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EFFECTS OF CONTAMINANTS ON REPRODUCTION OF BALD EAGLES ON GREEN BAY, LAKE MICHIGAN

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ABSTRACT

Bald eagles (Haliaeetus leucocephalus) nesting on Green Bay, Lake Michigan, have extremely low reproductive rates, in comparison to eagles nesting in inland Wisconsin and Michigan (0.4 vs. 1.1 young per occupied territory; Colborn 1991, Bowerman 1993). We investigated two factors which can affect eagle reproductive rates: organochlorine contaminants and food availability. Organochlorine contaminants (specifically DDE and total PCBs) were measured in addled eggs and nestling blood samples. Food availability was assessed by measurement of a behavioral index to food availability: food delivery rate to the nestlings. Other behavioral indices that have been associated with food availability (time spent feeding and adult attendance at nests) were also measured and compared to reference values for inland Wisconsin eagles. Mean contaminant concentrations in addled eggs from Green Bay were 10.3 ppm wet weight DDE and 35.0 ppm wet weight total PCBs (1986 - 1992, n=8). Mean concentrations in nestling blood plasma were 53 ppb wet weight DDE and 207 ppb wet weight total PCBs (1987 -1995, n=8). Indices of food availability were generally normal, in comparison to inland reference data. Mean food delivery rate to the nestlings was 2.21 ± .25 items per nestling per day (n=4 nests). Time spent feeding averaged 8.5%, 8.2% and 9.3% of the day in the early, mid, and late phases of the nestling period (n=3,4,4). Adult attendance at the nest averaged 88.9%, 26.5%, and 5.7% of the day in the early, mid and late phases (n=3,3,3). None of the behavioral measures differed significantly from inland reference values, which suggests that the prey base was adequate. We concluded that it is very likely that organochlorine contaminants caused all or most of the depression in reproductive rates of Green Bay bald eagles.

INTRODUCTION

Bald eagles were extirpated from historic Green Bay nest sites by 1970. The number of nesting pairs declined at the same time that other North American eagle populations decreased dramatically, after the introduction of organochlorine chemicals into the environment. After the ban on DDT and other organochlorines in the 1970s, many eagle populations increased because of improved reproductive rates. Along the Lake Michigan shore in Wisconsin, the first "post-DDT era" nest was initiated in 1986 at the Peshtigo River. The number of nesting pairs on the Wisconsin shore increased slowly, to a maximum of five pairs in 1993-1995. Elsewhere along Lake Michigan, a similar slow increase in nesting pairs has been documented (Bowerman 1993).

Despite population increases, the eagles nesting on the shores of Lake Michigan still exhibit reproductive rates lower than those of neighboring birds in inland Wisconsin and Michigan (Colborn 1991, Bowerman 1993). There is continued concern over the health of these eagles, not only because they are a members of a Threatened Species, but also because they serve as a sensitive indicator of the overall health of the Green Bay ecosystem.

In the Green Bay ecosystem, organochlorines in the sediments and water (Evans 1988) continue to contaminate the biota (Haseltine et al 1981, Heinz et al 1983). Double-crested cormorants (Phalacrocoras auritus) and Forster's terns (Sterna forsteri) continue to experience depressed reproduction, which was associated with the organochlorines in their prey (Kubiak et al 1989, Larson et al in press). Bald eagles are at higher risk from contaminants than either of these species, because the fish that eagles consume are larger and higher on the food chain than the fish eaten by cormorants and terns. In some locations, eagles also prey on cormorants and gulls, putting the eagles one step higher on the food chain (Dykstra 1995, Warnke 1996). Because of these dietary habits, eagles bioaccumulate lipophilic contaminants and thus suffer greater exposure to toxicants than species such as cormorants and terns.

However, depressed productivity in eagles is not always the result of organochlorine contamination. In relatively uncontaminated areas, eagle reproductive success (Hansen 1987) and population density (Gerrard et al 1983, Whitfield and Gerrard 1985, Dzus and Gerrard 1993) have been associated with prey abundance. On Wisconsin's Lake Superior shore, low reproduction was likely caused by low food availability in Lake Superior (Dykstra et al in prep). Eagle reproduction was also decreased at small lakes in the Upper Peninsula of Michigan when rough fish were removed (Bowerman 1991).

We investigated contaminant loads, food availability, and reproductive rates for the Green Bay eagle population. We here document reproductive rates of Green Bay eagles and compare them to reference populations in inland Wisconsin and on Lake Superior. We report total PCB and DDE concentrations in addled eggs and eaglet blood samples, as well as the route of exposure to contaminants (species consumed). We use food delivery rates by parent eagles to nestlings as an index to food availability in the environment, and finally, we assess whether current low productivity can be explained by organochlorine contaminants, low food availability, or neither.

METHODS

STUDY SITE--We included in the study all nests located within 8 km of the shore of Green Bay (including Little Bay de Noc and Big Bay de Noc). One nest located on the eastern shore of Door County, WI, was also included because the waters of Lake Michigan in that area are near enough to Green Bay proper to be influenced by any contaminant conditions there (Fig. 1).

REPRODUCTIVE RATE--Reproductive rate was assessed by the Wisconsin and Michigan Departments of Natural Resources by inspecting nests from the air twice during the breeding season, once during incubation and again when nestlings were 4-7 weeks old. In the first aerial survey, the eagle pairs that were attempting reproduction were counted, and in the second flight, the resulting nestlings were counted. For a regional summary, the total number of young produced was divided by the total number of territories where birds attempted breeding.

Bald eagle productivity is generally reported in terms of the number of young per occupied territory or the number of young per active territory. An occupied territory is one where eggs have been laid, or two eagles are present on the territory, or the nest has been visibly repaired (with 0-2 adults present; Postupalsky 1974). An active territory is one where there is evidence that eggs have been laid.

CONTAMINANT CONCENTRATIONS IN NESTLING BLOOD--In 1994 and 1995, eight blood samples were collected from bald eagle nestlings at three Green Bay/Lake

Michigan nests and two Fox River nests in Wisconsin (see Appendix 1 for Fox River data). Nestlings were sexed by footpad length (Bortolotti 1984), and aged by the length of the eighth primary (Bortolotti 1984) when age was not known from observations. Nestlings were age 5-8 weeks at the time of the blood collection. Syringes used were either sterile plastic or glass previously washed with hexanes and acetone. Approximately 10 mL of blood was drawn from the brachial vein. Blood was transferred to heparinized vacutainers, stored on ice until the end of the day, and separated by centrifuging in the evening. Plasma was drawn off, transferred to another vacutainer, and immediately frozen upright.

At the end of the 1994 field season, samples were shipped on dry ice to Michigan State University for analysis by Drs. John Giesy and William Bowerman. Samples from 1995 were handled similarly, but shipped to and analyzed by Hazelton Environmental Services, Inc., Madison, WI.

Organochlorine pesticides and total PCB concentrations in the nestling plasma were determined by gas chromatography, with confirmation by gas chromatography/mass spectrometry (Price et al 1986). Gas chromatography at Michigan State University was performed on a Varian 3700 gas chromatograph with electron capture detector. Detection limits were 2.5 ppb for DDE and 5.0 ppb for total PCBs. Contaminant concentrations below detection limits were assigned a value of half the detection limit for statistical analyses. Detailed methods have been described (Bowerman 1993; Mora et al 1993, U.S. EPA 1984). Residues measured in sibling nestlings in the same year were averaged (geometric mean) to produce one value, but residues from nests measured in more than one year were reported separately.

CONTAMINANT CONCENTRATIONS IN ADDLED EGGS--One addled egg was collected from nest MT-07, Peshtigo River, Marinette County, Wisconsin, on 31 May 1995. The egg was wrapped in aluminum foil, placed in a glass jar and refrigerated intact until opening; after the egg was opened, the egg contents were frozen in a chemically-clean jar until analysis. The egg has been submitted for analysis.

A dead nestling approximately 1-3 days old was recovered on 1 May 1995 from nest OC-04a, Oconto River/Thome, Oconto County, Wisconsin. The nestling was homogenized by personnel at the Wisconsin DNR but has not been analyzed to date.

FOOD DELIVERY RATES AND OTHER BEHAVIORS--Food delivery rates at four Green Bay eagle nests were measured in 1995 by two techniques, video cameras and direct observations. Two remote time-lapse video cameras were mounted above eagle nests at Moss Lake (nest number De-09), Delta County, Michigan, and Blueberry Island (MT-17), Marinette County, Wisconsin. At the Blueberry Island nest, the camera was mounted on February 1, 1995, before the eagles began nesting. The second camera was mounted at Peshtigo River North (MT-16) on February 15, 1995, but was removed when it became apparent that the pair was inactive. The second camera was then remounted at Moss Lake on 13 June 1995, when the single nestling was 5-6 weeks old. The time-lapse cameras exposed one frame per second. Each camera was connected by 300 m of coaxial cable to an 8mm Sony video recorder and two 12-V batteries, which were located such that they could not be seen from the nest. Thus, batteries and video tapes could be exchanged without disturbance to the eagles. Video tapes recorded 3-4 d of behavioral data, and tapes were run about once per week throughout the nesting season at Blueberry Island and from week 5 to fledging at Moss Lake. The amount of time recorded from hatching to fledging was 761 h at Blueberry Island (36 entire days and several partial days), and 328 h at Moss Lake (15 entire days and several partial days).

At two other nests, Toft Point (DO-01), Door County, Wisconsin, and Little Tail Point (OC-08), Oconto County, Wisconsin, direct observations were made using 20-60X spotting scopes. From blinds located approximately 150-300 m from the nests, observers recorded eagle behavior from dawn to dusk (approximately 15-17 h), throughout the breeding season. Observers entered the blind before daylight and exited the blind after dark, to avoid disturbing the eagles. Observer fatigue was prevented by switching observers every four hours. Nests at Toft Point and Little Tail Point were observed 9 and 11 dawn-to-dusk days (148 and 179 hours), respectively.

Observers recorded all behaviors of nestlings and adults, with the time of occurrence and duration (nearest minute). Behaviors included feeding, brooding, preening, fighting, exercising, sleeping, resting, etc. Observers also monitored prey deliveries by adults to the nestlings. We attempted to identify the taxonomic Class and the size of each prey item. Prey were categorized into one of three Classes: fish, bird, and mammal. Further identification to species or species-group was recorded if possible. Prey were categorized to one of four size-classes: 0-6", 6-12", 12-18", or 18+".

Video tapes were reviewed after the end of the field season. Prey deliveries and selected behaviors were recorded, with their time of occurrence and duration (nearest second). Prey items were classified as above. Behaviors selected for analysis were feeding and adult attendance at the nest, because these behaviors appear to be indicators of the adequacy or inadequacy of the prey base (Warnke 1996). Video data and direct observer data were combined for analysis because simultaneous observations with video cameras and direct observers (validations) indicated that the two techniques were nearly perfectly comparable for number of prey deliveries (Warnke 1996).

ANALYSIS OF BEHAVIORAL DATA--For both camera nests and direct observation nests, behavioral data were summarized based on the age of the nestling(s). The hatching day for the oldest nestling was defined as day 0. Week 0 included days 0-6; week 1 included days 7-13, etc. In most nests observed the hatching date was known to within 7 days. Feeding and adult attendance behaviors were strictly defined. All time in which a nestling fed itself or was fed by an adult was included in time spent feeding. Time that adults spent feeding themselves was not included. Time spent feeding was summed over each day (nearest minute) and divided by the total observation time for that day (which was equal to the daylength). For nests with two chicks, the nestlings' feeding-times were totaled separately and averaged. Adult attendance at the nest was defined as the time that at least one adult was present in the nest. Adults perching in the nest-tree were not counted as present at the nest. Adult attendance was summed over each day (nearest minute) and divided by the total observation time (daylength).

For behaviors and prey delivery rates, only days which were recorded completely from dawn to dusk were included in the analysis. When a nest was observed more than one day in a week, the multiple observations were averaged to produce a single pooled datum for that week (Warnke 1996). This technique was applied to feeding time, adult attendance, and prey delivery rates. For prey delivery rates, weekly data were averaged to produce a season-long prey delivery rate for each nest.

For analysis of prey Classes, sizes, and species, all available data were used, including partially-recorded days. Multiple observations in one week were not pooled.

STATISTICAL ANALYSES--All analyses were performed with Systat (Wilkinson 1988). Contaminant concentrations in blood samples and eggs are shown as geometric means (not log-transformed). Contaminant concentrations in blood and eggs were log-transformed before comparisons by t-test. Kruskal-Wallis one-way analysis of variance non-parametric tests were used for comparisons of behavioral data to inland reference data. A probability value <0.05 was considered significant.

RESULTS

PRODUCTIVITY AND POPULATION--The population of breeding pairs on Green Bay has increased slowly since about 1987, and has currently reached 11-12 occupied territories per year (Fig. 2). However, the productivity of these birds remains very low (Table 1, Fig. 3). Average productivity from 1990-1994 was 0.39 young per occupied territory on Green Bay and associated Lake Michigan waters, compared to 1.09 young per occupied territory in inland Wisconsin during the same years (1990-1993 were estimated, based on the ratio of occupied to active nests in the north-central district in 1994, and in Iron and Gogebic counties, Michigan, 1991-1993; S. Postupalsky, unpubl. data; see Dykstra 1995 for details).

Nest success in 1995 was low. Of five nest-attempts in Wisconsin in 1995, only three ended in success. One pair (Peshtigo River, MT-07) incubated an addled egg until it was recovered by researchers. A second pair (Oconto River--Thome, OC-04) successfully incubated their egg, but the nestling died of unknown causes at age 1-3 d.

CONTAMINANT CONCENTRATIONS IN BLOOD--Average concentration of DDE in nestling plasma was 53 ppb wet weight (geometric mean, n=8, 1987-1995; Table 2, Fig. 4), which was higher than that of nestlings in inland Wisconsin (4 ppb; t-test on log-transformed data, p=0.006, df=8.4). Average concentration of total PCBs in nestling plasma was 207 ppb wet weight (Table 2), compared to 34 ppb in inland Wisconsin nestlings (p<0.001, df=10.8, Fig. 5). Organochlorines other than DDE and PCBs were present only at very low levels (Appendix 2).

CONTAMINANT CONCENTRATIONS IN EGGS--Green Bay eggs had higher concentrations of DDE than did inland eggs ($\bar{x}$ = 10.3 ppm wet weight; n=8 Green Bay eggs, n=22 inland eggs, t-test on log-transformed data, p<0.001, df=9.8, Table 3, Fig. 6.). Concentrations of total PCBs in Green Bay eggs were also significantly higher than levels measured in inland Wisconsin eggs ($\bar{x}$ = 35.0 ppm wet weight, n=8 Green Bay eggs, n=22 inland eggs, p<0.001, df=14.3, Table 3, Fig. 7).

FOOD DELIVERY RATES AND OTHER BEHAVIORS--Food delivery rates to nestlings averaged 2.21 prey items per nestling per day (Table 4), which was slightly lower than the average delivery rate in inland Wisconsin (2.99 prey items per nestling-day; Warnke 1996), although the difference was not statistically significant (Kruskal-Wallis one way analysis of variance, p=0.43, n=4 Green Bay and 13 inland). Delivery rate did not vary with the age of the nestlings in either location (ANOVA, p=0.25, r^2=0.13, n=12 weeks, Fig. 8 , Warnke 1996).

A total of 212 prey items (78.5%) could be identified to taxonomic Class (Table 5). Most of the observed prey items were documented at Blueberry Island, which had the largest brood size and most observation days. Of the identified prey, the most common were fish (94.3% of all identified prey items; Fig. 9). Nearly all of the remaining prey items were birds (4.7% total; Fig. 9). Only two mammals were identified at Blueberry Island. The distribution of known prey types in the diet was different from that of inland eagles, whose diet contained 97% fish and only 1.4% birds (χ^2 = 8.62, df=3, 0.025<p<0.05, n=653 prey items in four taxonomic classes; Warnke unpublished data). However, Green Bay eagles had fewer birds in their diet than did Lake Superior eagles in 1992 (12%, Dykstra 1995; prey-type distributions differed, χ^2 = 13.82, df=2, p<0.001, n=276 prey items in three taxonomic classes).

Some prey items were identified to species or species-group. Of 200 fish identified, 74 were further categorized (Fig. 10). Only species-identifications which were characterized as "positive" or "very likely" were included in this subset. Northern pike, bullheads, and carp made up the largest proportions of the identified fish (29.7%, 18.9%, 17.6%, respectively; scientific names of all prey items in Appendix 3). Carp was the only species identified at all four nests. However, these proportions may not exactly equal the proportions of these species found in the entire diet; because these species are relatively easy to identify, they may be overrepresented in the "identified" subset. Of the 10 birds identified, 7 were further classified to species or species-group. Most were gulls (n=4, Fig. 11). Gulls were fed to nestlings at three of the four nests.

Prey remains collected in and near nests also provided anecdotal information on prey species consumed. Nests were visited once or twice in 1995. Prey remains found were generally similar to those observed (Table 6). Prey remains do not give a quantitative estimate of diet (Knight et al 1990), because birds and less-edible species are overrepresented.

Most prey items (87%) were classified to size-category (0-6", 6-12", 12-18", 18+"; Table 7). Distributions of prey sizes varied among nests (Fig. 12). The overall

distribution of known prey sizes was not statistically different from the inland Wisconsin distribution (χ^2 = 2.8, df=3, p>0.25, n=718 prey items in four size classes; Warnke unpublished data).

Time spent feeding, which is likely an indicator of food availability (Dykstra 1995, Warnke 1996), did not vary with nestling age (Table 8, Fig. 13). The time that nestlings spent feeding was summarized in three nestlings phases, to make the data comparable to the reference inland data. Phases were defined as Early (nestlings age 1-3 weeks), Mid (4-7 weeks) and Late (8-11 weeks). Within each phase, data from each nest were averaged to produce one value per nest. Methods of tallying totals for Green Bay differed slightly from that for inland, but a comparison of the two methods on a subset of the data indicated that the methods were statistically indistinguishable and hence the two populations could be legitimately compared (paired t-test, p=0.87, n=20 days of Green

DISCUSSION

PRODUCTIVITY--The productivity of Green Bay/Lake Michigan eagles was more than 60% below the normal rate of inland Wisconsin eagles. This reproductive rate is well below the rate which has been associated with a healthy population (1.0 young per occupied territory; Kubiak and Best 1991, Best at al 1994), and also below the rate required to maintain population numbers (0.7 young per occupied territory; Sprunt et al 1973). Such low rates are similar to those of the 1970s and suggest that some factor strongly depressed reproduction in this population during 1987 - 1995.

Productivity data (Table 1) indicate that successful nesting pairs on Green Bay raised an average of 1.3 young per pair, while inland Wisconsin parents averaged 1.7 young per successful nest (Dykstra 1995). The cause of this difference is unknown. It may have resulted from a small clutch size, loss of eggs/young nestlings, or nestling mortality at a later stage of the nestling period. For Wisconsin Green Bay nests in 1995, there was no evidence of later-stage nestling mortality (after the first third of the nestling period). It is possible that Green Bay pairs lost eggs or young nestlings due to infertility, embryo mortality or nestling mortality; such phenomena could have resulted from high contaminant loads. However, it is also possible that small clutches were laid; small clutch size may indicate that the breeding pair are young birds. It is not possible to determine the exact mechanism of low productivity without further intensive research.

Regardless of the mechanism, the low reproductive rates indicate that this subpopulation will be unable to maintain its numbers in the long-term without substantial immigration from outside the Green Bay area. It is likely that the highly-successful inland Wisconsin and inland Michigan subpopulations were the source of the birds that colonized the Green Bay shores in the past few years. These source subpopulations can likely continue to sustain the Green Bay subpopulation through repeated emigration.

CONTAMINANTS--Concentrations of both DDE and total PCBs in addled eggs from Green Bay eagles were very high. The concentrations of DDE in Green Bay eggs were similar to or higher than those in contemporary eggs from the most contaminated areas where eagles breed in the U.S.: Maine, the upper Klamath Basin, the Columbia River, and Lakes Erie and Superior (Frenzel 1985, Henny and Anthony 1989, Bowerman 1993, Welch 1994, Buck and Schuler 1995). Mean concentration of DDE (10.3 ppm wet weight; Table 3) was midway between the level associated with near-total reproductive failure (≥15-16 ppm), and that associated with healthy reproduction (≤3 - 3.6 ppm; Wiemeyer et al 1984, 1993, Fig. 6). These data suggest that some reproductive depression was likely caused by DDE.

The critical concentrations for total PCBs are less evident than those for DDE, because of the ubiquitous co-variance of PCBs and DDE (Nisbet 1989, Wiemeyer et al 1993). However, total PCB concentrations in Green Bay eggs (geometric mean 35.0 ppm) were higher than the level associated with near-total reproductive failure in a nationwide comprehensive study (>33 ppm, Wiemeyer et al 1984), and were much higher than the 4 ppm no-observable-adverse-effect-level (NOAEL) suggested by Giesy et al (1995). Concentrations in Green Bay eggs were also clearly higher than those in eggs from Maine, the upper Klamath Basin, the Columbia River and Lakes Erie and Superior (Frenzel 1985, Henny and Anthony 1989, Bowerman 1993, Welch 1994, Buck and Schuler 1995). Only Lake Huron eggs have higher total PCB levels than those found in Green Bay (Bowerman 1993). Such elevated concentrations suggest that some part of the reproductive impairment was caused by PCBs.

Nestling blood samples also contained significantly elevated levels of both DDE and total PCBs. The average concentrations at Green Bay were 6-14 times higher than at inland sites. Although these concentrations were among the highest documented in the state of Wisconsin, there is presently no standard with which to compare the concentrations in blood, as there is for eggs.

CONTAMINANT EXPOSURE VIA DIET--Analysis of prey items delivered to the nest indicated a plausible route of exposure to bioaccumulative toxicants. Carp in the diet probably constitute the highest risk of exposure, since carp are highly contaminated (Giesy et al 1995, WDNR unpublished data) and made up 18% of the fish in the diet (Fig. 10). Spawning carp were extremely abundant during the latter half of the nestling period near three of the four nests observed in 1995 (pers. obs.). The birds in the diet, mainly gulls, may also pose a significant risk of exposure for certain eagles and eaglets. The proportion of birds in the diet ranges as high as 15% (Moss Lake, Fig. 9), and the gulls and cormorants of Green Bay are highly contaminated (Dale and Stromborg 1993).

FOOD DELIVERY RATES AND BEHAVIORAL INDICES--Food delivery rates to nestlings on Green Bay were not significantly different from those measured in the reference inland population, but the Green Bay rates were clustered at the low end of the normal range. Green Bay eagles did not compensate for the slightly lower prey delivery rate by selecting larger prey items ($p > 0.25$). However, Green Bay eagles may compensate by their selection of prey species. Carp are very heavy for their length, compared to fish species commonly found in the inland diet (Dykstra 1995). Additionally, the inclusion of birds in the diet increased the available energy, because birds generally have 30 - 50% higher energy content than most fish (Dykstra 1995).

Quantitative behavioral indices of food availability, determined in a previous study (Dykstra 1995, Warnke 1996), revealed normal behavior in Green Bay eagles and eaglets. Time spent feeding was normal, suggesting an adequate food supply (in contrast to results for Lake Superior, where time spent feeding was significantly lower than at inland sites; Dykstra 1995, Warnke 1996). Adult attendance at the nests was statistically indistinguishable from that of inland eagles ($p > 0.30$). This contrasts with Lake Superior results, where adults spent more time away from the nest; Dykstra 1995, Warnke 1996). However, sample sizes for these two behaviors were small, so conclusions must be considered preliminary.

Unquantified behaviors also indicated that food-stress did not occur at Lake Michigan nests. Green Bay chicks often left food uneaten in the nest for hours after receiving it, and did not attempt to monopolize prey items. There was only minimal fighting among siblings at Blueberry Island, and it was not occasioned by the arrival of food. No known nestling mortality occurred at age 4-7 weeks. In contrast, food-stressed nestlings near Lake Superior did not leave uneaten food, and often fought over food or attempted to monopolize food. There was also considerable nestling mortality, especially at ages 4 - 7 weeks, when energy demands are highest (Dykstra 1995).

In sum, the preliminary behavioral data indicate that even if there was a slight depression in food abundance on Green Bay, it was not nearly as severe as at Lake Superior. Since the reproductive depression on Green Bay is so much greater than that at Lake Superior, only a very small portion of it, if any, should be attributed to food-stress.

RESEARCH NEEDS--Conclusions about food delivery rates and food availability must be considered preliminary, because sample size was small and because only one nest with two nestlings was studied. On Lake Superior, the effects of food-shortage were mainly evident in broods of two (Dykstra 1995, Warnke 1996). Additional observations of broods of two are needed.

Although it seems likely that organochlorine contaminants cause most of the depression in reproduction, one additional factor may also contribute to the problem. If the breeding eagles on Lake Michigan are younger than average, they may have lower reproductive success simply because of their inexperience (Newton 1979). Anecdotal evidence indicates that some of the breeding eagles of Lake Michigan are young (brown-streaked heads; pers. obs.). If reproduction were depressed by the inexperience of the parents, it should improve over time, as the parents gain skills. Available data do not support this conclusion (Table 1). However, overall reproduction would not improve over time if the breeding adults were constantly replaced by young parents. It has been suggested that Great Lakes parents have low adult survival rates and high replacement (turnover) rates (Kozie and Anderson 1991, Bowerman 1991, Kubiak and Best 1991), but there are presently no data to test this hypothesis. Ongoing research in the Wisconsin Department of Natural Resources may be used to address this question in the future.

CONCLUSION--It is very likely that organochlorine contaminants caused most or all the reduction in reproduction. Diet analysis indicated a plausible route of exposure to these contaminants. Separation of the effects of DDE and total PCBs is presently impossible. Levels of both contaminants are very high and both are likely to cause reproductive problems at the current concentrations

LITERATURE CITED

Best, D.A., W.W. Bowerman, IV., T.J. Kubiak, S.R. Winterstein, S. Postupalsky, M.C. Shieldcastle, and J.P. Giesy, Jr. 1994. Reproductive impairment of bald eagles Haliaeetus leucocephalus along the Great Lakes shorelines of Michigan and Ohio. Pp 697-702 in Raptor Conservation Today. Meyburg, B.-U., and R.D. Chancellor, eds. World Working Group on Birds of Prey. Pica Press, East Sussex, Great Britain.

Bortolotti, G.R. 1984. Criteria for determining age and sex of nestling bald eagles. J. Field Ornithol. 55:467-481.

Bowerman, W.W., IV. 1991. Factors influencing breeding success of bald eagles in upper Michigan. M.S. thesis, Northern Michigan University, Marquette, MI. 118 pp.

Bowerman, W.W., IV. 1993. Regulation of bald eagle (Haliaeetus leucocephalus) productivity in the Great Lakes basin: an ecological and toxicological approach. Ph.D. dissertation, Michigan State University. East Lansing. 291 pp.

Bowerman, W.W., IV., D.A. Best, J.P. Geisy, Jr., T.J. Kubiak, and J.G. Sikarskie. 1994. The influence of environmental contaminants on bald eagle Haliaeetus leucocephalus populations in the Laurentian Great Lakes, North America. Pp 703-707 in Raptor Conservation Today. Meyburg, B.-U., and R.D. Chancellor, eds. World Working Group on Birds of Prey. Pica Press, East Sussex, Great Britain.

Buck, J., and C. Schuler. 1995. Organochlorine contaminants in bald eagles and double-crested cormorants nesting along the lower Columbia River. U.S. Fish and Wildlife Service. Presented at the annual meeting of Society of Environmental Toxicology and Chemistry, November 1995, Vancouver, B.C.

Colborn, T. 1991. Epidemiology of Great Lakes bald eagles. J. Toxicol. Environ. Health 33:395-453.

Dale, T.B., and K.L. Stromborg. 1993. Reconnaissance surveys of contaminants potentially affecting Green Bay and Gravel Island National Wildlife Refuges. U.S. Fish and Wildlife Service. Unpublished report. 35 pp.

Dykstra, C.J.R. 1995. Effects of contaminants, food availability and weather on the reproductive rate of Lake Superior bald eagles (Haliaeetus leucocephalus). Ph.D.

dissertation. University of Wisconsin-Madison. 247 pp.

Dykstra, C.R., M.W. Meyer, D.K. Warnke, W.H. Karasov, and D.E. Andersen. In prep. Association of low reproductive rates of Lake Superior bald eagles with low food delivery rates.

Dzus, E.H., and J.M. Gerrard. 1993. Factors influencing bald eagle densities in north-central Saskatchewan. J. Wildl. Manage. 57:771-778.

Evans, M.S., ed. 1988. Toxic contaminants and ecosystem health: a Great Lakes focus, Vol. 21. Wiley Series Advances in Environmental Science and Technology. John Wiley and Sons. New York.

Frenzel, R.W. 1985. Environmental contaminants and ecology of bald eagles in southcentral Oregon. Ph.D. dissertation. Oregon State University. 143 pp.

Gerrard, J.M., P.N. Gerrard, G.R. Bortolotti, and D.W.A. Whitfield. 1983. A 14-year study of bald eagle reproduction on Besnard Lake, Saskatchewan. Pp. 47-58 in Biology and management of bald eagles and ospreys. Harpell Press, Ste. Anne de Bellevue, Quebec.

Giesy, J.P., W.W. Bowerman, M.A. Mora, D.A. Verbrugge, R.A. Othoudt, J.L. Newsted, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. 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 bald eagles. Arch. Environ. Contam. Toxicol. 29:309-321.

Hansen, A.J. 1987. Regulation of bald eagle reproductive rates in southeast Alaska. Ecol. 68:1387-1392.

Haseltine, S.D., G.H. Heinz, W.L. Reichel, and J.F. Moore. 1981. Organochlorine and metal residues in eggs of waterfowl nesting on islands in Lake Michigan off Door County, Wisconsin, 1977-1978. Pestic. Monit. J. 15:90-97.

Heinz, G.H., S.D. Haseltine, W.L. Reichel, and G.L. Hensler. 1983. Relationships of environmental contaminants to reproductive success in red-breasted mergansers Mergus serrator from Lake Michigan. Environ. Pollut. 32A:211-232.

Henny, C.J., and R.G. Anthony. 1989. Bald eagle and osprey. Western raptor management symposium and workshop. National Wildlife Federation, Scientific and technical series 12:66-82.

Knight, R.L., P.J. Randolph, G.T. Allen, L.S. Young and R.J. Wigen. 1990. Diets of nesting bald eagles, Haliaeetus leucocephalus in western Washington. Can. Field-Nat. 104:545-551.

Kozie, K.D., and R.K. Anderson. 1991. Productivity, diet, and environmental contaminants in bald eagles nesting near the Wisconsin shoreline of Lake Superior. Arch. Environ. Contam. and Toxicol. 20:41-48.

Kubiak, T.J., H.J. Harris, L.M. Smith, T.R. Schwartz, D.L. Stalling, J.A. Trick, L. Sileo, D.E. Docherty and T.C. Erdman. 1989. Microcontaminants and reproductive impairment of the Forster's tern on Green Bay, Lake Michigan-1983. Arch. Environ. Contam. and Toxicol. 18:706-727.

Kubiak, T.J., and D.A. Best. 1991. Wildlife risks associated with passage of contaminated, anadromous fish at Federal Energy Regulatory Commission licensed dams in Michigan. Unpubl. report, U.S. Fish and Wildlife Service, East Lansing, MI.

Larson, J.M., W.H. Karasov, L. Sileo, K.L. Stromborg, B.A. Hanbidge, J.P. Giesy, P.D. Jones, D.E. Tillitt, and D.A. Verbrugge. In press. Reproductive success, developmental anomalies and environmental contaminants in double-crested cormorants (Phalacrocorax auritus). Environ. Toxicol. Chem. 15.

Meyer, M.W., C.R. Dykstra, and D.K. Warnke. In prep. Bald eagle reproductive performance following video camera placement.

Mora, M.A., H.J. Auman, J.P. Ludwig, J.P. Giesy, D.A. Verbrugge, and M.E. Ludwig. 1993. Polychlorinated biphenyls and chlorinated insecticides in plasma of Caspian terns: relationships with age, productivity and colony site tenacity in the Great Lakes. Arch. Environ. Contam. Toxicol. 24:320-331.

Newton, I. 1979. Population Ecology of Raptors. Buteo Books. Vermillion, South Dakota. 339 pp.

Nisbet, I.C.T. 1989. Organochlorines, reproductive impairment and declines in bald eagles Haliaeetus leucocephalus populations: mechanisms and dose-response relationships. Pp. 483-489 in Raptors in the Modern World. Meyburg, B.-U., and R.D. Chancellor, eds. World Working Group on Birds of Prey, Berlin.

Postupalsky, S. 1974. Raptor reproductive success: some problems with methods, criteria, and terminology. pp. 21-31 in Hamerstrom, F.N.,Jr., B.E. Harrell, and R.R. Ohlendorff, eds. Management of Raptors. Proc. Conf. Raptor Conserv. Tech., Raptor Res. Report No. 2.

Price, H.A., R.L. Welch, R.H. Scheel, and L.A. Warren. 1986. Modified multiresidue method for chlordane, toxaphene, and polychlorinated biphenyls in fish. Bull. Environ. Contam. Toxicol. 37:1-9.

Sprunt, A., IV., W.B. Robertson, Jr., S. Postupalsky, R.J. Hensel, C.E. Knoder, and F.J. Ligas. 1973. Comparative productivity of six bald eagle populations. Trans. N. Amer. Wildl. Conf. 38:96-106.

U.S. Environmental Protection Agency (EPA). 1984. Method 608, Federal Register 49 (209):43321- 43336.

Warnke, D.K. 1996. Comparative behavioral ecology of two bald eagle populations in Northern Wisconsin. M.S. thesis. University of Minnesota, St. Paul.

Welch, L.J. 1994. Contaminant burdens and reproductive rates of bald eagles breeding in Maine. M.S. thesis. University of Maine. 86 pp.

Whitfield, D.W.A., and J.M. Gerrard. 1985. Correlation of bald eagle density with commercial fish catch. Pp. 191-193 in Bald Eagle in Canada: proceedings of Bald Eagle Days, 1983. Gerrard, J.M., and T.M. Ingram, eds. White Horse Plains Publishers, Headingley, Manitoba.

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

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

Wilkinson, L. 1988. Systat: the system for statistics. Systat, Inc. Evanston, Illinois.

Table 1. Green Bay/Door peninsula productivity, young per occupied territory, 1987-1995

STATE	NEST NUMBER	NEST NAME	87	88	89	90	91	92	93	94	95	
WI	BR-01 / OC-08	Little Tail Pt.							0	0	1	
WI	DO-01	Toft Point								1	1	
WI	MT-07	Peshtigo R.	1	0	0	0	0	0	0		0	
WI	MT-16	Peshtigo R. North						1	0	0		
WI	MT-17	Blueberry Island							0	2	2	
WI	OC-04	Oconto R.--Thome		0	0	1	0	0	0	1	0	
MI	De-09 / De-15	Moss L./Boutlier L.	1	0	0	1	0	0	0	1	1	
MI	De-13	Granskog L.	1	0	0	0	0	0	0	0	1	
MI	De-16	No-see-um Creek/North L.	2	2		1	0	1	1	2	1	
MI	De-17	Fishdam R.	1	0	0	0	0	0	0	0	2	
MI	De-18 / De-07	Squaw Point/Squaw Creek		0		0		0	0	0	0	
MI	De-20	St. Vital's Pt.							1	0	1	
MI	Mm-03	Deer Creek					2	2	0		0	
# Occupied			5	7	5	7	7	9	12	11	12	75
# Young			6	2	0	3	2	4	2	7	10	36
Young per Occupied			1.2	0.29	0	0.43	0.29	0.44	0.17	0.64	0.83	0.48

Notes: Wisconsin 1994 - 95 data in part provided by S. Stubenvoll, WDNR (pers. comm.). Michigan 1987-1993 data provided by Bowerman (pers. comm.), with confirmation of some data by S. Postupalsky. Michigan 1994-1995 data provided by Postupalsky (pers. comm.).

Michigan records for De-09/De-15 and De-18/De-07 were combined in this report at the suggestion of the surveyor (S. Postupalsky) who believes that each set probably represents a single nesting pair.

Table 2. Contaminant loads in nestling blood plasma samples from Green Bay/Lake Michigan nests, 1987-1995.

YEAR	STATE	NEST NUMBER	NEST NAME	BAND NUMBER	DDE (ppb wet wt)	TOTAL PCBs (ppb wet wt)
1987	MI	De-13	Granskog Lake[1]	unk	111	229
1987	MI	De-15	Boutlier Lake[1]	unk	235	319
1992	WI	MT-16	Peshtigo R. N.	629-36349	361	901
1994	WI	MT-17	Blueberry Is.	629-36416	4	83
1994	WI	DO-1	Toft Point	629-38277	46	121
1994	WI	OC-4	Oconto R.--Thome	629-38280	95	393
1995	WI	DO-01	Toft Point[2]	629-36438	29	150
1995	WI	MT-17	Blueberry Is.[2]	629-36468	13	87
GEOMETRIC MEANS					53	207

1. Michigan data provided by Bowerman (1991)
2. Data may be biased low (matrix spike recoveries low)

Table 3. Contaminant loads in addled eggs collected from Green Bay nests, 1986 - 1995.

YEAR	STATE	NEST NUMBER	NEST NAME	TOTAL PCBs (ppm wet wt)	DDE (ppm wet wt.)
1986	MI	De-15	Boutlier L. (2 eggs)[1]	55.1	29.9
1987	WI	MT-07	Peshtigo R.	19.0	2.4
1990	MI	De-17	Fishdam R. (2 eggs)[1]	26.4	10.0
1991	MI	De-17	Fishdam R.[1]	27.2	7.4
1991	WI	MT-07	Peshtigo R. (2 eggs)	56.5	12.0
1992	MI	De-18	Squaw Point[1]	28.7	12.3
1992	MI	De-17	Fishdam R. (2 eggs)[1]	27.8	10.7
1992	WI	MT-16	Peshtigo R. N. (2 eggs)	66.6	14.7
1995	WI	MT-07	Peshtigo R.	unanalyzed	unanalyzed
1995	WI	OC-04	Oconto R. (neonate)	unanalyzed	unanalyzed
GEOMETRIC MEAN				35.0	10.3

1. Michigan data provided by Dave Best, USFWS (unpubl. data).

Sibling eggs were averaged (geometric mean).

Table 4. Prey delivery rates for Green Bay/Lake Michigan nests, 1995

NEST	# DAYS OBSERVED	NESTLING AGE (wks)	BROOD SIZE	NESTLING SEX	PREY DELIVERIES DAY^{-1}	PREY DELIVERIES $NESTLING^{-1}$ DAY^{-1}
Little Tail Pt.	11	0 - 11	1	unknown	2.45	2.45
Toft's Pt.	9	1 - 10	1	male	2.77	2.77
Moss Lk.	15[1]	5 - 11	1	unknown	1.64	1.64
Blueberry Is.	36[1]	0 - 11	2	male, male	3.93	1.97
MEAN						2.21

1. Only complete days (dawn-to-dusk) were included in the calculation of prey delivery rates.

Table 5. Classes of prey delivered to Green Bay/Lake Michigan nests, 1995. Values are number of items and (% of total).

NEST	TOTAL	FISH	BIRDS	MAMMALS	UNKNOWNS
Little Tail Pt.	25	18 (72.0%)	2 (8.0%)	0 (0%)	5 (20.0%)
Toft's Pt.	27	18 (66.7%)	1 (3.7%)	0 (0%)	8 (29.6%)
Moss Lk.	39	22 (56.4%)	4 (10.2%)	0 (0%)	13 (33.3%)
Blueberry Is.	179	142 (79.3%)	3 (1.7%)	2 (1.1%)	32 (17.9%)
TOTAL	270	200 (74.1%)	10 (3.7%)	2 (0.7%)	58 (21.5%)

Table 6. Prey remains found in or near five Green Bay/Lake Michigan nests and one Fox River nest, 1995. Prey remains were found in nests, under nests, or under known perch trees at nest-visits during and after the 1995 nesting season. All easily-identified remains shown here. Lists do not quantitatively describe diet, because of the incomplete identification, and because of the bias toward less-digestible prey items (Knight et al 1990).

NEST	DATE OF NEST-VISIT	PREY REMAINS FOUND	MINIMUM NUMBER PRESENT
Moss Lake	6/6 & 6/13/95	carp	1
		northern pike	8
		double-crested cormorant	1
		raven	1
		small heron, sp. unknown	1
		duck, sp. unknown	1
		muskrat	1
		fox	1
Moss Lake	9/1/95	carp	3
		fish, sp. unknown	1
		crow	1
		medium birds, sp. unknown	4
Blueberry Island	6/14/95	carp	1
Blueberry Island	8/30/95	northern pike	3

		large bird, sp. unknown	1
Little Tail Point	7/24/95	northern pike	1
		rock bass	1
		bullhead or catfish	6
		medium bird, sp. unknown	1
Toft Point	7/19/95	northern pike	2
		alewife	1
		crow	1
		mature gull	1
		large bird, sp. unknown	1
		passerine	1
Oconto R./Thome	5/1/95	northern pike	2
		white sucker	2
		carp or buffalo	1
		mammal, sp. unknown	1
Kaukauna (FOX R.)	6/31/95	carp	2
		bird, sp. unknown	1

Table 7. Sizes of prey delivered to Green Bay/Lake Michigan nests, 1995. Values are number of items and (% of total).

NEST	TOTAL	SIZE 1	SIZE 2	SIZE 3	SIZE 4	UNKNOWNS
Little Tail Pt.	25	5 (20.0%)	8 (32.0%)	10 (40.0%)	0 (0%)	2 (8.0%)
Toft's Pt.	27	3 (11.1%)	12 (44.4%)	4 (14.8%)	1 (3.7%)	7 (25.9%)
Moss Lk.	39	1 (2.6%)	19 (48.7%)	8 (20.5%)	2 (5.1%)	9 (23.1%)
Blueberry Is.	179	18 (10.0%)	80 (44.7%)	61 (34.1%)	3 (1.7%)	17 (9.5%)
TOTAL	270	27 (10.0%)	119 (44.1%)	83 (30.7%)	6 (2.2%)	35 (13.0%)

Table 8. Time spent feeding at Green Bay/Lake Michigan eagle nests, 1995. Time shown is a percent of the total available daylight hours. Data from video-taped nests are weekly averages, including 1 - 6 days of data. Time spent feeding includes the time chicks fed themselves and the time that adults fed chicks. Data for Blueberry Island adjusted for brood size, so value shown is time spent feeding per chick.

WEEK	TIME SPENT FEEDING AT EACH NEST (% OF DAYLIGHT HOURS)				MEAN
	Little Tail Point	Toft's Point	Moss Lake	Blueberry Island	
0	6.1			4.8	5.5
1	8.9	8.7		8.5	8.7
2	8.3	8.7		9.0	8.6
3	8.3	8.3		8.2	8.3
4	9.5	4.8		6.5	6.9
5	6.0		14.0	4.9	8.3
6	5.1	4.2	11.5	5.2	6.5
7	4.8	10.5	17.3	5.4	9.5
8	7.2	6.7	13.8	6.9	8.7
9		11.3	9.0	8.5	9.6
10	8.5	9.4	14.1	11.4	10.9
11	2.2		10.0	14.8	9.0

Table 9. Adult attendance at Green Bay/Lake Michigan eagle nests, 1995. Time shown is a percent of the total available daylight hours. Data from video-taped nests are weekly averages, including 1 - 6 days of data. Moss Lake was not included in mean (see text for details). Adult attendance includes the amount of time when at least one adult was present in the nest.

WEEK	ADULT ATTENDANCE AT EACH NEST (% OF DAYLIGHT HOURS)				MEAN
	Little Tail Point	Toft's Point	Moss Lake	Blueberry Island	
0	99.9			100.0	99.9
1	99.9	97.0		99.2	98.7
2	99.8	96.2		85.1	93.7
3	55.4	99.7		68.0	74.4
4	58.2	62.0		54.5	58.2
5	22.7		0.0	14.6	18.6
6	5.7	26.7	0.0	8.0	13.5
7	9.5	9.9	0.3	13.5	10.9
8	4.7	5.7	0.1	19.9	10.1
9		6.7	0.0	2.7	4.7
10	1.5	8.2	0.0	2.1	3.9
11	0.0		0.0	7.5	3.8

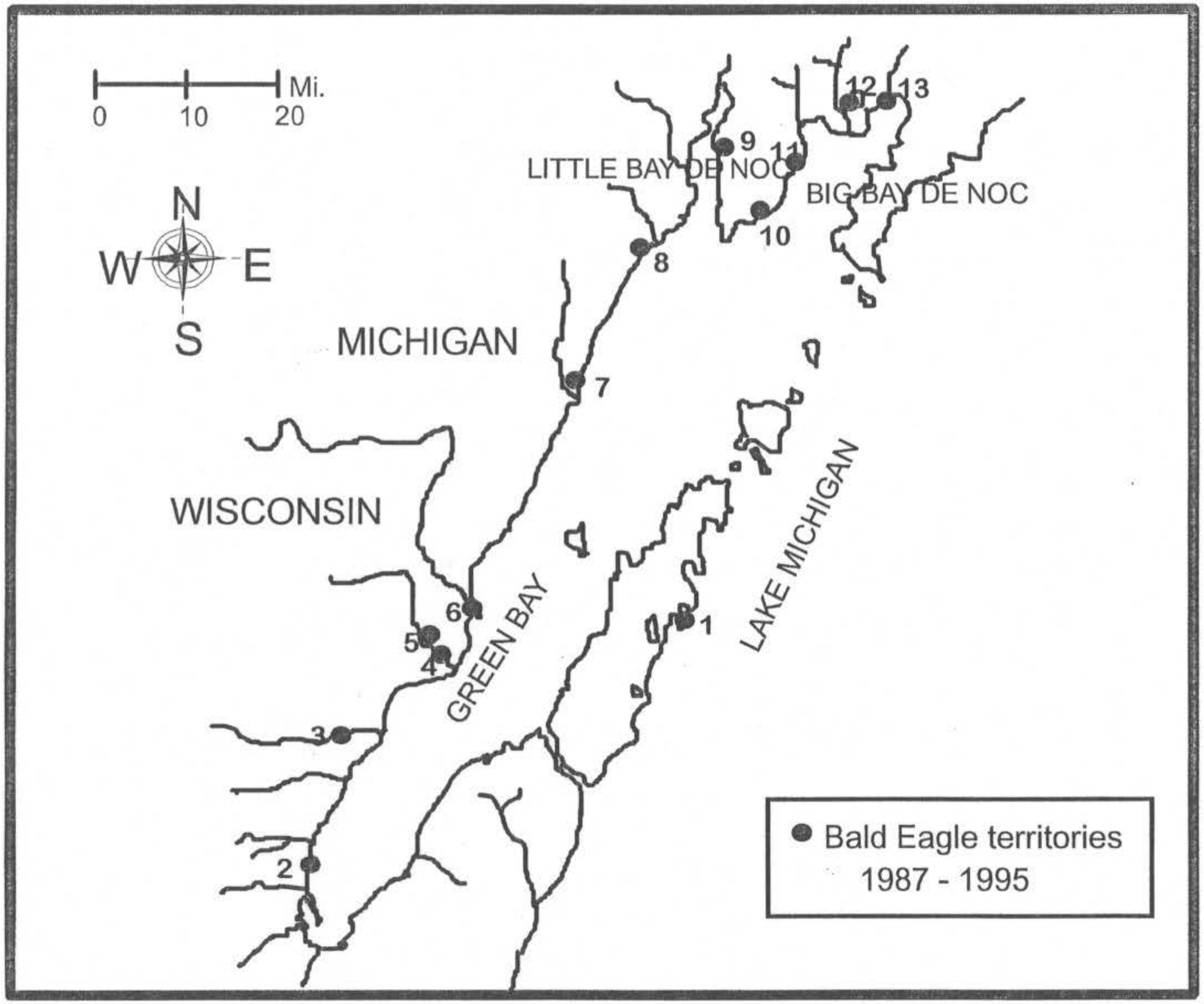

Figure 1. Locations of bald eagle nesting territories on Green Bay and associated Lake Michigan shores. Nest names and numbers correspond to figure labels: (1) Toft Point, DO-01, (2) Little Tail Point, OC-08/BR-01, (3) Oconto River--Thome, OC-04, (4) Peshtigo River (also called Highway BB), MT-07, (5) Peshtigo River North (also called Highway BB North), MT-16, (6) Blueberry Island, MT-17, (7) Deer Creek, Mm-03, (8) No-see-um Creek (also called North Lake), De-16, (9) Squaw Point and Squaw Creek territories, De-18 and De-07, (10) Granskog Lake, De-13, (11) St. Vital's Point, De-20, (12) Moss Lake and Boutlier Lake territories, De-09 and De-15, (13) Fishdam River, De-17. For notes on territory pairings, see Table 1.

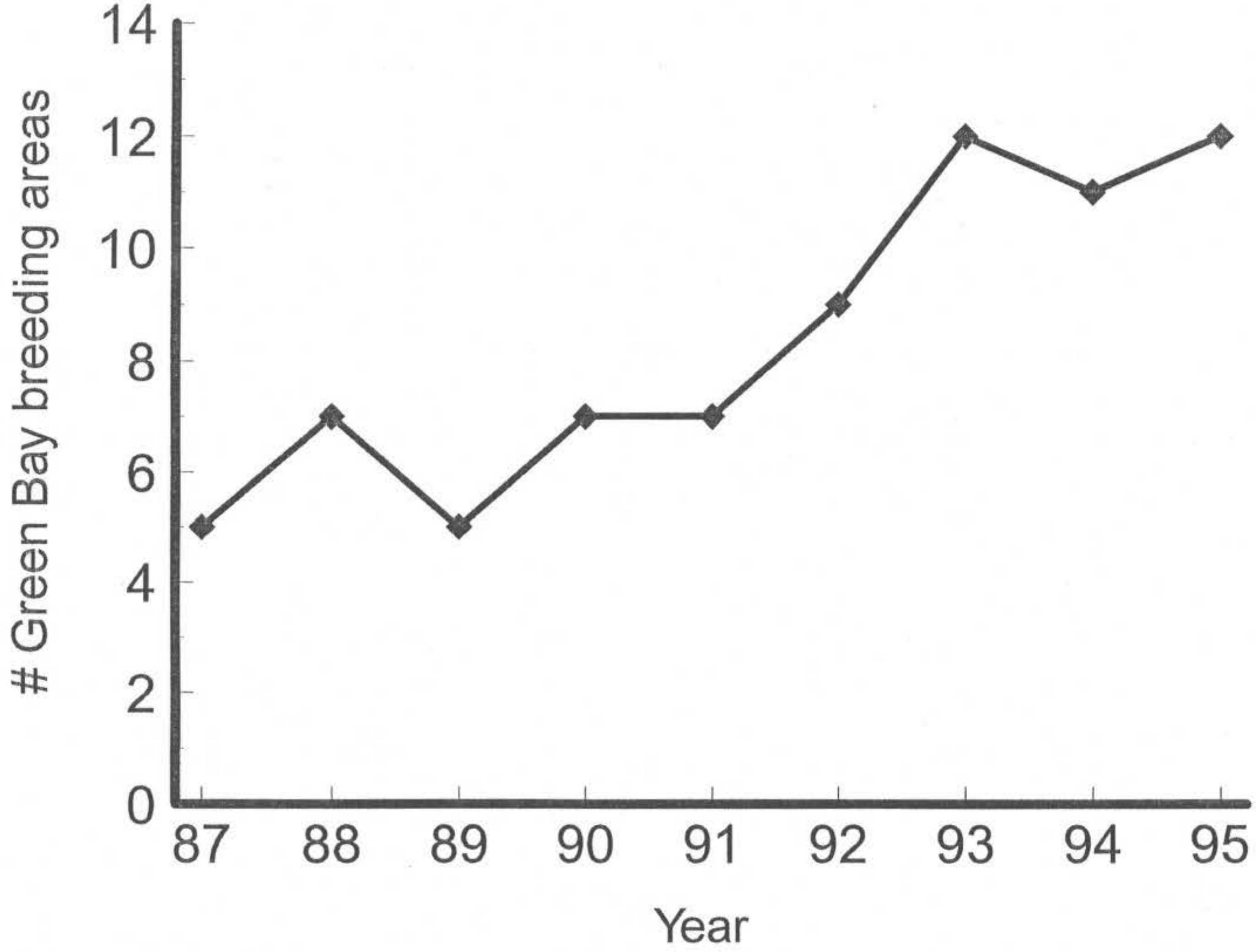

Figure 2. Green Bay bald eagle population, 1987 - 1995, in terms of number of occupied breeding territories

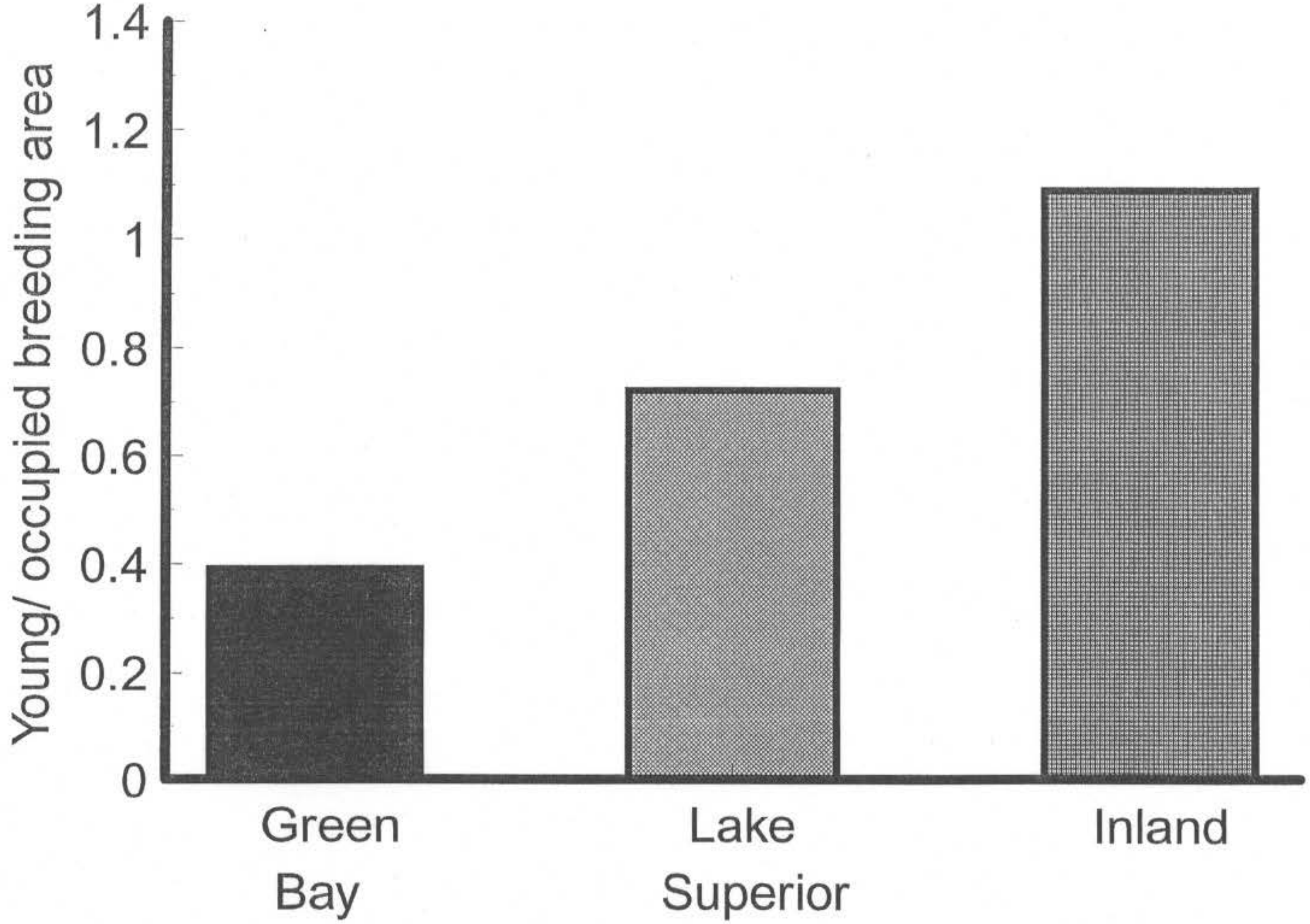

Figure 3. Mean productivity for Green Bay, Lake Superior, and inland Wisconsin, 1990-1994. Green Bay includes all nests within 8 km of the shore of Green Bay and associated Lake Michigan waters (all territories shown in Fig. 1). Inland Wisconsin includes all nests in Vilas and Oneida counties for 1990-1993 and the entire North-central district for 1994. Inland 1990-1993 estimated as indicated in text. Lake Superior, shown for comparison, includes nests within 8 km of the shoreline in Wisconsin. Productivity defined as young per occupied territory (Postupalsky 1974).

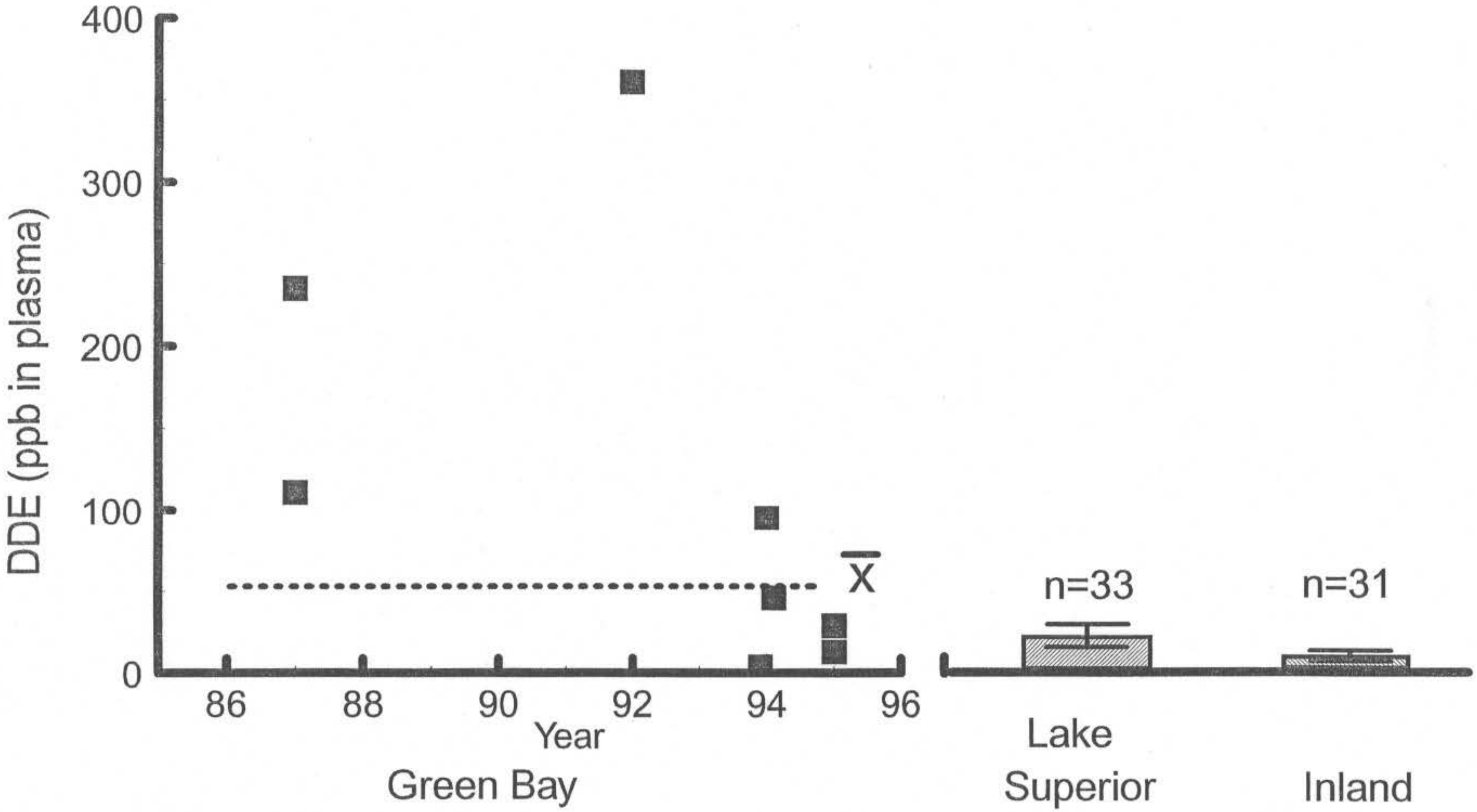

Figure 4. Concentrations of DDE in nestling plasma samples, 1987 - 1995, for Green Bay nestlings age 5-9 weeks. Samples from 1987 are from Bowerman (1991). Inland Wisconsin and Lake Superior means and 95% confidence intervals shown for comparison (from Dykstra et al in prep). Line at 53 ppb is the geometric mean for Green Bay samples (Table 2).

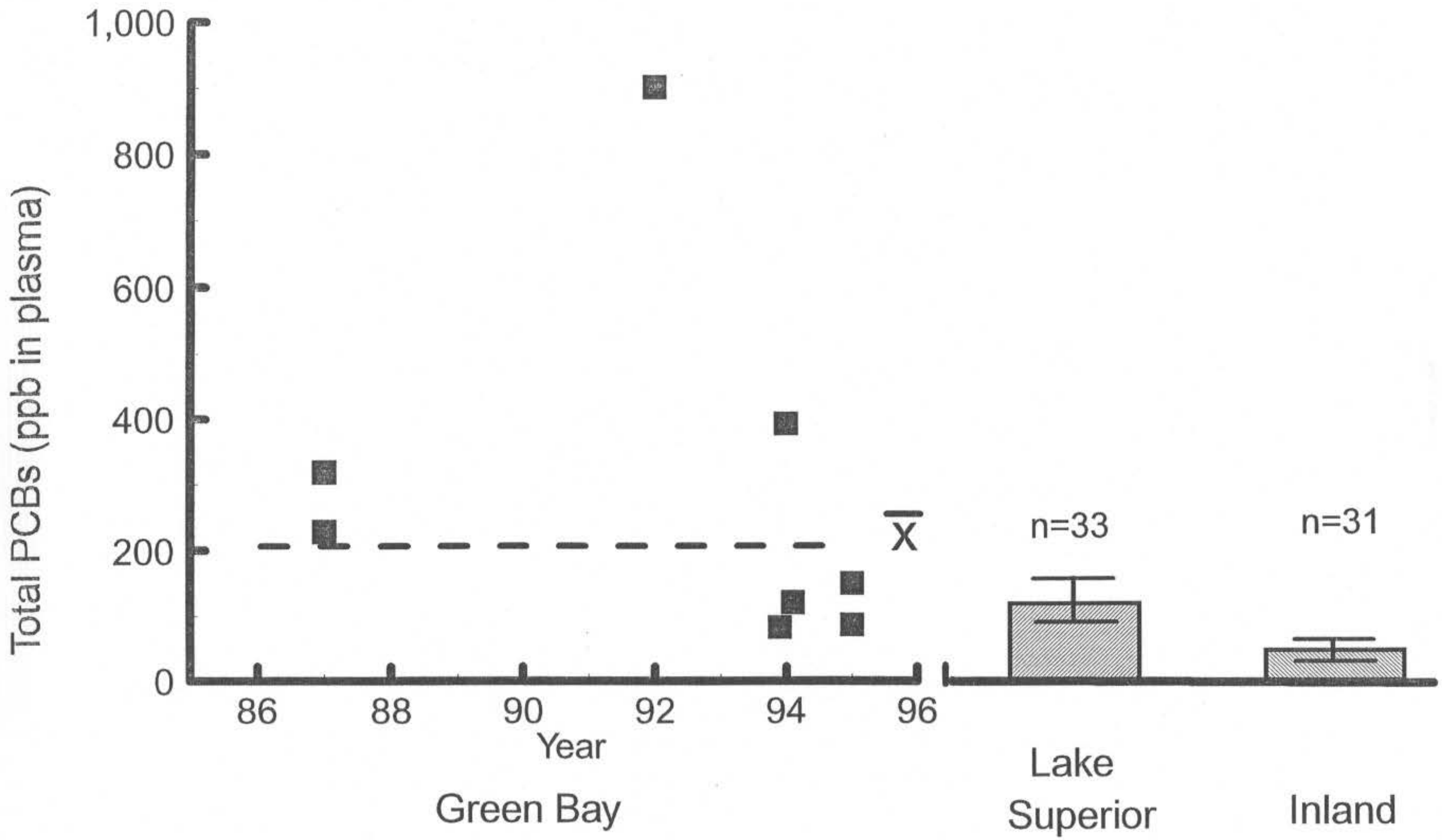

Figure 5. Total PCBs in nestling plasma samples, 1987-1995, for Green Bay nestlings age 5-9 weeks. Samples from 1987 are from Bowerman (1991). Inland Wisconsin and Lake Superior means and 95% confidence intervals shown for comparison (from Dykstra et al in prep). Line at 207 ppb is the geometric mean for Green Bay samples (Table 2).

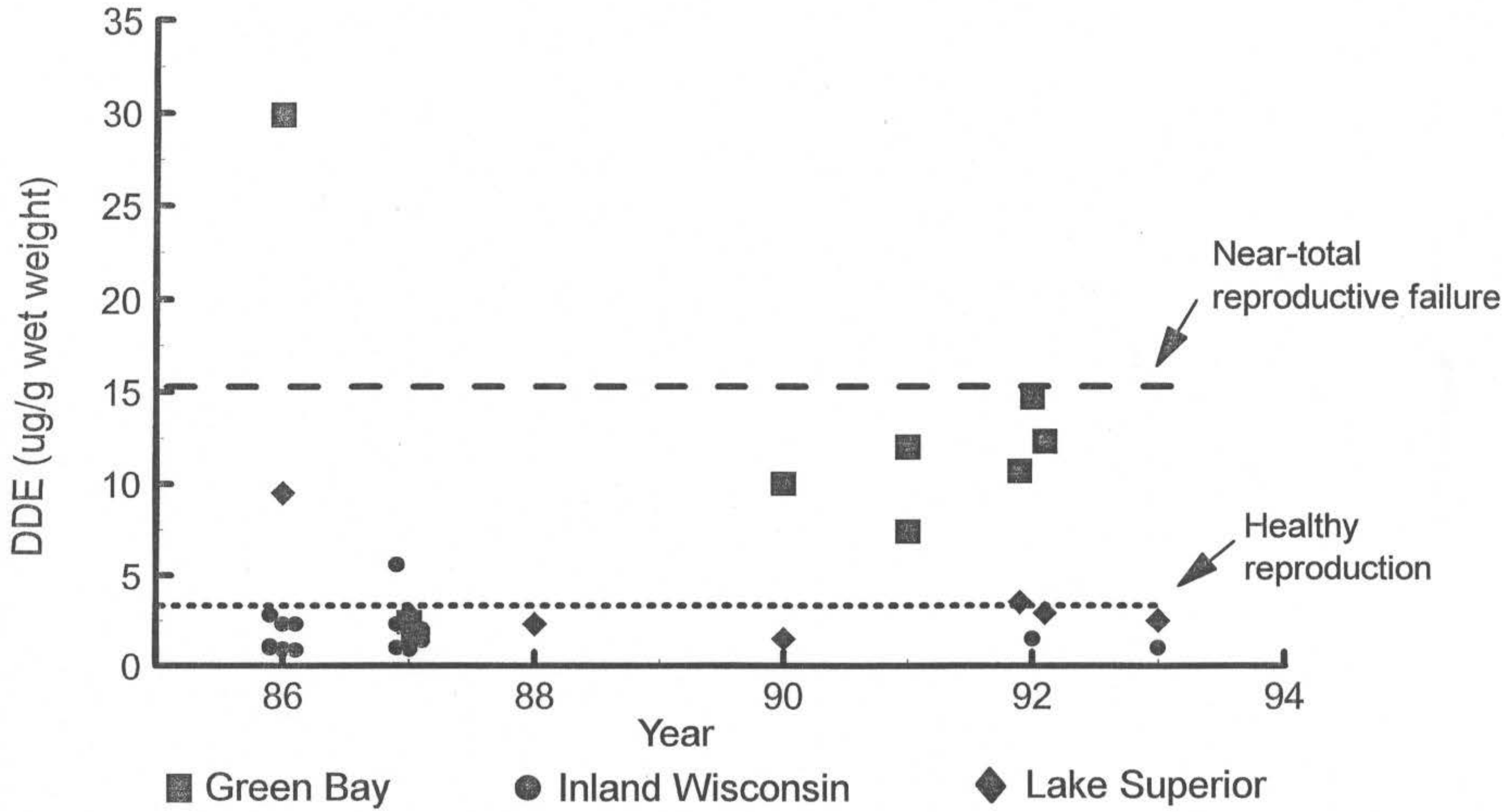

Figure 6. Concentrations of DDE in addled eggs from Green Bay nests 1986 - 1993. Eggs from inland Wisconsin and Lake Superior shown for comparison. Data for five Michigan Green Bay eggs or egg-pairs provided by Dave Best, USFWS (unpublished data); data for three Lake Superior eggs from Bowerman et al (1994). Other Lake Superior and inland Wisconsin data from WDNR (Meyer, unpublished data) and Dykstra et al (in prep). Line at >15-16 ppm is the concentration associated with near-total reproductive failure in a nationwide study (Wiemeyer et al 1984; 1993). Line at <3-3.6 ppm is the concentration associated with normal reproductive rates (Wiemeyer et al 1984, 1993).

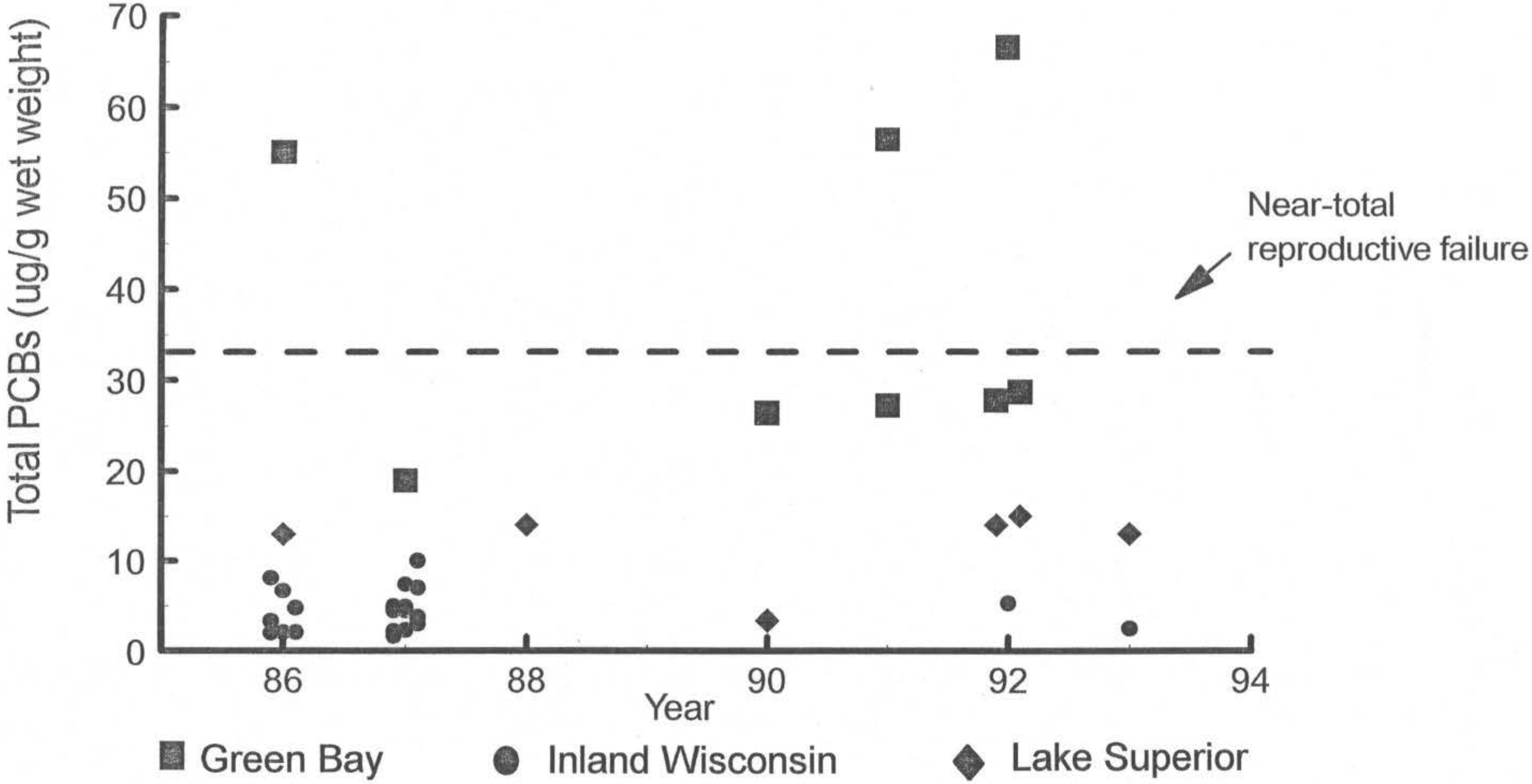

Figure 7. Total PCBs in addled eggs from Green Bay nests 1986 - 1993. Eggs from inland Wisconsin and Lake Superior shown for comparison. Data for five Michigan Green Bay eggs or egg-pairs provided by Dave Best (unpublished data); data for three Lake Superior eggs from Bowerman et al (1994). Other Lake Superior and inland Wisconsin data from WDNR (Meyer, unpublished data) and Dykstra et al (in prep). Line at >33 ppm is the concentration associated with near-total reproductive failure in a nationwide study (Wiemeyer et al 1984; see Discussion for caveats).

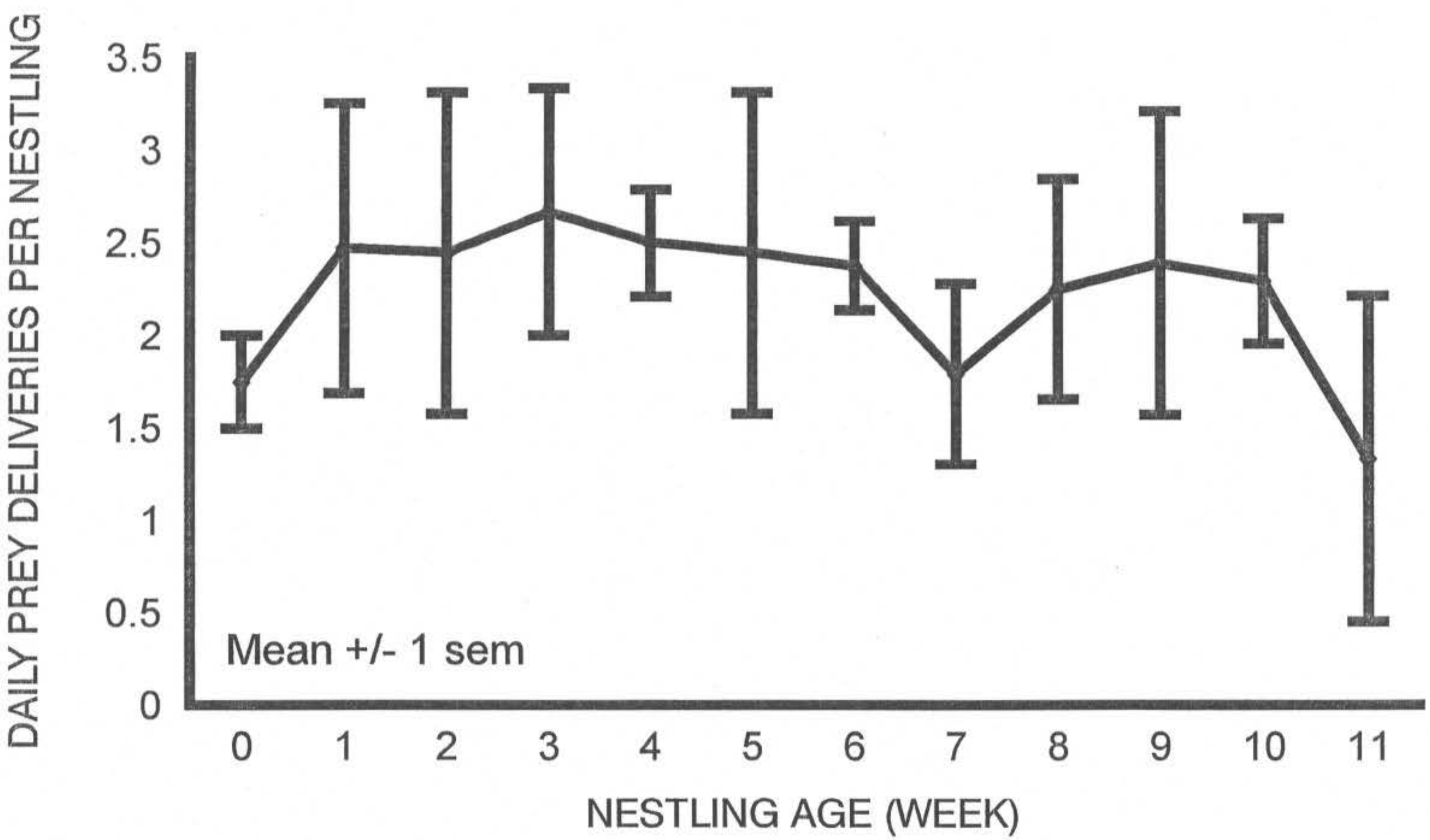

Figure 8. Daily prey delivery rates per nestling, Green Bay nests, 1995. Nests included were Blueberry Island, Moss Lake, Toft Point, and Little Tail Point. Multiple observations for a single nest in one week were averaged to produce a single value for each nest (see Methods). Not all nests were observed in every week. Only complete observation days (dawn-to-dusk) were included. Week 0= days 0-6, etc.

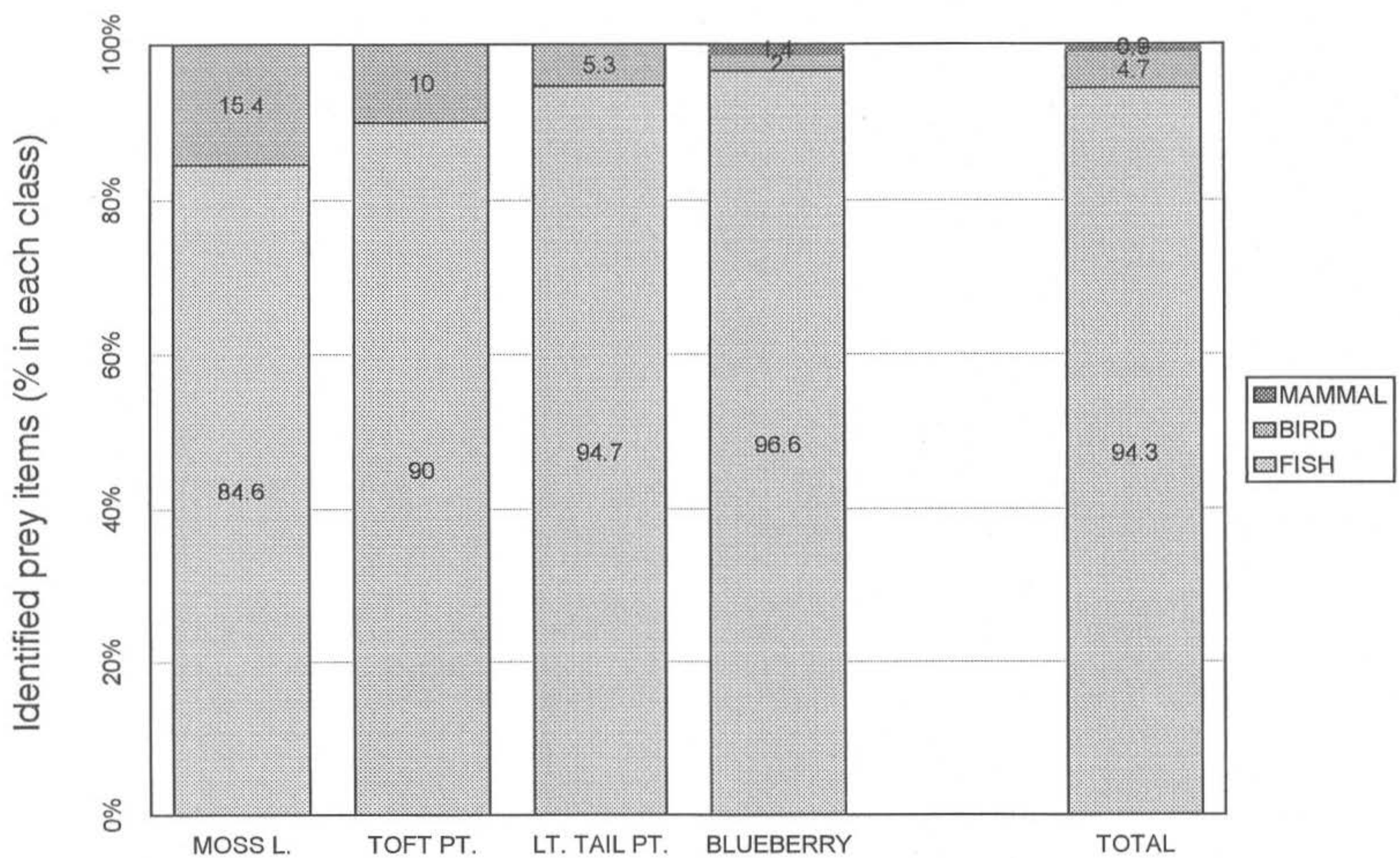

Figure 9. Taxonomic class of observed prey at Green Bay nests, 1995. Only prey which were identified to class are shown. Values shown are simple precentages (weekly values were not pooled; see Methods for details).

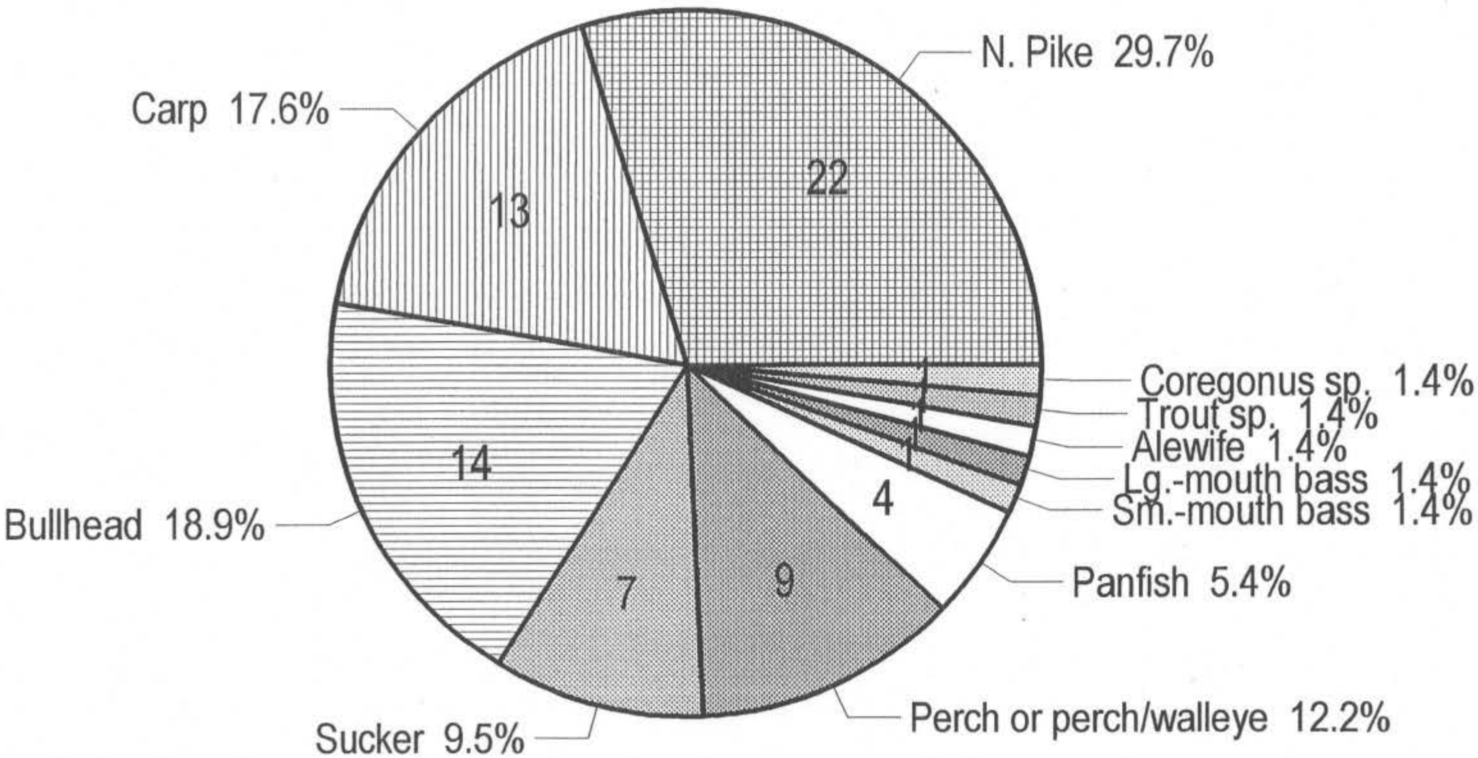

Figure 10. Prey fish species observed at Green Bay nests, 1995. Total number of fish classified to species or species-group = 74. Only prey items for which the species-identification was considered positive or "very likely" were included in the distribution. Values shown are simple percentages (weekly values not pooled: see Methods for details). Scientific names of prey species shown in Appendix 3. "Bullhead" species probably include mainly brown bullhead; "sucker" species, white suckers. "Perch" refers to yellow perch. "Panfish" probably consists mainly of bluegills and possibly crappies. "Coregonus species" likely refers to lake whitefish, but identification to species was not possible.

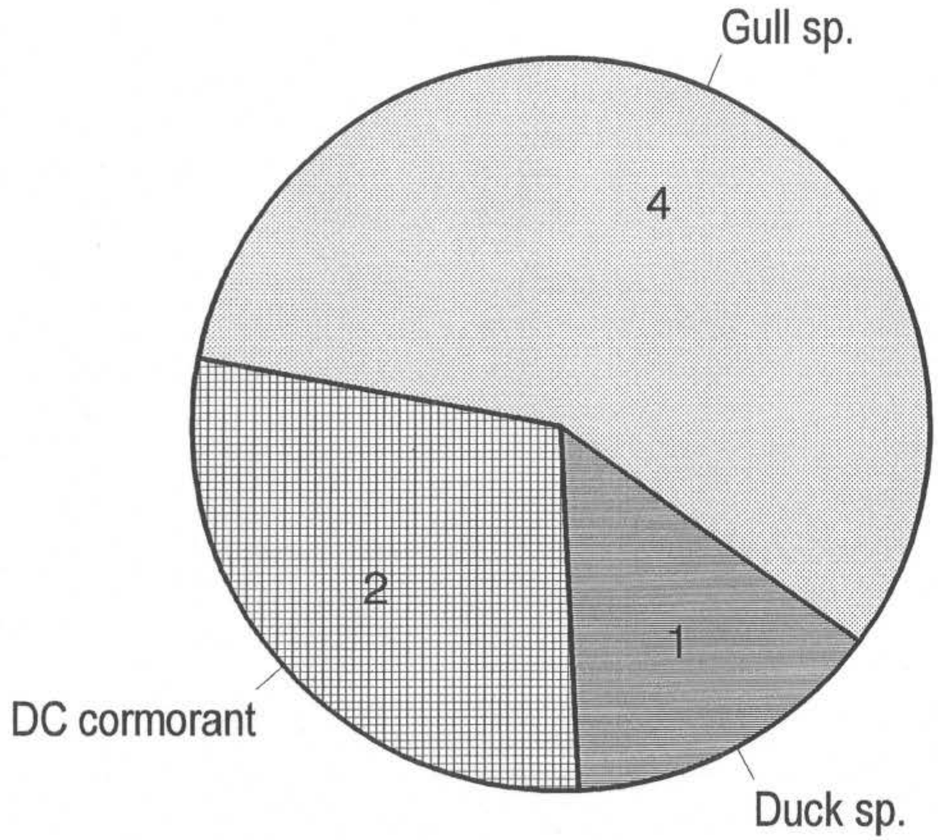

Figure 11. Prey bird species observed at Green Bay nests, 1995. Total number of birds classified to species or species-group = 7. Only prey items for which the species-identification was considered positive or "very likely" were included in the distribution. Values shown are simple percentages (weekly values not pooled: see Methods for details). DC cormorant = double-crested cormorant. One gull was identified by size as a mature Herring gull. Remaining gulls were full-grown Herring or Ring-billed gulls. Both cormorants were young nestling birds. The single duck observed was small ("teal-size"). Scientific names of prey species shown in Appendix 3.

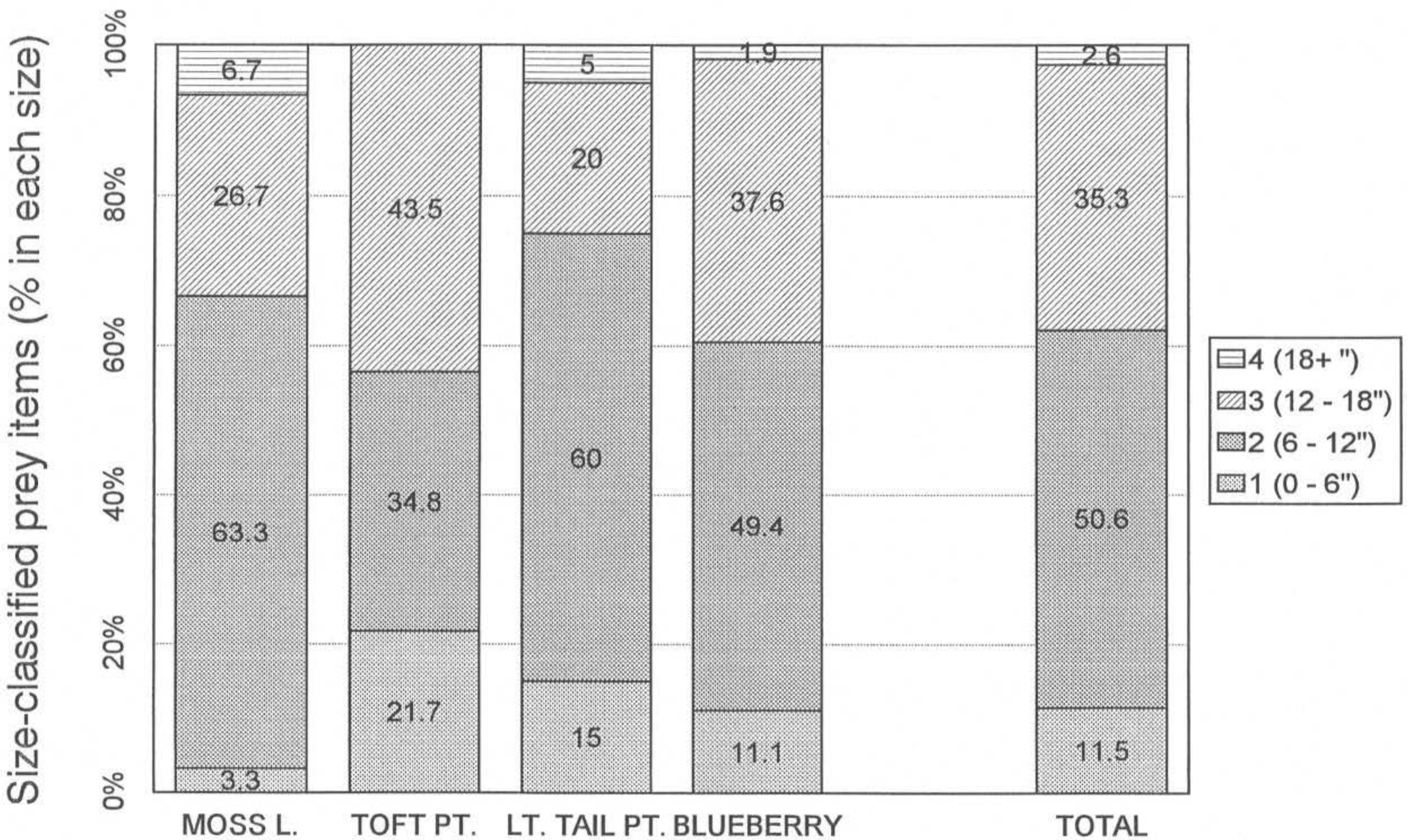

Figure 12. Size-categories of observed prey at Green Bay nests, 1995. Only prey which were identified to size-category are shown. Values shown are simple percentages (weekly values were not pooled: see Methods for details).

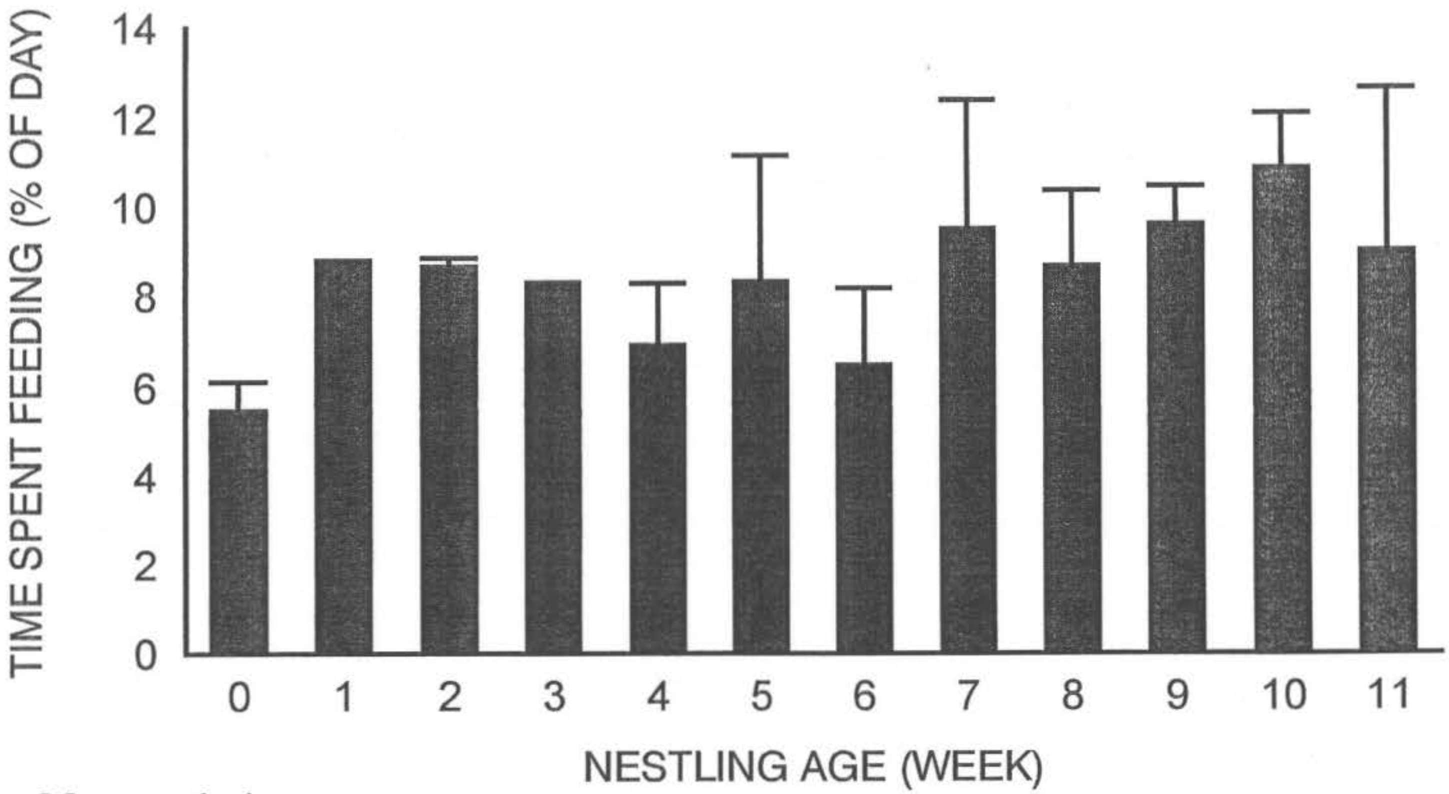

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Figure 13. Time spent feeding at Green Bay nests, 1995. Daily values were recorded as a percentage of the total available daylight. Time spent feeding defined as in text. Nests included were Blueberry Island, Moss Lake, Toft Point, and Little Tail Point. Multiple observations for a single nest in one week were average to produce a single value for each nest (see Methods). Not all nests were observed every week. Only complete observation days (dawn-to-dusk) were included. Week 0 = days 0 - 6, etc.

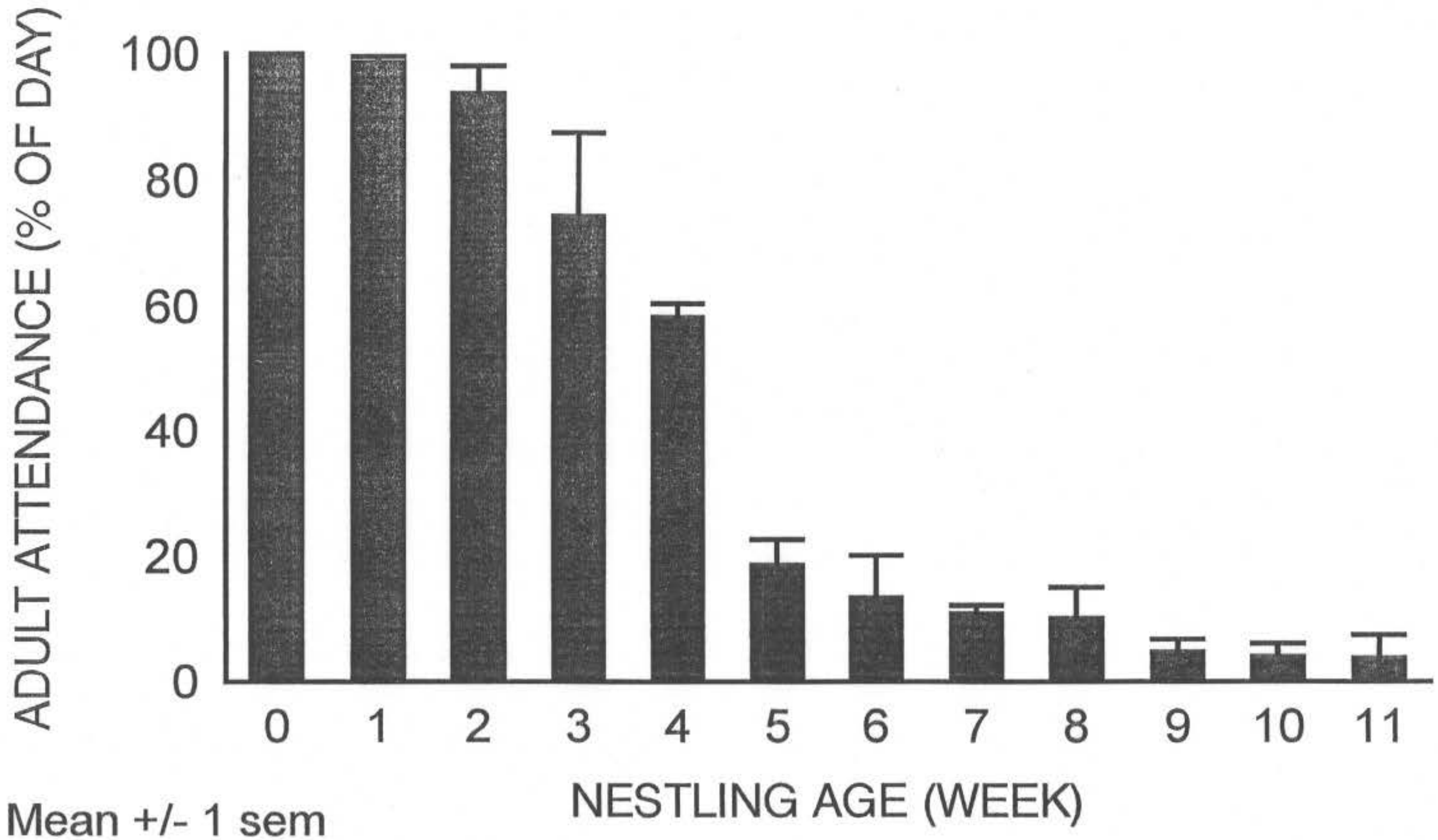

Figure 14. Adult attendance at Green Bay nests, 1995. Daily values were recorded as a percentage of the total available daylight. Adult attendance defined as in text. Nests included were Blueberry Island, Toft Point, and Little Tail Point. Multiple observations for a single nest in one week were averaged to produce a single value for each nest (see Methods). Not all nests were observed in every week. Only complete observation days (dawn-to-dusk) were included. Week 0 - days 0 - 6, etc.

APPENDIX 1

APPENDIX 1: FOX RIVER BALD EAGLES

The sediments of the Fox River in Wisconsin are the source of most of the organochlorine contamination in Green Bay; thus, it seems plausible to investigate the effects of contaminants on Fox River eagles together with the effects on Green Bay eagles. However, the Fox River differs from the Green Bay shoreline in several important ways. The Fox is highly industrialized, with little habitat suitable for nesting eagles. Consequently, the Fox River has very few breeding pairs, too few for any statistical conclusions regarding their productivity (Table 1). Second, the Fox River contaminant profile (in eagle tissue) differs from that found on Green Bay. The limited data available for the Fox River suggest that DDE concentrations in eggs and nestling blood are generally low (Table 2, Table 3); this contrasts with results from Green Bay, where DDE is present in significant concentrations. Additionally, PCB congener patterns in addled eagle eggs may also differ (unpublished data). For these reasons, the Fox River eagles and the Green Bay eagles should be considered separately, until additional data indicates otherwise.

Table 1. Bald eagle productivity on the Fox River, WI, young per occupied territory, 1988 - 1995

NEST NUMBER	NEST NAME	88	89	90	91	92	93	94	95	
OU-1a	Kaukauna	2	1	0	3	3	3	1	3	
WI-1	Mud Creek							2	3	
BR-2	East River							0		
# Occupied territories		1	1	1	1	1	1	3	2	11
# Young		2	1	0	3	3	3	3	6	21
#Young per Occupied		2	1	0	3	3	3	1	3	1.9

Table 2. Contaminant loads in addled eggs collected in nests on the Fox River, Wisconsin, 1990.

YEAR	NEST NUMBER	NEST NAME	TOTAL PCBs (ppm wet wt)	DDE (ppm wet wt)
1990	OU-1a	Kaukauna	36	1.1

Table 3. Contaminant loads in nestling blood samples from the Fox River, Wisconsin, 1991-1995.

YEAR	NEST NUMBER	NEST NAME	BAND NUMBER	DDE (ppb wet wt)	TOTAL PCBs (ppb wet wt)
1991	OU-1a	Kaukauna[1]	(2 chicks)	n.d.	120
1992	OU-1a	Kaukauna	629-36347	n.d.	318
1993	OU-1a	Kaukauna	629-38221	n.d.	226
1994	OU-1a	Kaukauna	629-36415	54	547
1995	OU-1a	Kaukauna	629-36435	9	290
1994	WI-1	Mud Creek	629-38275	unanalyzed	unanalyzed
GEOMETRIC MEANS				6	267

1. From Dykstra (1995)

APPENDIX 2

PCB-Total	0.012	0.15	0.087	0.29
alpha BHC	0.002	<0.002	<0.002	<0.002
alpha chlordane	0.002	<0.002	<0.002	<0.002
beta BHC	0.002	<0.002	<0.002	<0.002
dieldrin	0.002	0.008	0.002	<0.002
endrin	0.002	<0.002	<0.002	<0.002
gamma BHC	0.002	<0.002	<0.002	<0.002
gamma chlordane	0.002	<0.002	<0.002	<0.002
heptachlor epoxide	0.002	<0.002	<0.002	<0.002
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX 3

APPENDIX 3: SCIENTIFIC SPECIES NAMES

Table. Scientific names for prey species in text and figures.

COMMON NAME	SCIENTIFIC NAME
FISH	
Northern pike	*Esox lucius*
Carp	*Cyprinus carpio*
Suckers (typical ex: white sucker)	*Catostomus* sp.
Bullheads (typical ex: brown bullhead)	*Ictalurus* sp.
Perch or yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*
Large-mouth bass	*Micropterus salmoides*
Small-mouth bass	*Micropterus dolomieui*
Rock bass	*Ambloplites rupestris*
Alewife	*Alosa pseudoharengus*
Panfish (typical ex: bluegill)	*Lepomis macrochirus* and others
Coregonus sp.	*Coregonus* sp.
Trout sp.	*Salvelinus* sp. and *Salmo* sp
BIRDS	
Herring gull	*Larus argentatus*
Ring-billed gull	*Larus delawarensis*
Double-crested cormorant	*Phalacrocorax auritus*
Raven	*Corvus corax*
Crow	*Corvus brachyrhynchos*
MAMMALS	
Muskrat	*Ondatra zibethica*
Fox (red fox or gray fox)	*Vulpes fulva* or *Urocyon cineroargenteus*