

BREEDING AND FEEDING ECOLOGY OF BALD EAGLES IN
THE APOSTLE ISLAND NATIONAL LAKESHORE

by Karin Dana Kozie

A Thesis

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

College of Natural Resources
UNIVERSITY OF WISCONSIN
Stevens Point, Wisconsin

December 1986

APPROVED BY THE GRADUATE COMMITTEE OF;

R.K. Anderson

Dr. Raymond K. Anderson, Major Advisor
Professor of Wildlife

Neil F. Payne

Dr. Neil F. Payne
Professor of Wildlife

Byron Shaw

Dr. Byron Shaw
Professor of Water Resources

ACKNOWLEDGEMENTS

Many people donated considerable time and effort to this project. I wish to thank Drs. Neil Payne and Byron Shaw of my graduate committee, for providing useful comments on this manuscript; my committee chairman, Dr. Ray Anderson, whose support, patience and knowledge will long be appreciated. Special thanks to Chuck Sindelar, eagle biologist for the state of Wisconsin, for conducting aerial surveys, organizing banding crews and providing a vast supply of knowledge and time, and to Ron Eckstein and Dave Evans of the banding crew, for their climbing expertise. I greatly appreciate the help of the following National Park Service personnel: Merryll Bailey, ecologist, provided equipment, logistical arrangements and fisheries expertise; Maggie Ludwig graciously provided her home, assisted with fieldwork and helped coordinate project activities on the mainland while researchers were on the islands; park ranger/naturalists Brent McGinn, Erica Peterson, Neil Howk, Ellen Maurer and Carl and Nancy Loewecke donated their time and knowledge of the islands. Many people volunteered their time in fieldwork; including Jeff Rautio, Al Bath, Laura Stanley, John Foote, Sandy Okey, Linda Laack, Jack Massopust, Dave Ross, Joe Papp, Lori Mier, Kim Pemble and June Rado. Mona Colburn of the Illinois State Museum, identified fish bones. Steve LaValley assisted in scale identification. Dr. Stanley

Wiemeyer, U. S. Fish and Wildlife Service, Laurel, MD provided unpublished data. Chuck Sindelar, Al Harmata and Rick Frenzel also provided critical comments on this manuscript. I would like to thank my parents, for their encouragement and guidance and belief in happiness.

TABLE OF CONTENTS

Acknowledgements.....	iii
List of Tables.....	vi
List of Figures.....	vii
List of Appendices.....	viii
BREEDING AND FEEDING ECOLOGY OF BALD EAGLES IN THE APOSTLE ISLAND NATIONAL LAKESHORE.	
Abstract.....	1
Introduction.....	3
Study Area.....	6
Methods.....	9
Results and Discussion.....	13
Productivity.....	13
Survival.....	21
Contaminant Levels in Bald Eagles.....	23
Food Habits.....	29
Contaminants in Eagle Food Items.....	40
Recommendations for Future Research and Management.....	47
Literature Cited.....	49
Appendices.....	59

LIST OF TABLES

Table 1.	Productivity of bald eagles nesting in the Apostle Islands and along the Wisconsin shoreline of Lake Superior, 1984-1986.....	15
Table 2.	Thickness of eggshell fragments collected from bald eagle nests on the Apostle Islands and nearby mainland shoreline of Lake Superior, 1983-1985.....	19
Table 3.	Concentrations of environmental contaminants in 5 eaglets and 1 juvenile bald eagle from Lake Superior and inland Wisconsin nests, 1984 and 1985.....	24
Table 4.	Food remains collected at bald eagle nest and perch trees on the Apostle Islands and nearby mainland shoreline.....	36
Table 5.	Concentrations of environmental contaminants in fish from eagle foraging areas in the Apostle Islands, 1984 and 1985.....	42
Table 6.	Concentrations of environmental contaminants in herring gulls from the Apostle Islands, 1985.....	45

LIST OF FIGURES

Figure 1.	Study area and present bald eagle nest locations in the Apostle Islands and nearby mainland shoreline.....	7
Figure 2.	Nest attentiveness of adult eagles on Outer Island, 1984 and 1985.....	28
Figure 3.	Primary foraging areas and nest locations of bald eagles nesting within the AINL, 1984 and 1985.....	30
Figure 4.	Summer sightings of adult bald eagles on the Apostle Islands and nearby mainland shoreline, 1984 and 1985.....	32
Figure 5.	Percent occurrence of observed food items vs. prey remains collected at Outer, Michigan and North Twin Islands.....	38

APPENDIX

Appendix 1. Food items of bald eagles at individual nest sites on the Apostle Islands and nearby mainland shoreline..... 59

ABSTRACT

Food habits and foraging areas, and chemical contaminants in eagle foods and carcasses were studied in bald eagles (Haliaeetus leucocephalus) nesting within the Apostle Island National Lakeshore (AINL) during 1984 and 1985. Data on food habits collected during banding operations in 1983 and 1986 are also included. Productivity was monitored during 1984-1986. Food habits were determined by collecting prey remains from below nest and perch trees and by direct observation. Fish comprised 52.4% of prey remains and 97.0% of observations. Common species included longnose sucker (Catostomas catostomas), burbot (Lota lota), white sucker (Catostomus commersoni), and round whitefish (Prosopium cylindraceum). Birds, primarily herring gulls (Larus argentatus), comprised 46.9% of prey remains and 1.5% of observations. Mammals comprised 0.7% of food remains and 1.5% of observations. Organochlorine and PCB residues were present at low levels (DDE: \bar{x} = 0.07 ppm, PCB: \bar{x} = 0.21 ppm) (wet weight) in fish. Adult and immature herring gulls contained higher concentrations (DDE: \bar{x} = 5.4 ppm, PCB: \bar{x} = 13.5 ppm) and appear to be the major source of elevated contaminant levels in the Apostle Island bald eagle population. The source of herring gull contamination is unknown. Migratory birds, wintering in areas where DDT is still in use, may add additional contaminants to the eagle food chain. Eagle feeding areas were located primarily along the shores near nest areas

during late incubation, brood rearing and early post-fledging periods. An average of 0.9 young/occupied nest were produced in the Apostle Islands during 1984-1986 compared to an average of 1.3 young/occupied nest produced statewide in Wisconsin during those years. Nestling mortality was 27% among island nests (4 of 15 young). Contaminant levels in nestling bald eagle carcasses collected from Lake Superior nests were higher than those collected inland, suggesting local contamination. Replacement of adult females in 2 nests and the known death of an adult female at a 3rd nest, indicates a high turnover among breeding adults in the AINL during 1985. Current production in the Apostle Islands may be due to a younger breeding cohort, with low contaminant levels, dispersing from the inland population. Disturbance did not appear to be a factor affecting productivity or survival.

Bald eagle populations declined substantially from about 1947 through the early 1970's, concurrent with the use of the persistent organochlorine pesticide DDT in North America (Broley 1958, Sprunt and Ligas 1966, Abbott 1967, Newton 1979, Gerrard 1983). DDE, a metabolite of DDT, has been associated with eggshell thinning in many avian species (Heath et al. 1969, Peakall 1970, Wiemeyer and Porter 1970, Cade et al. 1971, McLane and Hall 1972, Cooke 1973, Lincer 1975, Henny 1977). Evidence of DDE induced eggshell thinning in bald eagles has also been documented (Hickey and Anderson 1968, Postupalsky 1971, Anderson and Hickey 1972, Weimeyer et al. 1972, Grier 1974, Rauber 1976, Grubb and Rubink 1978, Grier 1982, Wiemeyer et al. 1984). Decreases in shell thickness have resulted in subsequent population declines in raptors and other species (Porter and Wiemeyer 1969, Newton 1979, Blus 1982, Helander 1982, Mendenhall et al. 1983).

Eagles nesting along the shores of the Great Lakes were severely affected by organochlorine contaminants, producing an average of only 0.13 young/active nest from 1961-1970; a minimum of 0.7 young/active nest is needed to maintain a stable population (Sprunt et al. 1973). Inland production in the western Great Lake States began to increase shortly after the ban on DDT in 1972 (Madsen et al. 1985, Sindelar 1983), resulting in the dispersal of birds toward Lake Superior and other areas (Sindelar

1983). Eagles nesting along the Wisconsin shores of Lake Superior, however, continue to demonstrate poor reproductive success despite increased production at inland sites (Sindelar 1983, 1985).

In the Apostle Islands, nesting was already sporadic by the 1960's when population surveys were begun; only 2 successful nests were documented in the islands during that decade. However, the National Audubon Society reported 33 historic nests in the Apostle Islands during 1960-1969, suggesting eagles were common breeders there prior to that time. Nesting pairs were absent throughout the 1970's and began to re-establish territories among the islands between 1980 and 1983. However, they did not produce young until 1983, when an eagle was fledged from Outer Island (Sindelar 1983).

Addled eggs, collected from the Apostle Islands and Lake Superior south shore nests during 1970-1982, contained higher levels of organochlorine (DDE: 11.0-29.0 ppm, dieldrin: 0.3-1.6 ppm), PCB (6.8-98.0 ppm) and mercury (0.21-0.47 ppm) residues than inland Wisconsin eggs (Wiemeyer et al. 1984, S. Wiemeyer, unpub. data). The source of this contamination was unknown.

The purpose of this study was to determine the cause of reproductive failure in the Apostle Island National Lakeshore (AINL) bald eagle population. Specific objectives were to: (1) locate, document and monitor reproductive success of eagles nesting in the AINL, (2)

determine seasonal food habits and foraging areas of AINL eagles, (3) determine contaminant levels in eagle foods and carcasses, and (4) record and analyze pertinent life history information including behavior patterns and parental activities, inter- and intraspecific eagle behavior and disturbance factors for potential causes of low productivity.

Food habits and foraging areas, and chemical contaminants in eagle foods and carcasses were studied in bald eagles nesting within the AINL during 1984 and 1985. Data on food habits collected during banding operations in 1983 and 1986 are also included. Productivity was monitored during 1984-1986.

STUDY AREA

The AINL is located in northern Wisconsin, along the southwest shore of Lake Superior. It is composed of 20 islands and a 19-km unit of mainland shoreline (Fig. 1). Islands range in size from 1.2 ha (Gull Island) to 4021 ha (Stockton Island) and have a collective area of 15,967 ha. Outer Island, is the farthest island from the mainland, being 24 km away. Annual precipitation averaged 100 cm during 1984 and 1985. Mean temperature for January was -10 C and for July, 19 C. Lake Superior rarely freezes completely and influences climatic conditions within 32 km of its shoreline (Soil Conservation Service 1961, National Atmospheric and Oceanic Administration 1984, 1985).

The islands lie within the Boreal and Conifer-Hardwood interphase (Curtis 1959) and contain flora of both. Plant associations are diverse and vary with soil types. A yellow birch (Betula alleghaniensis) - white cedar (Thuja occidentalis) association predominates among forest cover types (Beals and Cottam 1960) although sugar maple (Acer saccharum), paper birch (Betula papyrifera), balsam fir (Abies balsamea) and trembling aspen (Populus tremuloides) have begun to replace this association in more recent times (Anderson and Stowell 1985). Bald eagles nest and perch in supracanopy trees; white pine (Pinus strobus) is the dominant supracanopy species in currently active nest territories. A more comprehensive description of select island cover types and associated

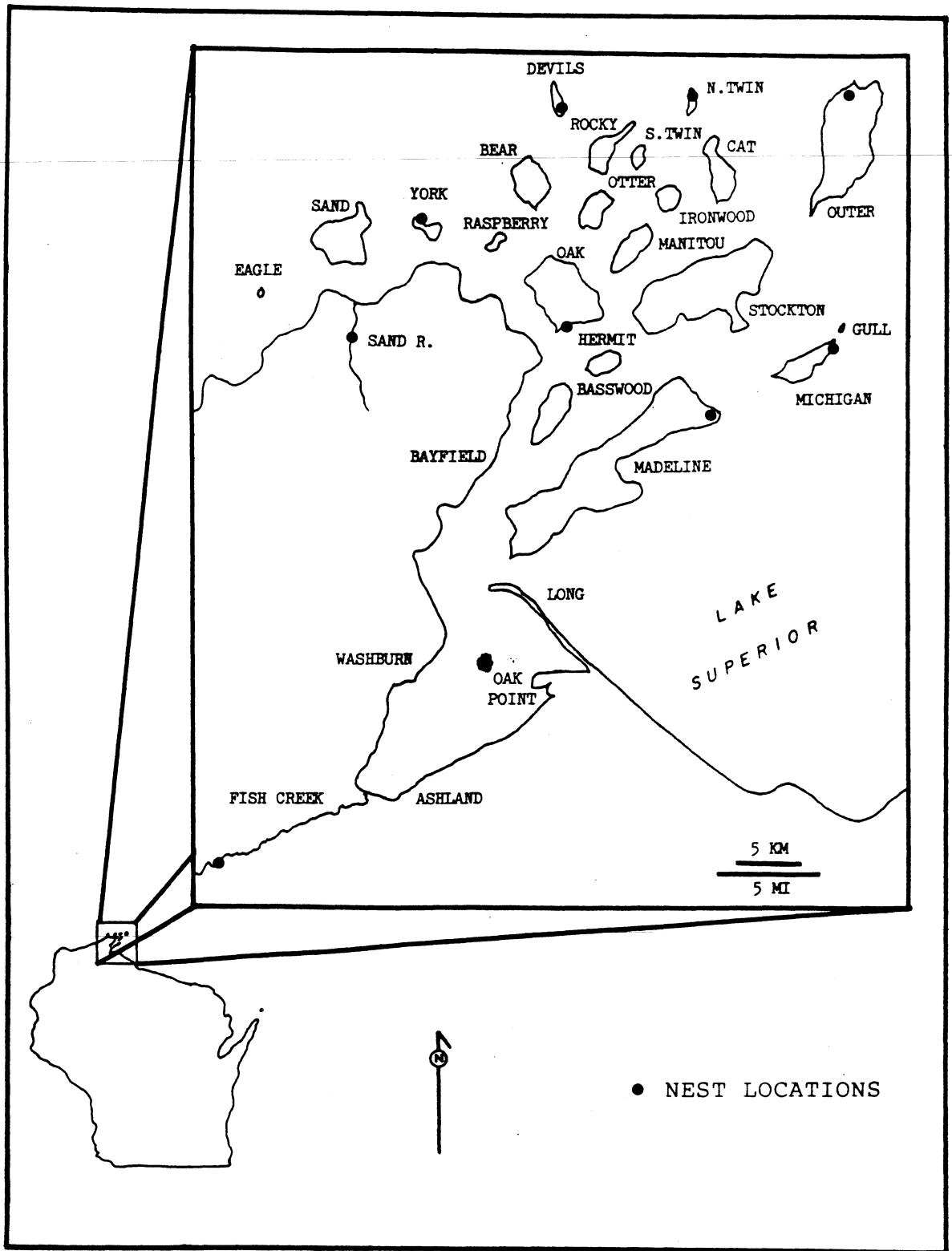


Fig. 1. Study area and present bald eagle nest locations on the Apostle Islands and nearby mainland shoreline.

wildlife can be found in Anderson and Stowell (1985).

Eight breeding pairs were monitored in this study, 6 nested on the islands, 1 each on Outer, Michigan, North Twin, Oak, Devils and York Islands and 2 nested near the mainland shoreline on Fish Creek and Sand River. Outer, Michigan, North Twin and Devils Islands are the 4 outermost islands; each supported an active bald eagle nest at some time between 1983 and 1986. The nest on Oak Island was not discovered until 1985 and was inactive at that time. The Fish Creek and Sand River nests are located outside AINL boundaries. The Fish Creek nest, located 12.9 km from Lake Superior on a stream draining into the lake, was included in this investigation, because of its past history of containing highly contaminated eggs (Wiemeyer et al. 1984). The Sand River nest was included due to its proximity to Lake Superior (2.6 km). All of these nests have similar histories, i.e., none successfully produced young prior to 1983 (Sindelar 1983).

METHODS

Active nests were located by airplane in mid-April during the annual Wisconsin bald eagle breeding survey conducted by the Wisconsin Department of Natural Resources (WDNR). A second aerial survey was conducted in late May to determine reproductive success. Active territories were observed between 14 May and 13 November in 1984 and 29 April and 27 September in 1985.

Food habits were determined by collecting prey remains at nest and perch trees and by direct observation. Food remains were initially collected from the 3 active nests on Outer, North Twin and Michigan Islands in mid-June while banding young in 1984 and 1985. Periodic collections from below nest and perch trees were continued until early September. The Fish Creek, Sand River, and Oak Island nests were monitored in 1985. Five visits were made to the Sand River nest and 1 to Fish Creek. Food remains were collected from the nest on Oak Island after 2 adults had been reported there consistently in early June 1985. Prey remains collected during banding operations at Outer and North Twin Islands in 1983 and Outer, Devils and York Islands in 1986 were also included. Food remains were also collected from the nest on North Twin Island which failed early in incubation in 1986. Methods used to determine food habits were similar to those of Mollhagen et al. (1972) for golden eagles (Aquila chrysaetos).

Species were identified by comparison with museum specimens. Minimum number of individuals was determined by the greatest number of identical bones or feathers per taxon. Fish scales were identified to family (Lagler 1952). All food debris was collected during each visit to a nest to avoid repetition in counting; fresh remains were wrapped in aluminum foil and frozen for contaminant analysis. Observations of fishing attempts were recorded with regard to location and estimated distance from shore. Water depths were determined from U.S. topographic maps.

Only the 3 successful island nests during 1983 and 1984 were observed. Nests on North Twin and Michigan Islands were monitored from a boat; observation points varied between 50 and 200 m from nests, but most often were about 50 m. The Outer island nest was observed from a lighthouse tower, 0.8 km distant, with a Questar 7 telescope (1600 f/14). Binoculars (20 X 70) facilitated observations at all nests. Nests were usually monitored from dawn to dusk.

Gill nets were set in eagle foraging areas to collect fish for contaminant analysis. Composite samples of 2-6 individuals of each species were collected. Fresh food items found in or below nest trees were analyzed separate from composite samples; samples were pooled where more than 1 of the same species was present. Six herring gulls (Larus argentatus), 3 adults and 3

immatures, were collected and analyzed for chemical contaminants; 2 adults were found dead, the rest were trapped or shot. Two dead nestling herring gulls were collected from the eagle nest on Michigan Island during banding.

Four dead eagles were collected for contaminant analysis. Two dead nestling eagles, 1 from Michigan and the other from North Twin Island, were collected in 1985. A juvenile eagle from North Twin Island, electrocuted in Salem, Florida at 6 months of age, and a 10-day old eaglet, from a mainland nest along the Lake Superior shoreline (Amnicon River), were recovered in 1984.

Contaminant analyses were conducted by the Wisconsin State Lab of Hygeine, Madison, WI. Fish were homogenized whole; skin, feet, beak and wings of herring gulls were removed prior to grinding. Breast, brain and kidney samples only were analyzed from bald eagles. A 10 g tissue sample was mixed with 60 g of anhydrous sodium sulfate and extracted in a 20 mm I.D. chromatographic column with 200 ml of dichloromethane at an elution rate of 5 ml/min. Tissue analysis was performed by electron capture gas chromatography on a 4% SE - 30 and 6% OV-210 glass column. Carrier gas was 90% argon/10% methane (Interum methods of organic analysis, unpub. lab manual, Wisc. State Lab of Hygeine, Madison, WI.). Recovery ranged from 80% to 110%. Residue levels were not corrected for recovery values. Detection limits were 0.05 ppm for o,p'-DDT, p,p'-DDT, o,p'-DDD, p,p'-DDD,

o,p'-DDE, p,p'-DDE, cis-chlordane, trans-chlordane, cis-nonachlor, trans-nonachlor and methoxychlor; 0.01 ppm for hexachlorobenzene (HCB), alpha benzene hexachloride (BHC) and gamma BHC; 0.02 ppm for dieldrin and endrin; and 0.2 ppm for PCB's. Toxaphene could not be quantified as samples contained only a limited number of the many possible toxaphene components and are therefore referred to as toxaphene-like compounds in the text. Detection limits were 1.0 ppm for toxaphene components. Mercury was analyzed via cold vapor atomic absorption (Manual of analytic methods, unpub. lab manual, Wisc. State Lab of Hygeine, Madison, WI.). Detection limits for mercury were 0.03 ppm. Contaminant values below the level of detection were assigned 1/2 the lower limit of detection to calculate means. Means for residue data are geometric. All contaminant concentrations are reported in ppm wet weight.

The distance at which perched adult eagles flushed from a 3 m inflatable research boat was recorded to determine responses of nesting eagles to boat disturbance. Initial flushing distances, determined early in the nesting season, were used to preclude any bias imposed by habituation of eagles to the research boat.

RESULTS AND DISCUSSION

Productivity

Eagles nesting on Outer, Michigan and North Twin Islands each produced young during 1984 and 1985. An inactive nest on Oak Island was climbed on 22 July 1985; it contained eggshell fragments and food remains but the condition of the lining material suggests that this nest was occupied in 1984. The eggs probably did not hatch. Commercial fishermen, who reported the nest, did not see any young there in 1984 despite almost daily observations from late May through August. Eagles nesting on Outer, York and Devils Islands successfully produced young in 1986.

The number of young/occupied nest has been used as an indication of population stability (Sprunt et al. 1973). An occupied nest is one at which evidence of a breeding pair exists; the pair may or may not produce eggs or young (Northern States Bald Eagle Recovery Plan 1983). It is estimated that at least 50% of nesting pairs must be successful and produce a minimum of 0.7 young/occupied nest to maintain a stable population (Sprunt et al. 1973). However, 1.0 young/occupied nest is more indicative of a healthy population (Wiemeyer et al. 1984).

The AINL had 4 occupied nests in 1984, 3 in 1985 and 5 in 1986 and produced an average of 0.9 young/occupied nest during those years. Nests along the Wisconsin

shoreline of Lake Superior (including the AINL) produced an average of 0.9 young/occupied nest from 1984 -1986 and had an average nest success of 57% (Table 1). These figures are below the statewide averages of 1.3 young/occupied nest and 75% nest success during 1984-1986. While productivity figures are useful indicators of population stability, they should be applied with caution to small populations. Five of the 10 nests adjacent to Lake Superior failed in 1984 and at least 3 of those that failed were inactive in 1985, resulting in only 5 and 4 successful nests in 1984 and 1985, respectively. Nesting attempts near Lake Superior increased in 1986. However, 2 of the 5 island nests or 5 of the 11 total nests along the Wisconsin shoreline of Lake Superior failed in 1986, increasing the number of successful nests to only 6.

The poor productivity of eagles nesting near Lake Superior can be attributed, in part, to nestling mortality; 5 young died in 1984. Two young died in the nest on Michigan Island at about 6 weeks of age; cause of death is unknown. A 10-day old nestling, from the Amnicon River, was killed in a fall from the nest tree. Multiple wounds on its body suggest sibling aggression may have been occurring in the nest. Feather remains of a 2nd nest mate and a 3rd, healthy young were also present. Feather remains found under the Sand River nest indicate the young produced there in 1984 died at about the time of fledging. A juvenile from North Twin Island,

Table 1. Productivity of bald eagles nesting in the Apostle Islands and along the Wisconsin shoreline of Lake Superior, 1984-1986.

Nest	1984		1985		1986	
	No. Young	No. Young Fledged	No. Young	No. Young Fledged	No. Young	No. Young Fledged
Outer Island	2	2	1	1	1	1
Michigan Island	2	F ^a	2	1		IA ^b
North Twin Island	2	2	1	F	0	F
Oak Island	0	F		IA		IA
York Island		IA		IA	2	2
Devils Island		--		--	2	2
Madeline Island		--		--	0	F
Chequamegon Point	2	2	0	F	1	1
Honest John Lake	0	F		IA	1	1
Fish Creek	2	2	2	2	0	F
Sand River	1	F	2	2	2	2
Bark River	0	F		IA	0	F
Amnicon River	3	1		IA		IA
Poplar River/Bardon Creek	—	IA	—	IA	0	F
Total	14	9	8	6	9	9
Young/Occupied Nest		0.9		1.0		0.8
Nestling Mortality		36%		25%		0%

^a F = Failed.

^b IA = Inactive.

about 6 months of age, was also recovered, after being electrocuted in Salem, Florida on 6 December 1984.

Young died in 2 island nests at about 5 weeks of age in 1985. One of 2 young died in the nest on Michigan Island; cause of death is unknown. The death of an adult may have contributed to the mortality of a single nestling on North Twin Island. Nest abandonment may occur after the death of 1 parent, resulting in nestling mortality (Ohmart and Sell 1980).

Nestling survival improved in 1986 along the Lake Superior shoreline. All of the 9 young produced there survived to fledging. However, 1 of 2 young from Devils Island was found in a weakened condition on 4 September 1986 on the Chippewa National Forest in Minnesota. It died shortly afterward. Necropsy is incomplete at this time. Post-fledging survival for most eagles produced near Lake Superior is unknown. The juvenile from North Twin Island which was electrocuted in Florida appeared to have been healthy prior to its death, e.g. no diseases were detected and lipid levels in the carcass indicated the bird was not starving.

The numbers of dead young found on the islands and nearby mainland shoreline during 1984 and 1985 were high compared to other areas. Nestling mortality among Lake Superior nests was 36% (5 of 14) in 1984 and 25% (2 of 8) in 1985. Four of the 7 dead young were from the Apostle Islands. Inland mortality was 3.7% (10 of 274) in 1984

and 3.9% (11 of 283) in 1985. Actual inland mortality was probably higher. The figures presented were calculated from the number of young found dead at the time of banding, reported to have died afterward, or found the following year. This does not include young that died early and were not present at nests during banding. Kussman (1977) reported 5.2% (3 of 58 nestlings) mortality for nestlings on the Chippewa National Forest, Minnesota from 1970-1973. Fraser (1981) found 6 of 164 nestlings dead in nests from the same area during 1974-1978. An additional 7 disappeared, some or all of which may have died in the nest and been removed by adults or scavengers, resulting in 8% nestling mortality.

Trends in reproductive success are a more accurate indicator of environmental quality than productivity within individual years (Wiemeyer et al. 1984). The trend toward increased production in the AINL since 1980 may be a result of several factors. Some of the failures were most certainly due to chemical contamination. Addled eggs collected from Madeline and Michigan Islands in 1980 and 1982 contained elevated levels of DDE (13, 14 ppm), dieldrin (1.0, 1.1 ppm), PCB (6.8, 12 ppm) and mercury (0.4, 0.47 ppm) (S. Wiemeyer, unpub. data). Wiemeyer et al. (1984) reported mean 5-year production was near normal in breeding areas containing <3.0 ppm DDE in eggs. Production decreased substantially at levels exceeding 5.1 ppm DDE and near complete failure occurred

in breeding areas where DDE was >15.0 ppm. Mean 5 year production estimates from Apostle Island eggs are 0.29 and 0.27 young/active nest for nests on Madeline and Michigan Islands, respectively. Dieldrin and mercury may adversely affect reproduction at egg levels >1.0 ppm and 0.5 ppm, respectively (Wiemeyer et al. 1984). Residues in bald eagle eggs from the Apostle Islands approach or exceed these values. Effects of PCB's on bald eagle reproduction are unknown as PCB's are commonly correlated with DDE residues (Weimeyer et al. 1984).

DDE levels are negatively correlated with eggshell thickness (Wiemeyer et al. 1984). Eggs probably did not hatch on Oak Island in 1984, but eggshell fragments did not implicate thinning as a factor (Table 2). Sindelar (1983) reported the presence of young birds in the AINL breeding population. Some nest failures may have been the result of young or non-breeding pairs laying eggs but not completing incubation (Newton 1979). Eggshell fragments collected from 5 nests during 1983 through 1985 showed only a moderate amount of thinning (0%-8%). These data are approximations only however, because the position of fragments on the egg was unknown and there is a potential for decrease in eggshell thickness during the latter part of embryonic development (Kreitzer 1972). Thinning >15-20% is associated with a declining population (Anderson and Hickey 1972, Newton 1979).

Weather may affect productivity in individual years

Table 2. Thickness of eggshell fragments collected from bald eagle nests on the Apostle Islands and nearby mainland shoreline of Lake Superior, 1983-1985.

Nest	Year	Success in year collected	Approximate adjusted thickness (mm)	% Change from pre-1946 norm
Outer Island	1983	1	0.64	+5
Oak Island	1984	F	0.61	0
N. Twin Island	1984	2	0.56	-8
Outer Island	1985	1	0.58	-5
Sand River	1985	2	0.60	-2

(Postupalsky 1967) or at individual nests but the consistency of reproductive failure in the Lake Superior bald eagle population suggests it is more likely related to other factors. In addition, some of the failures occurred late in the season when weather conditions were relatively mild.

Disturbance may also affect productivity and was monitored during 1984 and 1985. Eagles are known to be sensitive to a variety of disturbances during the nesting season although there is considerable variation among individuals (Mathisen 1968, Northern States Bald Eagle Recovery Plan 1983, BioSystems Analysis and University of California, Davis 1985, Fraser et al. 1985). Human disturbance in the AINL appears to be minimal during the critical periods of breeding, incubation and early hatching (March through mid-June). July and August are the periods of highest public use within the AINL, but visitation to islands with active nests was low throughout the summer. Visitation to Outer and Michigan Islands was only 3% of recorded island visitation and only 0.5% of total park visitation during 1984 and 1985. In addition, 97% of the visitors to Outer and Michigan Islands came after 30 June (Monthly public use report, AINL, unpub.). North Twin Island is currently designated as a "Protected Natural Area Subzone" (National Park Service 1984a). No docking or camping is allowed there and only 1 instance of visitation to this island was known. In addition, eagle nests in the AINL were generally located in remote

areas during 1984 and 1985, therefore boat disturbance would have been more common than other types, especially at Michigan and North Twin Islands where nests were located closer to the shoreline. In 1984, adults at Michigan and North Twin Islands flushed at 100 m and 50 m from the research boat, respectively, although eagles on Michigan Island were noticeably nervous and uttered defense calls from the nest when the research boat was within 150 m in 1985. This pair later became habituated and tolerated boat distances of 50 m or less. Only 7 boats with park visitors came within 200 m of the shoreline near nest areas at Michigan and North Twin Islands in 772 hours of observation. Park Service rangers also made weekly or biweekly boat patrols of these areas. Most of the boat traffic on Outer Island was associated with boats coming into the dock. Eagles used the bay east of the dock to hunt. However, eagles perched in the east bay did not flush as boats came into the dock, 0.8 km distant, and only once was an eagle on Outer Island observed to alter its flight direction in response to a moving boat. In general, disturbance did not appear to be a factor affecting productivity or survival.

Survival

Brown streaking on the head and tail of adult females at Outer and Michigan Islands indicate both pairs experienced a replacement in 1985. The documented death

of an adult eagle on North Twin island and the replacement of adults on Michigan and Outer Islands indicate a high turnover among breeding adults during 1985. Cause of death for the adult female on North Twin Island is unknown; decomposition of the carcass was too advanced for thorough autopsy or contaminant analysis. The bird was sexed by measurement according to Bortolotti (1984). Survival rates may be more important than reproductive success (Grier 1982), as population turnover may mask the loss of breeding adults. Increased productivity at individual nest sites is likely due to pair member replacement rather than decreases in contaminant loads of existing adults, as DDE loss rates in birds is slow (Stickel et al. 1984, Grier 1982). Grier (1982) suggested the rapid recovery of bald eagles in northwestern Ontario, following the ban on DDT, may have been due to a high turnover among breeding adults. The current production in the Apostle Islands and along the mainland shoreline of Lake Superior may also be due to a younger breeding population, with low contaminant levels, dispersing from the inland population. The Lake Superior population is likely maintained by ingress and might even be expected to increase as available habitat is filled. Occupied territories in the Apostle Islands increased from 3 in 1985 to 5 in 1986. Overall production, however, will probably not increase until contaminants sufficiently decrease in the prey base. Survival within

the Lake Superior population needs to be examined and may be the most important element of population dynamics among Lake Superior eagles.

Contaminant Levels in Bald Eagles

Chemical contaminants may have been a factor in the survival of nestling bald eagles. The dead nestling collected from Michigan Island in 1985 contained elevated brain and tissue levels of DDE and PCB's (Table 3), likely associated with the increased use of herring gulls as a food source at this nest. Levels of contaminants among the other dead eagles from nests near Lake Superior were low but still higher than elsewhere in the state (WDNR, unpub. data). Mercury levels were slightly elevated in the juvenile from North Twin Island that was eletrocuted in Florida at about 6 months of age. It had 4.4 ppm mercury in its kidney. The source of mercury is unknown; it may have been ingested locally or during migration. The nestling from the Amnicon River nest contained 2 ppm of a toxaphene-like substance. Toxaphene was banned as a pesticide in 1982 although existing stocks can be used through 1986 (Environmental Protection Agency 1979). Major use areas included the Dakotas, California and the southeastern United States (Rice and Evans 1984, International Joint Commission 1985). Toxaphene was detected in Lake Superior fish during this study and reported by Schmitt et al. (1983), suggesting

Table 3. Concentrations of environmental contaminants in 5 eaglets and 1 juvenile bald eagle from Lake Superior and inland Wisconsin nests, 1984 and 1985.

Nest	% lipid	<u>Residue concentration (ppm wet weight)</u>							mercury	
		o,p-DDT	o,p-DDD	p,p-DDD	p,p-DDE	dieldrin	endrin	PCB		
<u>Lake Superior</u>										
Michigan Is.										
Brain	---	0.18	0.16	0.28	16.0	0.97	0.17	42.0		
Breast	0.6	N.D. ^a	N.D.	0.06	5.3	0.29	0.03	14.0		
Kidney										0.54
Amnicon River ^b										
Brain	---	N.D.	N.D.	N.D.	1.8	0.13	N.D.	8.7		
Breast	0.8	N.D.	N.D.	0.06	1.1	0.07	N.D.	4.4		
Liver										1.0
N. Twin Is. ^c										
Brain	--	--	--	--	--	--	--	--		
Breast	0.8	N.D.	N.D.	N.D.	1.5	0.15	0.02	3.3		
Kidney										0.36
N. Twin Is. ^d										
Brain	8.0	0.05	0.06	0.09	1.5	0.19	0.05	2.9		
Breast	6.2	N.D.	N.D.	N.D.	0.12	0.03	N.D.	0.27		
Kidney										4.4
Liver										3.1
<u>Inland</u>										
Oneida Co.										
Brain	5.3	N.D.	N.D.	N.D.	0.09	0.04	N.D.	0.42		
Breast	7.2	N.D.	N.D.	N.D.	0.07	0.03	N.D.	0.27		
Kidney										0.52
Vilas Co.										
Brain	6.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
Breast	4.8	N.D.	N.D.	N.D.	0.06	N.D.	N.D.	N.D.		
Kidney										0.30

Table 3 continued.

Nest	c-chlordane	t-chlordane	c-nonachlor	t-nonachlor	hexachlorobenzene	gamma BHC	methoxychlor
<u>Lake Superior</u>							
Michigan Is.							
Brain	0.17	0.07	0.39	0.46	0.10	N.D.	0.14
Breast	N.D.	N.D.	0.07	0.14	0.03	N.D.	N.D.
Annicon River							
Brain	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Breast	N.D.	N.D.	N.D.	0.07	N.D.	N.D.	N.D.
N. Twin Is.							
Brain	--	--	--	--	--	--	--
Breast	N.D.	N.D.	N.D.	0.12	0.02	N.D.	N.D.
N. Twin Is.							
Brain	0.07	N.D.	0.10	0.11	0.02	0.01	N.D.
Breast	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
<u>Inland</u>							
Onieda Co.							
Brain	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Breast	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Vilas Co.							
Brain	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Breast	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

^a N.D. = not detectable.

^b Sample also contained 2 ppm of a toxaphene-like compound.

^c Sample is a 5 week old eaglet collected from the nest in 1985.

^d Sample is a 6 month old eagle from North Twin Island collected in Salem, Florida on 6 December 1984.

that atmospheric deposition is the major source of contamination (Rice and Evans 1984). Toxaphene was reported more often and in higher levels in Wisconsin bald eagle eggs than elsewhere in the U. S. between 1969 and 1979 (Wiemeyer et al. 1984). Its effect on birds is not well known. Although it is a lipophilic compound, domestic poultry and black ducks (Anas rubripes) were able to metabolize toxaphene faster than DDT or dieldrin (Bush et al. 1977, Haseltine et al. 1980), thereby reducing potential deleterious effects. Mehrle et al. (1979) found that reproduction and survival in black ducks fed 10 and 20 ppm toxaphene, was not affected although ducklings exhibited reduced growth and impaired backbones.

All contaminant levels in nestling bald eagles were well below those diagnostic of death due to pesticide poisoning. However, documentation on the effects of sub-lethal pesticide levels on nestling survival or parental behavior in bald eagles is lacking. Nestling mortality in pheasants (Phasianus colchicus) was significantly greater in the offspring of hens fed 50 mg PCB weekly than those fed 0 or 12.5 mg (Dahlgren and Linder 1971). Ring doves (Streptopelia risoria), fed a mixture of PCB, DDE, mirex and photomirex, altered incubation, brooding and feeding behavior and a dose related decrease in fledging success occurred (McArthur et al. 1983). Fox et al. (1978) found nest defense behavior and incubation attentiveness of Lake Ontario herring gulls negatively

correlated with female organochlorine levels. Incubation attentiveness decreased in ring doves fed 10 ppm PCB (Peakall and Peakall 1973). Dieldrin in the diet of mallards (Anas platyrhynchos) resulted in decreased flushing distance, nest defense and nest attentiveness and increased embryonic and duckling mortality rates (Winn 1973). However, sensitivity to organochlorine pollutants varies among species (Newton and Bogan 1978, Harris and Osborn 1981). PCB's did not significantly affect parental behavior or nestling survival in mallards (Custer and Heinz 1980), puffins (Fratercula arctica) (Harris and Osborn 1981), or British sparrowhawks (Accipiter nisus) (Newton and Bogan 1978). DDE contamination reduced nest defense behavior in merlins (Falco columbarus) (Fyfe et al. 1976, Fox and Donald 1980) but not in prairie falcons (Falco mexicanus) (Fyfe et al. 1976).

Nest attentiveness, i.e., percent of time adults spent in the nest or nest tree after hatching, was measured at Outer Island in 1984 and 1985. The same male was assumed to be present, however the female was replaced in 1985. Nest attentiveness was 100% during the 1st 2 weeks after hatching in 1985 and the 1st week in 1984 but decreased to 92% during the 2nd week in 1984 (Fig. 2). Bortolotti et al. (1983) and Gerrard et al. (1973) found nest attentiveness of bald eagles during the 1st 2 weeks after hatching was near 100% but varied

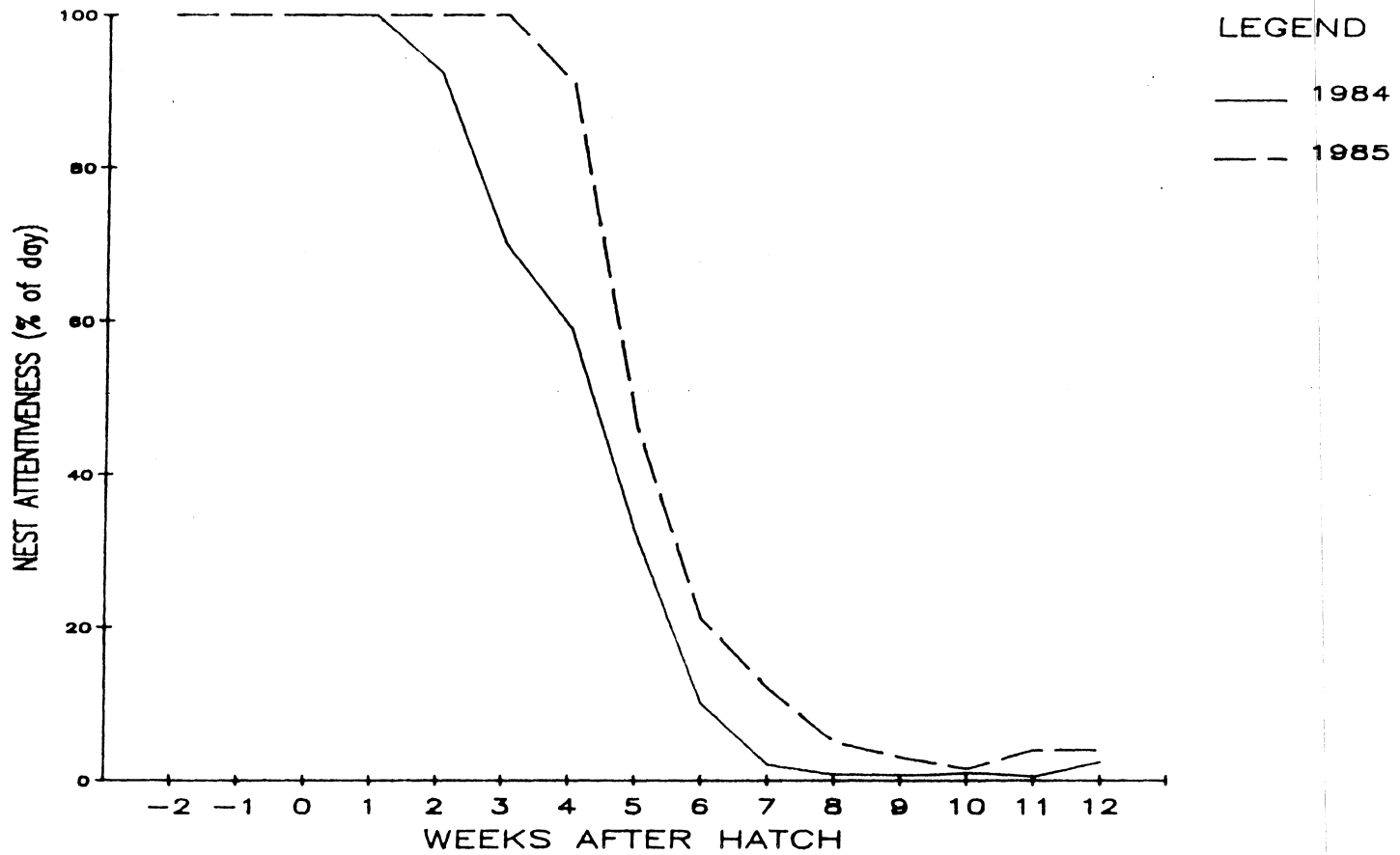


Fig. 2 Nest attentiveness of adult eagles on Outer Island, 1984 and 1985.

substantially after that time. Adults were on nearby perches an additional 3% of the time and may have been present on other perches not in the view of the observer the remaining 5%. Young were successfully fledged from the nest both years.

Food Habits

Feeding areas were located primarily along the shores near nest areas during late incubation, brood rearing and early post-fledging periods (Fig. 3). Ninety percent of 231 adult departures from the Outer Island nest area to adjacent shorelines were toward the north end of the island. The most heavily used area was the northwest or closest shoreline to the nest, with 87% of all northern departures being in that direction. Departures south or southwest, which may have been flights off the island, comprised only 5% each of all departures. In addition, the length of absence indicates that adults did not leave the island during all of these flights. The shorelines of nearby islands may also have afforded regular feeding areas for eagles nesting on Michigan and North Twin Islands. An adult eagle was observed flying from Michigan to Stockton Island on 12 June 1984 and an eagle of unknown age was seen flying from Michigan to Madeline Island on 4 July 1985. Sightings of adult bald eagles throughout the summer also suggest eagles are spending most of their time hunting near

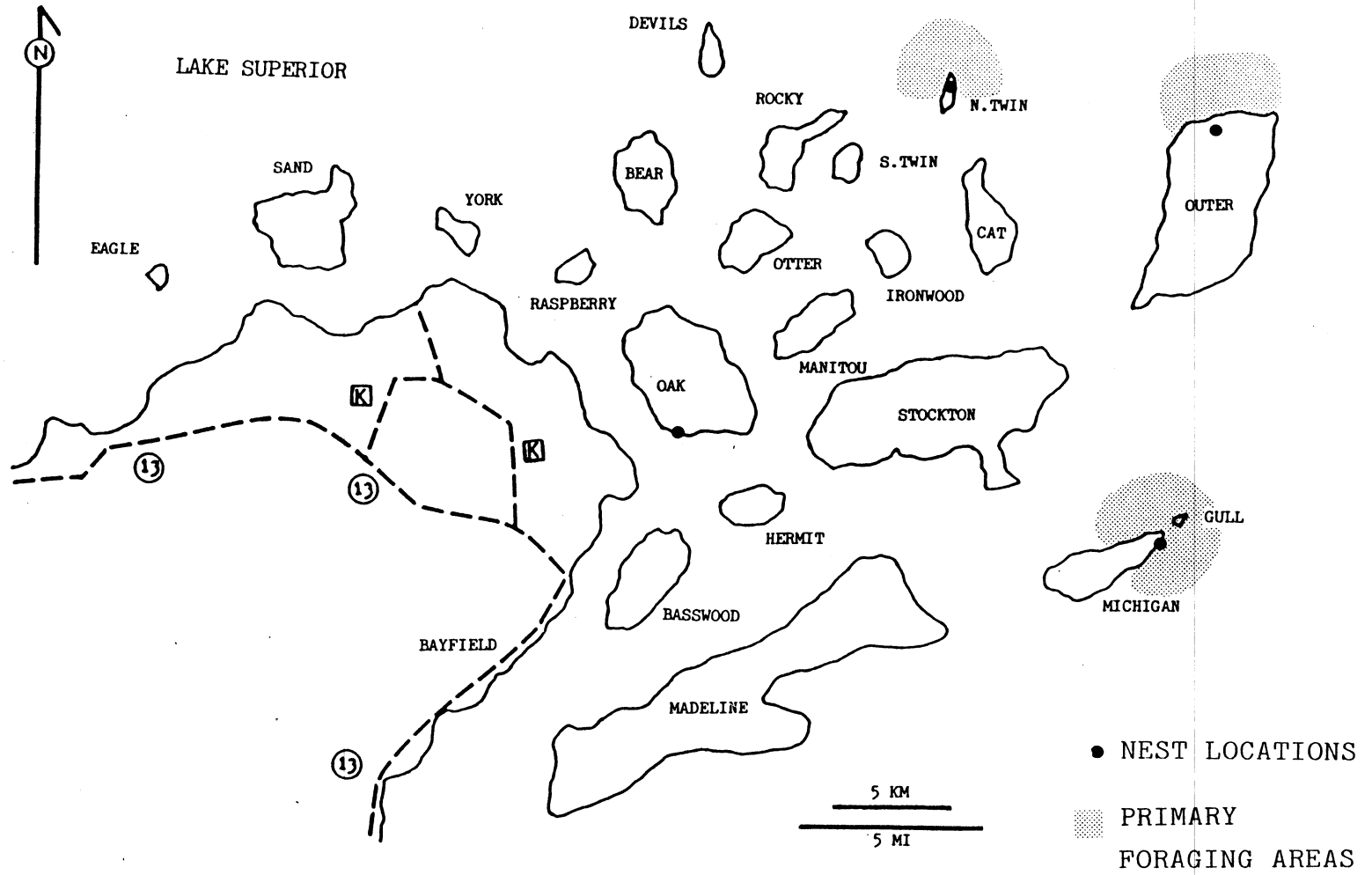


Fig. 3. Primary foraging areas and nest locations of bald eagles nesting within the AINL, 1984 and 1985.

nest areas (Fig. 4).

Fish species in food remains at nests were similar to those found in gill nets set along shorelines adjacent to nest areas, suggesting eagles were not foraging on the mainland where fish species would have varied slightly (Johannes et al. 1971). Seasonal variation in foraging areas may occur. In 1986, deer (Odocoileus virginianus) hair was found in the nest on North Twin Island which failed in early incubation (mid-April). This pair may have been hunting on or near the mainland during early spring as deer do not occur on the outer islands (Anderson and Stowell 1985). Eagles were observed leaving their nest areas to hunt after young fledged. Adult and young from North Twin Island were seen flying toward the north end of Stockton Island on 21 September 1984; eagles were reported by Park Service personnel to have been feeding there near this date.

Foraging attempts were observed 96 times: 86 involved fish and 10 involved avian prey. No scavenging was observed, except when eagles took rough fish thrown to them by commercial fishermen. Thirty-nine (45%) fishing attempts were farther than 1 km from the shoreline in water depths ranging from 5 m at Outer Island shoal to 76 m south of Michigan Island (\bar{x} water depth = 24 m). Twenty-eight (33%) fishing attempts occurred between 50 m and 1 km from the shoreline (\bar{x} water depth = 7 m) and 19 (22%) occurred <50 m from the shore. Low water temperatures of Lake Superior inhibit

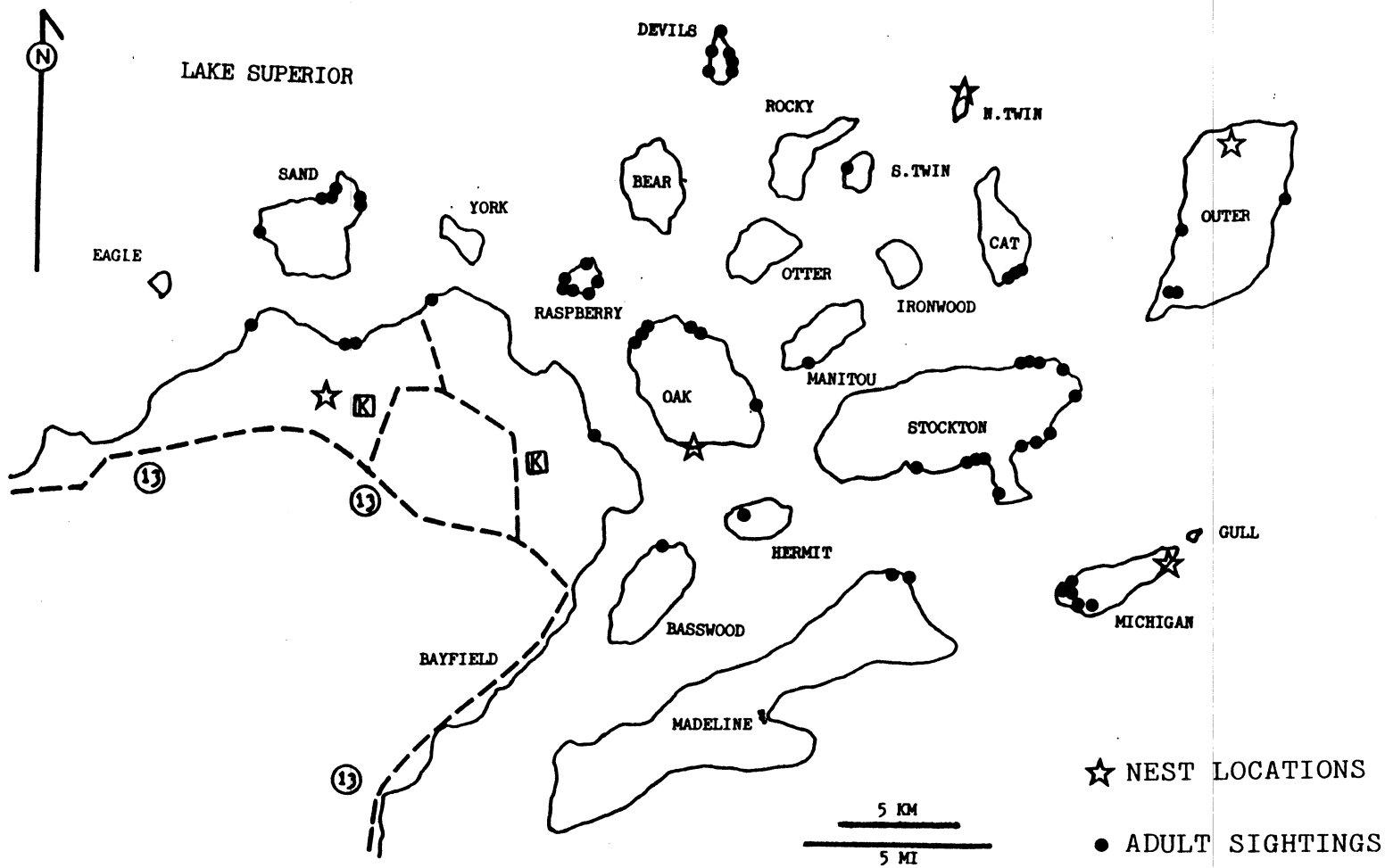


Fig. 4. Summer sightings of adult bald eagles on the Apostle Islands and nearby mainland shoreline, 1984 and 1985. Sightings near nest areas are not included.

bloating, resulting in dead fish sinking to the bottom, making them unavailable for eagles. Yet burbot, which are most common at 18-35 m during summer months in the Apostle Islands (Bailey 1972), were the 2nd most common species of fish in prey remains and were found throughout the summer. It is not known to what extent the commercial fishing industry contributes to the availability of certain fish species for eagles. Some fish may be injured or killed in nets and released which would explain their behavior near the surface of the water at distances so far from shore. Herrick (1934) noted eagles flying long distances out over Lake Erie. Presumably, this was hunting behavior similar to that observed in the Apostle Islands.

While eagles generally show a preference for fish (Wright 1953, Dunstan and Harper 1975, Ofelt 1975), diet may vary according to locality, time of year and prey availability (Retfalvi 1970, McEwan and Hirth 1980, Todd et al. 1982, Harmata 1984). Eagles are opportunistic feeders and will take advantage of seasonally abundant bird populations (Murie 1940, Wright 1953, Hayward et al. 1977, McEwan and Hirth 1980, Griffin et al. 1982). A large colony of herring gulls nest on Gull Island, 1.0 km from the eagle nest on Michigan Island. Gulls were a readily available food source for eagles at this nest and gull remains were found at the base of the eagle nest tree on Michigan Island during every visit. Seven

hunting attempts by eagles were observed on Gull Island. Adult gulls scattered at the approach of an eagle and began mobbing, leaving nestlings exposed. Four herring gull nestlings were present among food remains at the eagle nest on Michigan Island and a live immature gull was observed being taken on 8 August 1985. An adult gull was captured live by an eagle on North Twin Island in 1984. Double-crested cormorants (Phalacrocorax auritus) also nested in large numbers on Gull Island, and red-breasted mergansers (Mergus serrator) were common among the islands. However, these species were not represented in prey remains. Two adult eagles were observed cooperatively hunting a double-crested cormorant near Outer Island in 1984, but the attempt failed as did an attempt on a Canada goose (Branta canadensis) on 13 June 1985.

Harper (1974) estimated that 4 fish/day were brought to a Minnesota nest with 2 young. Observations of feeding flights of bald eagles in the AINL suggest similar feeding patterns. The average number of food items brought to the eagle nest on Outer Island with 2 young in 1984 was 3.4/day and to the nest with 1 young in 1985 was 2.6/day. These are estimates only as some deliveries were missed by observers due to the distance of the observation point from the nest (0.8 km). The number of food items brought to the nest does not vary substantially during the nestling, fledging and post-fledging periods (Retfalvi 1965, Harper 1974, this

study), although the amount of food consumed by the young changes over time. Craighead and Craighead (1956) concluded the average daily ration for nestling raptors was similar to that of adults. The average length of fish estimated from bones found among food remains in this study was 354 mm (range = 240-600 mm). Actual lengths of 4 fish found in nests averaged 366 mm. Weights averaged 0.3 kg.

Fish comprised 52.4% of prey remains at nests (Table 4). Common species at island nests included longnose and white suckers, burbot, and round whitefish. Families identified from scales include Catostomidae, Salmonidae (subfamily Coregoninae) and Cyprinidae. Available species include longnose and white suckers; round whitefish, lake whitefish (Coregonus clupeaformis), lake herring (Coregonus artedii) and bloater chub (Coregonus hoyi); and common carp. Birds, primarily herring gulls, comprised 46.9% of prey remains. White-tailed deer hair, found in the nest on North Twin Island, was the only mammal (0.7%) found among food remains, although 4 small rodents were observed being brought to the nest on Outer Island in 1984.

Similar food items were found at the Sand River and Fish Creek nests on the mainland. Fish species varied only slightly, and included species found both on the mainland and in Lake Superior. Scales were from fish in the families Catostomidae, Salmonidae (subfamily

Table 4. Food remains collected at bald eagle nest and perch trees on the Apostle Islands and nearby mainland shoreline.

Food Item	N	%
FISH		
Longnose sucker (<u>Catostomas catostomas</u>)	22	15.3
Burbot (<u>Lota lota</u>)	20	14.0
White sucker (<u>Catostomas commersoni</u>)	9	6.3
Sucker (<u>Catostomus</u> sp.)	9	6.3
Round whitefish (<u>Prosopium cylindraceum</u>)	5	3.5
Carp (<u>Cyprinus carpio</u>)	3	2.1
Brown bullhead (<u>Ictalurus nebulosus</u>)	2	1.4
Lake trout (<u>Salvelinus namaycush</u>)	2	1.4
Whitefish, chub or herring (<u>Coregonus</u> sp.)	2	1.4
Bloater chub (<u>Coregonus hoyi</u>)	1	0.7
TOTAL	75	52.4
BIRDS		
Herring gull (<u>Larus argentatus</u>)	28	19.6
Blue jay (<u>Cyanocitta cristata</u>)	7	4.9
Northern flicker (<u>Colaptes auratus</u>)	5	3.5
American bittern (<u>Botaurus lentiginosus</u>)	3	2.1
American coot (<u>Fulica americana</u>)	3	2.1
Broad-winged hawk (<u>Buteo platyperus</u>)	3	2.1
Sharp-shinned hawk (<u>Accipiter striatus</u>)	3	2.1
Common crow (<u>Corvus brachyrhynchos</u>)	2	1.4
Belted kingfisher (<u>Ceryle alcyon</u>)	2	1.4
Red-tailed hawk (<u>Buteo jamaicensis</u>)	1	0.7
Canvasback (<u>Aythya valisineria</u>)	1	0.7
Common merganser (<u>Mergus merganser</u>)	1	0.7
Wood duck (<u>Aix sponsa</u>)	1	0.7
Lesser golden plover (<u>Pluvialis dominica</u>)	1	0.7
Red-winged blackbird (<u>Agelaius phoeniceus</u>)	1	0.7
Hairy woodpecker (<u>Picoides villosus</u>)	1	0.7
Unidentified birds	4	2.8
TOTAL	67	46.9
MAMMALS		
White-tailed deer (<u>Odocoileus virginianus</u>)	1	0.7
TOTAL	1	0.7

Coregoninae), Cyprinidae, Percidae and Esocidae.

Available species for the additional families include walleye (Stizostedion vitreum) and yellow perch (Perca flavescens) in Percidae, and northern pike (Esox lucius) in Esocidae. All of the species in these families are commonly present along the mainland shoreline, tributaries draining into the lake, or inland sloughs (Johannes 1971, Becker 1983, Bailey, in prep). Eagles nesting on islands closer to the mainland, e.g., the nest on Oak Island in 1984 or the nest on York Island in 1986, may also feed on these species. Bird remains were present to a lesser extent at the 2 mainland nests. Mammals were absent in food remains at both mainland sites.

Food collections are a relatively accurate indicator of the variety of animals consumed but tend to underestimate fish whose parts are easily digested and decompose more rapidly than birds or mammals (Imler and Kalbach 1955, Dunstan and Harper 1975, Ofelt 1975, Todd et al. 1982). This was most notable on Outer Island where fish comprised 97% (N=218) of the observations and only 59% (N=19) of prey remains (Fig. 5). Fish represented 97% of total observations at all 3 nests. Birds and mammals each comprised 1.5% of observations.

Early spring food habits for bald eagles nesting in the AINL are unknown and may be a source of additional contamination. Prey selection just prior to egg laying would be especially important as increased body burdens

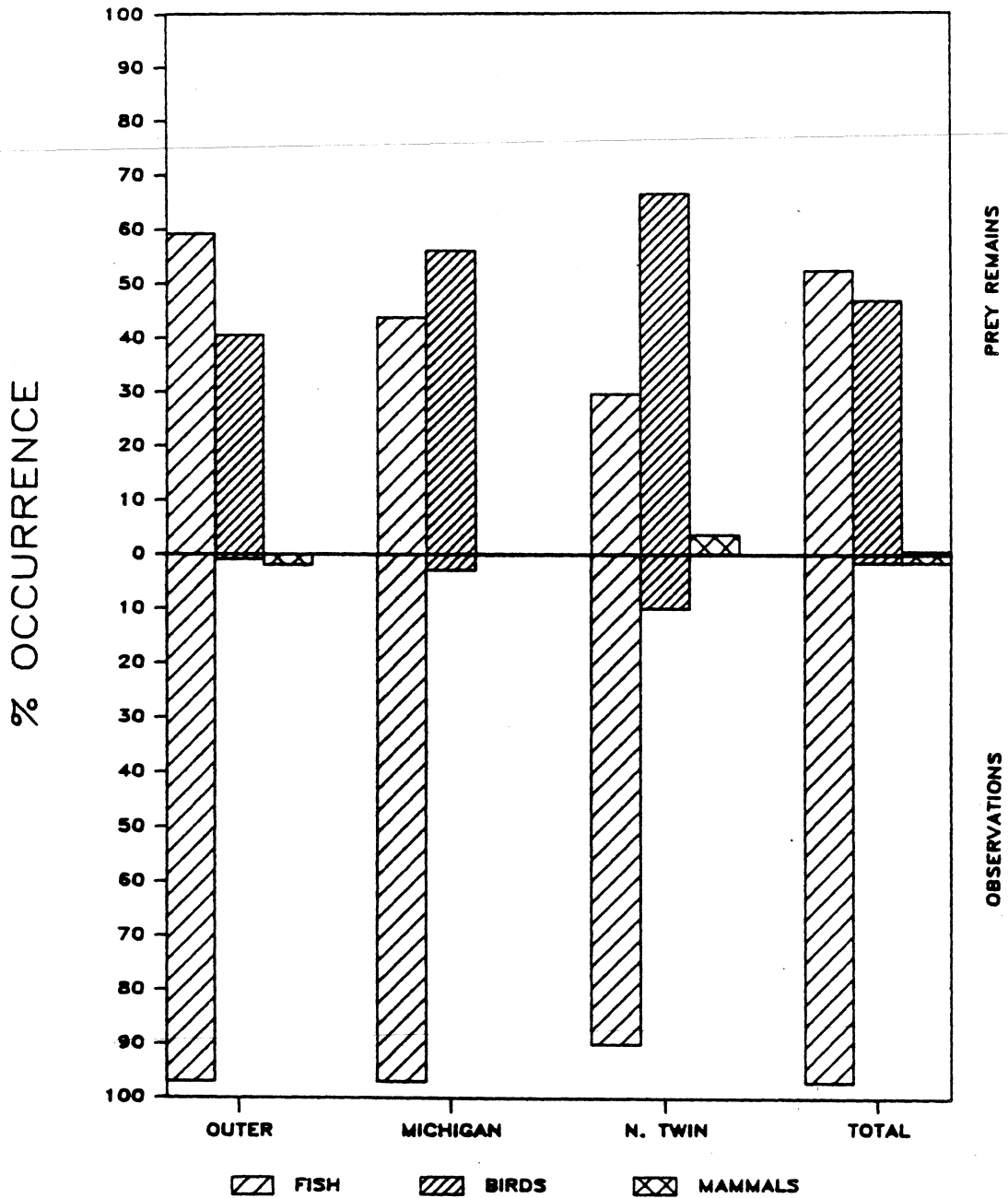


Fig. 5. Percent occurrence of observed food items vs. prey remains collected at Outer, Michigan and North Twin Islands. Total prey remains represents food items collected at all 8 nests.

at that time could result in excessive contamination of eggs and eggshell thinning (S. Wiemeyer, pers. commun.).

Herring gulls may be an available prey item in early spring when eagles return to breeding territories.

Herring gull remains were present at the nest on North Twin Island which failed in early incubation. Rough fish, discarded by commercial fishermen, may also be used prior to ice-out. The occurrence of migratory birds in the diet may increase during spring and fall. Lake Superior acts as a geographic barrier during migration. Birds funnel along its shoreline or congregate on the islands until favorable weather allows them to continue north across the lake (Temple and Harris 1985). Large waterfowl concentrations were present in the sloughs near Oak Point during the spring and fall of 1984 and adult and immature eagles were congregated near this area (T. Doolittle, Ashland bird bander, pers. commun., Andryk, 1984). Food remains collected from the nest on North Twin Island, which failed early in incubation, contained feathers from a broad-winged and a sharp-shinned hawk, suggesting migratory birds were used early in the nesting season. A snow goose (Chen caerulescens) was killed by eagles on Outer Island in the fall of 1981 (C. Loewecke, NPS ranger, pers. commun.). Migratory birds, wintering in areas where DDT or other organochlorine pesticides are still in use, may add additional contaminants to the eagle food chain.

Wintering areas are also a potential source of contamination although it is doubtful that the Lake Superior population winters in areas different from inland birds which are generally not experiencing reproductive problems. Migratory patterns, winter areas and winter diets of bald eagles in the Apostle Islands are unknown. There have been few band recoveries from Wisconsin adult eagles in winter (December-February). Most recoveries were related to accidental captures in traps set for furbearers; these birds were likely permanent residents associated with nesting territories (C. Sindelar, pers. commun.) and thus provide little information on wintering areas of other eagles.

Apostle Island eagles likely migrate most years although weather and food availability may cause a variance in the length of absence from nest areas. According to reports from commercial fisherman, local citizens, and Park Service personnel, eagles probably left the islands in late December and returned in late February to early March during 1984 and 1985. Numbers of reports increased in early March and included sightings on Michigan and Oak Islands in 1984 and 1985, respectively. Migration may not occur in mild winters.

Contaminants in Eagle Food Items

Eagles from the Apostle Islands were heavily dependent on fish during the breeding season, implicating

Lake Superior as a potential source of contamination. However, a comparison of contaminant concentrations in fish from Lake Superior with those reported in prey items of bald and white-tailed eagles (H. albicilla) (Koivurasaari et al. 1976, Wiemeyer et al. 1978, Frenzel 1984, Risebrough and Jarman 1985) indicated chemical concentrations in fish from the Apostle Island area were low (Table 5). DDE levels in fish from the Apostle Islands were also substantially lower than those found to cause eggshell thinning in American kestrels (Falco sparverius) (2.8 ppm) (Wiemeyer and Porter 1970) and also below 1 ppm which would represent the lower limit of cause for concern regarding eggshell thinning in bald eagles (S. Wiemeyer, pers. commun.).

Sources of contamination in Lake Superior fish are due almost entirely to atmospheric transport (International Joint Commission 1977, Murphy 1984, Schmidt and Andren 1984), although some local input has taken place. DDT and dieldrin contamination in the AINL area reflects past use in adjacent orchards on the Bayfield peninsula. (International Joint Commission 1977). Parismo et al. (1984) reported that an abundance of naturally occurring mercury deposits account for elevated mercury burdens in fish but mercury was also used as a pesticide by Bayfield orchard growers during the 1950's and 1960's (J. Torbick, Bayfield orchard grower, pers. commun.) and additional mercury was added to the ecosystem by pulp and paper industries during and

Table 5. Concentrations of environmental contaminants in fish from eagle foraging areas in the Apostle Islands, 1984 and 1985.

Species	Number of individuals per sample	% lipid	Residue concentration (ppm wet weight)			
			p,p'-DDE	Dieldrin	PCB	Mercury
Longnose sucker	5	3.4	0.14	0.02	0.34	0.09
Longnose sucker	5	2.8	N.D. ^a	N.D.	N.D.	N.D.
Longnose sucker	5	3.9	0.11	0.03	N.D.	0.10
Longnose sucker ^b	3	2.5	0.12	0.02	0.3	0.32
Round whitefish	6	4.6	0.03	N.D.	N.D.	0.03
Round whitefish ^c	2	1.6	0.06	N.D.	N.D.	0.08
Round whitefish ^d	1	3.2	N.D.	N.D.	N.D.	0.07
Burbot	2	4.4	0.10	0.02	0.38	0.29
Burbot ^e	2	6.0	0.13	0.03	0.50	0.45

^a N.D. = Not detectable.

^b Partially eaten fish from eagle nest on Michigan Island; samples are from 1/2 fish.

^c Sample is from eagle nest on N. Twin Island and contained 1 ppm of a toxaphene-like compound.

^d Fish found floating near shore on Outer Island.

^e Sample is from eagle nest on Michigan Island.

prior to the early 1970's (Shear 1984). Chemical contaminants in Lake Superior have decreased since the late 1960's. The average DDE concentration in fish collected in 1967-1968 was 0.46 ppm (range: 0.23-1.44 ppm) (Henderson et al. 1969). DDE concentrations in samples of AINL fish collected during this study averaged 0.07 ppm (range: N.D.-0.14 ppm). Contaminant concentrations in herring gull eggs also indicate there has been a downward trend in DDT, DDE, DDD, HCB, BHC, mirex and PCB's and samples of lake trout showed a decline in total DDT, PCB's and mercury. Dieldrin levels have remained consistently low (International Joint Commission 1985, Weseloh and Struger, unpub. manuscript, Can. Wildl. Serv., Burlington, Ont.). The highly oligotrophic water of Lake Superior retards the decomposition of contaminants. Thus, while contaminant levels are declining, residues of chemicals used in the past persist.

The proximity of the eagle nest on Michigan Island to Gull Island likely accounts for the disproportionate use of herring gulls as a food source by this pair. Bioaccumulated contaminants in the fish-eating herring gull probably contributes to the poor reproductive history at this nest. Herring gull eggs, sampled from 8 locations on Lake Superior, were analyzed in 1983 by the Canadian Wildlife Service. Eggs from Gull Island (AINL) contained the highest levels of DDE (4.65 ppm), dieldrin

(0.47 ppm), PCB's (28.4 ppm), HCB (0.08 ppm), oxychlorane (0.32 ppm) and heptachlor epoxide (0.25 ppm) of all areas sampled (Struger 1985). Herring gull eggs collected from Gull Island by the WDNR in 1979 also contained elevated levels of DDE (\bar{x} =17.7 ppm, range=8.8-40.4 ppm) and PCB (\bar{x} =27.6 ppm, range=13.4-61.6 ppm) (Matteson 1979). Higher levels of contaminants were attributed to the seasonal movements of some Lake Superior herring gulls to Lake Michigan, where their foods are more contaminated (Matteson 1979, Gilman et al. 1977). Contaminant concentrations in the eggs of 2 other fish-eating birds nesting near the AINL, common terns (*Sterna hirundo*) and ring-billed gulls (*Larus delawarensis*), were "low" (S. Matteson, pers. commun.).

Carcasses of adult, immature, and nestling herring gulls were analyzed (Table 6). The lower chemical concentrations in nestlings, compared to eggs, reflects a dilution of contaminants caused by rapid growth and low deposition rates of fat in young birds (Anderson and Hickey 1976). However, these levels were lower than expected given the age of the nestlings and the relatively high concentrations of contaminants in eggs (D. Weseloh, pers. commun.). The sample size was small and may not be representative of contaminant concentrations in nestlings from the AINL. Young gulls will continue to accumulate contaminants after fledging and attain levels similar to adults at about 1 year of age (Hickey et al. 1966). However, 2 of the immature

Table 6. Concentrations of environmental contaminants in herring gulls from the Apostle Islands, 1986.

Sample	Number of individuals per sample	% lipid	Residue concentration (ppm wet weight)							Mercury
			p,p'-DDE	Dieldrin	PCB	c-nonachlor	t-nonachlor	HCB	Heptachlor epoxide	
Adult	1	4.6	2.9	N.D. ^a	10.0	N.D.	N.D.	N.D.	N.D.	0.29
Adult	1	3.2	5.2	0.03	7.4	N.D.	N.D.	0.04	N.D.	0.16
Adult	1	2.2	8.0	0.04	9.6	N.D.	N.D.	0.02	N.D.	0.96
Immature ^b	1	18.0	5.2	0.25	14.0	0.09	0.11	0.06	N.D.	0.32
Immature ^c	1	18.0	6.9	0.39	20.0	0.13	0.18	0.06	0.59	0.46
Immature ^d	1	8.8	5.8	0.10	31.0	N.D.	N.D.	0.04	0.34	0.23
Nestling	2	7.3	0.31	N.D.	0.5	N.D.	N.D.	N.D.	N.D.	0.08

^a N.D. = Not detectable.

^b Sample is a juvenile-aged bird and also contained 5 ppm of a toxaphene-like compound and 0.07 ppm p,p'-DDD.

^c Sample is a juvenile-aged bird and also contained 4 ppm of a toxaphene-like compound.

^d Sample is a subadult bird and also contained 2 ppm of a toxaphene-like compound.

gulls sampled were juveniles which contained contaminant concentrations similar to or higher than those of adults. Higher lipid levels in juvenile gulls may have potentially increased the amount of stored contaminants. However, Anderson and Hickey (1976) reported that juvenile herring gulls contained lower contaminant burdens than adults in spring, despite higher lipid levels. Foraging habits of juvenile gulls may differ from those of adults. Juvenile gulls tend to feed at garbage dumps more often than adults, especially during fall dispersal (D. Weseloh, pers. commun.). Juvenile gulls feeding on the entrails of larger fish discarded by commercial fisherman into dumps near the AINL may increase contaminant burdens more quickly. The late sampling date for immatures (30 October) may also have influenced results. Due to the migratory habits of immature herring gulls (Gross 1940, Smith 1959, Gilman et al. 1977), these birds may not have originated in the AINL. Sample sizes were again small. The only other known sample of herring gulls from Lake Superior was a composite sample of 2 immatures and 1 adult gull collected on Isle Royale in 1983 which contained 10.6 ppm DDE and 28.8 ppm PCB's (National Park Service 1984b).

Adult and immature gulls from Lake Superior contained contaminant concentrations that were high enough (>2.8 ppm DDE) to contribute to the reproductive failure of bald eagles, especially when one considers the

numbers consumed by the Michigan Island pair. The impact of gull originated contaminants at the other island or Lake Superior shoreline nests in this study is problematic since numbers consumed during the nesting season appear to be low (Appendix 1). Food habits of eagles at the remaining nests along the Lake Superior shoreline are unknown although the carcass of an adult herring gull was found an eagle nest on the Bark River (Lake Superior) which failed prior to the 2nd survey flight in late May 1986.

Recommendations for Future Research and Management

Data on eagle food habits is lacking for other nests along the Lake Superior shoreline. An expanded study to include food habits and productivity of all eagles nesting near Lake Superior would provide important additional data. Monitoring of food habits and productivity of eagles nesting in the Apostle Islands should be continued. A complete aerial search of the islands should be conducted annually to locate active territories and provide accurate productivity data. Aerial surveys are currently limited to monitoring only previously active territories. Addled eggs and dead young or adults should be collected for contaminant analysis. The WDNR surveyed successful nests near Lake Superior weekly in 1986 to monitor nestling survival. This should be continued in succeeding years if nestling

mortality remains high among nests near Lake Superior.

Herring gulls appear to be the primary source of contamination in the AINL bald eagle population. Food habits, foraging areas, and migratory patterns of these gulls are unknown and should be determined. Trends in contaminant concentrations should be monitored in the Gull Island herring gull colony. Migratory birds, wintering in areas where DDT and other organochlorine pesticides are still in use, should also be sampled. The Apostle Islands are located adjacent to agricultural and industrial areas. The presence and effects of more recent environmental contaminants, e.g. organophosphates, carbamates, and dioxins should be determined.

Disturbance did not appear to affect productivity or survival of bald eagles in the AINL. Management recommendations in Anderson and Stowell (1985) should be used if buffer zones need to be established at nest sites. Visitor use is discouraged but not strictly prohibited on North Twin Island. North Twin should be closed to all human activity when an active nest exists on the island as eagles use the entire island during the nesting season. Boats should maintain a distance of 200 m from shore near all nest and foraging areas.

LITERATURE CITED

- Abbott, J. M. 1967. The Chesapeake bald eagles. *Atl. Nat.* 22:20-25.
- _____ and _____. 1972. Eggshell changes in certain North American birds. *Proc. Int. Ornithol. Congr.* 15:514-540.
- Anderson, D. W., and J. J. Hickey. 1976. Dynamics of storage of organochlorine pollutants in herring gulls. *Environ. Pollut.* 10:183-200.
- Anderson, R. K., and L. R. Stowell. 1985. Wildlife management plan for select habitats and species of the Apostle Islands National Lakeshore. Final Rep. to Natl. Park Serv., Omaha, NE. 184 pp.
- Andryk, T. 1984. Waterfowl survey of the Chequamegon Bay-Kakagon Slough area in northern Wisconsin. Great Lakes Indian Fish and Wildl. Comm., Biol. Serv. Div., Odonah, WI.
- Bailey, M. M. 1972. Age, growth, reproduction and food of the burbot, Lota lota (Linnaeus), in southwestern Lake Superior. *Trans. Am. Fish Soc.* 101:667-674.
- Bailey, M. M. In prep. Aquatic resources management plan for AINL. Natl. Park Serv., Apostle Island Natl. Lakeshore. Bayfield, WI.
- Becker, G. C. 1983. Fishes of Wisconsin. Univ. Wisc. Press, Madison. 1052 pp.
- Beals, E. W., and G. Cottam. 1960. The forest vegetation of the Apostle Islands, Wisconsin. *Ecology* 41:785-790.
- BioSystems Analysis, Inc., and University of California, Davis. 1985. Pit 3, 4, and 5 project. Bald eagle and fish study. Final Rep. to Pacific Gas and Electric Co.
- Blus, L. J. 1982. Further interpretation of the relation of organochlorine residues in brown pelican eggs to reproductive success. *Environ. Pollut.* 28A:15-33.
- Bortolotti, G. R. 1984. Sexual size dimorphism and age-related size variation in bald eagles. *J. Wildl. Manage.* 48:72-81.

- _____, J. M. Gerrard, P. N. Gerrard, and D. W. Whitfield. 1983. Minimizing investigator-induced disturbance to nesting bald eagles. Pages 85-103 in J. M. Gerrard and T. N. Ingram (eds.) The bald eagle in Canada. Proceedings of bald eagle days, 1983. Hignell Printing, Winnipeg, Manit.
- Broley, C. L. 1958. The plight of the American bald eagle. Audubon 6:162-171.
- Bush, P. B., J. T. Kiker, R. K. Page, N. H. Booth, and O. J. Fletcher. 1977. Effects of graded levels of toxaphene on poultry residue accumulation, egg production, shell quality, and hatchability in White Leghorns. J. Agric. Food Chem. 24:928-932.
- Cade, T. J., J. L. Lincer, C. M. White, D. G. Roseneau, and L. G. Swartz. 1971. DDE residues and eggshell changes in Alaskan falcons and hawks. Science 172:995-957.
- Cooke, A. S. 1973. Shell thinning in avian eggs by environmental pollutants. Environ. Pollut. 4:85-152.
- Craighead, J. J., and F. C. Craighead, Jr. 1956. Hawks, owls and wildlife. The Stackpole Co., Harrisburg, PA. 443 pp.
- Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wisc. Press, Madison. 657 pp.
- Custer, T. W., and G. H. Heinz. 1980. Reproductive success and nest attentiveness of mallard ducks fed Aroclor 1254. Environ. Pollut. 21A:313-318.
- Dahlgren, R. B., and R. L. Linder. 1974. Effects of dieldrin in penned pheasants through the third generation. J. Wildl. Manage. 38:320-330.
- Dunstan, T. C. and J. F. Harper. 1975. Food habits of bald eagles in north-central Minnesota. J. Wildl. Manage. 39:140-143.
- Environmental Protection Agency. 1979. Suspended and cancelled pesticides. Office of Public Awareness. Washington D.C. 20 pp.
- Fox, G. A., and T. Donald. 1980. Organochlorine pollutants, nest defense behavior and reproductive success in merlins. Condor 82:81-84.
- _____, A. P. Gilman, D. B. Peakall, and F. W. Anderka. 1978. Behavioral abnormalities of nesting Lake Ontario herring gulls. J. Wildl. Manage. 42:477-483.

- Fraser, J. D. 1981. The breeding biology and status of the bald eagle on the Chippewa National Forest. Ph.D. Thesis, Univ. Minn., St. Paul. 236 pp.
- _____, L. D. Frenzel and J. E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. *J. Wildl. Manage.* 49:585-592.
- Frenzel, R. W. 1984. Environmental contaminants and ecology of bald eagles in southcentral Oregon. Ph.D. Thesis, Oregon State Univ., Corvallis. 143 pp.
- Fyfe, R. W., R. W. Risebrough, and W. Walker II. 1976. Pollutant effects on the reproduction of the prairie falcons and merlins of the Canadian prairies. *Can. Field Nat.* 90:346-355.
- Gerrard, J. M. 1983. A review of the current status of bald eagles in North America. Pages 5-21 in D.M. Bird (chief ed.). *Biology and management of bald eagles and ospreys.* Harpell Press, Ste. Anne de Bellevue, Que.
- _____, P. N. Gerrard, D. W. Whitfield, and W. J. Maher. 1973. Bald eagle behaviour study. Part II. Final Rep. to Can. Wildl. Serv. 90 pp.
- Gilman, A. P., G. A. Fox, D. B. Peakall, S. M. Teeple, T. R. Carroll, and G. T. Haymes. 1977. Reproductive parameters and egg contaminant levels of Great Lakes herring gulls. *J. Wildl. Manage.* 41:458-468.
- Grier, J. W. 1974. Reproduction, organochlorines, and mercury in Northwest Ontario bald eagles. *Can. Field Nat.* 88:469-475.
- _____. 1982. Ban on DDT and subsequent recovery of reproduction in bald eagles. *Science* 218:1232-1235.
- Griffin, C. R., T. S. Baskett, and R. D. Sparrowe. 1982. Ecology of bald eagles wintering near a waterfowl concentration. U. S. Dep. Inter., Fish Wildl. Serv., Spec. Sci. Rep., Wildl. No. 247. 12 pp.
- Gross, A. O. 1940. The migration of Kent Island herring gulls. *Bird Banding* 11:129-155.
- Grubb, T. G., and D. M. Rubink. 1978. First bald eagle eggs collected for analysis in Arizona. U.S. Dep. Agric., For. Serv. Res. Note RM-352, 2 pp.

- Harmata, A. L. 1984. Bald eagles of the San Luis Valley, Colorado: their winter ecology and spring migration. Ph.D. Thesis, Mont. State Univ., Bozeman. 222 pp.
- Harper, J. F. 1974. Activities of fledgling bald eagles in north-central Minnesota. M.S. Thesis. Western Ill. Univ., Macomb. 68 pp.
- Harris, M. P., and D. Osborn. 1981. Effect of a polychlorinated biphenyl on the survival and breeding of puffins. J. Appl. Ecol. 18:471-475.
- Haseltine, S. D., M. T. Finley, and E. Cromartie. 1980. Reproduction and residue accumulation in black ducks fed toxaphene. Arch. Environ. Contam. Toxicol. 9:461-471.
- Hayward, J. L. Jr., W. H. Gillet, C. J. Amlaner, Jr. and J. F. Stout. 1977. Predation on gulls by bald eagles in Washington. Auk 94:375.
- Heath, R. G., J. W. Spann, and J. F. Kreitzer. 1969. Marked DDE impairment of mallard reproduction in controlled studies. Nature 224:47-48.
- Helander, B., M. Olsson, and L. Teutergardh. 1982. Residue levels of organochlorine and mercury compounds in unhatched eggs and relationships to breeding success in white-tailed sea eagles (Haliaeetus albicilla) in Sweden. Holarctic Ecol. 5:349-366.
- Henderson, C., W. L. Johnson, and A. Inglis. 1969. Organochlorine insecticide residues in fish (National Pesticide Monitoring Program). Pestic. Monit. J. 3: 145-171.
- Henny, C. J. 1977. Birds of prey, DDT, and tussock moths in Pacific Northwest. Trans. N. Am. Wildl. Conf. 42:397-411.
- Herrick, F. H. 1934. The American eagle: A study in natural and civil history. Appleton-Century Co., New York. 267 pp.
- Hickey, J. J. and D. W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162:271-273.
- _____, Keith J. A., and F. B. Coon. 1966. An exploration of pesticides in a Lake Michigan ecosystem. J. Appl. Ecol. 3 (suppl.):141-154.

- Imler, R. H. and E. R. Kalmbach. 1955. The bald eagle and its economic status. U.S. Fish and Wildl. Serv. Circ. 30. 51 pp.
- International Joint Commission. 1977. Waters of Lake Huron and Lake Superior. Vol. 1. Summary and recommendations. Great Lakes Reg. Off., Int. Joint Comm., Windsor, Ont. 236 pp.
- International Joint Commission. 1980. Pollution in the Great Lakes basin from land use activities. Great Lakes Reg. Off., Int. Joint Comm., Windsor, Ont. 141 pp.
- International Joint Commission. 1985. Report on Great Lakes water quality - 1985. Great Lakes Reg. Off., Int. Joint Comm., Windsor, Ont. 212 pp.
- Johannes, S. I., L. M. Sather, and C. W. Threinen. 1971. Surface water resources of Bayfield Co. Wisc. Dept. Nat. Resour., Madison. 372 pp.
- Koivusaari, J., I. Nuvja, R. Palokangas, and M-L. Hattula. 1976. Chlorinated hydrocarbons and total mercury in the prey of the white-tailed eagle (Haliaeetus albicilla L.) in the Quarken Straits of the Gulf of Bothnia, Finland. Bull. Environ. Contam. Toxicol. 15:235-241.
- Kreitzer, J. F. 1972. The effect of embryonic development on the thickness of the eggshells of Coturnix quail. Poultry Sci. 51:1764-1765.
- Kussman, J. V. 1977. Post-fledging behavior of the northern bald eagle (Haliaeetus leucocephalus alascanus Townsend), in the Chippewa National Forest, Minnesota. Ph.D. Thesis, Univ. Minn., St. Paul. 434 pp.
- Lagler, K. F. 1952. Freshwater fishery biology. W. C. Brown Co., Dubuque, Iowa. 360 pp.
- Lincer, J. L. 1975. DDE induced eggshell thinning in the American kestrel: a comparison of the field situation and laboratory results. J. Appl. Ecol. 12:781-793.
- Madsen, C. R., T. J. Sheldrake, J. T. Leach, and J. Engel. eds. 1985. Bald eagle production in the Great Lake States 1973-1985. U.S. Fish and Wildl. Serv., Twin Cities, MN. 25 pp.
- Mathisen, J. E. 1968. Effects of human disturbance on nesting of bald eagles. J. Wildl. Manage. 32:1-6.

- Matteson, S. W. 1979. Status of breeding gulls and terns on the Wisconsin shore of Lake Superior in 1979. Final rep. to Natl. Park Serv. and Wisc. Dep. Nat. Resour.
- McArthur, M. L., G. A. Fox, D. B. Peakall, and B. J. Philogene. 1983. Ecological significance of behavioral and hormonal abnormalities in breeding ring doves fed an organochlorine chemical mixture. Arch. Environ. Contam. Toxicol. 12:343-353.
- McEwan, L. C., and D. H. Hirth. 1980. Food habits of bald eagles in north-central Florida. Condor 82:229-231.
- McLane, M. A., and L.C. Hall. 1972. DDE thins screech owl egg-shells. Bull. Environ. Contam. Toxicol. 8:65-68.
- Mendenhall, V. M., E. E. Klaas, and M. A. McLane. 1983. Breeding success of barn owls (*Tyto alba*) fed low levels of DDE and dieldrin. Arch. Environ. Contam. Toxicol. 12:235-240.
- Mehrle, P. M., M. T. Finley, J. L. Ludke, F. L. Mayer, and T. E. Kaiser. 1979. Bone development in black ducks as affected by dietary toxaphene. Pestic. Biochem. Physiol. 10:168-173.
- Mollhagen, T. R., F. J. Wiley, and R. L. Packard. 1972. Prey remains in golden eagle nests: Texas and New Mexico. J. Wildl. Manage. 36:784-792.
- Murie, O. J. 1940. Food habits of the northern bald eagle in the Aleutian Islands. Condor 42:784-792.
- Murphy, T. J. 1984. Atmospheric inputs of chlorinated hydrocarbons to the Great Lakes. Pages 53-79 in J. O. Nriagu and M. S. Simmons (eds.). Toxic contaminants in the Great Lakes. John Wiley and Sons, New York.
- National Oceanic and Atmospheric Administration. 1984. Climatological data, annual summary - Wisconsin. Vol. 89, No. 13. U.S. Dep Commerce, Natl. Oceanic and Atmospheric Admin. 25 pp.
- National Oceanic and Atmospheric Administration. 1985. Climatological data, annual summary - Wisconsin. Vol. 90, No.13. U.S. Dep Commerce, Natl. Oceanic and Atmospheric Admin. 25 pp.
- National Park Service. 1984a. Land protection plan, Apostle Islands National Lakeshore. Natl. Park Serv., Apostle Island Natl. Lakeshore. 45 pp.

- National Park Service. 1984b. Peregrine Falcon reestablishment plan and environmental assessment. Natl. Park Srev., Isle Royale Natl. Park. 42 pp.
- Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, SD. 339 pp.
- _____, and J. Bogan. 1978. The role of different organochlorine compounds in the breeding of British sparrowhawks. J. Appl. Ecol. 15:105-116.
- Northern States Bald Eagle Recovery Team. 1983. Northern states bald eagle recovery plan. U.S. Dep. Inter., Fish and Wildl. Serv., Washington, D.C. 117 pp.
- Ofelt, J. C. 1975. Food habits of bald eagles in southeast Alaska. Condor 77:337-338.
- Ohmart, R. D., and R. J. Sell. 1980. The bald eagle of the southwest with special emphasis on the breeding population of Arizona. Final Rep. to U.S. Dept. Inter., Water and Power Res. Serv. 95 pp.
- Parismo, M. E., J. R. St. Amant, and T. B. Sheffy. 1984. Microcontaminants in Wisconsin's coastal zone. Pages 265-285 in J. O. Nriago and M. S. Simmons (eds.). Toxic contaminants in the Great Lakes. John Wiley and Sons, New York.
- Peakall, D. B. 1970. Pesticides and the reproduction of birds. Sci. Am. 222:73-78.
- _____, and M. L. Peakall. 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. J. Appl. Ecol. 10:863-868.
- Porter, R. D., and S. N. Wiemeyer. 1969. Dieldrin and DDT: effects on sparrowhawk eggshells and reproduction. Science 165:199-200.
- Postupalsky, S. 1967. Reproductive success and population trends in the bald eagle in Michigan. M.S. Thesis, Univ. Michigan Biol. Station, Ann Arbor.
- _____, 1971. Toxic chemicals and declining bald eagles and cormorants in Ontario. Can. Wildl. Serv., Pestic. Sect., Rep. No. 20. 45 pp.
- Prevost, Y. A. 1984. A perch snare for catching ospreys. J. Wildl. Manage. 48:991-993.
- Rauber, T. J. 1976. Notes on a New York nest of the bald eagle. Kingbird 26:122-135.

- Retfalvi, L. I. 1965. Breeding behavior and feeding habits of the bald eagle (Haliaeetus leucocephalus L.) on San Juan Island, Washington. M.S. Thesis, Univ. British Columbia, Vancouver. 180 pp.
- _____. 1970. Food of nesting bald eagles on San Juan Island, Washington. Condor 72:358-361.
- Rice, C. P., and M. S. Evans. 1984. Toxaphene in the Great Lakes. Pages 163-193 in O. J. Nriagu and M. S. Simmons (eds.). Toxic contaminants in the Great Lakes. John Wiley and Sons, New York.
- Risebrough, R. W., and W. M. Jarman. 1985. Organochlorine contaminants in California bald eagles: origins and potential effects on reproduction. Rep. to Pacific Gas and Electric Co. 28 pp.
- Schmidt, J. A. and A. W. Andren. 1984. Deposition of airborne metals into the Great Lakes: An evaluation of past and present estimates. Pages 81-103 in J. O. Nriagu and M. S. Simmons. Toxic contaminants in the Great Lakes. John Wiley and Sons, New York.
- Schmitt, C. J., M. A. Ribick, J. L. Ludke, and T. W. May. 1983. Organochlorine residues in freshwater fish, 1976-1979: Pesticide Monitoring Program. U. S. Fish Wildl. Serv., Resour. Pub. No. 152.
- Shear, H. 1984. Contaminants research and surveillance - A biological approach. Pages 31-51 in J. O. Nriagu and M. S. Simmons (eds.). Toxic contaminants in the Great Lakes. John Wiley and Sons, New York.
- Sindelar, C. R. 1983. Historical breeding of eagles amongst the Apostle Islands and the adjacent mainland shore. Historical records, current status and brief recommendations. Rep. to Natl. Park Serv. 44 pp.
- _____. 1985. Wisconsin bald eagle breeding survey - 1985. General Report. Wisc. Dep. Nat. Resour., Bur. End. Spec. 14 pp.
- Smith, W. J. 1959. Movements of Michigan herring gulls. Bird Banding 30:69-104.
- Soil Conservation Service 1961. Soil survey of Bayfield, Co. Ser. 1939. No. 30. U.S. Dep. Agric., Soil Conserv. Serv. 86 pp.
- Sprunt, A., IV and F. J. Ligas. 1966. Audubon bald eagle studies - 1960-1966. Proc. 22nd Annu. Conv. Natl. Audubon Soc., Sacramento, CA.

- Sprunt, A., IV, W. B. Robertson, Jr., S. Postupalsky, R. J. Hensel, C. E. Knoder and F. J. Ligas. 1973. Comparitvie productivity of six bald eagle populations. Trans. N. Am. Wildl. Nat. Resour. Conf. 38:96-106.
- Stickel, W. H., L. F. Stickel, R. A. Dyrland, and D. L. Hughes. 1984. DDE in birds: lethal residues and loss rate. Arch. Environ. Contam. Toxicol. 13:1-6.
- Struger, J. 1985. A report on the geographical distribution of contaminant and productivity measures of herring gulls in the Great Lakes: Lake Superior, 1983. Can. Wildl. Serv., Burlington, Ont. 9 pp.
- Temple, S. A., and J. T. Harris. 1985. Birds of the Apostle Islands. Wisc. Society for Ornithology, Hartland, WI. 62 pp.
- Todd, C. S., L. S. Young, R. B. Owen, Jr., and F. J. Gramlich. 1982. Food habits of bald eagles in Maine. J. Wildl. Manage. 46:636-645.
- Wiemeyer, S. N., A. A. Belisle, and F. J. Gramlich. 1978. Organochlorine reidues in potential food items of Maine bald eagles (Haliaeetus leucocephalus), 1966 and 1974. Bull. Environ. Contam. Toxicol. 13:529-549.
- _____, T. G. Lamont, C. M. Bunk, C. R. Sindelar, F. J. Gramlich, J. D. Fraser, and M. A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs - 1969-79 - and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13:529-549.
- _____, B. M. Mulhern, F. J. Ligas, R. J. Hensel, J. E. Mathisen, F. C. Robards, and S. Postupalsky. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury in bald eagle eggs and changes in shell thickness -- 1969 and 1970. Pestic. Monit. J. 6:50-55.
- _____, and R. D. Porter. 1970. DDE thins eggshells of captive American kestrels. Nature 227:737-738.
- Winn, D. S. 1973. Effects of sublethal levels of dieldrin on mallard breeding behavior and reproduction. M.S. Thesis, Utah State Univ., Logan. 124 pp.

Wright, B. S. 1953. The relation of bald eagles to
breeding ducks in New Brunswick. J. Wildl. Manage.
17:55-62.

Appendix 1. Food items of bald eagles at individual nest sites on the Apostle Islands and nearby mainland shoreline.

Nest	Food Item	N
Outer Island	FISH	
	Longnose sucker	9
	Burbot	5
	Round whitefish	1
	Bloater chub	1
	White sucker	1
	Sucker (<u>Catostomas spp.</u>)	1
	Whitefish, chub or herring (<u>Coregonus spp.</u>)	1
		<u>19</u>
	BIRDS	
	Blue jay	3
	Herring gull	2
	Northern flicker	2
	Canvasback	1
	Lesser golden plover	1
	Common merganser	1
	Red-winged blackbird	1
	Wood duck	1
	Unidentified birds	1
		<u>13</u>
MAMMALS	0	
Michigan Island	FISH	
	Burbot	10
	Longnose sucker	7
	White sucker	2
	Round whitefish	1
	Carp	1
		<u>21</u>
	BIRDS	
	Herring gull	
	adults	13
	juveniles	3
	nestlings	4
	Blue jay	1
	Northern flicker	1
	Common crow	1
	Broad-winged hawk	1
	Sharp-shinned hawk	1
	Unidentified birds	2
		<u>27</u>
	MAMMALS	0

Appendix 1 continued.

Nest	Food Item	N
North Twin Island	FISH	
	Burbot	3
	Longnose sucker	3
	Round whitefish	2
		8
	BIRDS	
	Herring gull	3
	Blue jay	2
	Broad-winged hawk	2
	Sharp-shinned hawk	2
	American bittern	2
	Common crow	1
	Red-tailed hawk	1
	Belted kingfisher	1
	Northern flicker	1
	Hairy woodpecker	1
	American coot	1
	Unidentified birds	1
		18
	MAMMALS	
	White-tailed deer	1
Oak Island	FISH	
	Sucker (<u>Catostomus</u> spp.)	4
	White sucker	1
	Burbot	1
	Carp	1
		7
	BIRDS	
	Herring gull	1
	MAMMALS	0
	York Island	FISH
White sucker		2
Lake trout		1
		3
BIRDS		
Herring gull		1
MAMMALS		0

Appendix 1 continued.

Nest	Food Item	N
Devils Island	FISH	0
	BIRDS	
	Blue jay	1
	American bittern	1
	Northern flicker	$\frac{1}{3}$
		3
	MAMMALS	0
Sand River	FISH	
	Longnose sucker	3
	White sucker	3
	Sucker (<u>Catostomas spp.</u>)	3
	Burbot	1
	Round whitefish	1
	Carp	1
	Lake trout	1
	Whitefish, chub or herring (<u>Coregonus spp.</u>)	$\frac{1}{14}$
		14
	BIRDS	
	American coot	2
	Herring gull	1
	Belted kingfisher	$\frac{1}{4}$
		4
MAMMALS	0	
Fish Creek	FISH	
	Brown bullhead	2
	Sucker (<u>Catostomas spp.</u>)	$\frac{1}{3}$
		3
	BIRDS	0
	MAMMALS	0