U.S. FISH AND WILDLIFE SERVICE
MAINE FIELD OFFICE
SPECIAL PROJECT REPORT: FY04-MEFO-1-EC

ENVIRONMENTAL CONTAMINANTS IN PIPING PLOVER, LEAST TERN & COMMON TERN EGGS FROM COASTAL MAINE

2003 NESTING SEASON

March 2004

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U.S. Fish and Wildlife Service

"Our mission is working with others to conserve, protect, and enhance the nation's fish and wildlife and their habitats for the continuing benefit of the American people."

Suggested citation: Mierzykowski S.E. and K.C. Carr. 2004. Environmental contaminants in piping plover, least tern and common tern eggs from coastal Maine - 2003 nesting season. USFWS. Spec. Proj. Rep. FY04-MEFO-1-EC. Old Town, ME.

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2003 NESTING SEASON

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March 2004

EXECUTIVE SUMMARY

Maine's coastal islands and beaches provide important nesting habitat for piping plover (*Charadrius melodus*), least tern (*Sterna antillarum*), and common tern (*Sterna hirundo*). These species are managed and regularly monitored by the U.S. Fish and Wildlife Service (USFWS), the National Audubon Society, and other partners in the Gulf of Maine Seabird Working Group (GOMSWG). Each nesting season, the number of nesting plover and tern pairs is recorded and fledgling production is measured. Adult, chick, or egg predation is also noted and examined. Many factors influence annual productivity or survival of plovers and terns including habitat loss or alteration, predation, human disturbance, and pollution. In Maine, relatively few contaminant investigations have been performed with piping plover, least terns and common terns, and little is known about current body burdens of contaminants in these species.

During annual GOMSWG censuses, wildlife biologists, beach wardens, park managers, and island interns regularly encounter abandoned nests, flooded nests, or nests with nonviable tern and plover eggs. In 2003, USFWS personnel and GOMSWG cooperators opportunistically collected unhatched eggs from piping plover, least tern, and common tern nests from seven locations. These eggs were analyzed to determine concentrations of organochlorine compounds and inorganic elements.

Thirty-two nonviable and abandoned eggs were collected between May and July, 2003. Piping plover eggs (n=4) were collected from Laudholm Beach and Parsons Beach between Wells and Kennebunkport. Least tern eggs (n=16) were collected from Crescent Surf Beach near Kennebunkport and on Higgins Beach on the south side of Cape Elizabeth, South Portland. Common tern eggs (n=12) were collected from Stratton Island off the coast of Old Orchard Beach, from Pond Island in the mouth of the Kennebec River, and from Petit Manan Island off the coast of Milbridge.

Common tern and least tern eggs were formed into five species-specific, location-specific composite samples. Piping plover eggs from two neighboring beaches were combined into one additional sample. Each composite sample was analyzed for 22 organochlorine compounds (e.g., polychlorinated biphenyls and DDT metabolites) and 19 inorganic elements (e.g., mercury, lead) by contract laboratories of the USFWS. Quality Assurance and Quality Control procedures and methods for the laboratories and samples were reviewed and approved by the USFWS's Patuxent Analytical Control Facility. Analytical egg data were adjusted to compensate for moisture loss and expressed in parts-per-million (ppm), fresh wet weight (fww).

Of the 22 organochlorine compounds in the analytical scan, only five compounds were found in egg composite samples - dieldrin, hexachlorobenzene (HCB), total polychlorinated biphenyl (Total PCB), p,p'-DDE, and trans-nonachlor. Of these five compounds, only HCB, PCB, and p,p'-DDE were found in all samples. The highest HCB level (0.007 ppm) was found in the least tern composite sample from Higgins Beach. A common tern composite sample from Pond Island National Wildlife Refuge had the highest PCB concentration (0.764 ppm), while DDE was highest in the piping plover

composite sample from Laudholm and Parsons Beaches (0.097 ppm). The organochlorine compound concentrations found in eggs were not highly elevated and did not exceed individual ecological effect benchmarks.

Nineteen inorganic elements were included in the analytical scan. Copper, iron, mercury, manganese, magnesium, selenium, strontium, and zinc were detected in all six samples. Eight elements, including cadmium, chromium, nickel, and lead, were not detected in any of the six egg composite samples. The highest concentrations of mercury (0.17 ppm), strontium (4.99 ppm), and zinc (12.7 ppm) were detected in the piping plover composite egg sample. The highest level of selenium (0.70 ppm) was found in the common tern composite sample from Petit Manan Island. In general, inorganic element concentrations were not highly elevated compared to ecological effect benchmarks.

Although highly elevated levels of organochlorine compounds and inorganic elements were not detected in these six egg composite samples, additional monitoring is recommended to quantify potential temporal and spatial contaminant trends in birds nesting along the Maine coast.

PREFACE

This report presents results of a screening-level contaminant survey of eggs collected during the 2003 nesting season from three bird species that nest along the Maine coast. Analytical work for this survey was completed under Patuxent Analytical Control Facility Catalog Number 5100005 - Purchase Orders No. 94420-03-Y309 (Organochlorines) and 94420-03-Y310 (Inorganics)

Questions, comments, and suggestions related to this report are encouraged. Written inquiries should refer to Report Number FY04-MEFO-1-EC and be directed to:

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ACKNOWLEDGMENTS

Funding for this survey was generously provided by T. Fannin, the Environmental Contaminants Coordinator for USFWS Region 5. Throughout the 2003 nesting season, tern and plover eggs were collected by staff and cooperators associated with Rachel Carson National Wildlife Refuge, Petit Manan National Wildlife Refuge, Maine Audubon Society, National Audubon Society, and the University of Maine. Their help is greatly appreciated. The efforts of K. O'Brien, J. Perkins, L. Welch, S. Kress, and S. Hall in collecting eggs for this contaminant survey are particularly noteworthy.

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1. Introduction

Maine's coastal islands and beaches provide important nesting habitat for piping plover (*Charadrius melodus*), least tern (*Sterna antillarum*), and common tern (*Sterna hirundo*). These species are managed and regularly monitored by the U.S. Fish and Wildlife Service (USFWS), the National Audubon Society, and other partners in the Gulf of Maine Seabird Working Group (GOMSWG). Each nesting season, the number of nesting plover and tern pairs is recorded and fledgling production is measured. Adult, chick, or egg predation is also noted and examined. Many factors may influence annual productivity or survival of plovers and terns including habitat loss or alteration, predation, human disturbance, and pollution. In Maine, relatively few contaminant investigations have been performed with piping plover, least terns and common terns, and little is known about current body burdens if contaminant. During annual GOMSWG censuses, wildlife biologists, beach wardens, park managers, and island interns regularly encounter abandoned nests, flooded nests, or nests with nonviable tern and plover eggs. In 2003, USFWS personnel and GOMSWG cooperators opportunistically collected unhatched eggs from piping plover, least tern, and common tern nests from seven locations for a screening-level contaminant survey.

2. Survey Purpose

The purpose of the survey was to determine levels of organochlorine compounds and inorganic elements in piping plover, least tern, and common tern eggs collected from the Maine coast in 2003.

3. Species Accounts and Study Areas

3.1 Species Accounts.

3.1.1 Piping Plover (alpha code: PIPL) - The piping plover is a small shorebird that breeds on open sandy beaches along the Atlantic coast and on beaches and sandflats associated with rivers and wetlands in the Great Plains (Haig 1992). The piping plover is listed under the Federal Endangered Species Act as a threatened species, and under the Maine Endangered Species Act as an endangered species. Piping plovers nest on approximately 20 southern coastal Maine beaches where they principally feed on marine invertebrates in the intertidal zone. The piping plover will lay a clutch of three to four eggs.

3.1.2 Least Tern (LETE) - The least terns is the smallest tern in North and Central America. The species breeds along coastal beaches and major interior rivers of the United States (Thompson *et al.* 1997). In Maine, least terns nest on the same open sandy beach habitat type along the southern coast as piping plover and the two species are often co-located. However, there are fewer than six least tern nesting sites in the state. The least tern is listed as an endangered species under the Maine Endangered Species Act. Least terns feed primarily on small fish and have a clutch of two to three eggs.

3.1.3 Common Tern (COTE) - Common terns breed along the Atlantic Coast, Great Lakes, and Gulf Coast in the United States (Nisbet 2002). Approximately two dozen island sites along the Maine coast may support 5,000 to 6,000 common tern nests. The nests may occur on rocks, pebble beaches, sand beaches, or uplands with minimal vegetation. At these island locations, common terns feed on small fish including hake (*Urophycis* sp.) and herring (*Clupea harengus*). The common tern egg clutch is usually two to three eggs.

3.2 Study Areas. Nonviable and abandoned piping plover, least tern, and common tern eggs were collected from seven areas along the Maine coast (Figure 1). South to north, the areas were Laudholm Beach, Crescent Surf Beach, Parsons Beach, Higgins Beach, Stratton Island, Pond Island, and Petit Manan Island. The approximate latitude and longitude of each collection location are listed in Table 1. Each of the collection locations represents critically important nesting habitat in the state.

3.2.1 Laudholm, Crescent Surf, and Parsons Beaches - Laudholm, Crescent Surf, and Parsons Beaches comprise a 2.2-mile (3.6-kilometer), nearly continuous length of sand beach habitat (Figure 2). Laudholm Beach is a 3,550-foot (1,080-meter) sand beach located in the Town of Wells, York County, between Drakes Island Beach and the mouth of the Little River. The southern bank of the Little River forms the northerly endpoint of Laudholm Beach. From the northern bank of the Little River, Crescent Surf Beach in the Town of Kennebunk begins. Crescent Surf Beach runs nearly one mile (1.6-kilometers) before transitioning into Parsons Beach. A natural rock outcrop separates Crescent Surf from Parsons Beach. The length of Parsons Beach runs nearly 3000-feet (946 meters). In 2003, the three beaches supported 18 nesting pairs of piping plovers and more than 77 pairs of least terns.

3.2.2 Stratton Island - Stratton Island is a 36-acre (14.5-hectare) coastal island located one mile south of Prout=s Neck in Saco Bay and three miles south of the mouth of the Scarborough River and its extensive marsh (Figure 3). The island is owned by the National Audubon Society and managed as the Phineas W. Sprague Wildlife Sanctuary. Stratton Island supports Maine=s second largest colony of endangered Roseate Terns. In 2003, Stratton Island had 305 common tern nests and 40 roseate tern nests.

3.2.3 Higgins Beach - Higgins Beach is 2,300-foot (700-meter) sand beach located in the Town of Scarborough, Cumberland County. A least tern colony of more than 50 pairs nest on a small spit of sand beach that extends into the mouth of the Spurwink River (Figure 4).

3.2.4 Pond Island - Pond Island National Wildlife Refuge is a 10-acre (4-hectare) coastal island in the terminus of the Kennebec River located less than one mile (1.6-kilometers) from Popham Beach (Figure 5). The island is owned by the U.S. Fish and Wildlife Service and co-managed by staff from Petit Manan National Wildlife Refuge and the National Audubon Society. Pond Island supports a common tern colony of approximately 300 nesting pairs. Roseate terns, a federally-listed endangered species, have occasionally nested on Pond Island with two pairs using the island in 2003.

3.2.5 Petit Manan Island - Petit Manan Island (PMI) is a 9-acre (3.6-hectare) island located approximately 3-miles (4.8-kilometers) southeast of Petit Manan Point in Pigeon Hill Bay, Milbridge, Washington County (Figure 6). The island is a refuge parcel owned by the U.S. Fish and Wildlife Service and managed by staff from Petit Manan National Wildlife Refuge stationed in Milbridge. More than 1,200 pairs of common terns and 30 pairs of roseate terns nested on the island in 2003.

Table 1. Coordinates of collection locations (south to north)

Location	Species	Latitude	Longitude
Laudholm Beach	PIPL	43° 20' 00"	070° 32' 29"
Crescent Surf Beach	LETE	43° 20' 11"	070° 32' 17"
Parson Beach	PIPL	43° 20' 42"	070° 31' 00"
Stratton Island	COTE	43° 30' 20"	070° 18' 43"
Higgins Beach	LETE	43° 33' 46"	070° 16' 22"
Pond Island	COTE	43° 44' 19"	069° 46' 14"
Petit Manan Island	COTE	44° 23' 02"	067° 49' 58"

Note: Piping plover eggs from Laudholm Beach and Parson Beach were combined into one composite sample. Coordinates were derived from a computer mapping program and should be considered approximate.

Figure 1. Map of the Maine Coast

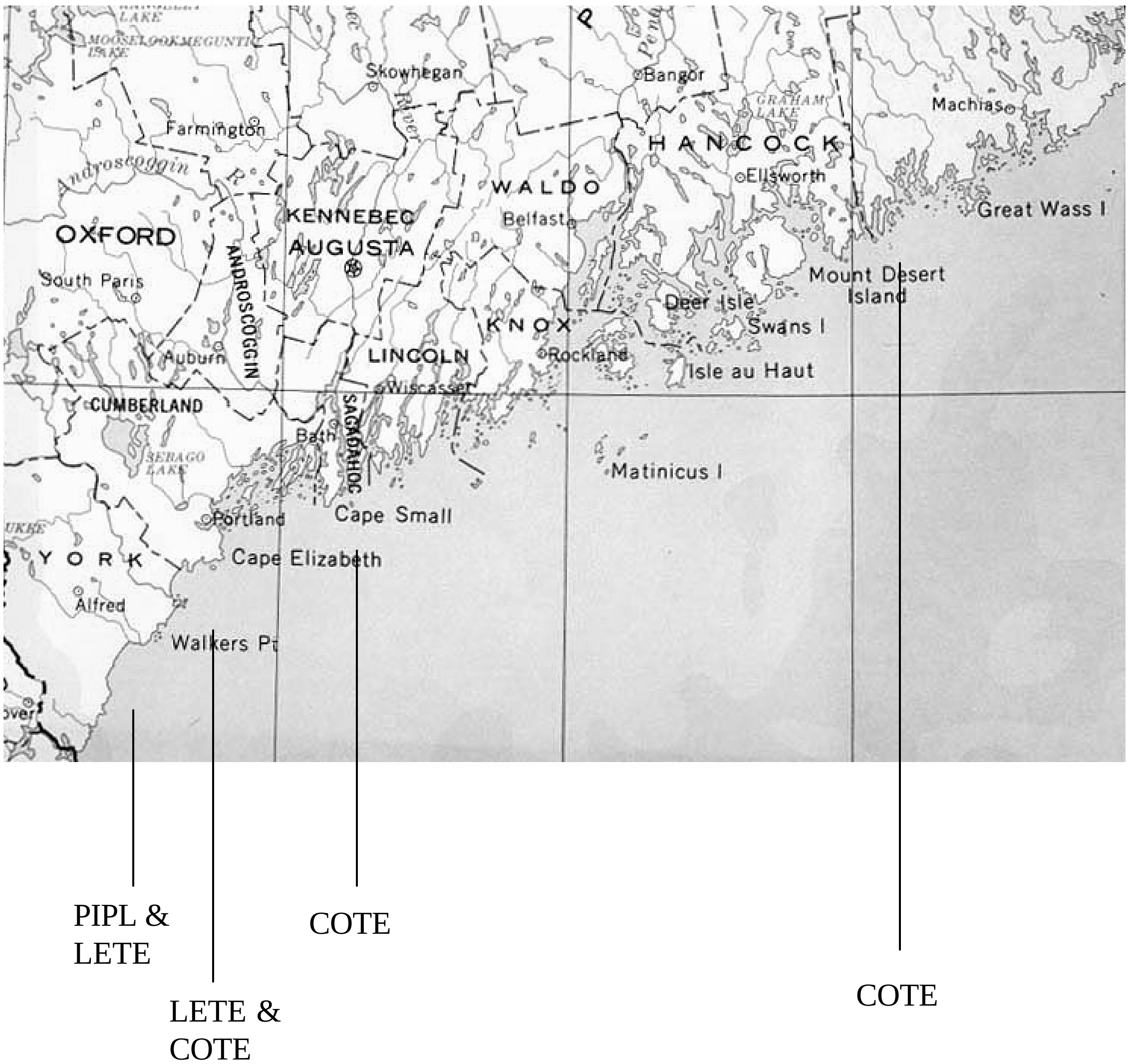


Figure 2. Egg collection locations at Laudholm, Crescent Surf, and Parsons Beaches

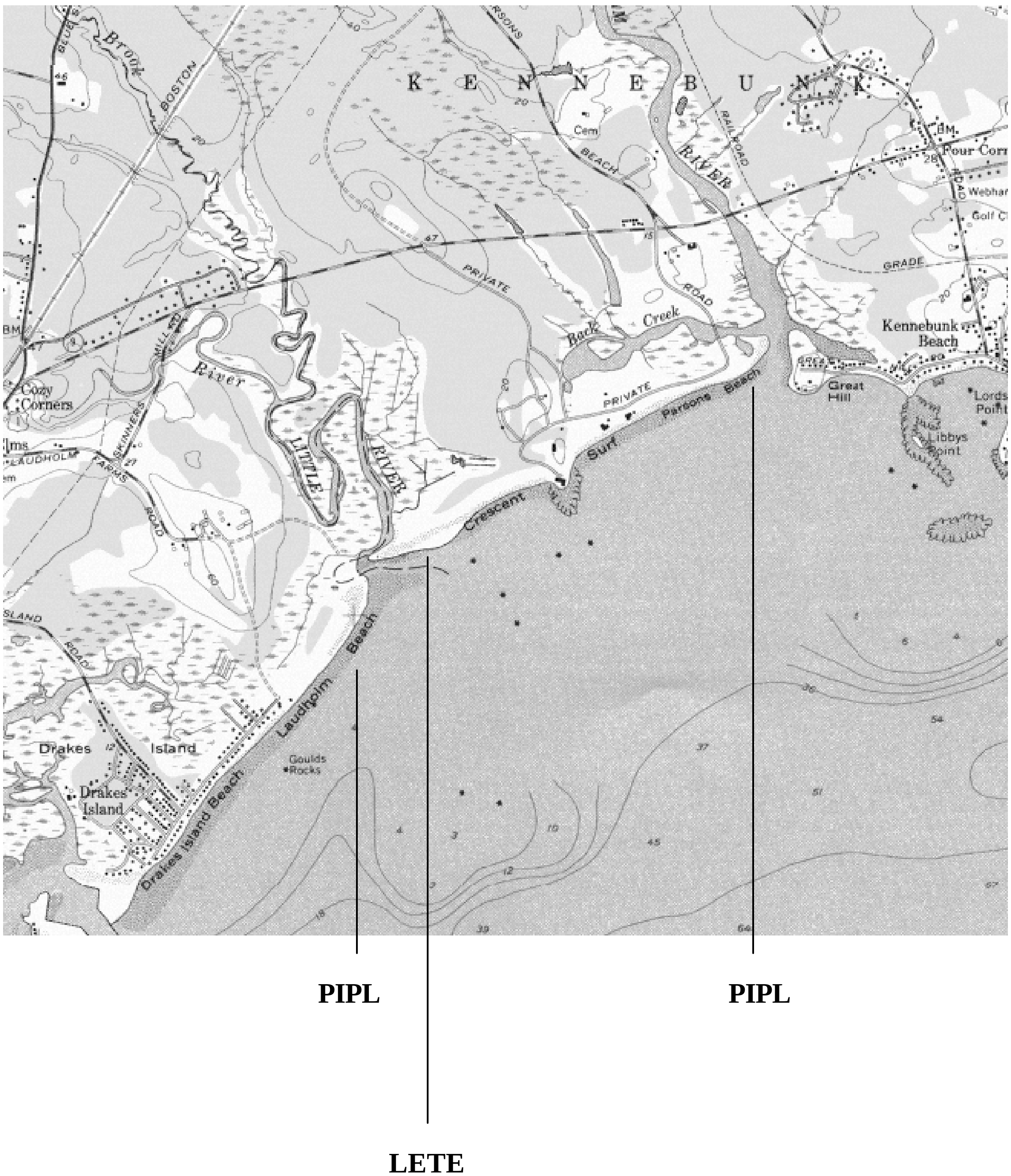


Figure 3. Location map – Stratton Island.

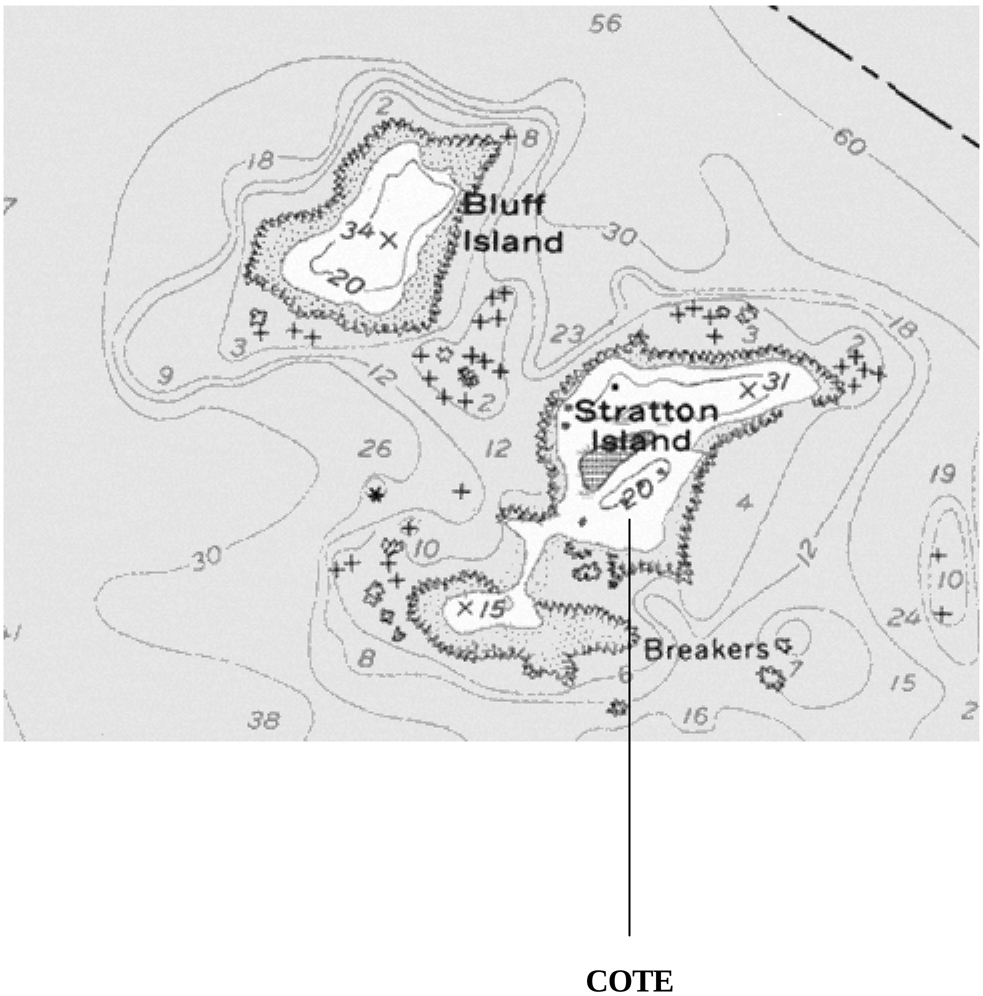
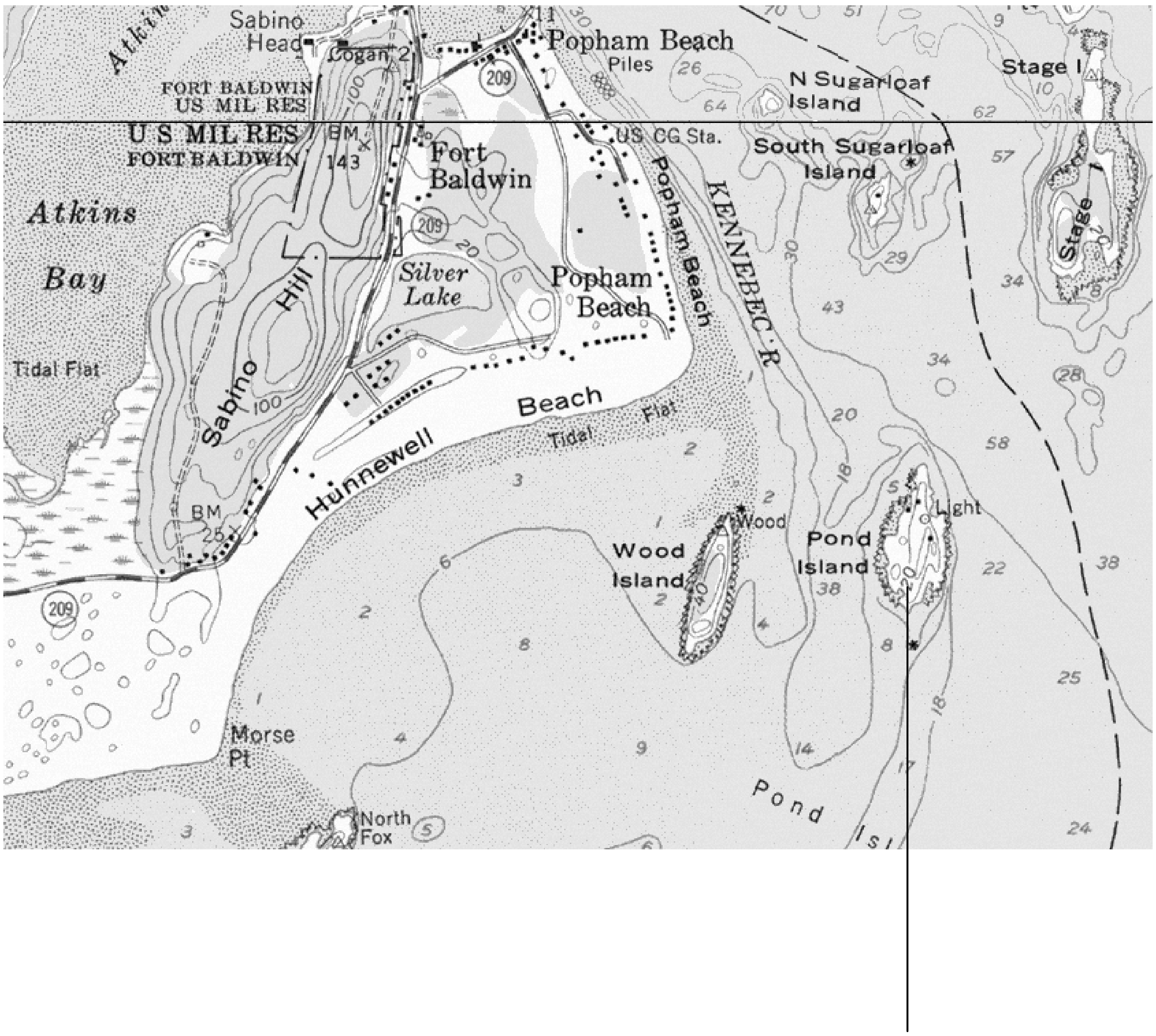


Figure 4. Location map – Higgins Beach

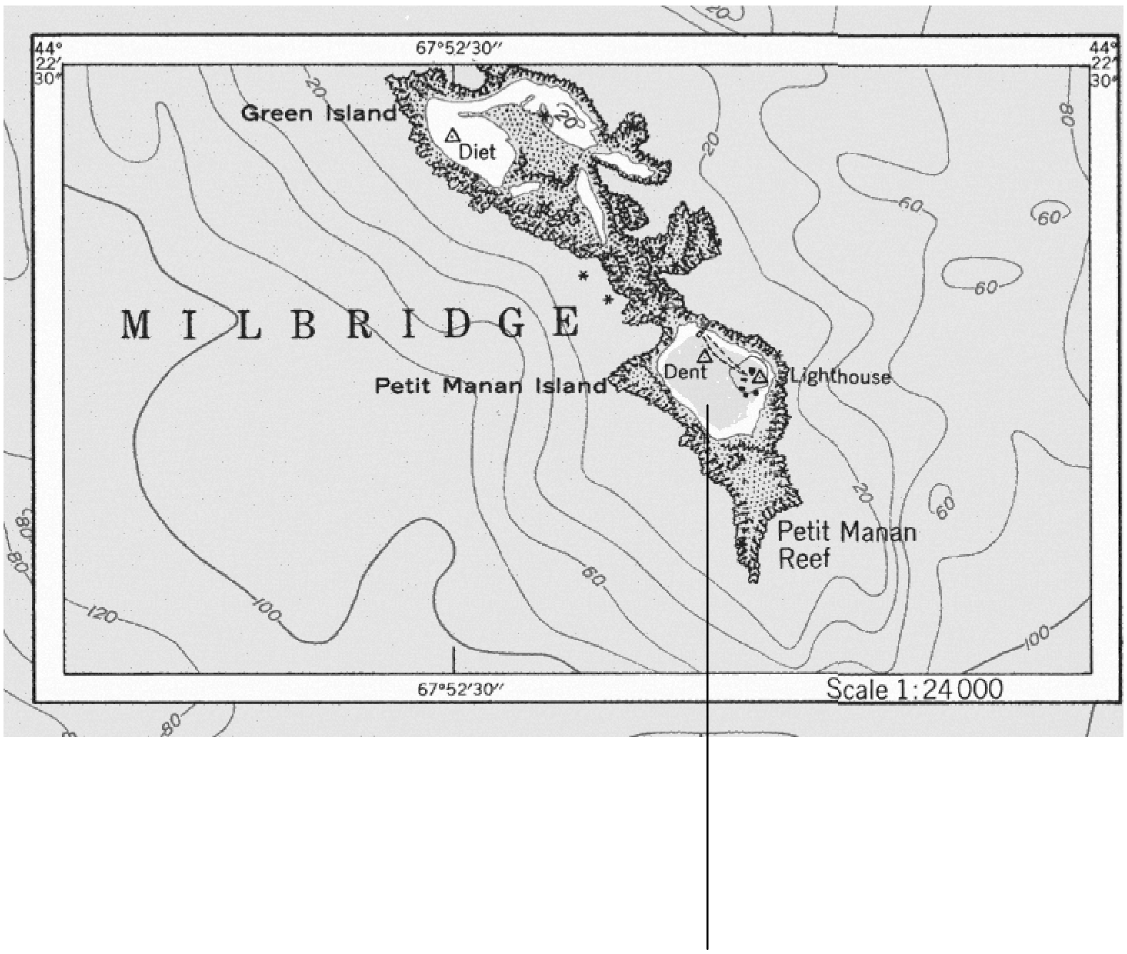
LETE

Figure 5. Location map – Pond Island National Wildlife Refuge.



COTE

Figure 6. Location map – Petit Manan Island.



COTE

4. Methods

During the 2003 nesting season (May through July), 32 nonviable and abandoned eggs from piping plover, least tern and common tern were collected from nests at seven locations along the Maine coast. Unbroken eggs were stored in freezers in chemically-clean jars or plastic bags until processed. At processing, each egg was weighed (grams), and the length and breadth were measured with vernier calipers to the nearest 0.1 millimeter. Eggs were scored with dedicated scalpels, opened at the equator, and, by species and location, the contents placed in labeled, chemically-clean jars. The sample jars were immediately frozen for storage. Upon catalog approval, the samples were shipped frozen via overnight priority mail to analytical laboratories.

Six composite samples were submitted to contract laboratories of the USFWS Patuxent Analytical Control Facility for contaminant analysis. Organochlorine compound analyses were performed by the Mississippi State Chemical Laboratory (MSCL) and inorganic element analyses were conducted by Laboratory & Environmental Testing, Incorporated (LET).

The organochlorine scan included the following compounds: HCB, PCB-Total, alpha BHC, alpha chlordane, beta BHC, cis-nonachlor, delta BHC, dieldrin, endrin, gamma BHC, gamma chlordane, heptachlor epoxide, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, p,p'-DDD, p,p'-DDE, p,p'-DDT, toxaphene, and trans-nonachlor. Organochlorine extraction, cleanup, and separation methods used by MSCL are described on pages 14 through 17 of Appendix A.

The inorganic scan included the following elements: aluminum (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), strontium (Sr), vanadium (V), and zinc (Zn). Inorganic element homogenization, digestion, and other analytical procedures used by LET are described on pages 11 through 42 of Appendix B.

Table 2. Composite sample metrics by species and location

Species and Location	No. Eggs in Composite	Total Sample Weight (g)	Percent Moisture[1]
PIPL -Laudholm & Parsons Beaches	4	23.3	66.5
LETE - Crescent Surf Beach	8	56.3	73.2
LETE - Higgins Beach	8	45.8	77.2
COTE - Stratton Island	5	72.3	76.2
COTE - Pond Island	2	28.6	77.5
COTE - Petit Manan Island	5	70.4	69.6

[1] Percent moisture values from lab homogenizing samples and forming initial aliquots

Table 3. Metrics for individual eggs in composites.

PIPL - Laudholm & Parson Beachs (LAU - P1)

Egg No.	Total Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	8	28.5	22.9	22.7
2	9	32.7	24.9	25.1
3	8	30.9	24.3	24.2
4	8	30.1	24.0	24.2

LETE - Crescent Surf Beach (CRE - L1)

Egg No.	Total Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	8	30.6	22.4	22.4
2	9	33.3	23.0	22.9
3	9	30.9	23.5	23.7
4	8	31.3	22.8	22.9
5	9	33.0	23.4	23.3
6	8	30.2	23.2	22.9
7	8	32.4	22.7	22.7
8	9	31.8	23.6	23.5

LETE - Higgins Beach (HIG - L1)

Egg No.	Total Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	7	30.5	21.5	21.6
2	9	32.5	23.0	22.9
3	6	31.2	20.9	20.8
4	5	30.1	22.3	22.5
5	8	30.2	23.1	23.2
6	7	29.5	23.5	23.2
7	8	33.8	22.6	22.4
8	8	32.5	22.5	22.4

Table 3. Metrics for individual eggs in composites (continued).

COTE - Stratton Island (STR - C1)

Egg No.	Total Egg Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	19	42.5	30.5	30.2
2	18	40.5	29.7	29.7
3	17	39.7	30.1	30.2
4	19	44.3	29.5	NM
5	13	39.9	29.2	29.1

NM = not measured due to swelling on one side.

COTE - Pond Island NWR (PND - C1)

Egg No.	Total Egg Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	20	45.7	31.8	31.5
2	15	41.1	29.8	29.5

COTE - Petit Manan Island (PMI - C1)

Egg No.	Total Egg Weight (g)	Length (mm)	Breadth 1 (mm)	Breadth 2 (mm)
1	15	42.2	29.7	29.8
2	16	41.0	29.4	29.3
3	19	41.9	30.5	30.3
4	17	44.9	30.8	30.9
5	16	41.1	30.5	30.3

5. Analytical Results

Analytical results are summarized below. Laboratory results are reported in the appendices in micrograms per gram (µg/g = parts-per-million) dry weight and wet weight. The results in the text and tables of this report are presented in **µg/g (ppm) on a fresh wet weight basis**. Fresh wet weight concentrations in egg composites were calculated by adjusting laboratory-reported wet weights to account for moisture loss after egg laying (Stickel *et al.* 1973, Hoyt 1979). Since several eggs were formed into species-specific composites, the mean sample weight and mean calculated egg volume were used to develop the fresh wet weight adjustment factor for each composite (Appendix C).

5.1 Organochlorines - The organochlorine scan included the following compounds: HCB, PCB-Total, alpha BHC, alpha chlordane, beta BHC, cis-nonachlor, delta BHC, dieldrin, endrin, gamma BHC, gamma chlordane, heptachlor epoxide, mirex, o,p'-DDD, o,p'-DDE, o,p'-DDT, oxychlordane, p,p'-DDD, p,p'-DDE, p,p'-DDT, toxaphene, and trans-nonachlor. Of the 22 organochlorine compounds in the analytical scan, only five compounds were found in egg composite samples - hexachlorobenzene (HCB), total polychlorinated biphenyl (PCB), dieldrin, p,p'-DDE, and trans-nonachlor (Table 5). Of these five compounds, only HCB, PCB, and p,p'-DDE were found in all samples.

5.1.1 Dieldrin - Dieldrin was detected in only two samples and at similar concentrations. The PIPL sample contained 0.005 µg/g of dieldrin, while the LETE sample from Higgins Beach contained 0.006 µg/g.

5.1.2 Hexachlorobenzene (HCB) - In the six composite egg samples, HCB concentrations ranged from 0.003 µg/g (PIPL) to 0.007 µg/g (LETE - Higgins Beach). The mean HCB levels in LETE and COTE were identical, 0.005 µg/g.

5.1.3 DDE - The para, para metabolite (p,p'-DDE) of DDE was found in all samples. DDE was highest in the PIPL sample (0.097 µg/g) and lowest in the COTE sample from Petit Manan Island (0.037 µg/g).

5.1.4 Total Polychlorinated Biphenyls (Total PCBs) - The COTE samples exhibited a wide range of Total PCB concentrations. The lowest Total PCB concentration in the survey was detected in the COTE composite sample from Petit Manan Island (0.291 µg/g) and the highest was found in the COTE sample from Pond Island µg/g) National Wildlife Refuge (0.764 µg/g). Total PCBs in the PIPL (0.560 µg/g) and LETE samples (mean 0.430 µg/g) fell within the middle of the range of values in the COTE.

5.1.5 Trans-nonachlor - Trans-nonachlor was detected in four of six samples. Only one COTE sample contained a detectable level of trans-nonachlor (COTE from Petit Manan Island 0.002 µg/g). Of the three species, trans-nonachlor appeared higher in PIPL (0.007 µg/g.). Both LETE contained trans-nonachlor at similar concentrations (0.010 µg/g and 0.011 µg/g).

5.2 Inorganics - The inorganics scan included the following elements: aluminum, arsenic, boron, barium, beryllium, cadmium, chromium, copper, iron, mercury, magnesium, manganese, molybdenum, nickel, lead, selenium, strontium, vanadium, and zinc. Eight elements, including cadmium, chromium, nickel, and lead, were not detected in the composite samples. Of the 11 remaining analytes, copper, iron, mercury, manganese, magnesium, selenium, strontium, and zinc were detected in all samples (Table 6).

5.2.1 Aluminum (Al) – Aluminum was found in all samples with the lowest concentrations found in COTE samples (mean 0.54 µg/g) and the highest in PIPL sample (0.75 µg/g).

5.2.2 Arsenic (As) – Arsenic was detected in five of six samples at 0.07 µg/g and 0.08 µg/g. The element was not detected in the PIPL composite sample.

5.2.3 Barium (Ba) – Barium was detected in only one sample, the PIPL composite sample from Laudholm and Parson Beaches at 0.05 µg/g.

5.2.4 Copper (Cu) – Copper concentrations in composite samples ranged from 0.55 to 0.66 µg/g. The mean Cu concentrations in LETE and COTE samples were similar (0.59 µg/g).

5.2.5 Iron (Fe) – LETE had a mean Fe concentration of 24.4 µg/g, while the COTE mean was 21.5 µg/g. The PIPL sample had a Fe level (21.7 µg/g) that was similar to COTE.

5.2.6 Mercury (Hg) – Mercury levels ranged from 0.08 µg/g (COTE from Pond Island and Petit Manan Island) to 0.17 µg/g (PIPL).

5.2.7 Magnesium (Mg) – Magnesium was highest in the LETE composite sample from Higgins Beach (111.5 µg/g) and lowest in the PIPL sample (80.7 µg/g).

5.2.8 Manganese (Mn) – The PIPL sample had the lowest Mn concentration (0.30 µg/g), while the LETE and COTE samples exhibited similar means, 0.40 µg/g and 0.41 µg/g, respectively.

5.2.9 Selenium (Se) - The highest level Se level (0.70 µg/g) was detected in the COTE sample from Petit Manan Island. Selenium was lowest in PIPL at 0.41 µg/g, slightly higher in LETE (mean 0.51 µg/g) and highest in COTE (mean 0.61 µg/g).

5.2.10 Strontium (Sr) - The highest concentration of Sr (4.99 µg/g) was detected in the PIPL composite sample. This level was well above the concentrations found in LETE (mean 1.24 µg/g) and COTE (mean 1.30 µg/g) composite samples.

5.2.11 Zinc (Zn) – Zinc levels were similar among the species composites: PIPL 12.7 µg/g, LETE 12.3 µg/g (mean), COTE 12.3 µg/g (mean).

5.3 Lipid Content - Lipids (fats) within the avian egg are the principal nutrient source for developing embryos (Proctor and Lynch 1993). Organochlorine compounds are lipophilic, and lipid content is routinely measured in tissue samples to help interpret organochlorine concentrations. The mean lipid content for the two LETE samples was 8.8%, while the mean for three COTE samples was 8.98 %. Lipid content was highest in the PIPL sample (16.1%) and lowest in the COTE sample from Pond Island (7.72%).

Table 4. Percent lipid in egg composites by species and location

Species and Location	Percent Lipid
PIPL - Laudholm & Parsons Beaches	16.1
LETE - Crescent Surf Beach	9.40
LETE - Higgins Beach	7.83
COTE - Stratton Island	8.42
COTE - Pond Island	7.72
COTE - Petit Manan Island	10.8

5.4 Quality Assurance/Quality Control (QA/QC) - QA/QC procedures included procedural blanks, duplicates, certified reference materials, and spike recoveries. Organochlorine compound QA/QC results are described on pages 6 through 11 of Appendix A. QA/QC review comments and approval from the Service's analytical chemist are described on pages 12 and 13 of Appendix A. Inorganic element QA/QC results are described on pages 5 through 10 of Appendix B. QA/QC review comments and approval from the Service's analytical chemist are included on page 10 of Appendix B.

Table 5. Organochlorine compounds in composite samples of plover and tern eggs - 2003, ug/g fww

Species	Sample No.		Dieldrin	HCB	p,p'-DDE	PCB-Total	trans-nonachlor
Piping Plover	LAU-P1		0.005	0.003	0.097	0.560	0.007
Least Tern	CRE-L1		nd	0.004	0.054	0.470	0.011
Least Tern	HIG-L1		0.006	0.007	0.066	0.389	0.010
		Mean	nc	0.005	0.060	0.430	0.010
Common Tern	STR-C1		nd	0.006	0.040	0.425	nd
Common Tern	PND-C1		nd	0.004	0.057	0.764	nd
Common Tern	PMI-C1		nd	0.005	0.037	0.291	0.002
		Mean	nd	0.005	0.045	0.493	nc

ug/g = parts-per-million, fww = fresh wet weight (i.e., adjusted for moisture loss)
nd = non-detect, nc = not calculated

Table 6. Inorganic elements in composite samples of plover and tern eggs - 2003, ug/g fww

Species	Sample Number		Al	As	Ba	Cu	Fe	Hg	Mg	Mn	Se	Sr	Zn
Piping Plover	LAU-P1		0.75	nd	0.05	0.66	21.7	0.17	80.7	0.30	0.41	4.99	12.7
Least Tern	CRE-L1		0.62	0.07	nd	0.59	24.8	0.12	93.1	0.42	0.54	0.98	12.2
Least Tern	HIG-L1		0.60	0.07	nd	0.60	23.9	0.11	111.5	0.39	0.49	1.50	12.4
		Mean	0.61	0.07	nd	0.59	24.4	0.12	102.3	0.40	0.51	1.24	12.3
Common Tern	STR-C1		0.56	0.08	nd	0.55	20.9	0.12	99.4	0.36	0.58	1.20	12.6
Common Tern	PND-C1		0.52	0.07	nd	0.56	20.8	0.08	95.7	0.45	0.54	1.41	11.6
Common Tern	PMI-C1		0.54	0.08	nd	0.66	23.0	0.08	86.4	0.43	0.70	1.30	12.5
		Mean	0.54	0.08	nd	0.59	21.5	0.10	93.9	0.41	0.61	1.30	12.3

ug/g = parts-per-million, fww = fresh wet weight (i.e., adjusted for moisture loss)
nd = non-detect

6. Discussion

Piping plover, least tern, and common tern eggs were examined in this survey because the eggs were opportunistically collected, and because USFWS and GOMSWG wildlife managers were interested in knowing if Gulf of Maine birds were at risk from contaminants in their diets. In this coarse screening-level survey, no pre-conceived study design or large sample sizes were developed to rigorously differentiate among species or locations. Basically, eggs that were available were analyzed. It has been reported that in certain species contaminant concentrations may vary within an egg clutch (Nisbet 1982, Becker 1992). In this survey, the use of multi-egg composites from several nests at each location should better represent overall contaminant conditions for a given location. Overall, decisions in the screening-level survey were based on practicality, technical utility, and the availability of samples and funding. Readers should take into account these limitations when making data interpretations.

Eggs in this survey were examined for organochlorine compounds and inorganic elements. Concentrations in eggs typically represent contaminants sequestered in the egg by females at the time of egg formation (Burger and Gochfeld 1996). These egg contaminants can be derived from recent exposure or from mobilization from other tissues in the female (Burger *et al.* 1999). Hence, the contaminant levels in eggs may reflect local contaminant conditions or reflect a contaminant burden accumulated by females during migration.

6.1 Organochlorines. Of the 22 organochlorine compounds in the analytical scan, only five compounds were found in egg composite samples - dieldrin, hexachlorobenzene (HCB), total polychlorinated biphenyl (PCB), p,p'-DDE, and trans-nonachlor (Table 4). Of these five compounds, only HCB, PCB, and p,p'-DDE were found in all samples.

6.1.1 Dieldrin - Dieldrin is a cyclodiene pesticide that is highly toxic to birds (Briggs 1992). Mortality and reproductive effects among seed-eating bird species (e.g., waterfowl and pheasants) can be extremely high immediately after applications of dieldrin to soil, seed, or crops in agricultural areas (Blus 2003). Although dieldrin use in the United States was cancelled in 1971, the insecticide persists in soils and biological tissues (Howard 1991, Briggs 1992). A suggested 0.70 µg/g dieldrin no-observed-effect-level or ecological effect benchmark for avian eggs appears based on falcon studies (Peakall 1996, RAIS 2004).

Dieldrin was found in only two of the six samples (PIPL 0.005 µg/g, LETE at Higgins Beach 0.006 µg/g). The levels were orders of magnitude below the suggested effect level.

6.1.2 Hexachlorobenzene (HCB) - HCB is a reaction by-product of PCB production by chlorination of phenol, and is found in wood preservatives, fungicides, and herbicides (Verschueren 1983, Gilbertson and Reynolds 1972). HCB is a component within the herbicide Dacthal, and is a persistent environmental pollutant (Wiemeyer 1996). Based on its ability to bind to the aryl hydrocarbon (Ah) receptor, its dioxin-like effects, and ability to bioaccumulate, it has been suggested that HCB be classified as a dioxin-like compound (van Birgelen 1998). HCB is often released to the atmosphere from the same sources that are releasing polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (e.g., chloralkali and wood-preserving plants, municipal and hazardous waste incinerators; ATSDR 1997, Environment Canada 1999). Dietary exposure in animals to HCB damaged the liver, thyroid, nervous system, bones, kidney, blood, and immune and endocrine systems (ATSDR 1997). Wiemeyer (1996) reviewed several studies and reported that the effects of HCB on reproduction of birds were variable among species. In one exposure study, Japanese quail eggs with an estimated HCB burden of 35 µg/g were not affected, while in another study, hatchability of chicken eggs was normal when containing as much as 100 µg HCB/g (Wiemeyer 1996).

None of the PIPL (0.003 µg/g), LETE (mean 0.005 µg/g), or COTE (mean 0.005 µg/g) egg composite samples examined in this study approached the suggested ecological screening benchmark value of 100 µg/g (Wiemeyer 1996, RAIS 2004).

6.1.3 DDE - DDE (1,1-dichloro-2,2-bis(p-chlorophenyl ethylene) is a metabolite of the pesticide DDT. Although the use of DDT in the United States was essentially discontinued in 1972 (EPA 1990), the compound and its metabolites continue to be detected in wildlife tissues. DDT metabolites are lipophilic and accumulate in lipid deposits and other fatty tissues (Blus 2003). DDE is a potent androgen receptor antagonist that may affect male sexual development in wildlife and humans (Kelce *et al.* 1995). In raptors and piscivorous birds, DDT metabolites cause eggshell thinning (Hickey and Anderson 1968). Eggs of piscivorous birds with DDE residues of 1 µg/g have a 5% to 10% reduction in eggshell thickness, and eggshells with 18% thinning are associated with declining populations (Blus 1996). In general, DDE residues in wildlife tissues have declined substantially since the DDT ban.

In 2003, DDE levels in PIPL (0.097 µg/g), LETE (mean 0.60 µg/g), and COTE (mean 0.045 µg/g) were all well below the effects threshold of 1 µg/g.

6.1.4 Polychlorinated Biphenyls (PCBs) - PCBs are lipophilic, highly persistent compounds that bioconcentrate in organisms and biomagnify in food chains (Eisler 1986). Reproductive effects caused by PCB exposure in birds include reduced hatchability, embryo mortality, and chick deformities (Hoffman *et al.* 1996). At Total PCB levels from 8 to 25 µg/g in eggs, decreased hatching success may occur in terns and other birds (Hoffman *et al.* 1996). PCB congeners with dioxin-like characteristics (e.g., non-ortho and di-ortho congeners) may be particularly toxic to bird eggs. However, congener-specific analyses were not conducted with the 2003 composite samples and the percentage of dioxin-like congeners within the Total PCB concentration is not known.

The highest Total PCB concentration in the six egg composite samples was 0.764 µg/g (COTE from Pond Island), well below the ecological effect benchmark. Of the remaining samples, the PIPL sample (0.560 µg/g) was the next highest concentration, perhaps due to its higher lipid content. There are only six data points, and a mixture of species with varying lipid content, but in a plot of the 2003 season samples, Total PCBs levels appear to decrease from south to north along the coast - with the exception of COTE at Pond Island (Figure 7).

6.1.5 Trans-nonachlor - Trans-nonachlor is persistent environmental contaminant that is regularly detected in wildlife tissues. Trans-nonachlor is a major constituent of chlordane, a cyclodiene insecticide (Verschueren 1983, Eisler 1990). Deaths of wildlife from chlordane exposure are typically related to consumption of contaminated material following a pesticide application. Bird mortality from chlordane exposure is usually acute and levels associated with reproduction effects or lethality in eggs are not known (Wiemeyer 1996).

Trans-nonchlor was detected in four of six samples - PIPL (0.007 µg/g), both LETE (mean 0.010 µg/g), and only one of the COTE composite samples (0.002 µg/g at Petit Manan Island).

6.2 Inorganic Elements. Eleven inorganic elements were found above detection limits in egg composite samples: aluminum, arsenic, barium, copper, iron, magnesium, manganese, mercury, selenium, strontium, and zinc (Table 5). Typically, aluminum, barium, iron, magnesium, manganese, and strontium are not of concern with respect to bioaccumulation in birds, and therefore are not discussed in this report. Brief notes on the hazards and potential effects associated with exposure to arsenic, copper, mercury, selenium, and zinc are provided below.

6.2.1 Arsenic (As) - Arsenic is a teratogen and carcinogen, which bioconcentrates in organisms, but does not biomagnify in food chains (Eisler 1994). In mallard dietary studies, As exposure did not affect hatching success and was not teratogenic, but did delay egg laying, reduced egg weight, and caused eggshell thinning (Stanley *et al.* 1994). In some bird studies, adverse reproductive effects were not expected when As residues in eggs were less than 9 µg/g (Hothem and Welsh 1994).

Arsenic levels in PIPL, LETE, and COTE from the Maine coast in 2003 (nondetect - 0.08 µg/g) were substantially less than 0.25 µg/g, the As effect level reported for waterfowl by Hothem and Welsh (1994).

6.2.2 Copper (Cu) - Copper is an essential element for vertebrates. At environmentally realistic concentrations, Cu is not carcinogenic, mutagenic or teratogenic (Eisler 1997). No data are available on Cu toxicity to avian wildlife, but at elevated dietary concentrations Cu accumulated in poultry liver, inhibited growth, and caused gizzard erosion (Eisler 1997, Hui *et al.* 1998).

Copper criteria for the protection of avian wildlife are not available (Eisler 1997), but the Cu levels found in 2003 egg composites do not appear elevated compared to other New England and U.S. studies (Conners *et al.* 1975, Carr and von Oettingen 1989, Mierzykowski *et al.* 2001).

6.2.3 Mercury (Hg) - Mercury is a mutagen, teratogen, and carcinogen which bioconcentrates in organisms and biomagnifies through food chains (Eisler 1987). Mercury concentrations of 0.5 µg/g to 2.0 µg/g in eggs are sufficient to reduce egg viability, hatchability, embryo survival and chick survival in nonmarine birds (Thompson 1996). Embryo deformities may occur in bird eggs containing about 1 µg Hg/g (Heinz and Hoffman 2003).

Concentrations of Hg in PIPL (0.17 µg/g), LETE (mean 0.12 µg/g) and COTE (mean 0.10 µg/g) eggs did not exceed the ecological effect screening benchmark value of 0.5 µg Hg/g (RAIS 2004). A slight decreasing south to north trend in Hg contamination was suggested in a plot of 2003 data (Figure 8). The mean Hg level in COTE eggs from Petit Manan Island in 2003 was similar to the mean concentration found in Arctic tern (*Sterna paradisea*) eggs from the island in 1993 (Mierzykowski *et al*. 2001).

6.2.4 Selenium (Se) - Selenium contamination in irrigation drainwater and surface water is a serious problem to fish and wildlife resources in the western United States, a region with seleniferous soils. In the eastern United States seleniferous soils are less common, but Se has been identified in the Northeast as an environmental contaminant in fish collected from rivers in industrialized areas. Selenium is an essential trace element for vertebrates. Selenium deficiency may cause death (Eisler 1985). Heinz (1996) reviewed several Se studies and concluded that a level of about 3 µg/g in bird eggs should be considered the threshold of reproductive impairment.

None of the PIPL (0.41 µg/g), LETE (mean 0.51 µg/g), or COTE (mean 0.61 µg/g) egg composites collected in the Maine survey had Se levels that approached the 3.0 µg/g ecological effect benchmark proposed by Heinz (1996).

6.2.5 Zinc (Zn) - Zinc is an essential element for vertebrates. Generally, Zn is efficiently regulated by wildlife and tissue concentrations are not reliable indicators of exposure except in extreme cases (Beyer and Storm 1995). Zinc is considered to be elevated in bird tissue when greater than 52 µg/g, and Zn poisoning occurs in birds with liver or kidney levels greater than 525 µg/g (Eisler 1993).

The Zn levels in PIPL, LETE, and COTE were slightly above 12 µg/g and well below the 52 µg/g ecological effect benchmark suggested by Eisler (1993).

Figure 7. Total PCBs in egg composites, ug/g fww.

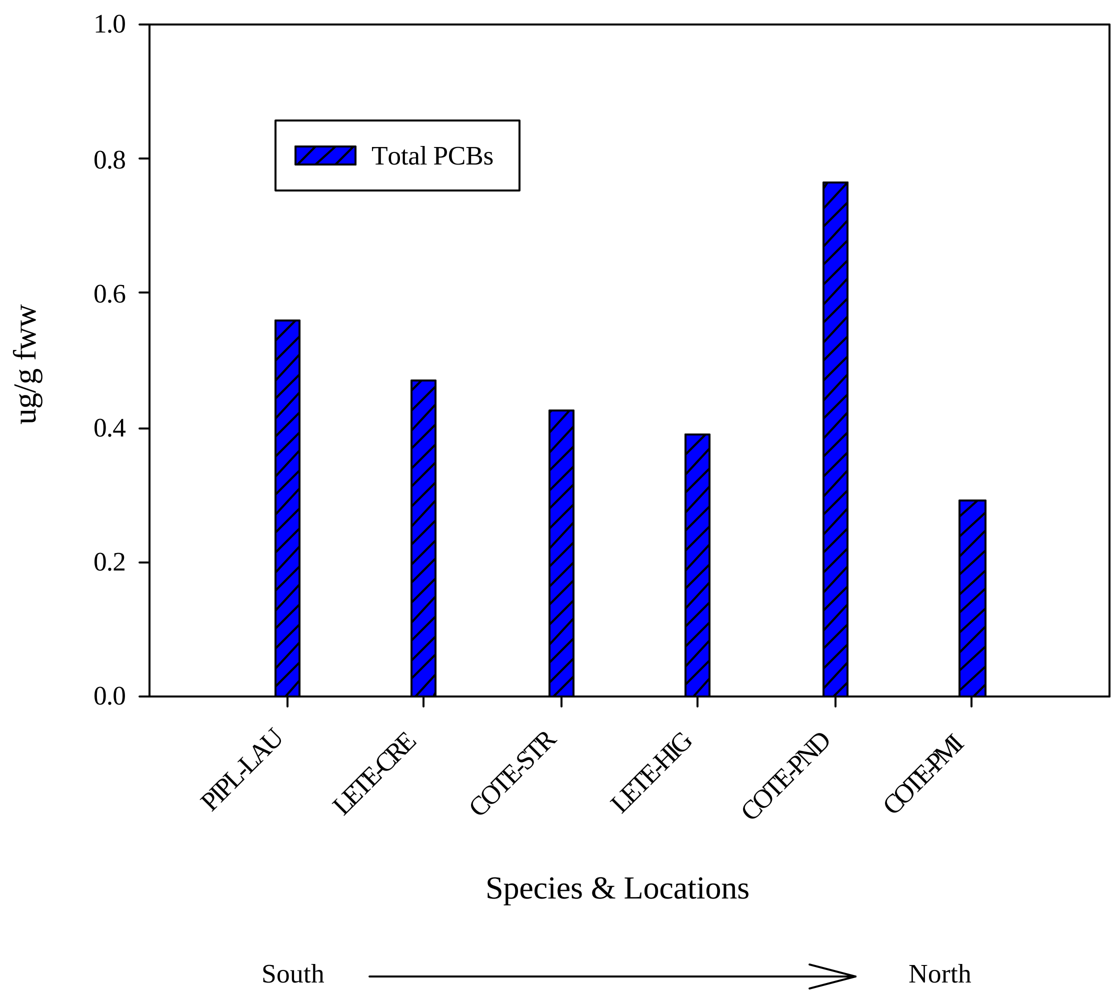
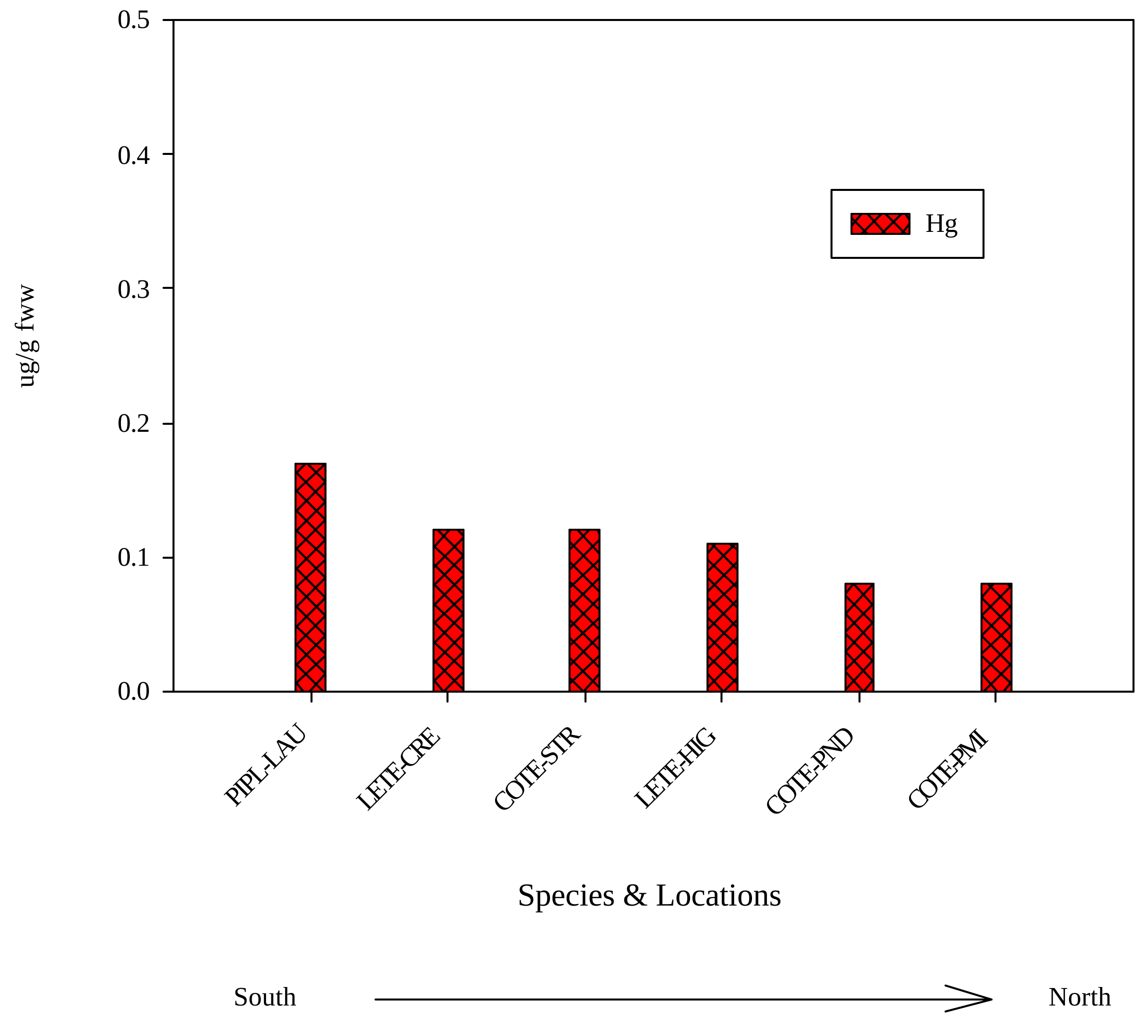


Figure 8. Mercury in egg composites, ug/g fww



7. Summary

Highly elevated levels of contaminants were not detected in piping plover, least tern, and common tern egg composites collected from seven locations on the Maine coast during the 2003 nesting season.

Although highly elevated levels or organochlorine compounds and inorganic elements were not detected in egg composite samples, additional monitoring is recommended to quantify and monitor temporal and spatial trends in contamination in birds nesting along the Maine coast.

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APPENDIX A

ORGANOCHLORINES

Mississippi State Chemical Laboratory
Mississippi State, MS

The analytical data package (17 pages) is available upon request from the Maine Field Office

APPENDIX B

INORGANIC ELEMENTS

Laboratory & Environmental Testing, Inc.
Columbia, MO

The analytical data package (42 pages) is available upon request from the Maine Field Office

APPENDIX C

CALCULATIONS

Mean Egg Volume for Species-Specific Composites

Adjustment Factors - Wet Weight to Fresh Wet Weight

The calculation tables (6 pages) are available upon request from the Maine Field Office