.29	1.83
	1996	30.01	4.66	0.90	2.34
	1997	41.17	4.56	1.81	1.62
Inland	1994	14.97	5.91	0.05	0.18
	1995	11.19	5.02	0.34	0.57
	1996	18.65	5.45	0.21	1.11
	1997	7.69	2.72	0.11	0.55
Sub-Region					
Lake Erie	1994	28.16	6.03	1.39	2.32
	1995	64.77	7.35	1.30	1.47
	1996	33.81	4.69	0.22	0.88
	1997	53.74	3.28	2.37	0.94
Sandusky Bay	1994	39.91	6.29	0.28	2.23
	1995	32.07	5.96	1.29	2.16
	1996	28.56	4.65	1.62	3.51
	1997	32.68	6.06	1.44	2.59
IWO	1994	30.67	6.21	0.04	4.79
	1995	6.38	3.56	0.27	5.23
	1996	9.73	3.54	0.18	5.10
	1997	3.23	1.01	0.03	1.61
NEO	1994	10.47	5.77	0.06	0.04
	1995	13.13	6.44	0.30	0.12
	1996	24.72	9.33	0.05	0.12
	1997	11.58	5.04	0.14	0.18
SE/SCO	1994	No data	No data	No data	No data
	1995	65.36	3.53	3.82	4.00
	1996	77.98	4.89	3.07	4.80
	1997	62.72	4.76	3.62	3.59

Table 3. Reproductive productivity and success of nestling bald eagles in Ohio from 1990-1997. Samples were grouped broadly as Lake Erie or Inland region and then they were broken down into the 5 breeding sub-regions within Ohio.

Breeding Region	Productivity	% Success
Lake Erie	1.07	63.81
Inland	1.34	77.94
Breeding Sub-Region		
Lake Erie	0.89	53.33
Sandusky Bay	1.20	70.49
IWO	1.33	79.17
NEO	1.32	78.05
SE/SCO	1.67	100.00