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**Reproductive Success and Environmental
Contaminants among Bald Eagles in Placentia and
Bonavista Bays, Newfoundland**

by

© Laura Dominguez

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the requirements for the degree of Master of Science

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Abstract

The bald eagle (*Haliaeetus leucocephalus*) population in Newfoundland is one of the largest in North America. The main breeding concentration is in Placentia Bay, the most industrialized bay in Newfoundland. This study investigated for the first time the reproductive and toxicological status of two major bald eagle breeding concentrations in Newfoundland. The main objectives of the study were: 1) to compare the reproductive performance and contaminant loads of bald eagles in a relatively industrialized area (i.e. Placentia Bay) and in a non-industrialized area (i.e. Bonavista Bay); 2) to compare the reproductive and toxicological status of bald eagles in Newfoundland with other bald eagle populations in North America. This study also provided baseline reproductive and toxicological data on the bald eagle population in Placentia Bay, before further large-scale industrial development (e.g. trans-shipment and storage oil facilities and proposed nickel smelter).

Reproductive surveys and sampling of bald eagle nestlings for toxicological analyses were conducted in Placentia Bay in 1996 and 1997 and in Bonavista Bay in 1997. Both populations had high breeding densities (0.1 and 0.06 occupied nests/km of shoreline in Placentia and Bonavista Bays, respectively) and a stable reproductive performance (82 % nest occupancy, 71 % nest success and 1.1 chicks/occupied nest in Placentia Bay and 92 % nest occupancy, 83 % nest success and 0.9 chicks/occupied nest in Bonavista Bay). There were no significant differences in nest occupancy, nest success

or chick production between bays.

Organochlorine and metal concentrations in nestling blood and in addled eggs were relatively low in both Placentia and Bonavista Bays. Mean concentrations of PCBs and DDE in nestling plasma were significantly higher in Placentia Bay (PCB geometric mean (G_m) = 0.03 ppm (wet wt.) and DDE G_m = 0.009 ppm) than in Bonavista Bay (PCB G_m = 0.01 ppm and DDE G_m = 0.002 ppm, respectively). Mean concentrations of mercury in nestling blood were not significantly different between Placentia and Bonavista Bays (G_m = 0.08 ppm and G_m = 0.07 ppm, respectively). The US naval base in Argentina, located on the east side of Placentia Bay, has been identified as a potential local source of PCB contamination. Nests that were located nearer Argentina (NEAR nests) also had higher mean concentrations of PCBs and DDE than nests located more distantly (DISTANT nests), while metal concentrations were similar between both groups. Analyses of prey remains collected at nest sites showed no significant difference in the frequency of occurrence of bird and fish specimens between Placentia and Bonavista Bays, or between NEAR and DISTANT nests in Placentia Bay. Analyses of stable nitrogen isotopes in nestling blood samples showed no differences in trophic level either between bays or between NEAR and DISTANT nests in Placentia Bay. Results of these dietary analyses further support the relationship of higher PCB and DDE concentrations to a local source of pollution on the east side of Placentia Bay. The bald eagle breeding populations studied in Newfoundland had breeding densities and reproductive success higher than those reported for populations in more heavily industrialized regions such as

the Great Lakes, Columbia River Estuary and Maine, and were comparable to those reported for stable and healthy populations in Alaska, inland Minnesota and Saskatchewan. Contaminant burdens in bald eagles from Newfoundland are lower than those reported for populations in the industrialized regions, and are lower than levels associated with impairment of reproduction.

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Table of Contents

Abstract	ii
Acknowledgments	v
Table of Contents	vii
List of Tables	x
List of Figures	xi
List of Appendices	xiv
List of Abbreviations	xv
Chapter 1. General Introduction	1
1.1 Background	1
1.2 Objectives	7
1.3 Hypotheses	8
1.4 Study area	9
Chapter 2. Reproductive Performance of Bald Eagles in Placentia and Bonavista Bays, Newfoundland	11
2.1 Introduction	11
2.2 Methodology	13
2.2.1 Reproductive surveys	13
2.2.2 Morphometric measurements of chicks	15
2.2.3 Statistical analyses	16
2.3 Results	17
2.3.1 Breeding population size, breeding density and breeding chronology	17
2.3.2 Nest occupancy, nest success and chick production	18
2.3.3 Brood size and chick body condition index	18

2.4 Discussion	19
2.4.1 Comparison of bald eagle breeding performance in Placentia and Bonavista Bays	19
2.4.2 Comparison with other bald eagle populations in North America ..	23
 Chapter 3. Contaminant Burdens of Bald Eagles in Placentia and Bonavista Bays, Newfoundland	38
3.1 Introduction	38
3.2 Methodology	41
3.2.1 Collection of biological samples	41
3.2.2 Processing of samples	42
3.2.3 Chemical analysis of samples	43
3.2.4 Dietary analyses	47
3.2.5 Statistical analysis	48
3.3 Results	51
3.3.1 Contaminants in plasma, blood, egg and liver samples	51
3.3.1.1 Contaminants in nestling plasma and whole blood	51
3.3.1.2 Contaminants in eggs	54
3.3.1.2 Contaminants in liver	55
3.3.2 Dietary analyses	55
3.3.2.1 Prey remains	55
3.3.2.2 Stable isotopes	56
3.3.3 Relationships between contaminant concentrations in nestling blood, distance to Argentia and stable isotopes	57
3.3.4. Relationships between nest productivity and nestling contaminant concentrations, lipid concentration in plasma, and distance to Argentia.	58

3.4 Discussion	58
3.4.1 Contaminant burdens in bald eagles in Placentia and Bonavista Bays	58
3.4.2 Diet of bald eagles in Placentia and Bonavista Bays and its relationship to contaminant concentrations.	62
3.4.3 Comparison with other bald eagle populations in North America .	64
 Chapter 4. General Conclusions and Management Recommendations	85
4.1 General conclusions	85
4.2 Management recommendations	87
 Literature Cited	90
Appendices	106

List of Tables

2.1	Bald eagle breeding densities in Placentia and Bonavista Bays, 1996-97	27
2.2	Reproductive performance of bald eagle breeding pairs in Placentia and Bonavista Bays, 1996-97	28
2.3	Statistical analyses of bald eagle nest occupancy (%), nest success (%) and mean chick production (nestlings/occupied nest) in Placentia and Bonavista Bays, 1996-97	29
3.1	Geometric mean contaminant (ppm, ww) and lipid (g/ml) concentrations, and ranges (in brackets) in bald eagle nestling plasma, whole blood and liver samples, and in bald eagle eggs from Placentia and Bonavista Bays, 1996-97	66
3.2	Summary of statistical analyses on differences in mean concentrations of DDE and PCBs (in plasma) and of mercury (in whole blood) in bald eagle nestlings from Placentia and Bonavista Bays, 1996-97.	67
3.3	Summary of statistical analyses on differences in mean concentration of DDE and PCBs (in plasma) and mercury (in whole blood) in bald eagle nestlings from the NEAR and DISTANT groups in Placentia Bay and from Bonavista Bay, 1996-97	68
3.4	Contaminant concentrations (ppm, ww) in liver samples from nestling and adult bald eagles in Newfoundland, 1995-97	69
3.5	Mean concentrations of stable isotopes ^{15}N and ^{13}C in bald eagle nestling blood from Placentia and Bonavista Bays, 1997	70

List of Figures

1.1	Study areas for reproductive and toxicological study of bald eagles in Newfoundland, 1996-97	10
2.1	Status of bald eagle nests in Placentia Bay, 1996-97	30
2.2	Status of bald eagle nests in Bonavista Bay, 1997	31
2.3	Bald eagle chick production in Placentia and Bonavista Bays, 1996-97	32
2.4	Bald eagle brood size distribution in Placentia and Bonavista Bays, 1996-97 ..	33
2.5	Bald eagle nest occupancy trends in Placentia Bay, 1990-95	34
2.6	Bald eagle breeding areas in Bonavista Bay, 1990-93	35
2.7	Nest success (%) in 21 bald eagle populations from western through to eastern North America	36
2.8	Mean chick production in 21 bald eagle populations from western through to eastern North America	37
3.1	Bald eagle nests sampled for contaminant analyses in Placentia Bay and arbitrary boundary line separating NEAR and DISTANT nests to Argentia , 1996-97	71
3.2	Bald eagle nests sampled for contaminant analyses in Bonavista Bay, 1997 ...	72
3.3	Geometric mean contaminant concentrations (ppm, ww) in bald eagle nestling plasma (DDE and PCBs) and blood (Hg) from Placentia and Bonavista Bays, 1996-97	73

3.4	Geometric mean contaminant concentrations (ppm, ww) in blood from bald eagle nestling #97-33a and in liver from bald eagle nestling #97-33b, Placentia Bay 1997, Newfoundland	74
3.5	Geometric mean contaminant concentrations in liver from two nestling and two adult bald eagles in Newfoundland, 1995-97	75
3.6	Prey remain composition in bald eagle nests from Placentia and Bonavista Bays, 1996-97	76
3.7	Relationship between DDE concentrations (ppm, ww) in bald eagle plasma and distance (km) to Argentia in Placentia Bay, 1996-97.	77
3.8	Relationship between PCB concentrations (ppm, ww) in bald eagle plasma and distance (km) to Argentia in Placentia Bay, 1996-97	78
3.9	Relationship between mercury concentrations (ppm, ww) in bald eagle blood and distance (km) to Argentia in Placentia Bay, 1996-97	79
3.10	Relationship between DDE concentrations (ppm, ww) in plasma and ¹³ C concentrations (pp mil) in blood of bald eagle nestlings from Placentia and Bonavista Bays, 1997	80
3.11	Relationship between PCB concentrations (ppm, ww) in plasma and ¹³ C concentrations (pp mil) in blood of bald eagle nestlings from Placentia and Bonavista Bays, 1997	81

3.12	Relationship between mercury concentrations (ppm, ww) and ¹³ C concentrations (pp mil) in bald eagle nestling blood in Placentia and Bonavista Bays, 1997	82
3.13	Geometric mean contaminant concentrations in nestling plasma (DDE and PCBs) and whole blood (mercury) from 11 bald eagle breeding populations in the 1980-90's.	83
3.14	Contaminant concentrations (ppm, ww) in addled eggs from 11 bald eagle populations, 1980-90's.	84

List of Appendices

2.1	Comparison of nest success, chick production and fledging ratio in 26 main bald eagle breeding regions in North America	106
3.1	Contaminant concentrations (ppm, wet weight) in plasma (DDE and PCBs) and blood (metals) of bald eagle nestlings from Placentia Bay, 1996-97.	108
3.2	Contaminant concentrations (ppm, ww) in plasma (DDE and PCBs) and blood (metals) of six nestling from Bonavista Bay, 1997.	109
3.3	Organochlorine concentrations (ppm, ww) in bald eagle plasma and egg samples from Placentia and Bonavista Bays, 1996-97.	110
3.4	Stable isotopes ^{15}N and ^{13}C concentrations (‰) in bald eagle nestling blood from Placentia and Bonavista Bays, 1997	112
3.5	Contaminant geometric mean concentrations (ppm, ww) in nestling plasma (DDE and PCBs) and blood (mercury) from 11 bald eagle breeding populations.	113
3.6	Contaminant mean concentrations (ppm, ww) in addled eggs from 11 bald eagle breeding populations.	114

List of Abbreviations

ANOVA	analysis of variance
CWS	Canadian Wildlife Service
DDE	1,1-dichloro ethylene <i>bis</i> (p-chlorophenyl)
G_m	Geometric mean
MUN	Memorial University of Newfoundland
NWLD	Newfoundland Wildlife Division
NWRC	National wildlife Research Center
OCs	organochlorines
PAH	poly-cyclic aromatic hydrocarbons
PCB	polychlorinated byphenyl
ppm	parts per million
pp mil	parts per mil
prand	p-value of randomization test
TNNP	Terra Nova National Park
USFWS	US Fish and Wildlife Service

Chapter 1. General Introduction

1.1 Background

The chronic accumulation of pollutants in the marine environment is a major concern when assessing the health of an ecosystem (Howells et al. 1990; Langston 1990; Hoffman 1994). Pollutants released directly or indirectly into aquatic ecosystems are generally stable molecules, highly persistent in water, air and sediments (Burton and Statham 1990; Chester and Murphy 1990; Luoma 1990). Once they enter food webs, many of these substances bioaccumulate and biomagnify through trophic levels (Springer et al. 1984; Nielsen and Dietz 1989; Howells et al. 1990). Major contaminants of concern are organochlorine compounds (e.g. DDE, PCBs, dioxins and furans), heavy metals (e.g. mercury, cadmium and lead) and petroleum hydrocarbons (PAHs).

In high latitude environments or sub-Arctic regions such as Newfoundland, cold seawater temperatures result in slowed break down of pollutant molecules and make marine ecosystems vulnerable to even longer-term persistence of toxic substances (Levy 1980; Furness and Monaghan 1987; Lock et al. 1994; Welch 1994). Furthermore, many pollutants (e.g. DDE, PCBs, dioxins) are lipophilic and are stored in the fatty tissues of marine animals in these cold environments (Norstrom et al. 1988; Ewins 1994). Thermoregulation and food stress can induce lipid mobilization and direct exposure to the toxic effects of accumulated contaminants (Furness 1993).

Contaminants in the marine environment are not necessarily closely linked to a

pollution source or to heavily industrialized areas. Some substances are atmospherically transported long distances and can be found in remote, supposedly pristine regions , e.g. Antarctic and Arctic Oceans (Nettlehip and Peakall 1987; Norstrom et al.1988).

Migratory species also transport pollutants “*in vivo*”. When interacting with food webs at their migratory destinations, these species introduce contaminants to pristine ecosystems (Cade et al. 1971; Springer et al. 1984; Furness 1993).

Chronic low-level pollution can produce deleterious changes that are often difficult to detect in wildlife populations (Howells et al. 1990; Langston 1990; Hoffman 1994). Contaminants usually have sub-lethal toxic effects on the physiology of individuals and subsequent long-term alterations of a population’s reproductive performance (Howells et al. 1990). Too often, these long-term, accumulative toxic effects are detected at population levels in advanced, sometimes irreversible stages (Nisbet 1989; Langston 1990; Colborn 1991). Such is the well-documented case of the disastrous effect which organochlorines had on the reproduction of birds of prey during the 1960s and 1970s, when contaminants surpassed threshold levels in these animals (Grier 1974; Wiemeyer et al. 1984; Peakall and Fox 1987; Court 1993). Interactions among different toxic substances should also be considered when assessing the potential negative effects of pollutants on the animal’s physiology. Interactive effects of multiple contaminants can be additive, synergistic or antagonistic, altering the expected toxicity of a specific pollutant (Howells et al. 1990; Hoffman 1994). For example, the common association of DDE, PCB and mercury residues found in wildlife populations obscures the

determination of their independent toxicities (Nisbet 1989; Colborn 1991; Anthony et al. 1993; Furness 1993; Wiemeyer et al. 1993).

Top predators are very sensitive species to the presence of persistent contaminants because they accumulate the highest concentrations of toxic substances through processes of bioaccumulation and biomagnification. It is therefore important to assay and monitor pollutants among these high trophic level consumers especially in cold environments, even when there are not obvious sources of local pollution. Systematically monitoring sensitive species can help detect increases in contaminant concentrations and prevent irreversible consequences at population levels. Furthermore, several studies have shown the advantages of using top predators as biological indicators of an ecosystem's toxicological status (NERC 1983; Furness and Monaghan 1987; Peakall and Fox 1987; Blondin and Viau 1992; Furness 1993; Monteiro and Furness 1995).

The bald eagle (*Haliaeetus leucocephalus*) is an apex species in coastal marine ecosystems in North America. Coastal populations of eagles feed on a range of species, from fish to seabirds, and even scavenge on marine mammals (Todd et al. 1982; Knight et al 1990). Bald eagle populations throughout North America were seriously affected by widespread use of organochlorines during the 1960s and 1970s (Grier 1982; Wiemeyer et al. 1984; Sindelar 1988; Bowerman 1991, 1993; Kozie and Anderson 1991; Anthony et al. 1993; Welch 1994; Grim and Kallemeyn 1995). Although many breeding populations have recovered in the last two decades (Grier 1982; Wiemeyer et al. 1984), contaminants still seem to be a limiting factor in the reproductive performance of some populations

today (Anthony et al. 1993; Welch 1994; Bowerman et al. 1995; Grim and Kalleyman 1995). Some bald eagle populations in the Great Lakes region have consistently produced less than 0.7 fledglings/occupied nest, which is the minimum productivity necessary for the maintenance of a stable population (Sindelar 1988; Bowerman 1991; Kozie and Anderson 1991). In the western Atlantic, populations in Maine have recently shown similar low productivity (Welch 1994). Pollutant monitoring programs have been conducted across Canada and the United States, using bald eagle nestlings as standard sampling animals for the assessment of the toxicological status of the populations (Colborn 1991; Anthony et al. 1993; McKeane and Weseloh 1993; Bowerman 1993; Bowerman et al. 1994; Welch 1994; Grim and Kallemeyn 1995). Tissue samples from bald eagle nestlings are considered to be good bioindicators for assessing a localized area of contamination over a relatively short period of time, and for monitoring the health of an ecosystem (Welch 1994).

One of the largest breeding concentrations of northern bald eagles (*Haliaeetus leucocephalus alaskanus*) in eastern North America is in Placentia Bay, Newfoundland. At the same time, important sources of chronic pollution occur in Placentia Bay and nearby areas. Organochlorine pollution (PCBs and dioxins) in Placentia Bay has been related to the U.S. Naval Base in Argentia (Jacques Whitford 1996). The Long Harbour Phosphorus Plant was active in the bay until 1989. Another industrial proposal for the area is INCO's nickel smelter for the Voisey's Bay mining development. Oil industries and oil-related activities include the Come By-Chance oil refinery, the former US Naval

Base in Argentina, the Marystown shipyard, the heavy shipping traffic and the upcoming Hibernia oil trans-shipment and storage facilities. Evidence of chronic oil pollution in Placentia Bay has been shown by the high incidence of oiled seabirds washing up along its shores (Montevocchi and Tuck 1987; Lock et al. 1994). Bald eagles are well-known scavengers that feed opportunistically on carcasses (Todd et al. 1982; Stalmaster 1987) and have been observed anecdotically preying and scavenging on oiled birds in Placentia Bay (T. Power, pers. comm.). Further evidence of bald eagles feeding on oiled seabirds is shown by the presence of oiled feathers in the prey remains collected at nest sites (present study). Finally, intense seabird hunting in Placentia, Fortune and St. Mary's Bays is a possible source of chronic lead contamination for bald eagles, through the ingestion of wounded prey (Pattee and Hennes 1983; Scheuhammer and Norris 1995).

Studies of chronic pollution and its impact on wildlife populations stress the importance of obtaining baseline data on the population's status prior to industrial development (Bowman et al. 1997). Comparisons with baseline data allow a wider interpretation of changes and trends in reproductive and demographic parameters, and of their relationship to changes in contaminant burdens. The bald eagle population in Placentia Bay has not been studied prior to industrialization of the area. Information on its present breeding performance is incomplete and contaminant levels have never been determined. In the face of further industrial development, it is essential to obtain a systematic assessment of the bald eagle population's reproductive and toxicological status, to identify potential present and future impacts, and to establish the appropriate

monitoring guidelines.

This study uses the bald eagle as a bio-indicator of chronic pollution in Placentia Bay. Contaminant concentrations in the tissues of bald eagle nestlings and the reproductive performance of the breeding pairs were studied in two consecutive breeding seasons. The reproductive and toxicological status of bald eagles in Placentia Bay are compared to another bald eagle population in Bonavista Bay, a non-industrialized site in Newfoundland, and to other bald eagle populations in North America.

1.2 Objectives

- 1.** to provide the first systematic population and reproductive assessment of the two main breeding concentrations of bald eagles in Newfoundland (Chapter 2);
- 2.** to provide the first toxicological assessment of Newfoundland bald eagles and establish baseline data on contaminant levels in Placentia Bay eagles prior to future large-scale industrial development (Chapter 3);
- 3.** to compare the reproductive and toxicological status of bald eagles in Placentia Bay (industrialized area) and Bonavista Bay (non-industrialized area) (Chapters 2 and 3);
- 4.** to compare the reproductive and toxicological status of bald eagles in Newfoundland with other bald eagle populations in North America (Chapters 2 and 3).

1.3 Hypotheses

- 1. The reproductive success of bald eagles is lower in a relatively industrialized site (i.e. Placentia Bay) than in a non-industrialized site (i.e. Bonavista Bay), in Newfoundland (Chapter 2) .**
- 2. The reproductive success of bald eagles is higher in Newfoundland than in more heavily industrialized regions in North America (i.e Great Lakes and Maine) (Chapter 2).**
- 3. Contaminant concentrations in bald eagle nestlings are higher in Placentia Bay than in Bonavista Bay (Chapter 3).**
- 4. Contaminant concentrations in bald eagle nestlings are lower in Newfoundland than in the Great Lakes and Maine (Chapter 3).**

1.4 Study area

Placentia Bay is located in the southeastern coast of Newfoundland, in easternmost Canada (see Fig 1.1). Placentia Bay is a coastal northern boreal ecosystem of great biological diversity. It sustains one of the richest fish biomasses in Newfoundland waters, important seabird colonies, wintering grounds for millions of seabirds and seaducks, breeding and wintering grounds for eagles, and feeding grounds for several species of seals, dolphins and whales. The tree cover along the coastline is densely packed and dominantly coniferous, including white spruce (*Picea glauca*), black spruce (*P. mariana*), and balsam fir (*Abies balsamea*).

Bonavista Bay, located in the east coast of Newfoundland (Fig 1.1), is also a typical northern boreal ecosystem, rich in fish, seabird, eagle and marine mammal populations. The tree cover is a mixed boreal forest mainly composed of white spruce, black spruce, balsam fir, white pine (*Pinus strobus*), trembling aspen (*Populus tremuloides*), and yellow birch (*Betula alleghaniensis*). The study area in Bonavista Bay is located within the boundaries of Terra Nova National Park (TNNP). The bald eagle population in Bonavista Bay was included in this study as a reference group for comparison of toxicological and reproductive parameters. This study area was chosen mainly due to the logistical support provided by Parks Canada that made possible the study, and because it was considered a non-industrialized site.

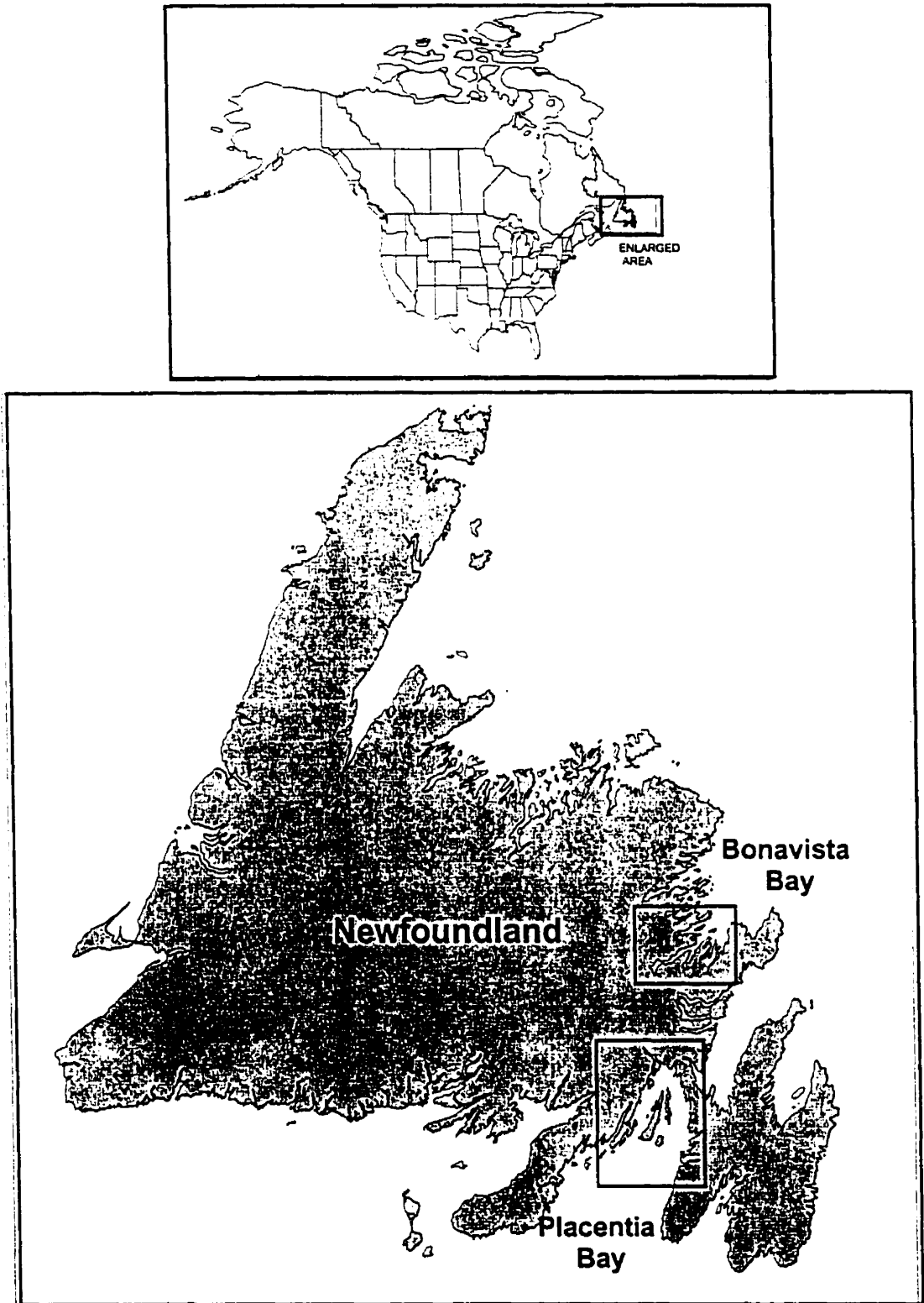


Fig. 1.1. Study areas for reproductive and toxicological study of bald eagles in Newfoundland, 1996-97.

Chapter 2. Reproductive Performance of Bald Eagles in Placentia and Bonavista Bays, Newfoundland

2.1 Introduction

The largest concentrations of breeding bald eagles have been reported in Alaska, Oregon, Minnesota, the Great Lakes region, Maine, Chesapeake Bay and Florida in the US, and in British Columbia, Saskatchewan, Manitoba, northern Ontario and Nova Scotia in Canada. Long after the banning of the use of organochlorines such as DDT and PCBs, some bald eagle populations from the Great Lakes, Columbia River Estuary (Oregon) and Maine still show impaired reproduction (nest success <50 % and productivity < 0.7 fledging/occupied nest), that has been related to the persistence of these contaminants in the environment (Colborn 1991; Anthony et al. 1993; Bowerman 1993; Welch 1994). Bald eagles breeding in Alaska, British Columbia, Minnesota, Saskatchewan and northern Ontario have the highest breeding densities and reproductive parameters indicative of healthy and stable populations (>50 % nest success and fledgling/occupied nest) (Grier 1974; Hodges 1982; Gerrard et al. 1983; Bowman et al. 1993; Grim and Kallemeyn 1995; Ritchie and Ambrose 1996). Bald eagle populations in Atlantic Canada (Nova Scotia and New Brunswick), although were considered to have marginal production in the early 80s (Stocek and Pearce 1981), have increased in numbers in the last decade and now exhibit reproductive parameters indicative of healthy and expanding populations (Stocek, unpublished data).

Newfoundland has a large coastal population of breeding eagles, and the number of breeding pairs has remained stable in the last decade (J. Brazil, unpublished data). Furthermore, Newfoundland eagles are apparently year-round residents on the island, with many wintering on the south coast, where they concentrate around open waters (J. Brazil, pers. comm.). Data on potential breeding population size has been gathered by provincial wildlife biologists over the past 10 years in the main areas of occurrence (J. Brazil, unpublished data), but there has been no consistent collection of information on reproductive performance.

This study in Placentia and Bonavista Bays provides the first systematic assessment of reproductive performance for two main breeding concentrations of bald eagles on the island of Newfoundland. Reproductive data were collected simultaneously with a study on contaminant burdens in the breeding populations (see Chapter 3). The bald eagle population in Bonavista Bay was used as a reference group in a non-industrialized bay to detect differences in reproductive performance potentially due to local industrial contaminants in Placentia Bay. This study tested the hypotheses that : i) bald eagle reproductive success would be lower in the industrialized Placentia Bay than in the non-industrialized Bonavista Bay; ii) bald eagle reproductive success would be higher in Newfoundland than in more heavily industrialized regions such as the Great Lakes and Maine.

2.2 Methodology

2.2.1 Reproductive surveys

Bald eagle breeding population size, distribution, density, and reproductive performance were studied in Placentia Bay in 1996 and 1997, and in Bonavista Bay in 1997. Variables measured to assess reproductive performance were breeding density, nest occupancy, nest success and chick production. Definitions of these terms and others used to describe reproductive parameters follow and are modified from Postupalsky (1974) and Kozié and Anderson (1991): i) *breeding area* - an area containing one or more nests within the range of one mated pair of birds; ii) *nest occupancy* - the proportion of nests (i.e. breeding areas) occupied by mated pairs in a breeding season; iii) *occupied nest* - a nest at which any of the following activity patterns were observed during the breeding season: a) two adults at or near the nest; b) one adult sitting low in the nest; c) a nest with fresh sticks, boughs, droppings, molted feathers, and/or fresh prey remains at the end of the chick rearing period; d) eggs were laid; or e) chicks were raised; iv) *nest success* - the proportion of breeding pairs in occupied breeding areas that raised one or more fledglings in a breeding season ; v) *successful nest* - an occupied nest from which at least one young fledged or was raised to an advanced stage of development (i.e. near fledging age); vi) *chick production* - mean number of fledglings (or large young) produced per nest in a population; vii) *fledging ratio* - ratio between the mean number of fledglings per successful nest and the mean number of fledglings per occupied nest. A minimum of two

surveys per breeding season (as stressed by Postupalsky 1974) were conducted to determine the number of breeding areas, nest occupancy, nest success and chick production. Breeding areas containing more than one nest were inferred by distance between nests (< 1 km) and by comparing occupancy of the nests throughout the years (J. Brazil, unpublished data). Reproductive surveys were conducted aerially and/or by boat. Aerial surveys were conducted by helicopter (Bell 206) in Placentia Bay and by fixed-wing (Twin Otter) in Bonavista Bay, with a cruising speed of 120-140 km/h and a flying altitude of 50-100 m above tree line. Survey schedules and methodology follow Postupalsky (1974), Fraser et al. (1983) and Grier (1974, 1982), and results are corrected for sampling and measurement errors in aerial counts (Fraser et al. 1983, Fraser 1984). Boat surveys were conducted by cruising along the coast line with a 20 feet fiber-glass boat at a cruising speed of 5-10 knots.

The first survey in late April-early May assessed breeding population size, nest-site locations and nest occupancy. In Placentia Bay this survey was conducted by boat in 1996 (400 km of coastline) and by helicopter in 1997 (300 km of coastline). In 1996, 50 breeding areas were surveyed for the assessment of nest occupancy. In 1997 the logistic efforts were focused on surveying the east coastline of the bay for the first time and identifying new nest locations around the main industrial sites. As a consequence, only 39 breeding areas, out of the 50 that were surveyed in the previous year, were surveyed for nest occupancy (see Fig. 2.1). In Bonavista Bay (in 1997) the first survey was conducted by fixed-wing and by boat (205 km of coastline), and 13 breeding areas were

surveyed for the assessment of nest occupancy. Nest locations were recorded in both bays using Global Positioning System (GPS) and entered into a Geographic Information System (GIS; MapInfo). Surveyed distances were also calculated with Mapinfo. Historical bald eagle nest locations were provided by the Newfoundland Inland Fish and Wildlife Division (NWLD) (J. Brazil, unpublished data) and by Terra Nova National Park (TNNP), Parks Canada. A second survey in early June assessed clutch/brood size and chick development. This survey was conducted by helicopter in both years in Placentia Bay and by boat/land in Bonavista Bay in 1997. The third survey in late June-early July assessed nest success, chick mortality and chick production prior to fledging. This survey was conducted by boat and by climbing to the nests in both bays. In Placentia Bay, 30 and 28 breeding pairs were surveyed in 1996 and 1997, respectively, for the assessment of nest success and chick production. In Bonavista Bay 12 breeding pairs were surveyed for the assessment of nest success and chick production.

2.2.2 Morphometric measurements of chicks

Morphometric measurements taken to sex and age young included: mass, culmen length, bill depth, pad length, helix claw length, 8th primary length and wing chord length (see Bortolotti 1984). Measurements from wing and foot were taken from the left side of the bird. All siblings from all nests were banded with a metal USFWS band on the right leg. Laying dates were calculated from the age of chicks, determined from the morphometric measurements (Bortolotti 1984), and assuming an incubation period of 35

days (Stalmaster 1987). A body condition index was calculated for each one of the eaglets based on the ratio mass/wing length. The wing measurement used was the eighth primary length, which had a strong positive correlation ($r = 0.99$) with wing chord.

2.2.3 Statistical analysis

Differences in nest occupancy and nest success between the two breeding areas were examined with a Chi-square test of independence. One-way analyses of variance (ANOVAs) were used to test for differences in chick production and laying date means between years or locations. Laying dates were assigned a number from 1 to 60 that corresponded to the day of the month starting April 1 and finishing May 30, for the purpose of statistical analysis. Mean laying dates (based on first eggs of clutches) between study areas were compared with data from 1997. Differences in body condition of chicks from the two study areas in 1997 were examined with a one-way ANOVA. Differences in brood size of successful pairs in the two study areas were investigated by analyzing the proportion of nests that produced one versus two nestlings, using a Fisher's Exact test. Randomization tests (10,000 runs, Adams and Anthony 1996) were applied to defend results from parametric tests when residuals did not show a normal distribution. Statistical tests were conducted with Minitab. A value of $\alpha = 0.05$ was used in all tests.

2.3 Results

2.3.1 Breeding population size, density and chronology

In Placentia Bay, a total of 400 km of coast line were surveyed in 1996-97, and 55 breeding areas were identified, containing 61 nests in good condition and three that were destroyed (see Fig.2.1). A systematic population census conducted in April 1996 showed a total of 71 adult, 1 sub-adult and 4 immature eagles. Two nests that were occupied and successful in 1996 were found blown down in 1997. In Bonavista Bay, a total of 205 km of coast line was surveyed in 1997, and 13 breeding areas were identified (see Fig. 2.2). A systematic census conducted in June showed a population of 17 adult and 4 immature bald eagles.

Breeding densities of both study areas in 1996 and 1997 are shown in Table 2.1. In Placentia Bay, mean breeding density of both years was 0.1 occupied nests/km of coastline. In Bonavista Bay, breeding density in 1997 was 0.05 occupied nests/km of coast line.

Mean laying dates of accessed successful nests in Placentia Bay were 7 and 8 April in 1996 ($n = 18$) and 1997 ($n = 15$), respectively (ranging from 30 March to 26 April in both years). There were no significant differences in mean laying dates between years ($F_{1,44} = 0.37$; $p = 0.5$). In Bonavista Bay, the mean laying date of six successful nests was 16 April 1997 (ranging from 3 April to 5 May). Mean laying date in 1997 was 8 days earlier in Placentia Bay than in Bonavista Bay, although this difference was not

statistically significant ($F_{1, 19} = 3.98$; $p = 0.06$).

2.3.2 Nest occupancy, nest success and chick production

Nest occupancy, nest success and chick production of the surveyed breeding areas in 1996 and 1997 are shown in Table 2.2. Mean nest occupancy of 1996-97 in Placentia Bay was 82 % and was not significantly different between years ($\chi^2 = 1.82$; $df = 1$; $p = 0.18$). Nest occupancy in Bonavista Bay in 1997 was 92 % . Nest occupancy was not significantly different between Placentia and Bonavista Bays (Table 2.3).

Mean nest success of 1996-97 in Placentia Bay was 71.5 % and was not significantly different between years ($\chi^2 = 1.59$; $df = 1$; $p = 0.2$). Nest success in Bonavista Bay in 1997 was 83%. Nest success was not significantly different between the two study areas (Table 2.3).

Mean chick production of 1996-97 in Placentia Bay was 1.1 nestlings/occupied nest and was not significantly different between years ($F_{1, 56} = 3.47$; $p = 0.07$). Chick production in Bonavista Bay was 0.9 nestlings/occupied nest. Chick production was not significantly different between the two study areas (Table 2.3; Fig. 2.3).

2.3.3 Brood size and chick body condition index

The proportion of successful nests producing one versus two nestlings were not significantly different either between 1996 and 1997 in Placentia Bay ($N = 42$, 1 df , $p = 0.2$) or between Placentia and Bonavista Bays in 1997 ($N = 28$, 1 df , $p = 0.1$). Placentia

Bay in 1996 had a significantly higher proportion of nests that produced two nestlings than Bonavista Bay in 1997 ($N = 24$, 1 df, $p = 0.045$) (see Fig. 2.4).

Mean body condition index (mass/wing length) of chicks was not significantly different between Placentia and Bonavista Bays in 1997 ($t = 0.025$ and $t = 0.029$, respectively; $F_{1,25} = 1.12$; $p = 0.3$).

2.4 Discussion

2.4.1 Comparison of bald eagle breeding performance in Placentia and Bonavista Bays

Nest occupancy, nest success and chick production of bald eagles in Placentia and Bonavista Bays are indicative of a healthy and stable breeding population. Bald eagle breeding populations are considered to be stable when nest success is $>50\%$, and chick production is 0.7 nestling/occupied nest (Sprunt et al. 1973; Colborn 1991; Wiemeyer et al. 1993). Under ideal conditions, chick production is considered to be 1.4 nestlings/successful nest (Colborn 1991). Colborn (1991) uses a fledging ratio (ratio between the number of fledglings per successful nest and the number of fledglings per occupied nest) to assess the status of bald eagle breeding populations and to assist in separating the different stresses on their reproductive performance. As reproductive conditions improve, the fledging ratio approaches one. Fledging ratios in Placentia and Bonavista Bays were also indicative of a stable breeding population (see Table 2.2). The

observed differences in mean chick production (of successful nests) between study sites (1.4 nestlings/successful nest in Placentia Bay versus 1.1 nestlings /successful nest in Bonavista Bay, in 1997) were not statistically significant. Also, mean chick production in Bonavista Bay in 1997 could have been higher than reported in this study because some nests could not be accessed and counts of nestlings made from the ground or nearby trees might have underestimated nest success or brood size.

There is some discrepancy between the nest occupancy percentages observed in this study and those recorded by the NWLD during 1991-95 in Placentia Bay. The mean nest occupancy of 15 surveyed breeding areas during 1991-95 was 67 %. (J. Brazil, unpublished data) (see Fig.2.5). This value is lower than the nest occupancy percentage found in this study for the whole population. However, the difference could be attributed to the lack of two systematic surveys per breeding season for some breeding areas during 1991-95 and, consequently, to the smaller sample size of breeding areas systematically surveyed during this period that was comparable to the data from 1996-97 (Postupalsky 1974; Fraser et al. 1984). Also, owing to a lack of systematic surveys in Bonavista Bay in previous years, it is possible that some breeding areas could have been overlooked in the present study, thus affecting the real nest occupancy and nest success percentages of the breeding population in this study area.

Bald eagle breeding density in Placentia Bay was twice the breeding density in the study area in Bonavista Bay (0.1 versus 0.05 occupied nests/km coastline). Possible factors influencing the observed higher bald eagle breeding density and overall chick

production in Placentia Bay are nesting habitat, prey abundance and availability, climatology, and human activities. First, some differences were observed in the topography and tree composition of the potential nesting and foraging habitat for bald eagles in Placentia and Bonavista Bays. In Placentia Bay, the coast line offers abundant optimal nesting and foraging habitat, including high cliff faces overlooking the water, protected harbours, numerous islands, narrows and shallow waters. Some of these topographic characteristics (e.g. islands in islands clusters, island-like points and peninsulas on the mainland) have been described as preferred nesting habitat for bald eagles in a lacustrine ecosystem in Minnesota (Grim and Kalemeyn 1995). The study area in Bonavista Bay has a much more uniform coastline, and islands, harbours and cliff faces close to the shoreline are less abundant. In Placentia Bay, 72% of the surveyed nests were located on cliff ledges or on small trees (spruce or balsam fir) overhanging cliff ledges, and 28 % on trees (spruce or balsam fir) on hill slopes, while in Bonavista Bay 31% of the surveyed nests were found on cliff ledges or on small trees overhanging cliff ledges and 69 % were on large trees (white pine, aspen, birch, spruce, fir) on the shoreline or on hill slopes. This difference in the proportions of cliff versus tree nesters in the two study areas could reflect a difference in nesting habitat. Second, there are also some differences in food resources and availability between both study areas. Placentia Bay contains much higher breeding densities of seabirds than Bonavista Bay (Cairns et al. 1989; Lock et al. 1994). Placentia Bay has had intense fishing activity in the past and still sustains a rich lobster fishery, while fishing activities are not so intense in the study area

in Bonavista Bay. Fishing activities have been related to high breeding densities of seagulls, common prey species for coastal bald eagles (Todd et al. 1982; Knight et al. 1990; Welch 1994). Third, weather conditions can also differ during the winter and spring in Placentia and Bonavista Bays. Bonavista Bay is located on the north-east coast of Newfoundland and the pack-ice stayed until June in 1997, while in Placentia Bay there were open waters all year round. The presence of ice could have potentially affected the availability of food resources for bald eagles during the mating and incubation periods in Bonavista Bay. Laying date was found to be influenced by proximity to spring food resources in a bald eagle population in southeast Alaska (Hansen 1987). Also, the potential difference in mean air temperature at the beginning of the breeding season, due to the presence of pack-ice in Bonavista Bay, could be another factor influencing breeding densities and laying chronology. Mean air temperatures in April and density of breeding eagles were found to be positively correlated for a population of bald eagles in Saskatchewan (Ritche and Ambrose 1996). Finally, although Placentia Bay has a higher industrial development than Bonavista Bay, directly disturbing human activities are relatively low in both sites and contaminants in eaglets from both populations are under the thresholds known to be correlated with impaired reproduction (see Chapter 3).

However, results of this comparison of breeding densities between both bays should be considered cautiously due to the difference in size of the two study areas, and to a lack of regular and systematic surveying in Bonavista Bay prior to this study. The higher breeding density observed in Placentia Bay could be due to a clustering of

breeding pairs on the islands at the head of the Bay (see Fig. 2.1). Similar possible clusters of bald eagles on the islands outside and to the north of the study area in Bonavista Bay (see Fig. 2.6) could translate into a higher breeding density in the entire Bay. Data on bald eagle breeding distribution collected by the NWLD from 1990 to 1993 in Bonavista Bay, outside of TNNP boundaries, show breeding densities of 0.01 occupied nests/km of coastline (Fig. 2.6). These densities are ten times lower than those found in Placentia Bay in 1996-97, and five times lower than those found in the study area in Bonavista Bay in 1997. However, surveys of different transects of coastline were conducted in different years during 1990-93 in Bonavista Bay. A more systematic survey of the coastline outside of the study area presented in this study needs to be conducted to draw conclusions on breeding densities in the whole area of Bonavista Bay.

In conclusion, the hypothesis tested in this study that bald eagles in Bonavista Bay would have a higher reproductive success than bald eagles in Placentia Bay is rejected. Furthermore, because of the climatological and ecological differences between the two study areas, Bonavista Bay would not be an optimal choice as a future reference study site for detecting differences in bald eagle reproductive performance due to industrial activities and contaminants in Placentia Bay.

2.4.2 Comparison with other bald eagle populations in North America

The highest breeding densities of bald eagles in North America occur in Alaska (Hodges 1982; Hansen and Hodges 1985) and British Columbia (Hodges and King 1984).

A breeding density of 0.6 occupied nest/km of shoreline was considered a saturation level in southeastern Alaska, where high rates of non-breeding adults occur (Hansen and Hodges 1985). Nesting densities of bald eagles in Placentia Bay in 1996-97 were higher than those described for the populations in Maritime Canada and Atlantic USA (Wetmore and Gillspie 1976; Stoeck 1980; Stoeck and Pearce 1981; Welch 1994). Bald eagle breeding density in Placentia Bay was also higher than reported for an important bald eagle breeding concentration in Besnard Lake, Saskatchewan (Gerrard et al. 1983). However, these comparisons should be considered cautiously since calculations of breeding densities based on the length of shoreline (as reported in these studies) in areas with convoluted coastlines (such as Newfoundland) can lead to anomalous results, and measurements on fractal scales should be applied to obtain accurate comparisons (Pennyquick and Kline 1986).

Nest occupancy, nest success and chick production in Newfoundland are also high and do not fall in the pattern of marginal production that is characteristic of bald eagle populations in Maritime Canada and Maine (Stoeck and Pearce 1981; Welch 1994). They are comparable to the reproductive parameters of the most stable and productive populations of Alaska, Saskatchewan, Minnesota, Greater Yellowstone, Chippewa National Forest and northwestern Ontario (see Figs. 2.7 and 2.8; Appendix 2.1). Reproductive data from most regions dates from the last two decades and represents the 'recovery' period after the depression of bald eagle populations during the 1960s-1970s due to organochlorine residues. Nevertheless, some populations (Maine, Lake Nipigon,

Lake Superior, Michigan, Wisconsin, Lake Huron, Columbia River Estuary) still show chick production values under the estimated minimum value for a stable population (Sprunt et al. 1973), and have fledging ratios indicative of possible limiting effects of contaminants on reproduction (Colborn 1991). Of the marine regions, Placentia Bay's chick production in 1996-97 is the highest, together with Kodiak Island's (Alaska) in 1973-74. Nest success is also among the three highest percentages of all regions, and the highest of the marine areas. Newfoundland's fledging ratios are the closest to the optimum ratio 1 (Colborn 1991) of 21 regions. Again, comparative analyses of the different populations should be considered cautiously because reproductive data were collected by different researchers using different surveying methodology, and in different years.

High breeding densities and reproductive output of bald eagles in marine ecosystems have been mainly associated with the availability and quality of nesting habitat and with food abundance and availability (Hansen 1987). The distribution of bald eagle breeding pairs might also be associated with available suitable shoreline perch areas (Chandler et al. 1995). Other factors influencing bald eagle breeding distribution and reproductive success are human activities (Buehler et al. 1991; Grubb and King 1991; Grubb et al. 1992) and environmental contaminants. Newfoundland offers good quality and abundant nesting and perching habitat for bald eagles. Fish and seabirds are also very abundant as food resources. Historical fishing activity is another factor that could positively influence food availability and breeding densities of bald eagles in

Newfoundland. Finally, Newfoundland can still be described as a relatively pristine area, with low human disturbance around the main bald eagle breeding areas, and relatively low levels of organochlorine and heavy metal residues in the environment (see Chapter 3).

In conclusion, this comparison supports the hypothesis that the reproductive success of bald eagles is higher in Newfoundland than in more industrialized regions of North America such as Maine and the Great Lakes. Nevertheless, chronic oil pollution in southern Newfoundland (Montevecchi and Tuck 1987) and large-scale industrial development in Placentia Bay are presently increasing. These activities could create potential disturbances of the bald eagle population's breeding activities, and potential contaminant burdens that negatively influence bald eagle reproductive performance. Therefore, efforts should be made to monitor the bald eagle breeding population in Placentia Bay in the future to detect any trends in reproductive performance.

Table 2.1 Bald eagle breeding densities in Placentia and Bonavista Bays, 1996-97.

Location	breeding areas / km shoreline	occupied nest / km shoreline	km shoreline surveyed
Placentia Bay, 1996	0.14	0.1	400
Placentia Bay, 1997	0.13	0.1	300
Bonavista Bay, 1997	0.064	0.058	205

Table 2.2 Reproductive performance of bald eagle breeding pairs in Placentia and Bonavista Bays, 1996-97.

Location	year	nest occupancy (%)	nest success (%)	nestlings/ successful nest \pm SE	nestlings/ occupied nest \pm SE	fledging ratio
Placentia Bay	1996	87	77	1.5 \pm 0.15	1.3 \pm 0.15	1.1
Placentia Bay	1997	77	68	1.4 \pm 0.15	0.9 \pm 0.15	1.5
Bonavista Bay	1997	92	83	1.1 \pm 0.15	0.9 \pm 0.15	1.2

Table 2.3 Statistical analyses of bald eagle nest occupancy (%), nest success (%), and mean chick production (nestlings/occupied nest) in Placentia and Bonavista Bays, 1996-97.

location/year	reproductive parameter	N	statistic	p	significant difference
nest occupancy					
Placentia / 1996	87	46	$\chi^2 = 0.3, 1 \text{ df}$	0.5	No
Bonavista / 1997	92	13			
Placentia / 1997	77	39	$\chi^2 = 1.7, 1 \text{ df}$	0.2	No
Bonavista / 1997	92	13			
nest success					
Placentia / 1996	77	33	$\chi^2 = 0.01, 1 \text{ df}$	0.9	No
Bonavista / 1997	83	12			
Placentia / 1997	68	28	$\chi^2 = 1.1, 1 \text{ df}$	0.3	No
Bonavista / 1997	83	12			
chick production					
Placentia / 1996	1.3	31	$F_{1,41} = 2.47$	0.1	No
Bonavista / 1997	0.9	12			
Placentia / 1996	0.9	27	$F_{1,37} = 0.009$	0.9	No
Bonavista / 1997	0.9	12			

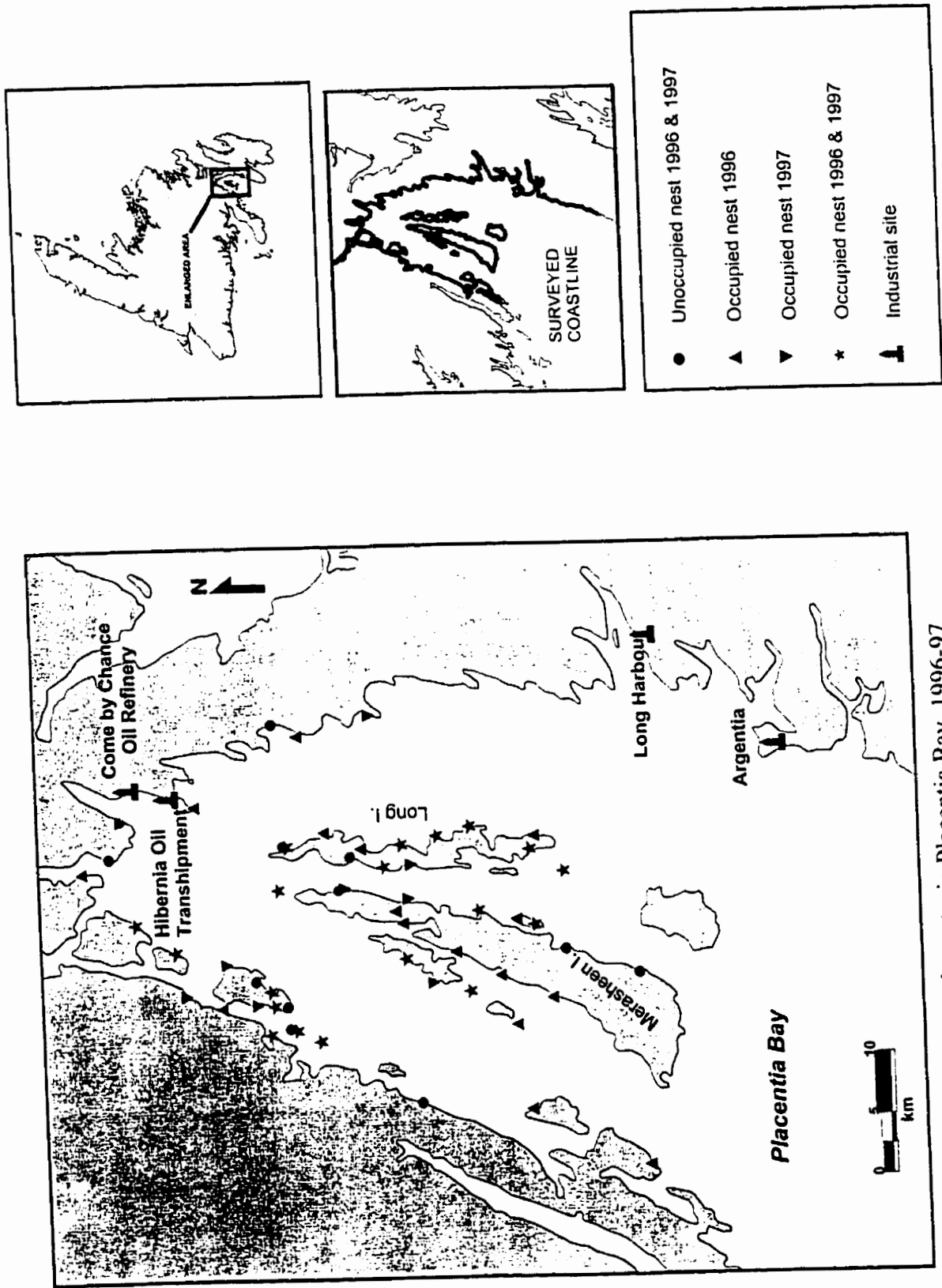


Fig. 2.1. Status of bald eagle nests in Placentia Bay, 1996-97.

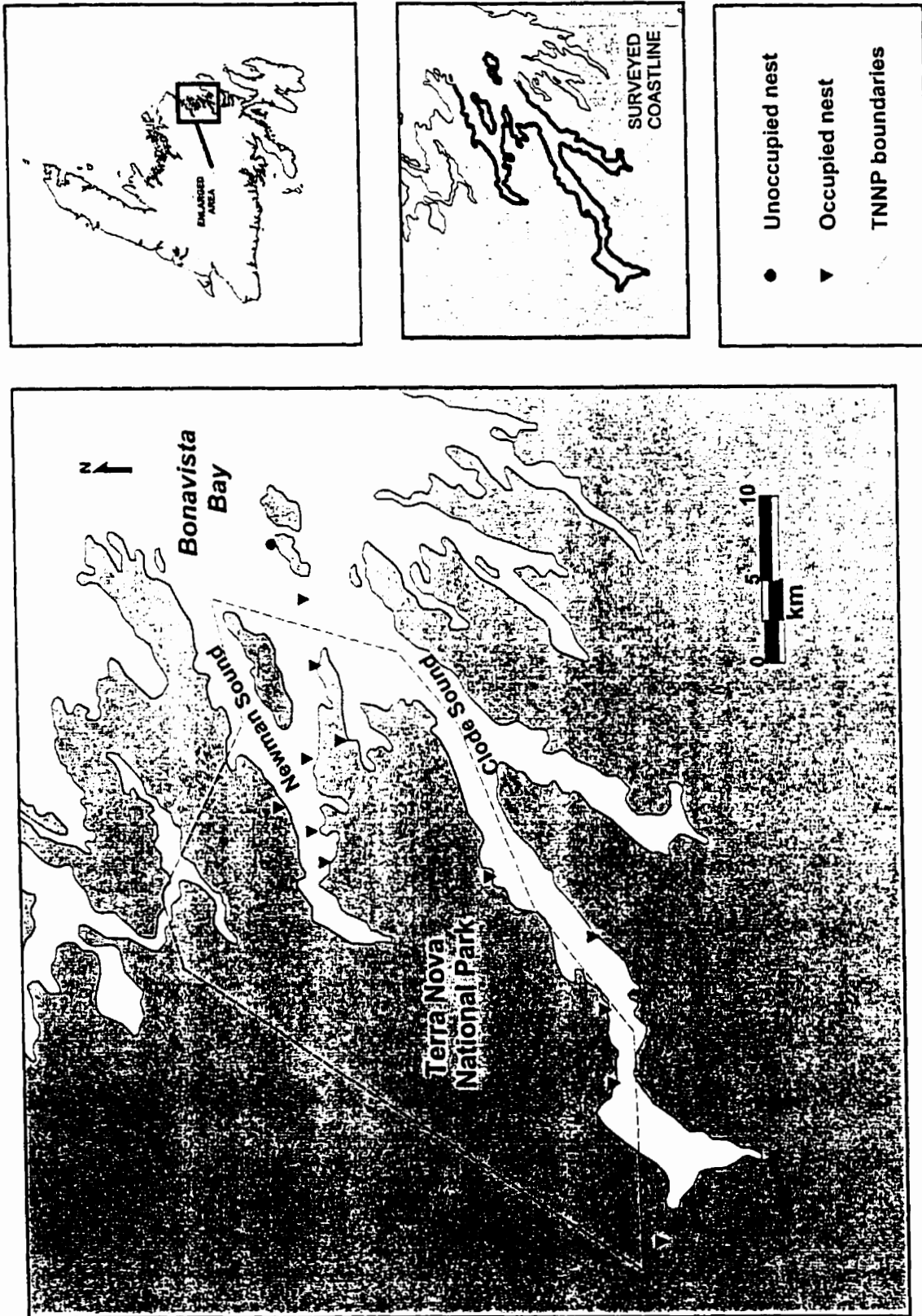


Fig. 2.2. Status of bald eagle nests in Bonavista Bay, 1997.

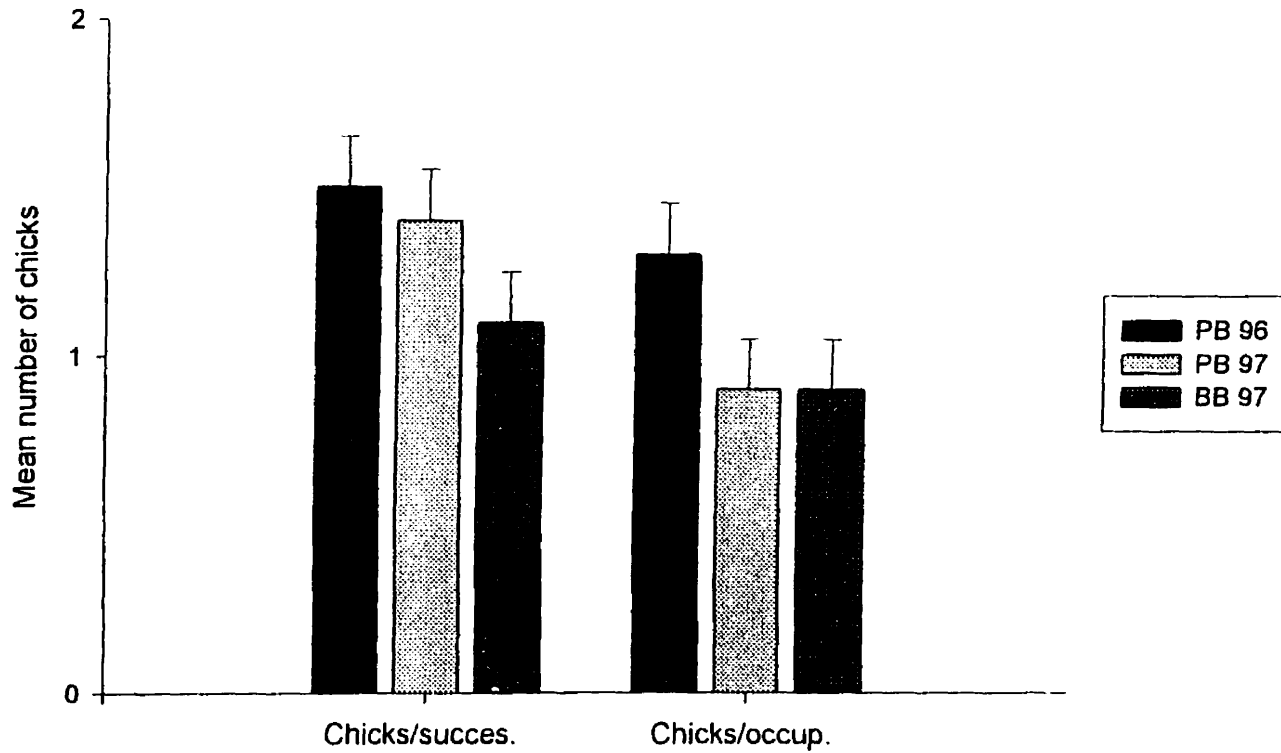


Fig. 2.3. Bald eagle chick production in Placentia and Bonavista Bays, 1996-97. PB 96 = Placentia Bay 1996; PB 97 = Placentia Bay 1997; BB 97 = Bonavista Bay 1997; succes. = successful nest; occup. = occupied nest; error bar = standard error.

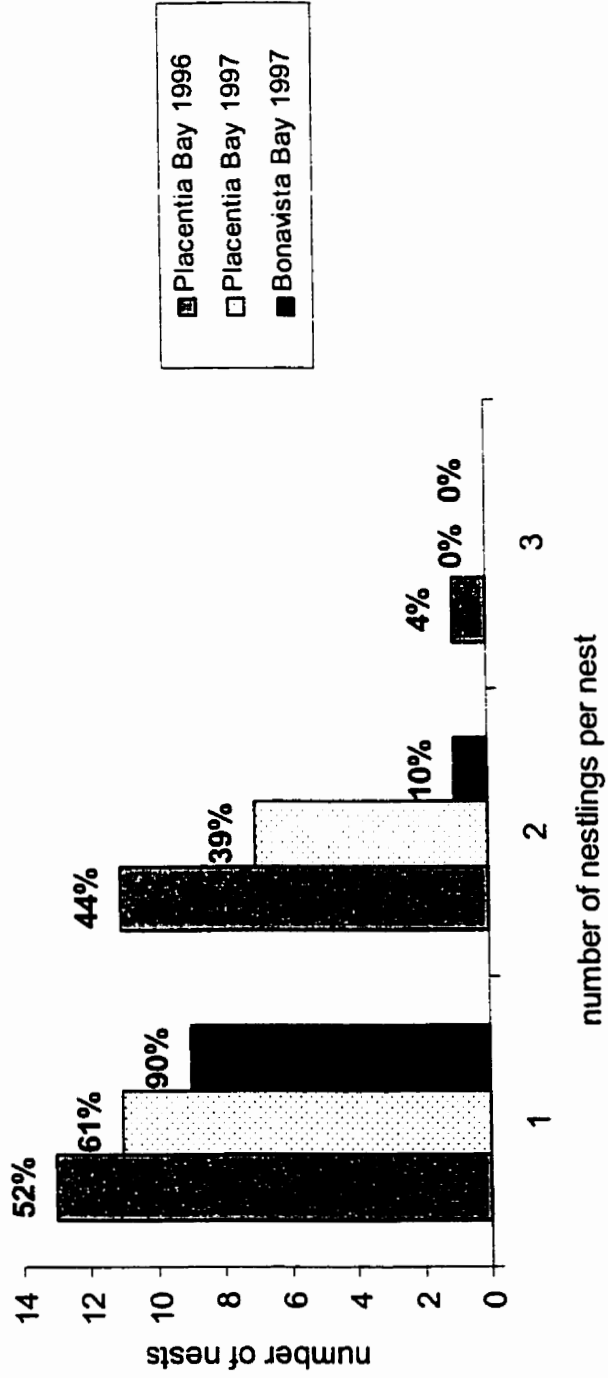


Fig. 2.4. Bald eagle brood size distribution in Placentia and Bonavista Bays, 1996-97

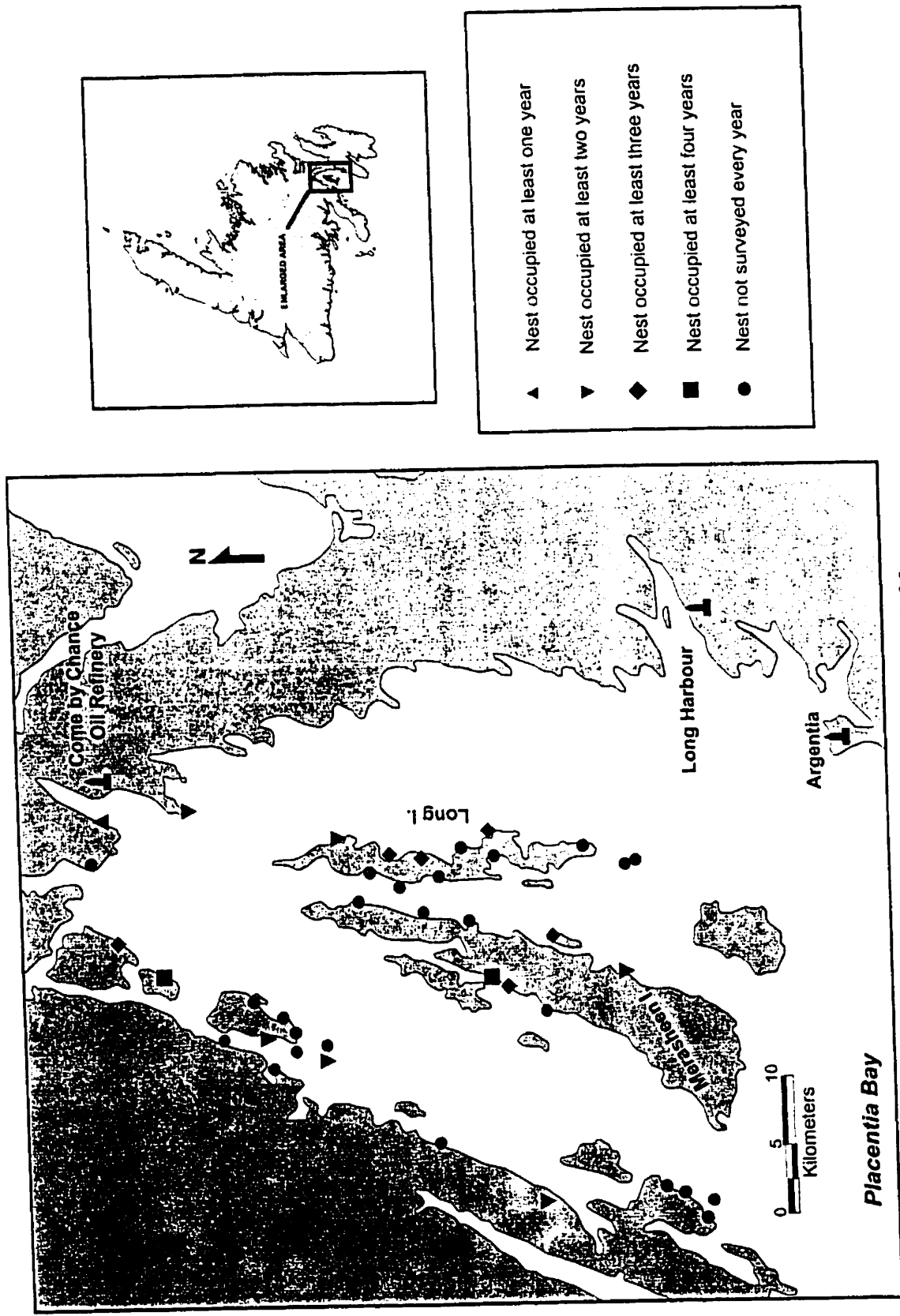


Fig. 2.5. Bald eagle nest occupancy trends in Placentia Bay, 1990-95.

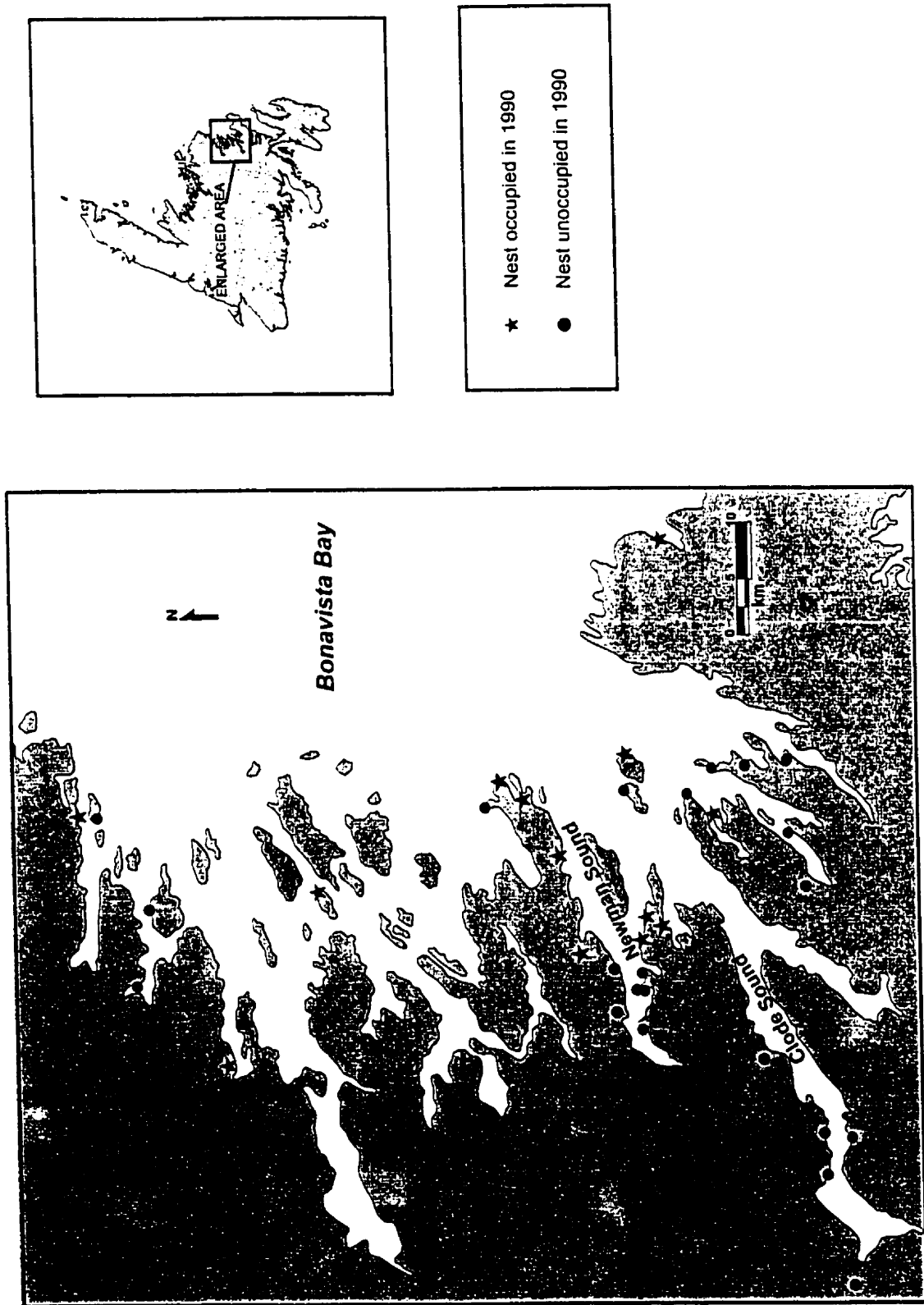


Fig. 2.6. Bald eagle nest locations in Bonavista Bay, 1990-93. Status of nests corresponds to year 1990.

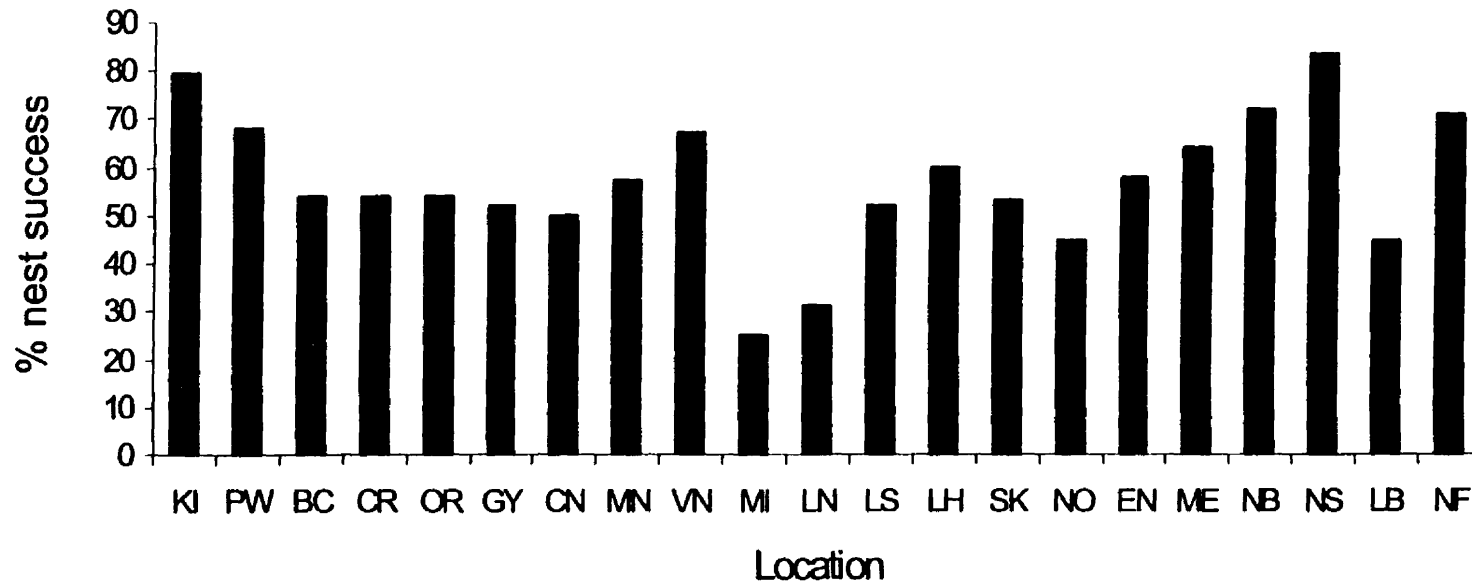


Fig. 2.7. Nest success (%) in 21 bald eagle populations from western through to eastern North America. Study site abbreviations are as follows: KI = Kodiak I. (Alaska), 1973-74; PW = Prince William Sound (Alaska), 1989-92; BC = British Columbia, 1992-94; CR = Columbia River Estuary, 1980-87; OR = Oregon, 1979-92; GY = Greater Yellowstone, 1976-82; CN = Chipewa National Forest (Minnesota), 1979; MN = Minnesota inland, 1982-86; VN = Voyageurs National Park (Minnesota), 1987-93; MI = Michigan State, 1983; LN = Lake Nipigon, 1971; LS = Lake Superior, 1982-86; LH = Lake Huron, 1982-86; SK = Saskatchewan, 1973-81; NO = North west Ontario, 1981; EN = Everglades National Park (Florida), 1988; ME = Maine, 1982-92; NB = New Brunswick, 1974-80; NS = Nova Scotia, 1968; LB = Labrador, 1970-73; NF = Newfoundland, 1996-97. For references see Appendix 2.1.

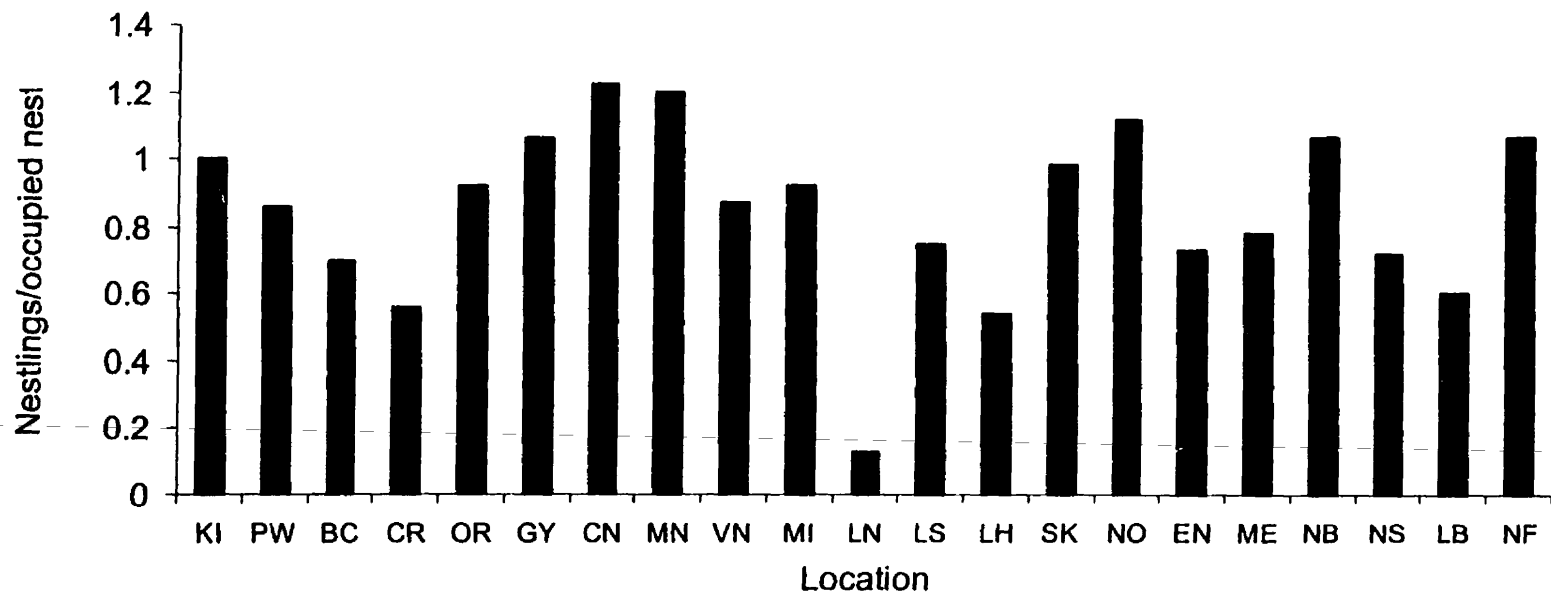


Fig. 2.8. Mean chick production in 21 bald eagle populations from western through to eastern North America. Study site abbreviations and references same as in Fig. 2.7.

Chapter 3. Contaminant Burdens of Bald Eagles in Placentia and Bonavista Bays, Newfoundland

3.1 Introduction

The bald eagle population in Placentia Bay has been potentially exposed to marine chronic pollution from local industrial activities such as the oil refinery in Come by Chance, the US military naval base in Argentia, the phosphorus plant in Long Harbour and the intense shipping traffic in the area. Contaminants transported atmospherically or through ocean currents are another possible source of chronic pollution in Placentia Bay. Toxicological analyses of lobster tissues in Placentia Bay have already shown bioaccumulation of some organochlorine residues and of mercury (Jacques Whitford 1996). Future industrialization of the bay (i.e. Hibernia's oil transshipment and storage facilities and the proposed INCO's nickel smelter) carries with it further potential increase in chronic pollution and could be a threat for a sensitive apex predator such as the bald eagle.

Establishing contaminant baseline data in bald eagles in Placentia Bay is essential for gauging the potential impact of future local polluting activities. Moreover, it is still important to monitor contaminants in top predators in relatively remote and pristine northern regions such as Newfoundland, regardless of industrial development (Furness 1993).

This study investigated the current toxicological status of the breeding population

of bald eagles in Placentia Bay, and established baseline data prior to further industrial development. The target contaminants were organochlorines (e.g. DDE, PCBs) and heavy metals (e.g. mercury, lead, cadmium, nickel). Contaminant burdens of bald eagles in Placentia Bay were compared to contaminant burdens of bald eagles in a non-industrialized reference site (Bonavista Bay). This study tested the hypotheses that: i) contaminant concentrations in bald eagle nestlings would be higher in Placentia Bay than in Bonavista Bay; ii) contaminant concentrations in bald eagle nestlings would be lower in Newfoundland than in more heavily industrialized regions (i.e. Great Lakes and Maine). The hypothesis that contaminant levels would be higher in Placentia Bay than in Bonavista Bay was mainly focused on PCBs because there is a known local source of PCB pollution at the American Naval Base in Argentia (Placentia Bay) and PCBs have already been detected in tissues of lobsters near the site (Jacques Whitford 1996). Therefore, tests presented in this study that investigated patterns of contaminant distribution in the study areas were designed in relation to Argentia as a potential source of local PCB pollution. However, it is also acknowledged that there are other potential local sources of pollution in Placentia Bay (e.g. Long Harbour Phosphorus Plant, Come by Chance Oil Refinery), from which there are no available marine contaminant data. DDE, other organochlorines and mercury were investigated because of their widespread dispersion by atmospheric and oceanic transport (Norstrom et al. 1988; Furness 1993). Mercury and other metals were also investigated to obtain baseline data before the potential development of mining-related activities in Placentia Bay (i.e. the proposed

nickel smelter in Argentina), and before further development of the oil industry.

Pollutants were determined in bald eagle eggs and in blood and liver samples from eaglets. Blood samples were systematically collected in Placentia Bay in 1996 and 1997, and in Bonavista Bay in 1997 (see Figs. 3.1 and 3.2). Blood samples from the non-industrialized Bonavista Bay were used as a reference group for comparison of contaminant levels, and to help distinguish background contamination from local sources of pollution in Placentia Bay. Addled eggs and nestling carcasses were collected when found in the nests and provided additional information on contaminant bioaccumulation.

Potential differences between eagle pairs in dietary habits and trophic level were investigated by studying prey remain composition and by conducting isotopic analyses of blood samples. Traditionally, a combination of prey remain analyses and direct observation of feeding events were needed to accurately assess diet composition in bald eagles. However, isotopic analyses of tissue samples is currently an alternative technique to assess trophic relationships in birds (Hobson and Montevecchi 1992; Hobson et al. 1994; Sydeman et al. 1997). Stable nitrogen isotopes are used to predict trophic position and stable carbon isotopes are used as indicators of inshore vs. offshore feeding preferences in marine environments (Hobson et al. 1994). Stable nitrogen isotopes were used in this study to compare the trophic level of bald eagles between and within study areas, and to investigate relationships between contaminant concentrations and trophic level.

3.2 Methodology

3.2.1 Collection of biological samples

Sampling was conducted in late June-early July in both breeding seasons. Nest sites were approached by boat and accessed by rock and tree climbing techniques for the collection of blood and feather samples. Only one nestling per nest was sampled since other studies show no significant differences in contaminant levels among siblings (Welch 1994). Nestlings were sampled when they were approximately six to eight weeks of age (= 44 days; range = 23-57 days). Sampling from eaglets consisted of withdrawing 12-15 cc of blood from the left brachial vein and clipping 5-7 breast feathers. The volume of blood collected was calculated based on body mass, and always under 1 % of the bird's body mass. The blood collecting methodology differed from 1996 to 1997. Blood was collected using a heparinized 20 cc syringe and 23 ga needle and was then transferred into a 15 ml heparanized vacuum tube (Vacutainer[®] #6489 green-top) in 1996. Blood was withdrawn directly from the vein into metal-free 7 ml heparanized vacuum tubes (Vacutainer[®] #369736 blue-top) by using a 23 ga butterfly blood withdrawing set (Vacutainer[®] #6253) in 1997. This last procedure prevented blood from contacting contaminated surfaces (i.e. syringe, 15 ml non metal-free vacutainer). Blood samples were kept in a cooler until being processed at the end of the day in camp. Addled eggs collected from the nests were kept refrigerated until analyzed in the chemical laboratory. A physical exam, which involved recording the condition of plumage, breast muscle,

crop, eyes, mouth, nostrils, ear, feet and external parasite load was conducted on each nestling. Prey remains and adult feathers were also collected from nest sites. Two dead nestlings fallen from the nest, found in Placentia Bay in 1997, were preserved frozen and were later necropsied. Liver, kidney, muscle, brain and fatty tissue samples were taken and preserved frozen in chemically-clean glassware for chemical analyses.

Two adult bald eagles that had been found dead in the province (one in Notre Dame Bay and one with no recorded location) prior to this study, and that had been stored frozen by the NWLD, were necropsied and sampled following the same procedures used with the two dead nestlings. The results were included in this study because they are the first contaminant data from adult bald eagles in Newfoundland.

3.2.2 Processing of samples

Blood samples were processed daily in camp in the following manner: 4-6 cc of whole blood was frozen at -20 C in chemically-clean (nitric-acid rinsed) criovials or in the same metal-free vacuum tubes where blood was collected for metal determination; 0.3 cc of whole blood was refrigerated at 4 C for DNA analysis. The remainder of the blood was centrifuged for plasma separation. Three to six cc of plasma were frozen at -20 C in chemically-clean (acetone/hexane rinsed) glass tubes for organochlorine analysis, 1-2 cc of plasma were frozen in liquid nitrogen for hormone determination, and the remaining blood cells were also frozen in liquid nitrogen for DNA and isotopic analysis. Procedural blank samples consisting of chemically-clean water were collected

through the same equipment used to collect blood and were processed and stored in the same way as the whole blood and plasma for quality control of metal and organochlorine results. Blood smears were prepared, fixed (Cytospray[®] # 151, Pharma Science Inc.) and stained (Diff-Quick[™] Stain Set, Dade Diagnostics) for parasite examination. Plasma, whole blood, eggs, tissue and feather samples were sent (preserved in dry ice or refrigerated) to the Canadian Wildlife Service National Wildlife Research Center (NWRC) in Hull, Quebec, for mercury and organochlorine analyses. Whole blood was sent to the Biochemistry Laboratory at Memorial University of Newfoundland (MUN) for other metal (lead, cadmium, nickel, cobalt, aluminum, zinc, manganese, molybdenum) analyses.

Eggshell thickness was measured in the NWRC using a 0.001 mm dial indicator (Fowler & NISK, Digitrix II). Shell measurements were taken at the midline and included the inner membrane. An average thickness was determined from five measurements for each egg.

3.2.3 Chemical analysis of samples

Organochlorine determination in plasma, egg and liver tissues was conducted by gas chromatography-mass spectrometry using a Hewlett Packard gas chromatograph model 5890 Series II, coupled to a HP mass selective detector HP 5971. Methods of analyses are described in Turle and Nostrom (1987), Jarman et al. (1992) and in the NWRC Laboratory Service Manuals MET-CHEM-OC-02A and MET-CHEM-OC-01A .

Briefly, plasma samples were deproteinized with methanol and internal standards were added at the time of deproteinization. Lipid-OCs/PCBs were extracted with hexane. Liver samples were dehydrated by grinding with excess anhydrous sodium sulfate and column extracted with 50% methylene chloride in hexane. The hexane extract of all samples was evaporated to about 2 ml and cleanup conducted by Florisil column chromatography. Quantitative analysis of OCs and PCBs was performed using a capillary chromatograph, coupled with a mass selective detector operated in selected ion monitoring mode. The sample was injected twice. The first injection was designed to determine OCs by using 21 OCs standards and the second injection to determine PCBs by using Aroclor 1242/1254/1260, (1:1:1) quantitation standard mixture. Aliquots of the herring gull diluted egg pool Reference Material were included for quality control. Lipid content was determined by Sulpho-Phospho Vanilin Reaction (Frings *et al.* 1972). Recoveries of internal standards ranged from 74 % to 104 %. Using Aldrin as surrogate, all residues were corrected for extraction and evaporation recovery. Detection limits were 0.0001 ppm for both OCs and PCBs. 100 % of the samples analyzed had values above the detection limits for both DDE and PCBs.

Mercury in blood, egg and liver tissues was analyzed by cold vapor technique using a 3030-AAS (Perkin-Elmer) equipped with VGA-76 (Varian) hydride generator and PSC-55 (Varian) autosampler. The standard procedure used is described in the NWRC Laboratory Service Manual MET-CHEM-AA-03C. Briefly, liver and egg tissues were weighed out into glass pre-weighed, acid-washed test tubes, freeze-dried and their

dry weights were recorded. Blood samples were weighed out into glass test tubes and wet weights were recorded. For digestion, 0.5 ml deionized water and 1.0 ml HNO₃ (70%) were added to each test tube. Samples were then heated, loosely capped, at 70 °C for 1 hr. After cooling, 1.0 ml of H₂SO₄ (95-97 %) and then 0.5 ml of HCl (37 %) were added. They were heated again at 70 °C for 2 hours. After cooling the volumes were adjusted to 10 ml with 2 mM K₂Cr₂O₇ in 3 % HCl. Volumes were then adjusted to 20 ml with 9.9 ml 1.5 % HCl and 100 µg octanol. The accuracy of the analysis was determined by analyzing standard reference material DOLT-2 (dogfish liver) and DORM-2 (dogfish muscle). Two blanks were also included in each set of digestion. All blood samples and one random liver sample were analyzed in duplicate. Recoveries of reference materials were within the certified range. The detection limit was 0.04 ppm wet wt for blood samples, 0.1 ppm dry wt for egg samples and 0.03 ppm wet wt for liver samples. 100 % of the samples analyzed had mercury concentrations above the detection limits.

Other metals in blood samples were analyzed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) with an Elan Model 250 and methods of analysis are described by Friel et al. (1990). For tissue preparation blood samples were air-dried to constant mass in a drying oven (Fisher Scientific Co.) overnight at 55 °C. Dried samples were weighed accurately into the Teflon cup (Teflon PFA) of a high-pressure microwave acid-digestion bomb (Parr Instrument CO.) Sub-boiling doubly distilled concentrated nitric acid (2ml) was added to the organic tissue and the vessel was sealed. Samples were digested in a conventional microwave oven (Panasonic, model NE-6660C, 700 W),

containing a rotating turntable. The digestion vessel was then cooled in a freezer (-20 C) for 30 min. An additional 0.1 g of the sample was added directly to the initial digestion, followed by 1 ml of nitric acid. The digestion and cooling were repeated as described above, and the final sample preparation was washed into an acid-washed Teflon beaker with de-ionized water. Samples were transferred to a hot-plate at 90 C and boiled to near dryness. Standard reference material 1577a (bovine liver) was included for quality control. Two blanks and sample duplicates were included in each set of digestion. Recoveries of standard reference material were within the certified range except for Pb, for which recovery values were one order higher than the values of the standard reference material. Therefore, Pb concentrations in blood samples were considered unreliable and are not reported. For Ni and Al there were no standard reference materials. Although duplicate samples had very close values, it is not possible to verify the accuracy of the results. For this reason these two elements are also not reported. Detection limits of the metals reported (expressed in wet weight) were: 0.05 ppm for copper (Cu); 0.004 ppm for manganese (Mn) and cobalt (Co); 0.05 for cadmium (Cd); 0.001 ppm for molybdenum (Mo). The percentages of samples having detectable concentrations of Cd, Co, Cu, Mn and Mo were 22 %, 48 %, 100 % , 100 % and 52 %, respectively.

Lead was analyzed in liver samples at the NWRC by Graphite Furnace Atomic Absorption Spectrometry (GFAAS) using a Perkin Elmer 3030b equipped with a Deuterium Background Corrector. The standard procedure used is described in the NWRC Laboratory Service Manual MET-CHEM-AA-02C. Preparation, digestion and

quality assurance of samples followed the methodologies described for mercury analyses. Determinations were made with the calibration performed versus acid standards (10% Nitric Acid). The detection limit in the digest under these conditions was 0.005 µg/ml (0.10 µg/g dry wt. in tissue for 0.2g sample). Recovery of reference material was 90.5% and 90.9% for DOLT-2, 106% for the analytical spike and 88% for the matrix spike.

Feather samples were not analyzed and were archived in the NWRC for potential future analyses. Field procedural blanks were included in all chemical analyses. All toxicology results are given in ppm (µg/g) in wet weight (ww), unless otherwise indicated.

3.2.4 Dietary analyses

Prey remains

Prey remains, pellets and a sample of fine nest material (to check for fish scales and other small remains) were collected from the nest bowl and nest-site surroundings. Prey remains were classified as fishes, birds and mammals. Prey remain composition is expressed as percent occurrence of minimum number of individuals for each of the three prey classes (Todd et al. 1982; Knight et al. 1990). Nests were also individually categorized by their prey remain composition: the first category included nests that had all or mostly fish remains; the second category included nests that had about equal proportion of bird and fish remains; the third category included nests that had all or

mostly bird remains.

Stable isotopes

Stable isotope ratios $^{15}\text{N}/^{14}\text{N}$ and $^{13}\text{C}/^{12}\text{C}$ were determined in 12 blood samples from Placentia Bay and 6 blood samples from Bonavista Bay collected in 1997. For analysis, dried blood samples were loaded into tin cups and combusted at 1850 C in a Robo-Pre elemental analyzer interfaced with a Europa 20:20 continuous flow isotope ratio mass spectrometer (CFIRMS). For every 5 unknowns, two standards were measured in sequence. Based on thousands of measurements, analytical error is estimated to be ± 0.3 per mil for ^{15}N and ± 0.1 per mil for ^{13}C . Stable-isotope concentrations in blood samples are reported in delta notation as parts per thousands according to the following:

$$X = (R_{\text{sample}} / R_{\text{standard}}) - 1 \times 1000$$

where X is ^{15}N or ^{13}C and R is the corresponding ratio $^{15}\text{N}/^{14}\text{N}$ or $^{13}\text{C}/^{12}\text{C}$. R_{standard} for ^{15}N and ^{13}C are atmospheric N_2 (AIR) and the PDB standard, respectively.

3.2.5 Statistical analysis

Contaminant data, expressed in ppm (wet weight), were transformed to \log_{10} to achieve a normal distribution and geometric means were calculated. The logarithmic transformation was successful in normalizing the data. Contaminant data were not lipid-

normalized for statistical analyses since there were no strong correlations between log-transformed concentrations of DDE, PCBs or mercury and plasma lipid concentrations ($r = 0.07$, $r = 0.2$ and $r = 0.2$, respectively). When samples had contaminant concentrations below the analytical detection limit, a value of one half the minimum detection limit was assigned.

One-way ANOVAs were used to test differences in the mean residue concentrations between years in Placentia Bay and between Placentia and Bonavista Bays. Since there were no significant differences in the mean residue concentrations for any contaminant in 1996 and 1997 in Placentia Bay, contaminant data from both years were then lumped together to calculate the mean residue concentrations used in further statistical analyses. Replicate samples from the different years from the same nest were averaged and treated as one single independent sample (this was done to avoid duplicating the same sample based on the assumption that the same breeding pair occupied the same nest both years).

Nests from Placentia Bay were grouped into NEAR and DISTANT to test differences in contaminant concentrations in relation to proximity to a potential local source of pollution in Argentina on the east side of the bay. The following criteria were used to classify the nests as NEAR or DISTANT: i) nest distance to Argentina, calculated on a straight line with Mapinfo; ii) probable foraging range of the breeding pair (i.e. on the south-east side or on the north-west side of the bay); iii) location of nests in relation to surface ocean current direction (i.e. up/down current and distance from source of

pollution). Results of this classification are shown in Fig. 3.1, by means of an artificial boundary line on the map. A buffer zone was projected between the NEAR and DISTANT groups, but this generated a small sample size in the two categories of nests because most nests were located in an intermediate zone in relation to distance to Argentina. NEAR nests were located on the east coast of the bay, Long Island and the east coast of Merasheen Island. DISTANT nests were located on the west coast of Merasheen Island, and the west and northwest coast of the bay. One-way ANOVAs were used to test differences in the mean contaminant concentrations of these two groups (with and without the buffer zone), and between each of these and the reference sample group from Bonavista Bay. Lastly, to investigate a gradient of contaminant concentrations, relationships between pollutant levels in nestling tissues and nest distance to Argentina (as a continuous variable) were also assessed using regression analyses.

Dietary analyses were conducted to test for differences in trophic level (between bald eagles from the two study areas and between groups in Placentia Bay). Differences in prey remain composition between study areas, groups of nests in Placentia Bay and years were examined with a chi-square test of independence and a Fisher's exact test. Duplicate samples of prey remains collected at the same nest site in different years were combined and treated as one sample for statistical analyses. Differences in the means of stable isotope ratios ^{15}N and ^{13}C between study areas and between the NEAR and DISTANT groups in Placentia Bay were tested with a one-way ANOVA. Differences in contaminant concentrations in relation to the prey remain category of the nests were

investigated with a one-way ANOVA. Relationships between contaminant concentrations and isotopic values were also investigated using regression analyses. Relationships between trophic level and distance to Argentina were also investigated using regression analyses, to account for any coincidental patterns between contaminant concentrations and trophic level in relation to nest distance to Argentina.

Finally, relationships between chick production, chick body condition, contaminant concentrations and distance to Argentina were also studied using correlation analyses.

Randomization (10,000 runs; Adams and Anthony 1996) and/or Kruskal Wallis tests were conducted to defend parametric test results when residuals from the ANOVAs did not show a normal distribution. A value of $\alpha = 0.05$ was used in all tests. Statistical tests were conducted with Minitab and Systat.

3.3 Results

3.3.1 Contaminants in blood, egg and liver samples

3.3.1.1 Contaminants in nestling plasma and whole blood

Twenty one blood samples collected in Placentia Bay (10 from 1996, 11 from 1997) and six blood samples collected in Bonavista Bay in 1997 were submitted for chemical analyses. Geometric mean concentrations of the main contaminants detected are

summarized in Table 3.1. A summary of the results of the statistical analyses conducted to test differences in contaminant concentrations between both bays is shown in Table 3.2. In the results of the statistical analyses, p-values from randomization tests (p_{rand}) are reported following the p-value from the ANOVA when the residuals from this parametric test did not have a normal distribution. All results are based on the comparison of the means of the \log_{10} -transformed contaminant concentrations. Since there were no significant differences in the mean concentrations of any contaminant between 1996 and 1997 in Placentia Bay (see below), data were pooled across years for further statistical analyses. Contaminant concentrations of replicate samples (four nests were sampled in both 1996 and 1997) were averaged and treated as a single independent data point for each nest.

Organochlorines

In Placentia Bay, plasma concentrations of DDE and PCBs were 0.1 ppm in all samples (Appendix 3.1). There were no significant differences in mean concentrations of DDE and PCBs between years ($F_{1,20} = 0.58$; $p = 0.4$ $n = 21$, $p_{\text{rand}} = 0.1$ and $F_{1,20} = 1.92$; $p = 0.2$, $p_{\text{rand}} = 0.1$, respectively). Mean concentrations of PCBs and DDE in blood samples collected from NEAR nests were higher than in blood samples from DISTANT nests ($F_{1,15} = 4.7$; $p = 0.04$ and $F_{1,15} = 4.22$; $p = 0.05$, respectively), although these differences only approached significance for PCBs when a non-parametric randomization test was conducted ($n = 17$, $p_{\text{rand}} = 0.05$ and $n = 17$, $p_{\text{rand}} = 0.06$, respectively). In Bonavista Bay,

plasma concentrations of DDE and PCBs were 0.04 ppm in all samples (see Appendix 3.2).

Geometric mean concentrations of DDE and PCBs in nestling plasma were significantly higher in Placentia Bay than in Bonavista Bay (Table 3.2, Fig. 3.3). Geometric mean contaminant concentrations in plasma samples from NEAR and DISTANT nests in Placentia Bay were compared independently with mean contaminant concentrations in plasma samples from nests in Bonavista Bay. Results of the statistical analyses conducted are given in Table 3.3 and show that : i) mean concentrations of PCBs and DDE were significantly higher in NEAR nests than in nests in Bonavista Bay; ii) mean concentrations of PCBs and DDE were not significantly different between DISTANT nests and nests in Bonavista Bay.

Residue concentrations of other organochlorines were under 0.005 ppm in all samples, and in many cases under detectable levels, and are given in Appendix 3.3.

Metals

In Placentia Bay, mercury concentrations in whole blood were under 0.3 ppm in all samples (Appendix 3.1) and there were no significant differences in mean concentrations between years ($F_{1,20} < 0.001$; $p = 0.9$; $p_{\text{rand}} = 0.3$). Concentrations of other metal residues (i.e. cobalt, copper, molybdenum, cadmium, manganese) in whole blood were relatively low (see Appendix 3.1). There were no significant differences in mean mercury concentrations between the NEAR and DISTANT groups ($F_{1,15} = 1.78$; $p = 0.2$;

$p_{\text{rand}} = 0.2$). Mean concentrations of other metals were not significantly different between NEAR and DISTANT nests either (magnesium $F_{1,15} = 0.54$, $p = 0.47$; manganese $F_{1,15} = 1.5$, $p = 0.2$; cobalt $F_{1,15} = 1.23$, $p = 0.3$; copper $F_{1,15} = 0.61$, $p = 0.4$; zinc $F_{1,15} = 0.26$, $p = 0.6$; and molybdenum $F_{1,15} = 1.01$, $p = 0.3$). Only 17 % (3 out of 17) of the samples had detectable concentrations of cadmium and therefore an ANOVA test was considered inappropriate.

In Bonavista Bay, mercury concentrations in whole blood were under 0.3 ppm in all samples and other metal residues were present in low concentrations (Appendix 3.2).

There were no significant differences in geometric mean concentrations of mercury ($F_{1,21} = 1.44$, $p = 0.2$), copper ($F_{1,21} = 0.41$, $p = 0.5$), cobalt ($F_{1,21} = 0.3$, $p = 0.6$) and manganese ($F_{1,21} = 1.62$, $p = 0.2$) between bays, while molybdenum was significantly higher in Placentia Bay ($F_{1,21} = 14.32$, $p = 0.003$) (none of the samples from Bonavista Bay had detectable concentrations of this metal).

3.3.1.2 Contaminants in eggs

Two addled eggs were collected in Placentia Bay, one in 1996 and one in 1997. Mean concentrations of DDE, PCB and mercury are given in Table 3.1. Other organochlorine residues are given in Appendix 3.3. Eggshell thickness for the two eggs were 0.556 mm and 0.555 mm.

3.3.1.3 Contaminants in liver

Contaminant concentrations in the livers of the two dead nestlings found in Placentia Bay in 1997, and of the two dead adult bald eagles are given in Table 3.4. Liver concentrations of DDE and PCBs were relatively low (< 5 ppm) in all samples. Mercury concentrations were also relatively low in the two adults (= 5.45 ppm) and in the two nestlings (= 0. 145 ppm). Lead concentrations were relatively low in the two adults (= 0.2 ppm) and below detection limits (< 0.02 ppm) in the two nestlings. Contaminant concentrations in the liver of the dead nestling from nest #33 can be compared to contaminant concentrations in the blood of its alive sibling (see Fig. 3.4). The ratios of nestling DDE (liver/plasma), PCBs (liver/plasma) and mercury (liver/whole blood) concentrations were 1.6, 1 and 1.4, respectively. Mean concentrations of DDE, PCBs and mercury in liver from the two adults were 28-, 41- and 30-fold the mean concentrations of the two nestling livers, respectively (see Fig. 3.5).

3.3.2 Dietary analyses

3.3.2.1 Prey remains

In Placentia Bay, prey remains collected from 22 nest sites in both years consisted of 69 % bird remains (mainly seabirds), 25 % fish remains and 5.5 % mammal remains. Seabird species were dominated by gulls (*Larus spp.*) and alcids (*Uria spp.*). Fish species included yellow-tail flounder (*Limanda ferruginea*), wolffish (*Anarhichas sp*), sculpin

(*Myxocephalus scorpioides*), lump fish (*Cyclopterus lumpus*), cod (*Gadus morhua*), red fish (*Sebastes sp*), herring (*Clupea harengus*) and lobster (*Homerus americanus*).

Mammal remains included snowshoe hare (*Lepus americanus*). Percentages of occurrence of bird and fish remains were not significantly different either between years ($n = 80$, $\chi^2 = 0.1$; $df = 1$; $p = 0.2$) or between NEAR and DISTANT nests ($n = 80$, $\chi^2 = 0.07$, $df = 1$, $p = 0.7$)

In Bonavista Bay, prey remains collected from 8 nests consisted of 50 % bird remains, 40 % fish remains and 10 % mammal remains. Bird remains were also dominated by gulls and alcids. Fish remains included flounder, herring, cod and lump fish. Mammal remains included snowshoe hare.

The percentages of occurrence of prey specimens in the three prey remain groups (fish, birds and mammals) in Placentia and Bonavista Bay are shown in Fig. 3.6. There were no significant differences in prey remain composition between Placentia and Bonavista Bays ($n = 102$, $\chi^2 = 0.9$, 1 df , $p = 0.3$).

3.3.2.2 Stable isotopes

^{15}N and ^{13}C values of 19 blood samples from Placentia and Bonavista Bay from 1997 are shown in Appendix 3.4; mean values for each study area are shown in Table 3.5.

In Placentia Bay, mean concentrations of ^{15}N were not significantly different between NEAR and DISTANT nests ($F_{1,11} = 3.34$, $p = 0.09$) while mean concentrations

of ^{13}C were significantly more enriched in DISTANT nests than in NEAR nests ($F_{1,11} = 10.29$, $p = 0.008$).

There were no differences in ^{15}N blood mean concentrations between Placentia and Bonavista Bay ($F_{1,17} = 1.69$, $p = 0.2$). Blood ^{13}C values were more enriched in Bonavista Bay than in Placentia Bay ($F_{1,17} = 4.95$, $p = 0.05$). Blood ^{13}C values from nests in Bonavista Bay were significantly more enriched than ^{13}C values in NEAR nests ($F_{1,12} = 14.18$, $p = 0.003$), but similar to ^{13}C values in DISTANT nests ($F_{1,9} = 0.05$, $p = 0.8$).

3.3.3 Relationships between contaminant concentrations in nestling blood, distance to Argentina and dietary trophic level

All relationships with DDE, PCBs and mercury are based on the \log_{10} -transformed contaminant data. DDE and PCB concentrations were negatively related to nest distance to Argentina (Figs. 3.7 and 3.8). There was no significant relationship between mercury and nest distance to Argentina (Fig. 3.9).

There were no significant differences in DDE, PCBs, and mercury concentrations among nests classified in the three prey remain categories ($F_{2,14} = 0.75$, $p = 0.5$, $F_{2,14} = 1.07$, $p = 0.4$ and $F_{2,14} = 0.17$, $p = 0.8$, respectively).

Concentrations of ^{15}N in blood samples were not significantly related to either nest distance to Argentina ($r = 0.16$, $r^2 = 0.02$, $F_{1,11} = 0.24$, $p = 0.6$), DDE plasma concentrations ($r = 0.006$, $r^2 = 0.03$, $F_{1,15} = 0.44$, $p = 0.5$), PCB plasma concentrations

($r = 0.04$, $r^2 = 0.002$, $F_{1,15} = 0.03$, $p = 0.8$), or mercury whole blood concentrations ($r = 0.03$, $r^2 = 0.001$, $F_{1,15} = 0.02$, $p = 0.9$).

^{13}C was positively related to distance to Argentina ($r = 0.69$; $r^2 = 0.48$; $F_{1,9} = 8.3$; $p = 0.018$) and negatively related to DDE (Fig. 3.10) and PCBs (Fig. 3.11). There was no significant relationship between ^{13}C and mercury (Fig. 3.12).

3.3.4. Relationships between chick production, chick body condition and contaminant concentrations

Nest chick production in 1996-97 was not correlated with nestling plasma concentrations of either DDE ($r = 0.02$) or PCBs ($r = 0.07$), or with whole blood concentrations of mercury ($r = 0.2$). Body condition index was not correlated with nestling plasma concentrations of either DDE ($r = 0.09$) or PCBs ($r = 0.04$), or with whole blood concentrations of mercury ($r = -0.02$).

3.4 Discussion

3.4.1 Contaminant burdens in bald eagles in Placentia and Bonavista Bays

Mean concentrations of DDE, PCBs, mercury and other metals in nestling blood were low in general in both study areas. Geometric mean concentrations of DDE and PCBs in plasma were below 0.1 and 0.4 ppm (ww), respectively, values above which overall productivity fell under one nestling/occupied nest in ten bald eagle sub-

populations in the Great Lakes region (Bowerman et al. 1995). Relationships between mercury concentrations in nestling blood and reproductive success have not been clearly established yet, primarily due to the common association of mercury and organochlorine residues (Bowerman et al. 1994, 1995). However, geometric mean concentrations of mercury in nestling feathers in the Great Lakes region, ranging from 13 to 21 ppm, were not correlated with the population's productivity or nest success (Bowerman et al. 1994). Nestling blood mercury concentrations in the present study are well below the levels found in the Great Lakes, which had no effect on reproduction¹.

DDE mean concentrations in nestling plasma were significantly higher in Placentia Bay than in Bonavista Bay. Although DDE residues are very low in all nestlings and could be due to background atmospheric deposition or oceanic transport, the east side of Placentia Bay is more heavily populated by humans and developed than the study area in Bonavista Bay. NEAR nests on the east side of Placentia Bay also had higher concentrations of DDE than DISTANT nests on the northwest side of the bay, and than nests in Bonavista Bay. Finally, regression analyses showed a significant negative relationship between DDE concentrations and distance to Argentina. All these results point to a possible local source of DDE from human activities on the more industrialized (American Naval Base and Long Harbour Phosphorus Plant) and populated east side of Placentia Bay.

¹ Blood levels from Great Lakes nestlings were extrapolated from the reported feather concentrations in Bowerman et al. (1994) for comparison with the present study. Extrapolation was based on correlations of mercury concentrations in blood and feathers from bald eagle nestlings found in other studies (Welch 1994; Wood et al. 1995).

Mean PCB concentrations in nestling plasma were higher in Placentia Bay than in Bonavista Bay. NEAR nests also had higher PCB concentrations than DISTANT nests and than nests in Bonavista Bay. There was also a negative relationship between PCB concentrations and distance to Argentina. The abandoned US naval base in Argentina has been identified as a potential local source of PCB contamination in Placentia Bay (Jacques Whitford 1996). These results also point to a local origin of PCB residues in the east side of Placentia Bay.

Mercury concentrations in nestling blood were not significantly different either between bays or between NEAR and DISTANT nests. There was no relationship between mercury concentrations and distance to Argentina. Similar relatively low mercury concentrations in nestlings from both areas could be due to general background levels. Concentrations of other metals (cobalt, copper, cadmium, manganese) were low and similar in both bays, and may also reflect general background levels.

DDE concentrations in the two eggs were relatively low and below the NOAEC (no observable adverse effect concentration) of 3.6 ppm (ww) (Wiemeyer et al. 1993; Bowerman et al. 1995). PCB concentrations in both eggs were also below the NOAEC of 4 ppm (ww) proposed by Bowerman et al. (1995). However, one of the eggs had PCB concentrations close to this value (3.5 ppm). Mercury concentrations in both eggs were also below 0.5 ppm (ww), the theoretical NOAEC proposed for bald eagle eggs (Wiemeyer et al. 1984), and below a theoretical LOAEC (lowest observable adverse effect concentration) of 1 ppm for white-tailed eagle (*Haliaeetus albicilla*) eggs given by

Helander et al. (1982). DDE, PCB and mercury concentrations detected in the eggs show bioaccumulation of these contaminants in adult females, but they do not necessarily represent a local source of contamination. Determination of wintering grounds of the breeding pairs would be necessary to account for other possible sources of contamination.

DDE and PCB concentrations in the livers from the two adult eagles and the two nestlings were also relatively low and mercury concentrations fall within the ranges attributed to areas with little or no industrial sources of mercury (Scheuhammer 1987). Ratios of adult/nestling liver mercury concentrations found in this study are higher than those reported by Wood et al. (1995). Lead concentrations in the livers from the two adults were relatively low and within the background levels found in adult bird species living in relatively uncontaminated areas (Scheuhammer 1987). Lead concentrations in the livers of the two nestlings were below detection limits. Bald eagles in Newfoundland are potentially exposed to lead mainly through the ingestion of shot birds from the murre and seaduck hunt during the fall and winter months and, therefore, nestlings would not be directly exposed to this source of lead during the breeding season.

In summary, this study supports the hypothesis that DDE and PCB concentrations in bald eagle nestling blood are higher in Placentia Bay than in Bonavista Bay, potentially due to local source of contamination. However, distance to a local source of pollution only explained 30-45 % of the variance in contaminant concentrations and other unidentified factors could also be playing a role.

3.4.2 Diet of bald eagles in Placentia and Bonavista Bays and its relationship to contaminant concentrations.

A possible factor influencing contaminant concentrations in bald eagles is a difference in dietary habits and trophic level. Bald eagles that feed mainly on seabirds, especially gulls, are known to bioaccumulate higher concentrations of contaminants than eagles feeding mainly on fishes or terrestrial herbivores (Kozie and Anderson 1991; Welch 1994). Analyses of prey remains from both bays are similar to those found in other bald eagle coastal populations, where seabirds seem to dominate prey composition (Todd et al. 1982; Knight et al 1990; Welch 1994). Statistical analyses showed no significant differences in percentage occurrence of bird and fish remains between Placentia and Bonavista Bays, or between groups in Placentia Bay.

Contaminant concentrations were not significantly different among nests classified in the three different trophic levels. Analyses of ^{15}N in nestling blood samples also showed no trophic differences between Placentia and Bonavista Bays, or between NEAR and DISTANT nests in Placentia Bay. There was no relationship either between ^{15}N concentrations and nest distance to Argentina. Thus, differences in contaminant concentrations detected in this study do not seem to be due to differences in dietary trophic level among breeding pairs.

On the other hand, ^{13}C values were more depleted in NEAR nests than in DISTANT nests and in nests in Bonavista Bay, and there was a positive relationship between ^{13}C and distance to Argentina. Enriched ^{13}C values in birds in the marine

environment have been related to a more inshore/benthic based diet, while more depleted ^{13}C values have been related to a more offshore/pelagic based diet (Hobson et al. 1994). The group of DISTANT nests in Placentia Bay is located close to the head of the bay and the group of nests in Bonavista Bay is located in a long sound that begins in an estuary, also at the head of the bay. NEAR nests in Placentia Bay are mainly located on islands, closer to the mouth of the bay. This difference in geographical distribution of the breeding areas could influence ^{13}C values, where bald eagles foraging closer to estuarine habitats or fresh water systems would have a more terrestrial/benthic based diet than bald eagles foraging from the islands. However, all nests in Placentia Bay are located within the bay and distances from the islands to the mainland only range from 5 to 25 km. This would not categorize the islands as 'offshore'. Differences in prey composition (benthic versus pelagic) could also influence ^{13}C values. Analyses of prey remains did not show a clear difference in bird species composition between bays or between groups of nests in Placentia Bay. However, potential differences in fish species composition could not be determined from the prey remain study because of the small sample size. Differences in fish prey composition in the breeding pairs could be due to differences in prey availability, to differences in foraging strategies and to supplementary feeding provided by fishermen at some nests. Direct observation of dietary habits are needed to provide more information on potential differences in diet composition among the breeding pairs.

There was also a negative relationship between ^{13}C values and DDE and PCB concentrations, but no relationship between ^{13}C and mercury concentrations. The fact

that mercury and other metals do not change with ^{13}C could indicate that another factor (i.e. distance to Argentina) is playing a more important role than ^{13}C concentrations in the variation of DDE and PCB concentrations. However, relationships between organochlorine/metal bioaccumulation and benthic/pelagic prey species should be further investigated.

Finally, there was no significant relationship between contaminant concentrations and chick production or chick body condition index. Contaminant concentrations detected in this study were well below the burdens related with impaired reproduction and were not expected to be correlated with either chick production or body condition index. Other factors such as food availability and weather probably play a much more important role on chick production and on chick body condition in the two study areas.

3.4.3 Comparison with other bald eagle populations in North America

DDE, PCB and mercury concentrations in nestling blood and in addled eggs from the main bald eagle breeding populations in North America in the last two decades are shown in Figs. 3.13 and 3.14 and in Appendices 3.5 and 3.6. Newfoundland's DDE and PCB burdens are higher than those of Alaska and are in general lower than those of more industrialized regions such as the Great Lakes, Columbia River Estuary, British Columbia and Maine. However, mercury concentrations in blood and eggs from Placentia Bay are similar to those found in coastal bald eagles in Maine, coastal British Columbia, Florida, and higher than those found in Alaska, Arizona, Ohio and Chesapeake Bay. A general

increase in mercury background levels in aquatic systems due to atmospheric deposition has been observed in the last two decades (Soreson et al. 1990). Also, natural variations in mercury levels are caused by a combination of geological, climatic and topographic influences, still not well understood in marine environments (Rasmussen et al. 1998). Both atmospheric deposition and natural factors could explain higher mercury burdens detected in relatively unindustrialized marine regions such as Newfoundland.

In conclusion, these results support the hypothesis that contaminant levels are lower in Newfoundland than in more industrialized regions in North America, with the exception of mercury that seems to have similar general background levels across all the North American marine regions that were compared.

Table 3.1 Geometric mean contaminant (ppm, ww) and lipid (g/ml) concentrations, and ranges (in brackets) in bald eagle nestling plasma, whole blood and liver samples, and in bald eagle eggs from Placentia and Bonavista Bays, 1996-97. na = not analyzed; nd = below detection limit;^a = combined samples from 1996 and 1997; ^b = same values; ^p = plasma concentration.

Location	Sample	Residue geometric mean concentrations (ppm, ww)							
		Lipid	DDE	PCBs	Mercury	Cobalt	Copper	Molybdenum	Manganese
Placentia Bay	Blood ^a (n = 17)	0.79 ^p (0.65-0.96)	0.009 ^p (0.001-0.04)	0.03 ^p (0.01-0.1)	0.08 (0.06-0.25)	nd	0.39 (0.2-0.8)	0.003 (nd -.02)	0.07 (0.03-0.1)
Placentia Bay	Egg (n = 2)	4.9 (4.1-5.9)	1.7 (1.5-2.0)	3.1 (2.9-3.5)	0.2 ^b	na	na	na	na
Placentia Bay	Liver (n = 2)	2.6 (2.57-2.61)	0.04 (0.03-0.05)	0.1 ^b	0.1 (0.13-0.16)	na	na	na	na
Bonavista Bay	Blood (n = 6)	0.86 ^p (0.71-1.21)	0.002 ^p (.0004-.005)	0.01 ^p (.008-0.04)	0.07 (0.05-0.1)	nd	0.3 (0.2-0.5)	nd	0.05 (0.02-0.2)

Table 3.2 Summary of statistical analyses on differences in mean concentrations of DDE and PCBs (in plasma) and of mercury (in whole blood) in bald eagle nestlings from Placentia and Bonavista Bays, 1996-97.

Contaminant	Geometric mean concentration (ppm, ww)		Statistic	Significant difference
	Placentia Bay (n=17)	Bonavista Bay (n=6)		
DDE	0.009	0.002	$F_{1,21} = 3.99$; $p_F = 0.05$ $p_{ran} = 0.03$	Yes
PCBs	0.03	0.01	$F_{1,21} = 6.32$; $p_F = 0.02$ $p_{ran} = 0.003$	Yes
Mercury	0.08	0.07	$F_{1,21} = 1.44$; $p_F = 0.2$ $p_{ran} = 0.2$	No

p_F = p-value of F-distribution
 p_{ran} = p-value of randomization

Table 3.3 Summary of statistical analyses on differences in mean concentration of DDE and PCBs (in plasma) and mercury (in whole blood) in bald eagle nestlings from the NEAR and DISTANT groups in Placentia Bay and from Bonavista Bay, 1996-97. PB_{NEAR} = NEAR nests in Placentia Bay; $PB_{DISTANT}$ = DISTANT nests in Placentia Bay; BB = nests in Bonavista Bay.

Compared groups	N	DDE	PCBs	Mercury
PB_{NEAR}	12	$F_{1,15} = 4.7; p_F = 0.04$ $p_{ran} = 0.05$	$F_{1,15} = 4.22; p_F = 0.05$ $p_{ran} = 0.06$	$F_{1,15} = 1.78; p_F = 0.2$ $p_{ran} = 0.2$
$PB_{DISTANT}$	5			
PB_{NEAR}	12	$F_{1,16} = 18.1; p_F = 0.001$ $p_{ran} = 0.01$	$F_{1,16} = 13.33; p_F = 0.002$ $p_{ran} = 0.01$	$F_{1,16} = 1.65; p_F = 0.2$ $p_{ran} = 0.3$
BB	6			
$PB_{DISTANT}$	5	$F_{1,9} = 1.01; p_F = 0.3$ $p_{ran} = 0.35$	$F_{1,9} = 2.07; p_F = 0.18$ $p_{ran} = 0.19$	$F_{1,9} = 0.1; p_F = 0.9$ $p_{ran} = 0.9$
BB	6			

p_F = p-value of F-distribution

p_{ran} = p-value of randomization

Table 3.4 Contaminant concentrations (ppm, ww) in liver samples from nestling and adult bald eagles in Newfoundland, 1995-97.

Nest	Age	Location	Year	Residue concentration (ppm, ww)						
				DDE	Oxychlorane	Dieldrin	t-Nonachlor	PCBs	Mercury	Lead
33	nestling	Placentia Bay	1997	0.05	0.004	nd	0.01	0.1	0.13	nd
24	nestling	Placentia Bay	1997	0.03	0.003	nd	0.006	0.1	0.16	nd
-	adult	unknown	1996	1.0	0.1	0.1	0.2	4.8	8.3	0.3
-	adult	Notre Dame Bay	1995	1.2	0.1	0.08	0.3	3.3	2.6	0.03

nd = not detected.

Detection limits: DDE, oxychlorane, dieldrin, t- Nonachlor and PCBs, 0.001 ppm; mercury, 0.04 ppm; lead 0.02 ppm

Table 3.5. Mean concentrations of stable isotopes ^{15}N and ^{13}C in bald eagle nestling blood from Placentia and Bonavista Bays, 1997.

Location	N	Mean concentration (‰) ● SD	
		^{15}N	^{13}C
Placentia Bay	13	15.95 ± 0.44	-18.26 ± 0.46
Bonavista Bay	6	15.71 ± 0.19	-17.84 ± 0.19

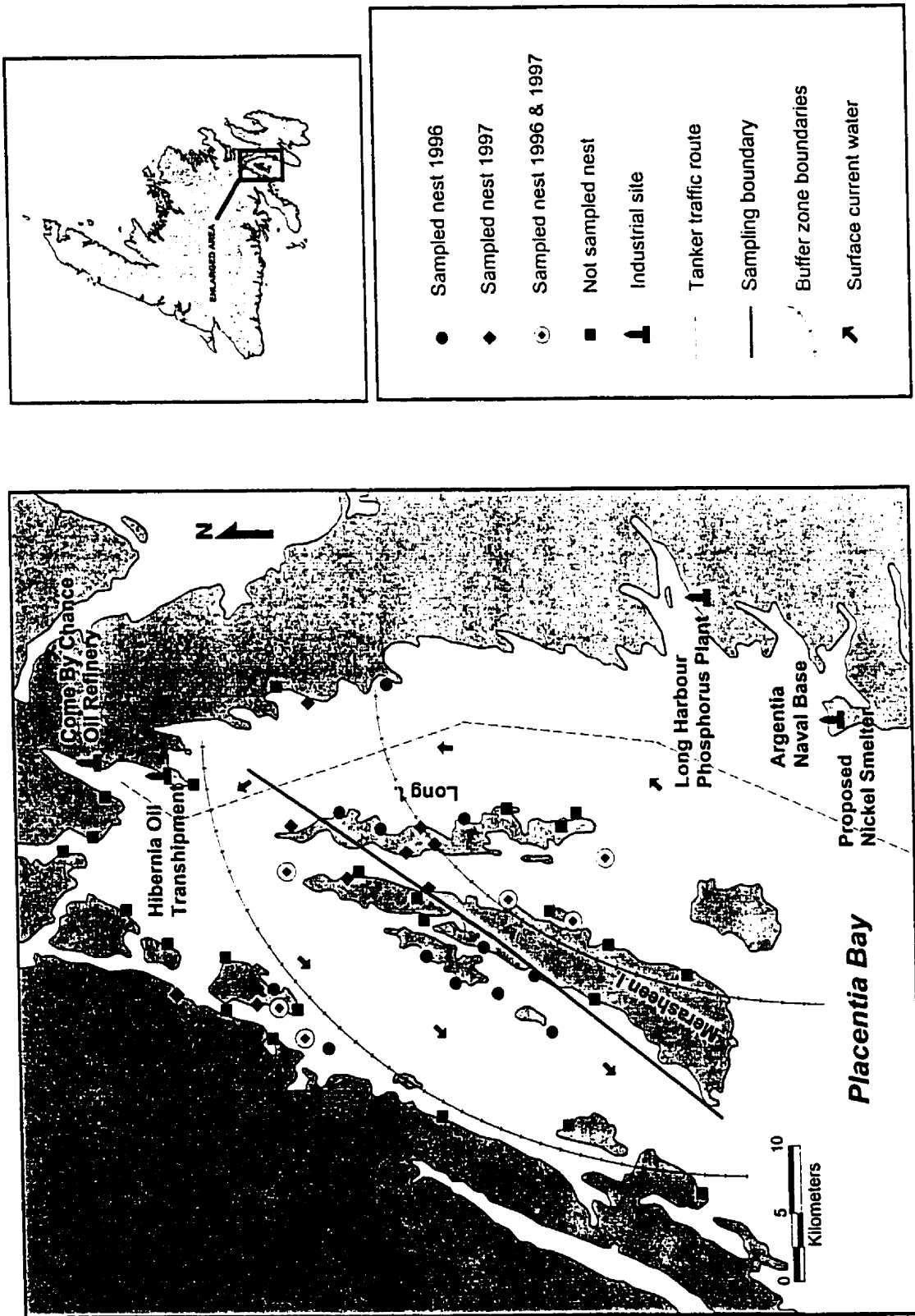


Fig. 3.1. Bald eagle nests sampled for contaminant analyses in Placentia Bay, 1996-97, and arbitrary boundary line separating NEAR nests from DISTANT nests to Argentina.

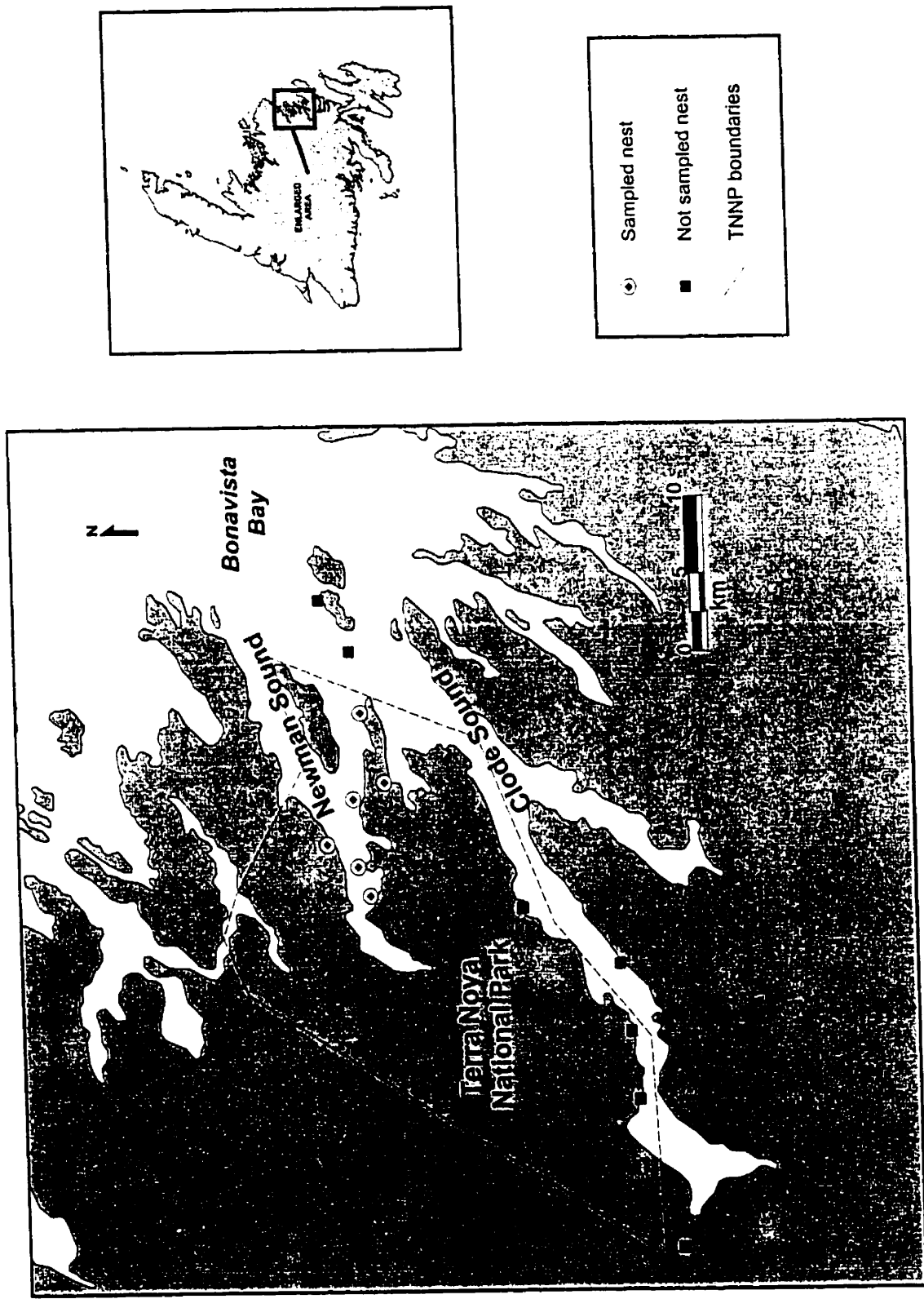


Fig. 3.2. Bald eagle nests sampled for contaminant analyses in Bonavista Bay, 1997.

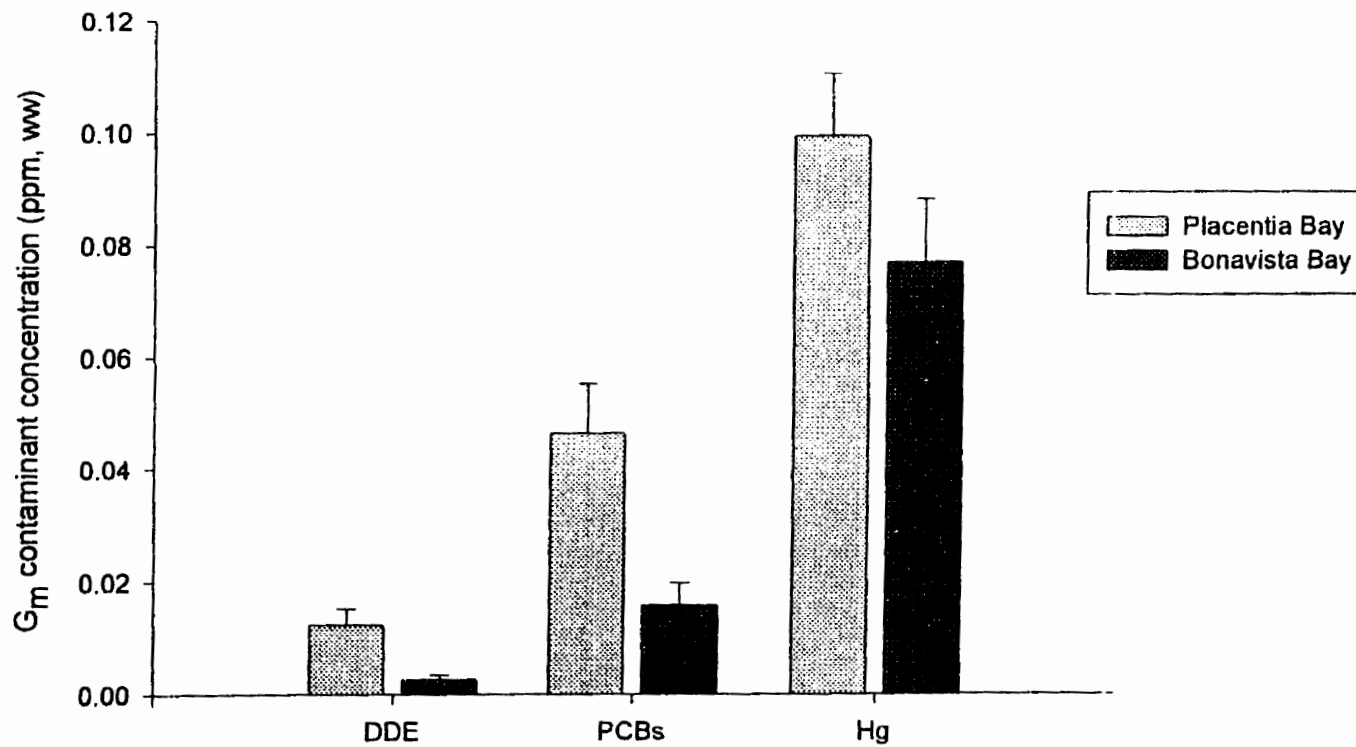


Fig. 3.3. Geometric mean (G_m) contaminant concentrations (ppm, ww) in bald eagle nestling plasma (DDE and PCBs) and blood (Hg) from Placentia and Bonavista Bays, 1996-97. Error bar = standard error.

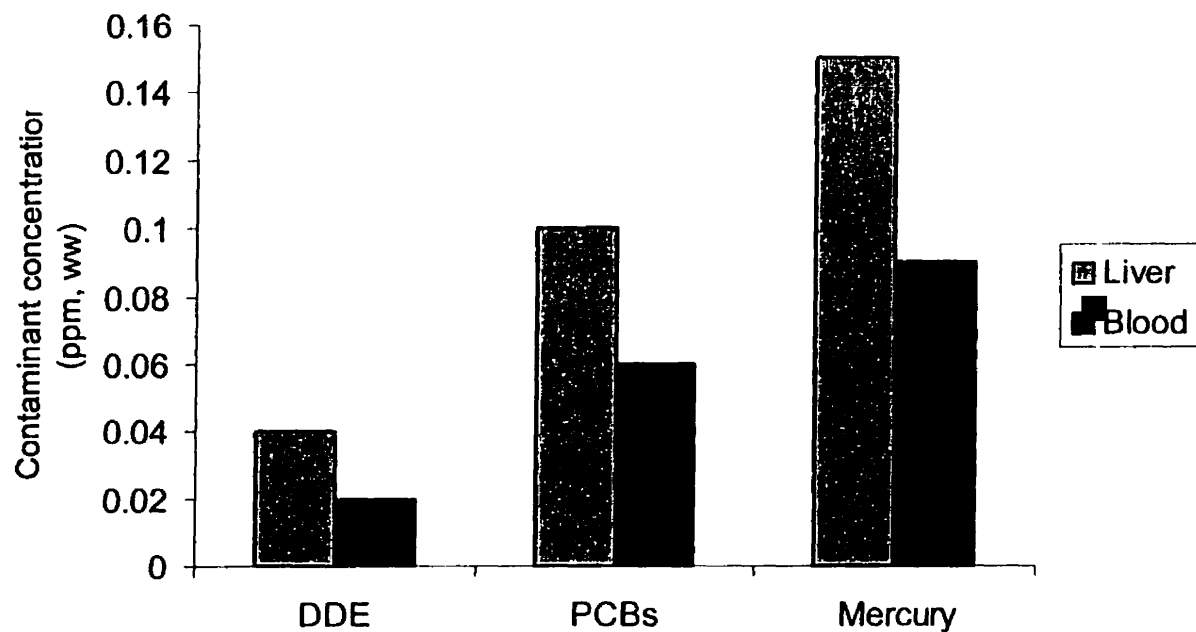


Fig. 3.4. Geometric mean contaminant concentrations (ppm, ww) in blood from bald eagle nestling #97-33a and in liver from bald eagle nestling #97-33b, Placentia Bay 1997, Newfoundland. (These two nestlings were siblings. DDE, PCBs = plasma concentrations; mercury = whole blood concentrations)

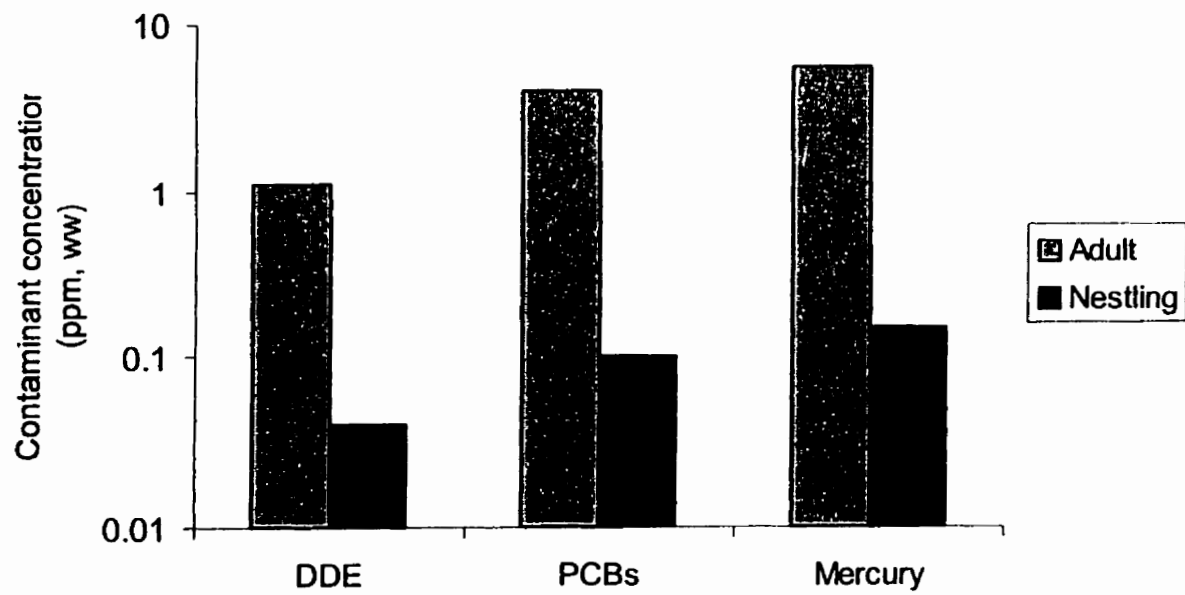


Fig. 3.5. Geometric mean contaminant concentrations (ppm, ww) in liver from two nestling and two adult bald eagles in Newfoundland, 1995-97.

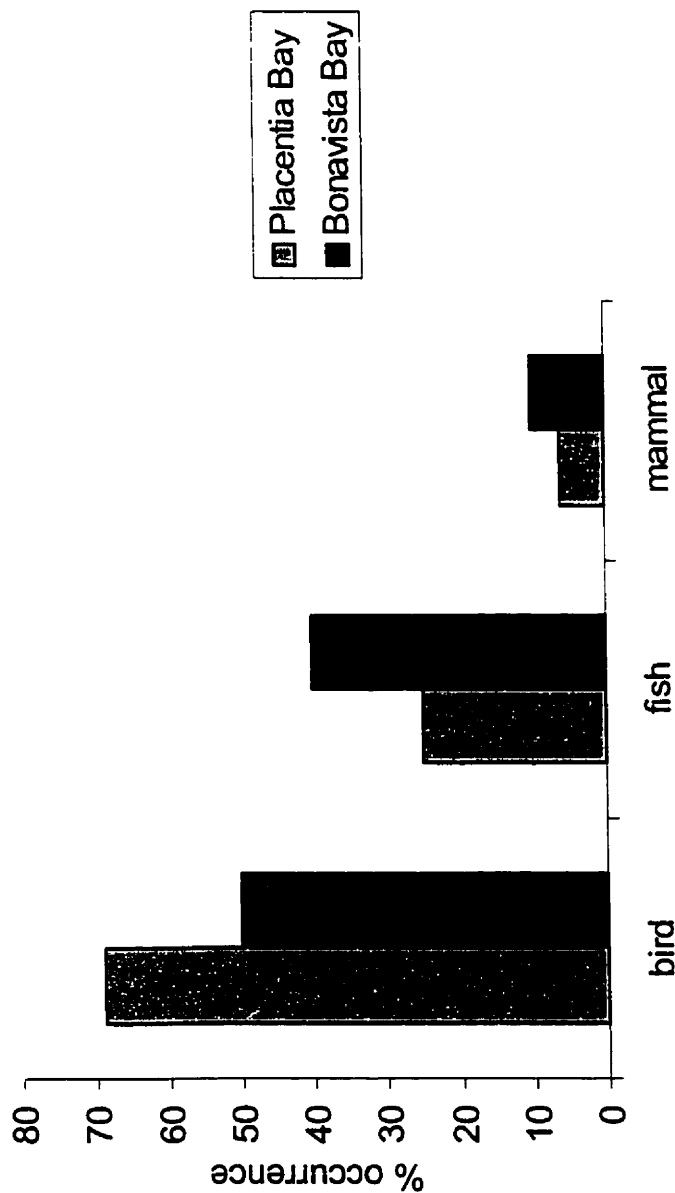


Fig. 3.6. Prey remain composition in bald eagle nests from Placentia and Bonavista Bays, 1996-97.

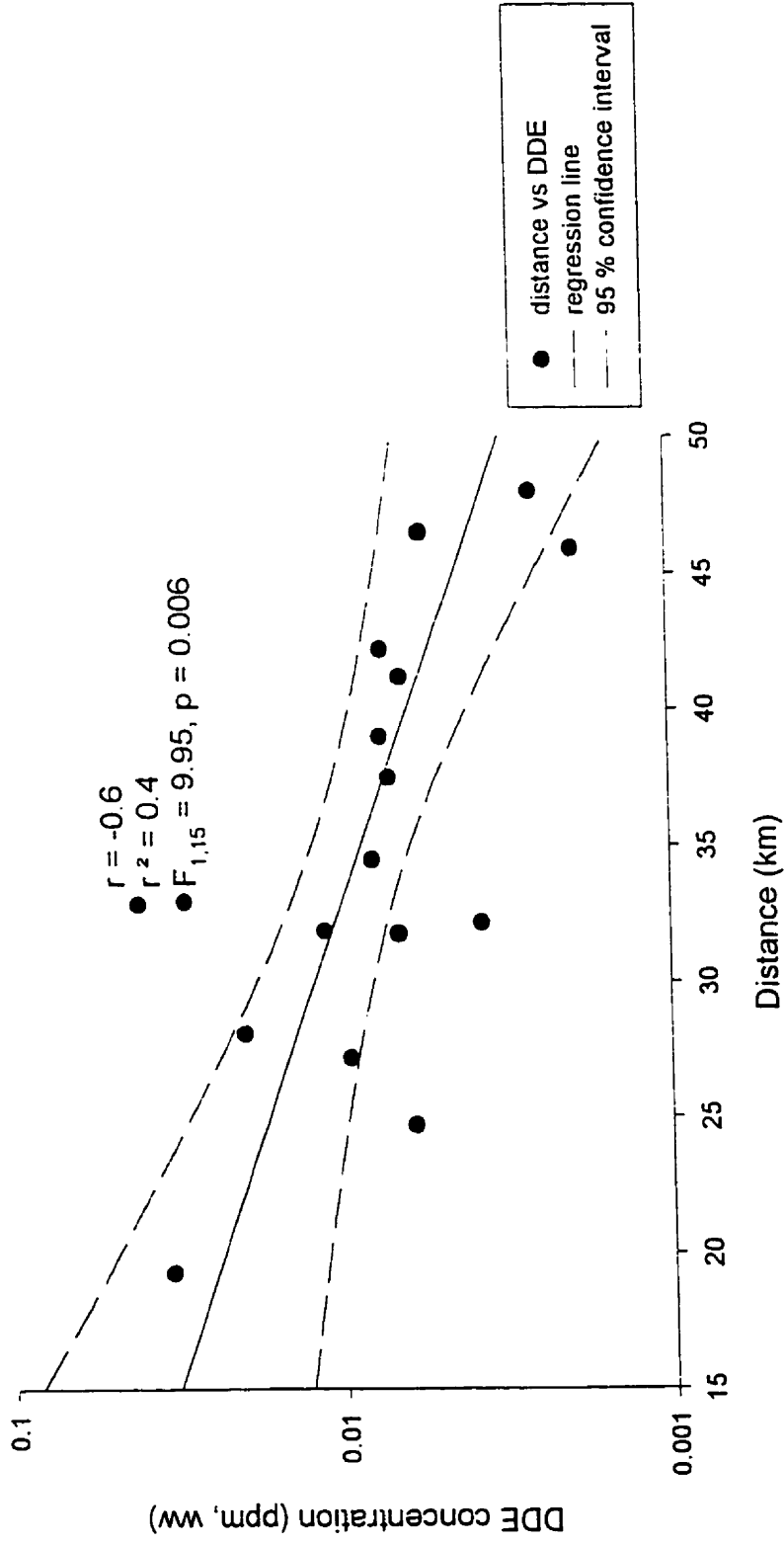


Fig. 3.7. Relationship between DDE concentrations (ppm, ww) in bald eagle plasma and distance (km) to Argentina in Placentia Bay, 1996-97.

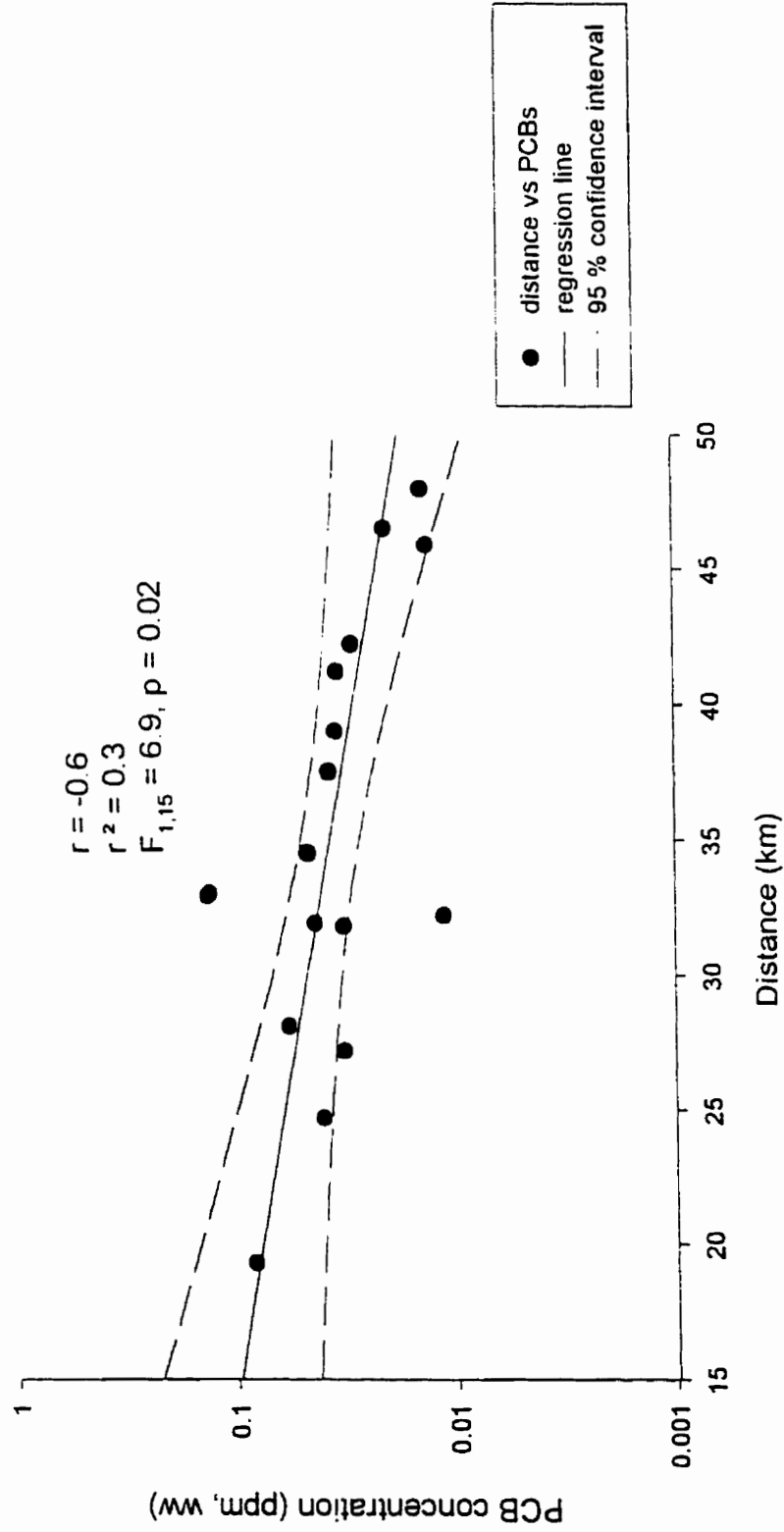


Fig. 3.8. Relationship between PCB concentrations (ppm, ww) in bald eagle plasma and distance (km) to Argentina in Placentia Bay, 1996-97.

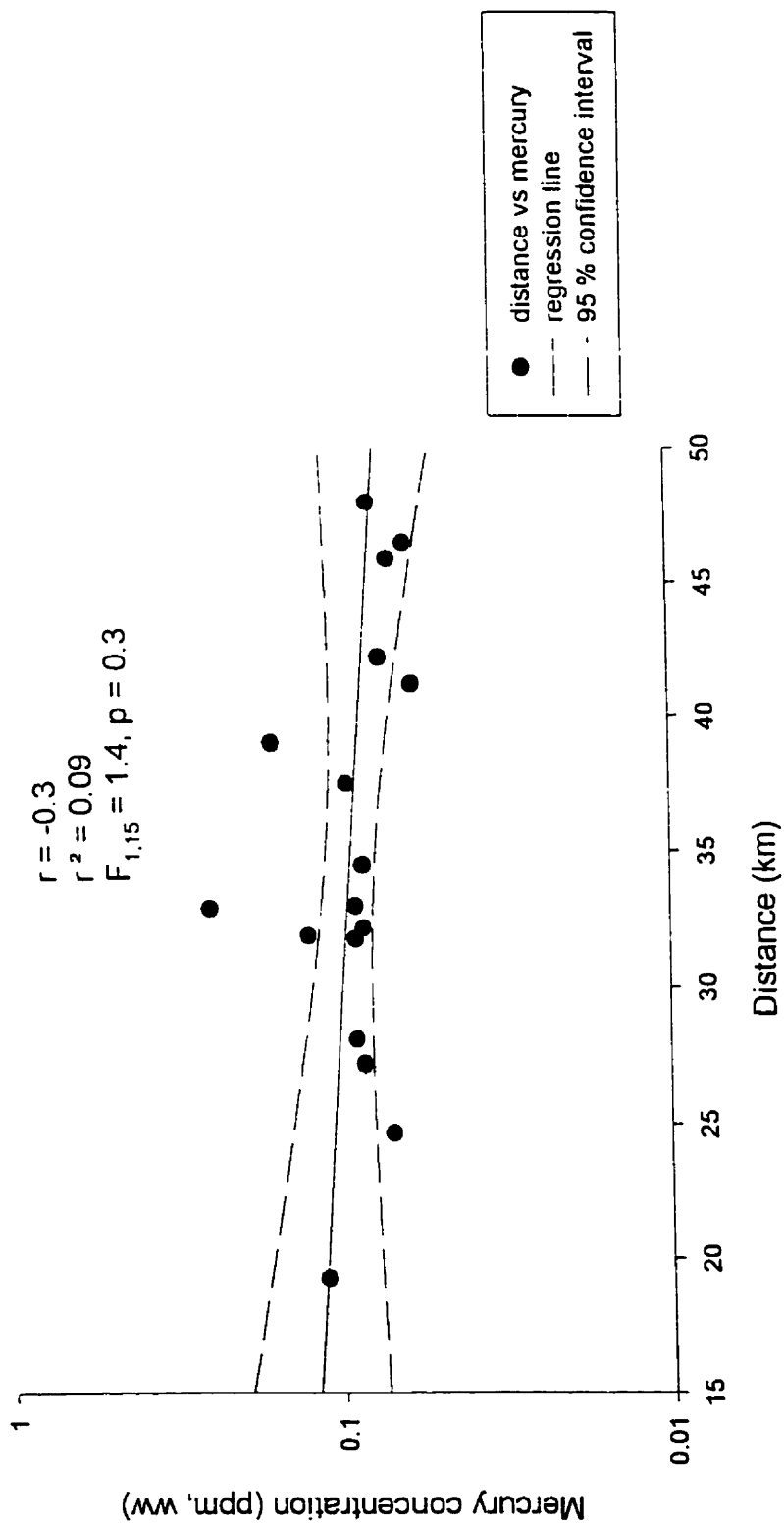


Fig. 3.9. Relationship between mercury concentrations (ppm, ww) in bald eagle blood and distance (km) to Argentina in Placentia Bay, 1996-97.

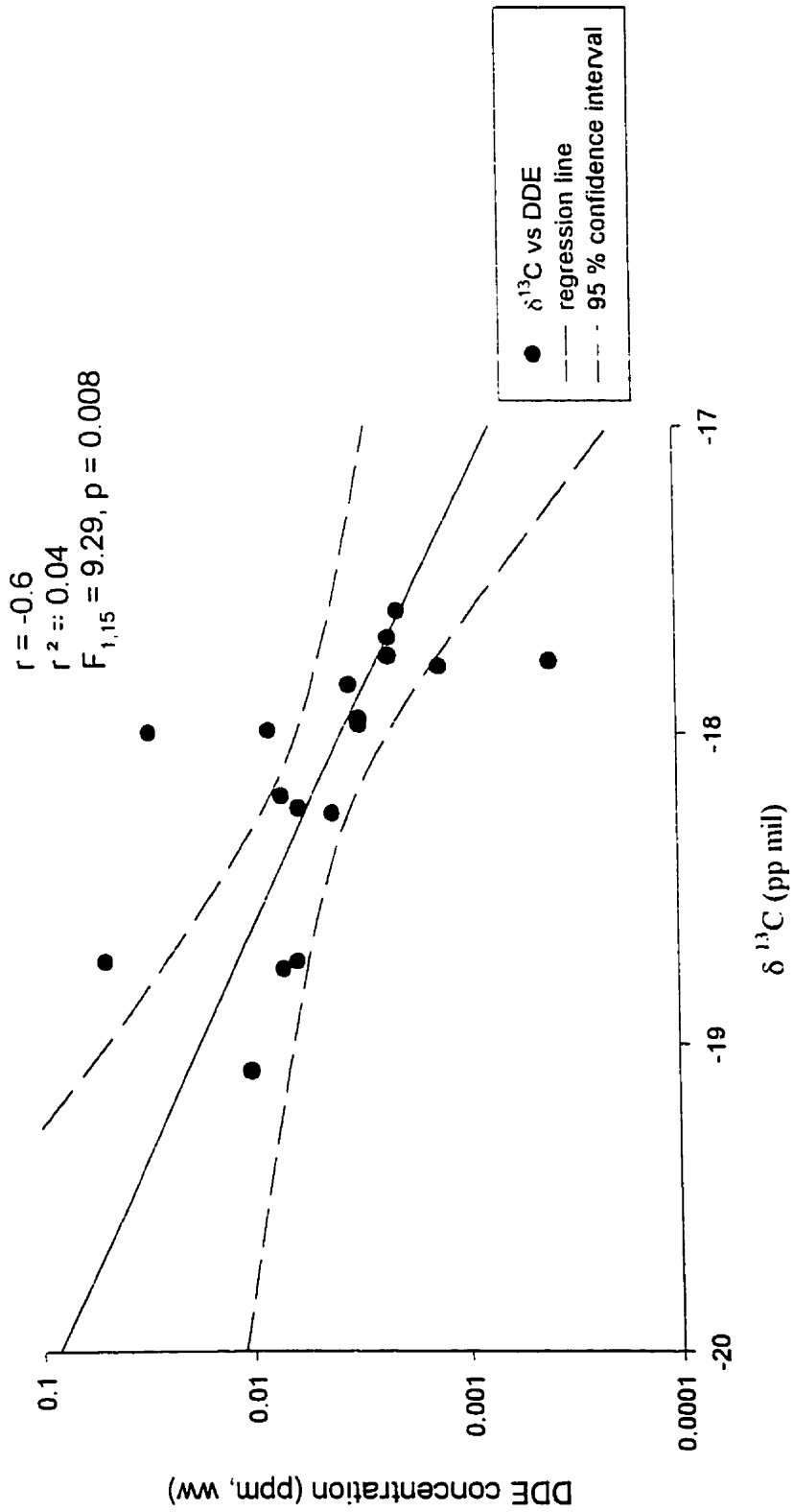


Fig. 3.10. Relationship between DDE concentrations (ppm, ww) in plasma and $\delta^{13}\text{C}$ concentrations (pp mil) in blood of bald eagle nestlings from Placentia and Bonavista Bays, 1997.

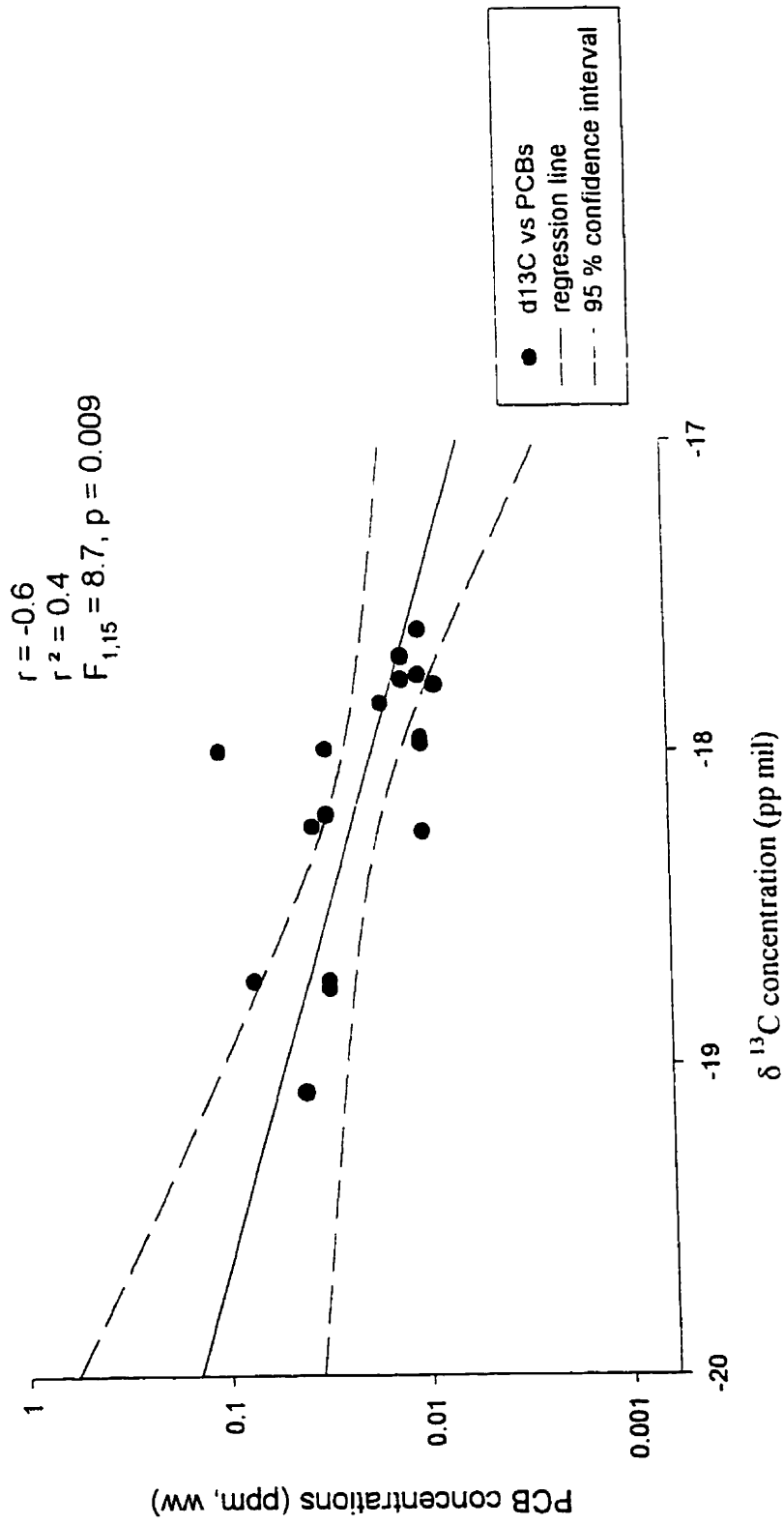


Fig. 3.11. Relationship between PCB concentrations (ppm, ww) in plasma and $\delta^{13}\text{C}$ (pp mil) in blood of bald eagle nestlings from Placentia and Bonavista Bays, 1997.

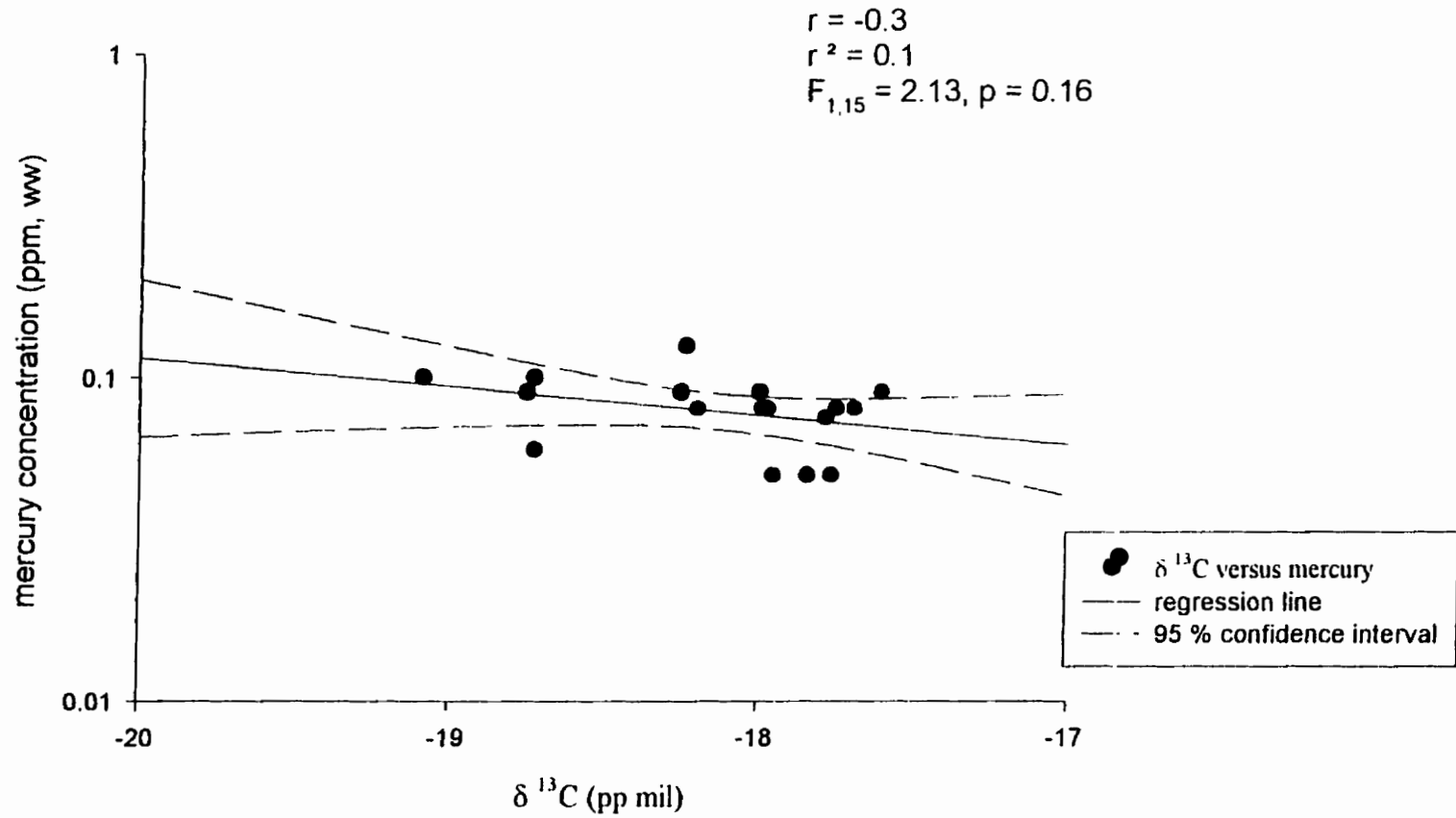


Fig. 3.12. Relationship between mercury concentrations (ppm, ww) and $\delta^{13}\text{C}$ (pp mil) in bald eagle nestling blood from Placentia and Bonavista Bays, 1997.

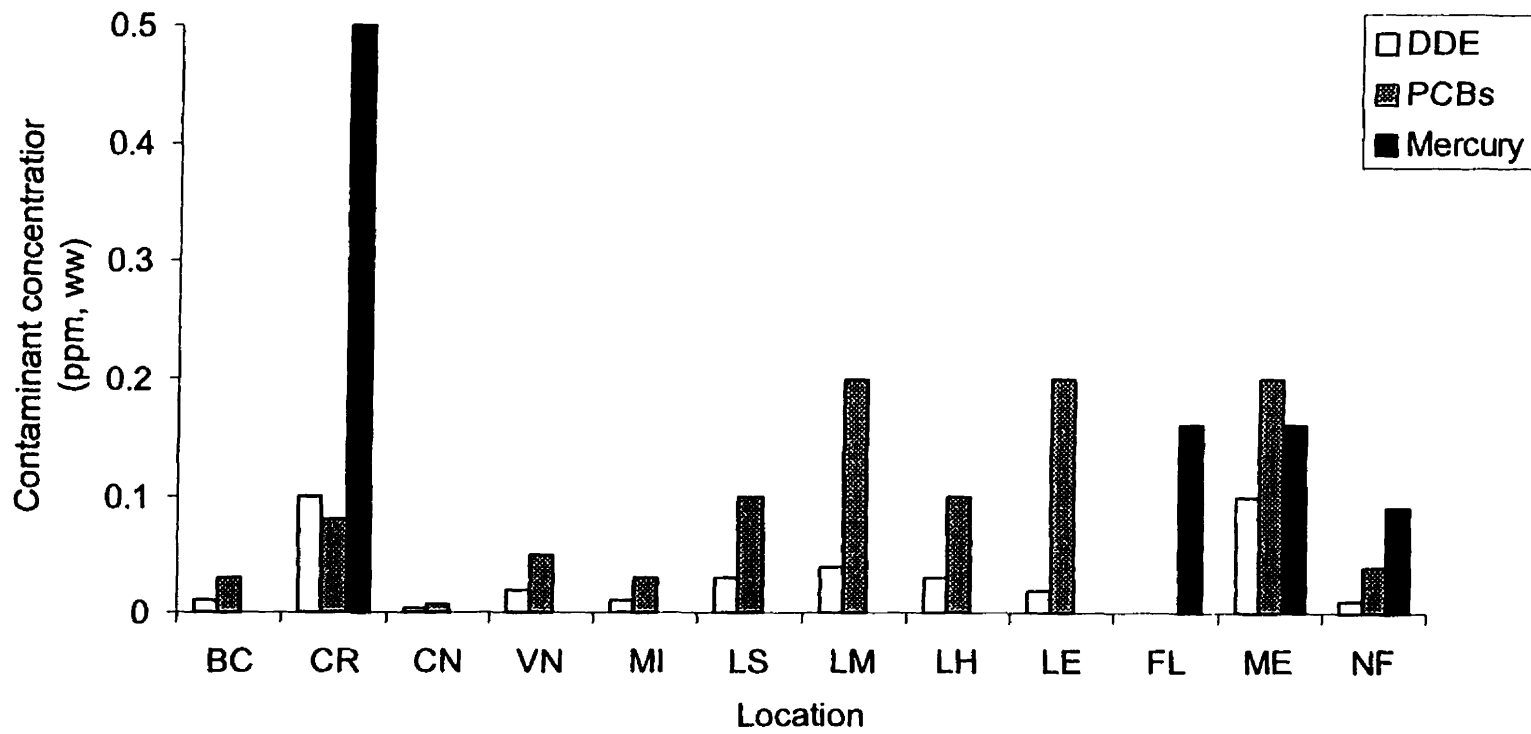


Fig. 3.13. Geometric mean contaminant concentrations in nestling plasma (DDE and PCBs) and whole blood (mercury) from 11 bald eagle breeding populations in the 1980-90's. Abbreviations are as follows: BC = British Columbia; CR = Columbia River Estuary, Oregon, 1984-86; CN = Chippewa National Forest, Minnesota, 1987-93; VN = Voyageurs National Park, Minnesota, 1987-93; MI = Michigan, 1987-93; ML = Lake Superior, 1987-93; LM = Lake Michigan, 1987-93; LH = Lake Huron, 1987-93; LE = Lake Erie, 1987-93; FL = Florida, 1991-93; ME = Maine (coastal), 1991-92; NF = Newfoundland (coastal), 1996-97. BC, CR, VN, MI, LS, LH and LE had not reported mercury concentrations. FL had not reported DDE and PCBs concentrations. References are given in Appendix 3.5.

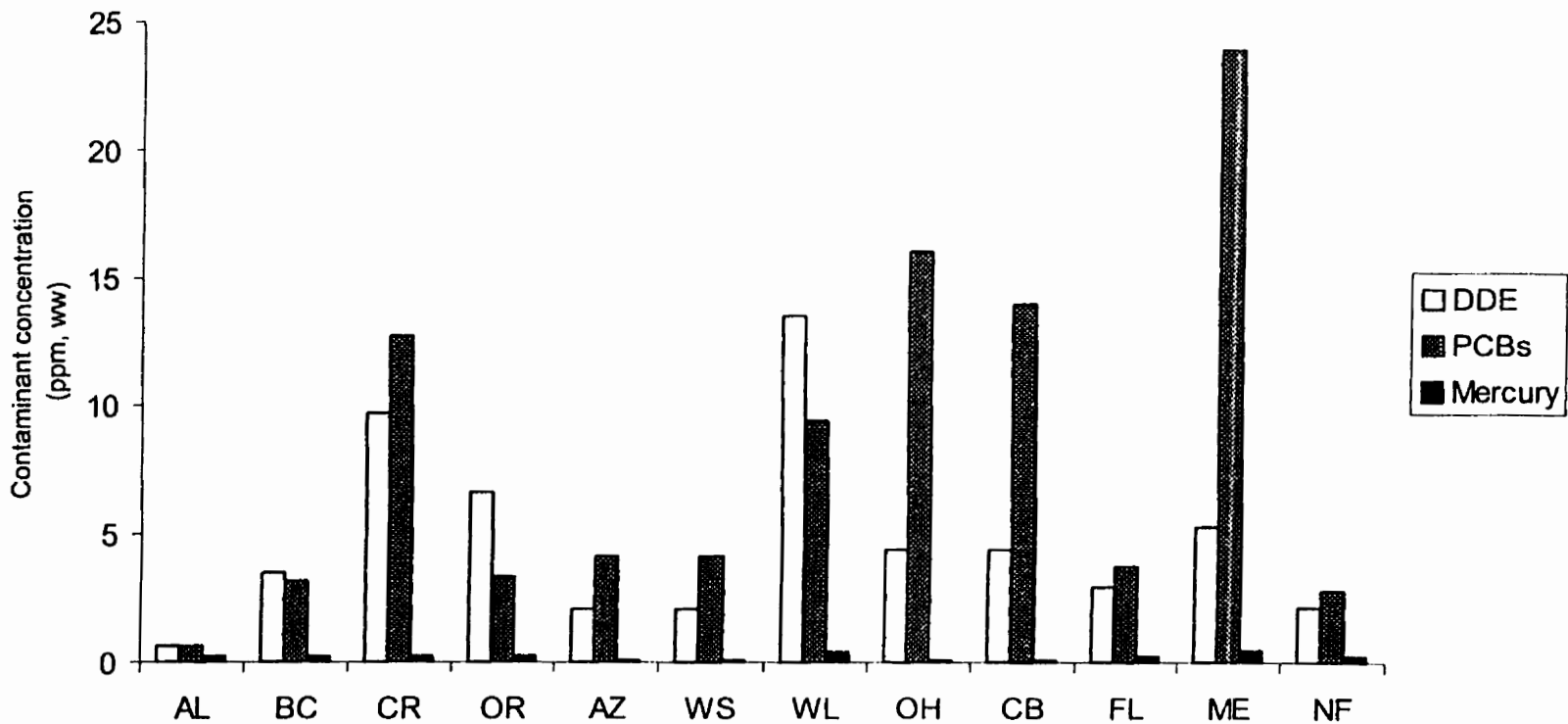


Fig. 3.14. Contaminant concentrations (ppm, ww) in addled eggs from 11 bald eagle breeding populations in the 1980-90's. Site abbreviations correspond as follows: AL = Alaska, 1983; BC = British Columbia, 1993-94; CR = Columbia River Estuary, 1985-87; OR = Oregon, 1980-83; AZ = Arizona, 1982-84; WS = Wisconsin, 1980-83; WL = Wisconsin shoreline of Lake Superior, 1983-88; OH = Ohio, 1981-84; CB = Chesapeake Bay, 1980-84; FL = Florida, 1981-83; ME = Maine (coastal), 1991; NF = Newfoundland (coastal), 1996-97. References are given in Appendix 3.6.

Chapter 4. General Conclusions and Management Recommendations

4.1 General conclusions

The two bald eagle breeding concentrations studied in Newfoundland had the highest densities and reproductive success of the coastal populations reported in eastern North America. Bald eagles in Maine are considered to be the stronghold of the species in northeastern United States, but recent studies have shown an impaired breeding performance related to high levels of contaminants (Welch 1994). Bald eagles breeding in New Brunswick and Nova Scotia in the late 1990s exhibited reproductive parameters indicative of expanding populations. Therefore, eagles breeding in Atlantic Canada, and in particular in Newfoundland, seem to be important populations for the maintenance of the species' stability in northeastern North America.

Placentia Bay is a very important breeding area for bald eagles in Newfoundland. Results from this study indicate that Placentia Bay has a higher breeding density of bald eagles and an overall higher production of eaglets than Bonavista Bay. However, more regular and systematic surveys are needed in Bonavista Bay to accurately assess population size and breeding density in a larger area than that surveyed in the present study. The current breeding densities and reproductive performance of bald eagles on the rest of the island, inland and in other coastal regions is unknown and needs to be studied.

Because of climatological and ecological differences (laying dates, food resources), Bonavista is not an optimal site to use as a non-industrialized comparison of

bald eagle reproductive performance with Placentia Bay. Fortune Bay, which lies adjacent to Placentia Bay in the south coast of Newfoundland, might be a more appropriate comparative site.

Current contaminant burdens in bald eagles in Newfoundland are relatively low and below levels associated with reproductive impairment. Comparisons of contaminant levels in blood and plasma from eaglets between study areas point to an exposure of the bald eagle breeding population in Placentia Bay to a source of DDE and PCB pollution on the east side of the bay. However, part of the contaminant loads that the bald eagle chicks carry could have been transferred from their mothers via the egg (e.g. Welch 1994; Elliot 1995). Bald eagle females could be picking up contaminants during the winter from areas out of their breeding range. Therefore, overlapping in the wintering ranges of the females from the two study areas could alter the significance of the differences in contaminant loads observed in the chicks from Placentia and Bonavista Bays. In conclusion, wintering ranges of adult bald eagles should be taken into account for an accurate interpretation of the differences in contaminant levels observed in the chicks from the two breeding areas. Little is known about the wintering population of bald eagles in Newfoundland. Bald eagles from Placentia and Bonavista Bay could be either wintering in their respective breeding areas, or they could have overlapping wintering ranges in Placentia Bay and the south coast of Newfoundland, or they could be even migrating to regions outside of Newfoundland. A comprehensive study of the wintering dynamics of bald eagles breeding in Newfoundland is needed to address this matter.

4.2 Management recommendations

The bald eagle population in Placentia Bay, an area with increasing industrialization, should be monitored systematically to observe trends in population dynamics, reproduction and contaminant loads. Bowman et al. (1997) emphasize the importance of regular and frequent surveys for providing reproductive baseline data in bald eagle populations exposed to human activities and specifically recommend periodical surveys of the population at least every 4-5 years. However, they also note that in areas with oil tanker traffic or other potential hazards, the survey methods and intervals should be designed for the particular population, its status and the potential magnitude of the environmental threats. Wiemeyer et al. (1984) noted that trends in reproduction are more accurate indicators of population status than reproductive success values. Grubbs et al. (1983) indicated that annual intervals are more suitable than surveys at less frequent intervals for assessing trends in bald eagles. Elliot (1995) recommends a minimum of three years of consecutive annual collection of reproductive data to account for variability when establishing baselines in bald eagle populations. In summary, regular (preferably annual) reproductive surveys should be conducted systematically on the studied area in Placentia Bay, or at least in selected sections of the study area. Survey methodology should follow that in the present study to maximize comparative value of data.

With respect to monitoring programs designed for the purpose of environmental risk assessments, it is important to emphasize that bald eagles should be monitored at a larger-scale level than at the level of individual nests in the immediate vicinity of

industrial developments. The size of bald eagle foraging ranges and the mobility of their potentially contaminated prey can alter the modeled impact of local sources of pollution or other industrial activities on a breeding population. These factors should be accounted for and other breeding pairs than those located in the vicinity of the source of pollution should be included in monitoring programs when necessary. A study on the foraging ranges of bald eagles in Placentia Bay is needed to understand the potential impact of industrial activities on the breeding population. Furthermore, in areas where bald eagles are residents all year long, such in Newfoundland, wintering grounds should also be considered in environmental impact studies.

Reproductive performance has been until present the main parameter used to assess the stability of raptor populations and the impact of chronic pollution. However, in the case of long-lived species with delayed breeding, such as the bald eagle, survival rates and longevity play critical roles on population growth and stability (Grier 1974, 1982; Bowman et al. 1995). Efforts should be made to monitor bald eagle survival rates, as well as reproductive performance, especially in areas submitted to long-term industrial activities such as Placentia Bay. Newfoundland bald eagles are thought to be resident on the island, but there are no studies on dispersal patterns of young, wintering grounds, and survival rates, and these should be investigated.

Efforts should be made to collect and analyze carcasses of adult eagles found dead around the province, especially in Placentia Bay, and/or blood samples from injured eagles that are brought to the rehabilitation center in Salmonier Nature Park. This would

provide more information on the toxicological status of adult bald eagles in Newfoundland.

Although not included in the present study, chronic oil pollution is another concern in Placentia Bay. Bald eagles are potentially exposed to the chronic ingestion of oiled birds and to direct oiling from chronic or accidental spills during their fishing and hunting activities. The increased risk, due to oil industry development, of an accidental large-scale oil spill and of increases in chronic oil pollution further emphasize the importance of regularly monitoring the bald eagle population in Placentia Bay.

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Appendix 2.1 Comparison of nest success, chick production and fledging ratio in 26 main bald eagle breeding regions in North America. Habitats are categorized as marine (M), lacustrine (L), riparian (R), and estuarine (E).

Location	Year	Habitat	% Nest success	Nestlings/ successful nest	Nestlings/ occupied nest	Fledging ratio	Source
Maine	1982-92	M	64	1.4	0.78	1.8	Welch 1994
Alaska (Kodiak I)	1973-74	M	—	1.6	1.0	1.6	Hodges 1982
Alaska (interior)	1978-95	R	79.5	—	1.57 ^a	—	Ritchie & Ambrose 1996
Alaska (Prince William Sound)	1989-92	M	—	—	0.86	—	Bowman et al. 1993
British Columbia	1992-94	M	54 ^b	1.3 ^b	0.7 ^b	1.8	Elliot 1995
Minnesota (Chipewa National Forest)	1979	L/R	68	1.8	1.2	1.5	Colborn 1991
Minnesota (inland)	1982-86	L/R	—	1.72	1.2	1.4	Colborn 1991
Minnesota (Voyageours National Park)	1987-93	L/R	—	1.44	0.87	1.6	Grim & Kallemeyn 1995
Florida (Everglades National Park)	1988	E	50	1.47	0.73	2	Colborn 1991
Wisconsin (Lake Superior)	1983-88	L	57	—	0.8	—	Kozie & Anderson 1991
Greater Yellowstone Basin	1976-82	L/R	67	1.58	1.06	1.5	Swenson et al. 1986
Michigan State	1983	L	58	1.58	0.92	1.7	Postupalsky 1983
Lake Nipigon	1971	L	13	1.00	0.13	7.7	Postupalsky 1971b
Lake Superior	1982-86	L	52	1.46	0.75	2	Colborn 1991

Appendix 2.1 cont.

Michigan and Wisconsin Great Lakes' shoreline	1982-86	L	25	1.5	0.37	4	Colborn 1991
Lake Huron	1982-86	L	31	1.75	0.54	3.2	Colborn 1991
Columbia River Estuary	1980-87	E	39	–	0.56	–	Anthony 1993
Oregon	1979-92	E/R	60	1.51	0.92	1.6	Anthony et al. 1994
Saskatchewan	1973-81	L	73	1.61	1.17	1.4	Gerrard et al. 1983
north west Ontario	1981	L	36	1.5	–	–	Grier 1974
Canadian Maritime Provinces	1975	M/L/R	54	1.53	0.80	1.9	Stocek & Pearce 1981
Nova Scotia	1968	M/L/R	54	1.36	0.72	1.8	Stocek & Pearce 1981
New Brunswick	1974-80	M/L/R	72	1.5	1.06	1.4	Stocek, unpublished data
Labrador	1970-73	M/L/R	45	1.20	0.6	2	Wetmore and Gillispie 1976
Newfoundland (Placentia Bay)	1996-97	M	73	1.5	1.1	1.3	Present study
Newfoundland (Bonavista Bay)	1997	M	83	1	0.9	1.2	Present study

^a = based on large young (before fledging)

^b = values are the means of 9 study sites reported by the author

– = not reported.

Appendix 3.1. Contaminant concentrations (ppm, wet weight) in plasma (DDE and PCBs) and blood (metals) of bald eagle nestlings from Placentia Bay, 1996-97. * = values of samples collected in the same nest in different years are the means of both years. G_m = geometric mean; nd = below detection limit; Hg = mercury; Co = cobalt; Cu = copper; Mo = molybdenum; Cd = cadmium; Mn = manganese.

nest	% lipid	DDE	PCBs	Hg	Co	Cu	Mo	Cd	Mn
13	0.68	0.004	0.01	0.09	nd	0.4	nd	nd	0.07
*15	0.74	0.009	0.03	0.09	0.009	0.8	0.01	nd	0.1
17	0.77	0.006	0.04	0.07	nd	0.2	0.006	nd	0.05
*21	0.82	0.03	0.08	0.1	nd	0.4	0.005	nd	0.1
24	0.96	0.02	0.06	0.09	nd	0.3	0.006	nd	0.08
27	0.84	0.007	0.03	0.09	0.01	0.3	0.004	nd	0.06
28	0.89	0.008	0.05	0.09	nd	0.3	nd	nd	0.07
29	0.81	0.007	0.04	0.1	nd	0.4	nd	nd	0.04
30	0.70	0.006	0.03	0.06	nd	0.4	0.004	nd	0.07
33	0.75	0.03	0.1	0.09	nd	0.5	nd	nd	0.07
48	0.79	0.01	0.04	0.1	nd	0.5	0.02	nd	0.1
*55	0.75	0.002	0.01	0.07	0.005	0.5	0.01	nd	0.06
*73	0.79	0.006	0.02	0.06	0.008	0.5	0.02	nd	0.07
76	0.79	0.007	0.03	0.08	nd	0.3	0.008	nd	0.03
101	0.92	0.04	0.1	0.08	nd	0.3	0.006	nd	0.1
103	0.83	0.003	0.01	0.08	nd	0.5	nd	nd	0.05
106	0.65	0.008	0.03	0.08	nd	0.4	0.01	nd	0.09
	0.79	0.01	0.04	0.08	nd	0.4	0.006	nd	0.07
G_m	0.79	0.009	0.03	0.08	nd	0.4	0.003	nd	0.07

Appendix 3.2 Contaminant concentrations (ppm, ww) in plasma (DDE and PCBs) and blood (metals) of six nestling from Bonavista Bay, 1997. G_m = Geometric mean; nd = below detection limit; Hg = mercury; Co = cobalt; Cu = copper; Mo = molybdenum; Cd = cadmium; Mn = manganese

Nest	% Lipid	Contaminant concentrations (ppm, ww)							
		DDE	PCBs	Hg	Co	Cu	Mo	Cd	Mn
110	0.71	0.003	0.01	0.05	nd	0.2	nd	nd	0.03
111	0.71	0.001	0.008	0.08	nd	0.2	nd	0.05	0.02
117	0.84	0.002	0.01	0.08	0.008	0.4	nd	nd	0.1
118	0.95	0.002	0.01	0.08	nd	0.5	nd	nd	0.02
119	0.89	0.0004	0.01	0.05	0.004	0.5	nd	nd	0.2
121	1.21	0.006	0.04	0.13	0.002	0.4	nd	nd	0.08
	0.88	0.002	0.02	0.08	nd	0.4	nd	nd	0.08
G_m	0.86	0.002	0.01	0.07	nd	0.3	nd	nd	0.05

Appendix 3.3 Organochlorine concentrations (ppm, ww) in bald eagle plasma and egg samples from Placentia and Bonavista Bays, 1996-97.

Sample #	Lipid	1245CB	1234CB	penta-CB	HCB	OCS	t-nonachlor	pp'-DDE	p-mirex	mirex	a-HCH	b-HCH	g-HCH	oxychlor
Placentia Bay 1996														
96-15	0.1	nd	nd	nd	0.0005	nd	0.0012	0.0080	0.0003	0.0005	nd	nd	nd	0.0014
96-17	0.1	0.001	nd	nd	0.0010	nd	0.0027	0.0061	0.0003	0.0003	nd	nd	nd	0.0012
96-21	0.0	nd	0.0002	nd	0.0023	0.0002	0.0031	0.205	0.0006	0.0006	nd	nd	nd	0.0036
96-24	0.2	nd	nd	nd	0.0021	nd	0.0019	0.0198	0.0009	0.0009	nd	nd	nd	0.0036
96-28	0.1	nd	nd	nd	0.0005	nd	0.0026	0.0080	0.0005	0.0004	nd	nd	nd	0.0007
96-29	0.1	nd	nd	nd	0.0007	nd	0.0008	0.0071	0.0005	0.0006	nd	nd	nd	0.0003
96-48	0.1	nd	nd	nd	0.0011	0.0001	0.0017	0.0112	0.0005	0.0005	nd	nd	nd	0.0009
96-55	0.1	nd	nd	nd	0.0005	nd	0.0009	0.0017	nd	nd	nd	nd	nd	0.0003
96-73	0.1	nd	nd	nd	0.0006	0.0001	0.0021	0.0082	0.0005	0.0007	nd	nd	nd	0.0006
96-101	0.1	nd	nd	0.0006	0.0030	0.0002	0.0039	0.0414	0.0012	0.0025	nd	nd	nd	0.0035
96-blank	0.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
EG 96-7	4.1	nd	0.0134	nd	0.0369	0.0246	0.246	1.5087	0.0251	0.0312	nd	0.0167	nd	0.1159
Placentia Bay 1997														
97-13	0.1	nd	nd	nd	0.0005	nd	0.0014	0.0038	nd	nd	nd	nd	nd	0.0004
97-15	0.1	nd	nd	nd	0.0010	nd	0.0022	0.0109	0.0004	0.0003	nd	nd	nd	0.0009
97-21	0.1	nd	0.0003	nd	0.0034	0.0002	0.0039	0.0471	0.0005	0.0007	nd	nd	nd	0.0028
97-27	0.1	nd	0.0003	nd	0.0017	0.0001	0.0019	0.0067	0.0003	0.0002	nd	nd	nd	0.0010
97-30	0.1	nd	0.0002	nd	0.0015	0.0001	0.0028	0.0065	0.0001	0.0003	nd	nd	nd	0.0007
97-55	0.0	nd	nd	nd	0.0006	nd	0.0012	0.0022	nd	nd	nd	nd	nd	0.0003
97-73	0.1	nd	nd	nd	0.0004	nd	0.0017	0.0030	nd	0.0001	nd	nd	nd	0.0005
97-76	0.1	nd	nd	nd	0.0012	nd	0.0018	0.0074	0.0003	0.0002	nd	nd	nd	0.0011
97-103	0.2	nd	0.0001	nd	0.0005	nd	0.0016	0.0026	nd	nd	nd	nd	nd	0.0004
97-106	0.1	nd	0.0001	nd	0.0017	nd	0.0015	0.0075	0.0004	0.0006	nd	nd	nd	0.0019
97-blank	0.0	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
EG 97-73	5.9	nd	0.0031	nd	0.0320	0.0113	0.4443	2.0280	0.0347	0.0399	nd	0.0137	nd	0.1359
Bonavista Bay 1997														
97-110	0.2	nd	nd	nd	0.0006	nd	0.0019	0.0033	0.0005	nd	nd	nd	nd	0.0007
97-111	0.2	nd	nd	nd	0.0005	nd	0.0009	0.0013	nd	nd	nd	nd	nd	0.0002
97-117	0.3	nd	nd	nd	0.0006	nd	0.0013	0.0022	0.0003	nd	nd	nd	nd	0.0004
97-118	0.4	nd	nd	nd	0.0007	nd	0.0016	0.0022	0.0003	0.0002	nd	nd	nd	0.0004
97-119	0.1	0.0004	nd	nd	0.0007	nd	0.0016	0.0004	0.0002	nd	nd	nd	nd	0.0005
97-121	0.1	nd	0.0002	nd	0.0013	nd	0.0028	0.0058	0.0010	0.0003	nd	nd	nd	0.0013

Appendix 3.3 Cont. Lipid content in mg/ml. EG = egg; blank = procedural blank; nd = not detected.

Sample #	Lipid	t-chlordane	CIS-chlor	pp-DDD	c-nonachlor	pp-DDT	H.E.	Dieldrin	TCPM
97-13	0.1	0.0006	0.0004	nd	0.0004	0.0004	0.0002	nd	nd
97-15	0.1	nd	nd	nd	0.0004	0.0004	nd	nd	nd
97-21	0.0	nd	0.0009	nd	0.0009	0.0009	0.0008	nd	nd
97-27	0.2	nd	0.0005	nd	0.0005	0.0005	0.0003	nd	nd
97-30	0.1	0.0003	0.0009	nd	0.0007	0.0007	0.0004	nd	nd
97-55	0.1	0.0003	0.0003	nd	0.0003	0.0003	0.0004	nd	nd
97-73	0.1	nd	0.0004	nd	0.0004	0.0004	0.0003	nd	nd
97-76	0.1	nd	0.0005	nd	0.0006	0.0006	0.0004	nd	nd
97-103	0.1	nd	0.0005	nd	0.0005	0.0005	0.0003	nd	nd
97-106	0.1	nd	0.0004	nd	0.0004	0.0004	0.0003	nd	nd
97-blank	0.0	nd	nd	nd	nd	nd	nd	nd	0.0095
EG 97-73	4.1	0.0013	0.0080	0.0157	0.0374	0.0202	0.0379	0.0631	0.0095

Piacentia Bay 1996									
96-15	0.1	nd	0.0002	nd	0.0002	0.0002	nd	nd	nd
96-17	0.1	nd	0.0004	nd	0.0007	0.0007	0.0003	nd	nd
96-21	0.1	nd	0.0005	nd	0.0008	0.0006	0.0007	nd	nd
96-24	0.1	nd	0.0004	nd	0.0006	0.0006	0.0004	nd	nd
96-28	0.1	nd	0.0002	nd	0.0005	0.0005	0.0003	nd	nd
96-29	0.0	nd	nd	nd	nd	nd	0.0002	nd	nd
96-48	0.1	nd	0.0002	nd	0.0003	0.0003	0.0003	nd	nd
96-55	0.1	nd	0.0003	nd	0.0003	0.0003	nd	nd	nd
96-73	0.2	nd	0.0002	nd	0.0004	0.0004	0.0008	nd	nd
96-101	0.1	nd	0.0003	nd	0.0006	0.0005	0.0011	nd	nd
96-blank	0.0	nd	nd	nd	nd	nd	nd	nd	0.0121
EG 96-7	5.9	0.0023	0.0079	0.0229	0.0353	0.0115	0.0286	0.0519	0.0121

Bonaville Bay 1997									
97-110	0.2	nd	0.0004	nd	0.0005	0.0005	nd	nd	nd
97-111	0.2	nd	0.0003	nd	0.0003	0.0003	nd	nd	nd
97-117	0.3	nd	0.0003	nd	0.0003	0.0003	0.0003	nd	nd
97-118	0.4	nd	0.0005	nd	0.0004	0.0004	0.0002	nd	nd
97-119	0.1	nd	0.0005	nd	0.0004	0.0004	nd	nd	nd
97-121	0.1	nd	0.0005	nd	0.0007	0.0007	0.0004	nd	nd

Appendix 3.4. Stable isotopes ^{15}N and ^{13}C concentrations (‰) in bald eagle nestling blood from Placentia and Bonavista Bays, 1997.

nest	^{15}N	^{13}C
Placentia Bay		
13	16.32	-18.26
15	15.02	-19.09
21	16.31	-18.73
27	15.77	-18.76
30	15.59	-18.73
33	16.17	-18.00
35	15.56	-18.53
55	15.98	-17.60
73	15.85	-17.95
76	16.20	-18.20
102	16.49	-17.65
103	16.57	-17.97
106	15.64	-17.99
± SD	15.95 ± 0.44	-18.26 ± 0.46
Bonavista Bay		
110	15.85	-17.84
111	15.41	-17.78
117	15.65	-17.75
118	15.59	-17.69
119	15.93	-17.77
121	15.84	-18.24
± SD	15.71 ± 0.19	-17.84 ± 0.19

Appendix 3.5. Contaminant geometric mean concentrations (ppm, ww) in nestling plasma (DDE and PCBs) and blood (mercury) from 11 bald eagle breeding populations.

Location	Year	N	DDE	PCBs	Mercury	Source
British Columbia ^a	1993-94	50	0.01	0.03	--	Elliot 1995
Columbia River Estuary, Oregon	1984-86	15	0.1 ^{bc}	0.08 ^{bc}	0.5 ^b	Anthony et al. 1993
Chippewa National Forest, Minnesota	1987-93	43	0.003	0.007	--	Bowerman 1993
Voyageurs National Park, MN	1987-93	21	0.02	0.05	--	Bowerman 1993
Michigan	1987-93	113	0.01	0.03	--	Bowerman 1993
Lake Superior	1987-93	45	0.03	0.1	--	Bowerman 1993
Lake Michigan	1987-93	25	0.04	0.2	--	Bowerman 1993
Lake Huron	1987-93	12	0.03	0.1	--	Bowerman 1993
Lake Erie	1987-93	35	0.02	0.2	--	Bowerman 1993
Florida	1991-93	48	--	--	0.16	Wood et al. 1995
Maine (coastal)	1991-92	107	0.1 ^c	0.2 ^c	0.16	Welch 1994
Newfoundland	1996-97	26	0.01	0.04	0.09	present study

^a = contaminant values are the means of 8 study sites reported by the author; ^b = arithmetic mean; ^c = corrected for plasma concentration; -- = not reported.

Appendix 3.6. Contaminant mean concentrations (ppm, ww) in addled eggs from 11 bald eagle breeding populations.

Location	Year	N	DDE	PCBs	Mercury	Egg shell thickness (mm)	Source
Alaska	1983	1	0.6	0.6	0.2	0.59	Wiemeyer et al. 1993
British Columbia ^a	1990-92	34	3.5 ^b	3.2 ^b	0.2 ^b	0.57	Elliot 1995
Columbia River Estuary	1985-87	17	9.7	12.7	0.2	0.55	Anthony et al. 1993
Oregon	1980-83	7	6.6	3.3	0.2	0.54	Wiemeyer et al. 1993
Arizona	1982-84	4	2.1	4.1	0.1	0.55	Wiemeyer et el. 1993
Wisconsin	1980-83	28	2.1	4.1	0.1	0.56	Wiemeyer et el. 1993
Wisconsin shoreline of Lake Superior	1983-88	2	13.5	9.4	0.4	0.59	Kozie and Anderson 1991
Ohio	1981-84	4	4.4	16	0.06	0.54	Wiemeyer et el. 1993
Chesapeake Bay	1980-84	15	4.4	14	0.07	--	Wiemeyer et el. 1993
Florida	1981-83	3	2.9	3.7	0.2	0.48	Wiemeyer et el. 1993
Maine	1991	7	5.3 ^b	23.9 ^b	0.5 ^b	0.62	Welch 1994
Newfoundland	1996-97	2	2.2 ^b	2.8 ^b	0.2 ^b	0.55	present study

^a = values are the means of 8 study sites reported by the author; ^b = geometric mean; -- = not reported