NISTIR

SEABIRD TISSUE ARCHIVAL AND MONITORING PROJECT: Egg Collections and Analytical Results for 1999 - 2002

Stacy S. Vander Pol[1]
Steven J. Christopher[1]
David G. Roseneau[2]
Paul R. Becker[1]
Russell D. Day[1]
John R. Kucklick[1]
Rebecca S. Pugh[1]
Kristin S. Simac[3]
Geoff W. York[3]

[1]National Institute of Standards and Technology, Chemical Science and Technology Laboratory, Hollings Marine Laboratory
[2]U.S. Department of the Interior, U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge
[3]U.S. Department of the Interior, U.S. Geological Survey, Alaska Science Center

March 2003

Contents

List of Tables

List of Figures

ACKNOWLEDGMENTS

The following individuals are acknowledged for their contributions in developing and conducting STAMP: Lyman Thorsteinson (USGS), G. Vernon Byrd (USFWS), Barbara J. Porter (NIST), Scott Hatch (USGS), David Irons (USFWS), Kevin Winker (University of Alaska Museum), Alan M. Springer (University of Alaska and FALCO), Edward C. Murphy (University of Alaska), C. Loren Buck (University of Alaska), Earl Kingik (Point Hope IRA Council), Little Diomede Island Villagers, Laura Greffenius (USFWS), Susan Hatch (USFWS), Arthur B. Kettle (USFWS), Dean Kildaw (USFWS), Laurie Ness (USFWS), Alexis Paul (USFWS), Nora Rojek (USFWS), Leslie Slater (USFWS), Kent Sundseth (USFWS), Cleveland Cowles (MMS) and Steve Treacy (MMS). John Fauth (College of Charleston) and Lori Schwacke (NOAA) provided much needed assistance with statistics.

DISCLAIMER

Certain commercial equipment or instruments are identified in this paper to specify adequately the experimental procedures. Such identification does not imply recommendations or endorsement by the National Institute of Standards and Technology nor does it imply that the equipment or instruments are the best available for the purpose.

BACKGROUND

In 1998, the U.S. Geological Survey Biological Resources Division (USGS-BRD), the U.S. Fish and Wildlife Service (USFWS) Alaska Maritime National Wildlife Refuge (AMNWR), and the National Institute of Standards and Technology (NIST) began the Seabird Tissue Archival and Monitoring Project (STAMP) to collect and cryogenically bank tissues from seabirds in Alaska for future retrospective analysis of anthropogenic contaminants. The approach of STAMP was similar to that of the Alaska Marine Mammal Tissue Archival Project (AMMTAP). AMMTAP was started in 1987 by NIST and the National Oceanic and Atmospheric Administration (NOAA) as part of the Outer Continental Shelf Environmental Assessment Program sponsored by the Minerals Management Service. Presently sponsored by the USGS-BRD, AMMTAP continues its work as part of a larger national program, the Marine Mammal Health and Stranding Response Program. AMMTAP developed carefully designed sampling and specimen banking protocols. Since 1987, AMMTAP has collected tissues from marine mammals taken in Alaska Native subsistence hunts and has cryogenically banked these tissues at the NIST National Biomonitoring Specimen Bank (NBSB). Through its own analytical work and working in partnership with other researchers both within and outside Alaska, AMMTAP has helped to develop a substantial database on contaminants in Alaska marine mammals. In contrast, there is very limited data on contaminants in Alaska seabirds, which are similar to marine mammals in that they feed near the top of the food chain and have the potential for accumulating anthropogenic contaminants.

During its early planning stages, STAMP identified the seabird egg as the first tissue of choice for the project. There is a relatively long history of using bird eggs for environmental monitoring and for investigating the health status of bird populations. Since 1998, protocols for collecting and processing eggs, and cryogenically banking egg samples have been developed by STAMP (see York *et al.* 2001). Eggs are being collected on an annual basis for several species at nesting colonies throughout Alaska. Aliquots of these egg samples are being analyzed on a regular basis for persistent organic pollutants and mercury. Results of this work have been published in scientific journals (Christopher *et al.* 2002) and in conference proceedings (Kucklick *et al.* 2002; Vander Pol *et al.* 2002a, 2002b).

The intent of this report is to provide an up-to-date description of STAMP. The report contains the most recent egg collection inventory, analytical data, preliminary interpretations based on these data, and a discussion of the future development of the project.

THE SEABIRD EGG AS A MATRIX FOR MARINE ENVIRONMENTAL MONITORING

The term "persistent organic pollutants" or POPs has been fairly well accepted by the environmental chemistry community over the past decade to denote long-lived organic compounds that bioaccumulate as they move through the food chain and have toxic effects. Examples of such compounds are polychlorinated biphenyls (PCBs), chlorinated pesticides (i.e., DDT, chlordane, toxaphene, hexachlorocyclohexane [HCH], and dieldrin), hexachlorobenzene (HCB), dioxins and furans. Although restricted or banned in many developed countries, POPs are still manufactured for export and remain in use in many developing countries. POPs can also appear in the environment many thousands of kilometers from their points of release due to

atmospheric transport as gases and aerosols. Based on the "Global Fractionation and Cold Condensation" theory of Wania and Mackay (1996), POPs may be fractionated based on the physical properties of the individual compounds and be globally transported at different rates, undergoing condensation and deposition in low-temperature regions, and eventually depositing in the cold polar regions.

Mercury is similar to POPs in that it can be atmospherically transported globally from points of release to remote regions. Bioavailability of mercury depends on microbial conversion of the inorganic mercury to methylmercury, which is fat-soluble, bioaccumulates much like POPs, and is toxic. Although the majority of emissions of mercury to the atmosphere is natural (volcanic emissions), the greatest source of anthropogenic emissions to Arctic atmosphere occurs from stationary fossil fuel combustion (particularly coal) and waste incineration (AMAP, 2002).

The analysis of seabird tissues, particularly eggs, has played an important role in temporal and spatial environmental monitoring of POPs and mercury. For example, since the 1970s seabird eggs have been used to monitor such contaminants in the Canadian Arctic (Muir *et al.* 1999). Temporal changes in PCB, chlorinated pesticide, and mercury concentrations have been documented in the eastern Canadian high arctic (see Braune *et al.* 2001), and in the Barents and Baltic seas (see Barrett *et al*. 1996 and Bignert *et al.* 1995, respectively) using eggs from several colonial nesting species. Analyses of northern fulmar (*Fulmarus glacialis*), black-legged kittiwake (*Rissa tridactyla*), and thick-billed murre (*Uria lomvia*) eggs from colonies on Prince Leopold Island in the eastern Canadian arctic suggest that most POP levels have decreased and mercury levels have increased in this region since the mid-1970s (Braune *et al.* 2001). This finding is consistent with other pollutant studies that suggest mercury is increasing in the environment worldwide.

The international Arctic Monitoring and Assessment Programme (AMAP) identified eggs from the seabird family Alcidae (murres, murrelets, auklets, guillemots, puffins, dovekies, and razorbills) as key materials for circumpolar monitoring of POPs by all arctic nations (AMAP Scientific Experts Workshop, Girdwood, Alaska, April 1998). The first AMAP report on the state of the arctic environment summarized information on POPs and mercury levels in seabirds living in northern regions of Canada and Scandinavia (AMAP, 1998). This report, which is currently being updated, contains data indicating that POPs levels in seabird eggs were higher in the Scandinavian arctic than in the Canadian arctic. Within Canada, levels were greater in the high eastern arctic regions than in the lower western arctic regions. Also, PCB concentrations approaching levels known to affect hatching success were found in thick-billed murre, common murre (*U. aalge*), puffin (*Fratercula* spp.), black guillemot (*Cepphus grylle*), and black-legged kittiwake eggs from northern Canada and Norway (AMAP 1998).

Extrapolating POPs and mercury values from the Canadian arctic database to Alaska is not appropriate, because sources of these contaminants for Alaska are different. The Bering and Chukchi seas are not only under the influence of airborne contaminants transported across the pole from Eastern Europe, but also from atmospheric and oceanic transport from Asia across the Pacific Ocean. Overall contaminant patterns and levels in Alaskan seabirds are probably influenced by atmospheric transport of contaminants from Asia eastward and northward into the Gulf of Alaska, oceanic transport from Asia via the eastward flowing North Pacific Current, and the transport of substances into the Bering and Chukchi seas from the Northern Gulf of Alaska via the westward moving Alaskan Stream and Alaskan Coastal Current (Stabeno *et al.* 1999; Li

et al. 2002). Local contaminant sources from existing and former military installations may also play roles in "hot spot" pollution patterns in Alaska.

Factors that have to be considered when interpreting concentrations in seabird eggs include:

- Incorporation from lipids during egg formation
- Length of time on colony before egg laying begins
- Seasonal movements of the nesting birds
- Variation among individual eggs of a clutch
- Feeding strategy and prey types
- Atmospheric & oceanic transport patterns
- Physical & chemical behavior of the contaminants

Concentrations of contaminants in the egg reflect burdens in the female at the time the egg is laid (Braune and Norstrom 1989). Fat reserves in the female are mobilized during egg formation and the fat, with its associated lipophilic contaminants, are transferred to the egg. However, it is not known what percentage of these fat reserves with their associated contaminant residues reflect what has been assimilated by the female at the nesting location before and during egg formation, versus what has been previously assimilated at other feeding locations during the year (such as what is assimilated in the wintering areas).

For species that lay more than one egg per clutch (i.e., kittiwakes, gulls, and guillemots), the first-laid egg may have substantially different concentrations of contaminants than subsequently laid eggs. This variability could be eliminated by only collecting first-laid eggs, or by pooling individual eggs in a clutch as a single sample. Both of these approaches have drawbacks. The first approach requires that the collector be at the nest when the first egg is laid, which in the remote and hazardous locations of these seabird colonies is not always practical. The second approach requires that the collector is sure that all eggs in a clutch have been collected and that all eggs in a collected clutch are not broken in shipment; or that, if an egg is broken in shipment, the collector knows within what order it was laid. Even more of problem, multiple egg clutches may include one, two, or three eggs, which may vary among birds of a colony. If an egg is lost at a nest before collection (knocked off the ledge or taken by a predator), the collector might never know that the clutch collected is not really a full clutch. This could introduce an unrecognized variability to the specimen collections.

Different seabird species represent different feeding "guilds" and prey on different species. For example, murres are pursuit divers, diving to depths of up to 200 m to feed on fish and invertebrates. Kittiwakes in comparison are surface-feeding piscivores that feed on forage fish that are generally smaller in size than those preyed on by the murres. Storm petrels (*Oceanodroma* spp.) are surface plankton feeders. These three groups of seabirds feed at different trophic levels and in different parts of the water column; thus their exposure to contaminants that biomagnify are quite different. Contaminant concentrations may also be confounded by a seabird population shifting its dietary pattern over time. Prey-shifts can occur in seabird populations from many different causes, i.e., reproductive failure of the predominant prey, environmental changes in the oceanic regime, etc. A temporal change in contaminant concentrations in eggs may, therefore, be the result of a switch in prey used by the birds rather than a change in concentrations in the environment.

Although a substantial amount of recent research has been conducted on contaminants in Alaskan marine mammals, few data exist on colonial seabirds nesting in Alaska. Kawano *et al.* (1988) reported chlordane concentrations in thick-billed murres collected in the North Pacific and Gulf of Alaska in 1980 and 1982 and Ohlendorf *et al.* (1982) provided information on a limited number of organochlorine analytes measured in seabird eggs collected from Alaskan colonies in the 1970s. Like marine mammals, seabirds are an important group of upper trophic level marine organisms with a potential for accumulating lipophilic contaminants. Realizing the value of colonial seabirds in environmental monitoring and the lack of recent data from Alaskan seabird colonies, in 1998 the USGS-BRD, USFWS-AMNWR and NIST initiated the Seabird Tissue Archival and Monitoring Project (STAMP).

GOAL AND OBJECTIVES

The original goal of STAMP (as stated in York *et al.* 2001) was to archive a representative collection of tissues from Alaskan colonial seabird species for future contaminant analyses and documentation of long-term trends in environmental quality. The goal has now expanded to include routine chemical analysis of aliquots of egg samples collected and banked by the project. Also for comparisons, seabird colonies outside of Alaska are being considered for including in the project. The revised goal of STAMP is to monitor long-term trends in environmental quality by (1) collecting eggs (and other tissues) at seabird colonies using carefully designed and standard protocols, (2) processing and banking the samples under conditions that ensure chemical stability during long-term (decadal) storage, and (3) analyzing subsamples of the stored material for anthropogenic contaminants.

THE VALUE OF SPECIMEN BANKING

The cryogenic banking of seabird specimens for retrospective analysis is an important component of STAMP. The long-term storage of carefully selected, representative samples in an environmental specimen bank is an important complement to the real-time monitoring of the environment. These banked specimens permit (1) the use of subsequently developed innovative analytical technology that was not available at the time the samples were archived, for clear state-of-art identification and quantification of analytes of interest, (2) the identification and quantification of analytes that are of subsequent interest but that were not of interest at the time the samples were banked, and (3) the comparison of present and past analytical techniques and values, providing continued credibility of past analytical values, and allowing flexibility in environmental monitoring programs.

Two good examples of the value of specimen banking in environmental monitoring result from the use of seabird eggs banked by the Canadian Wildlife Service. The Canadian Wildlife Service successfully documented temporal changes in PCBs and pesticides in the Great Lakes by analyzing herring gull (*Larus argentatus*) eggs that were collected and banked as part of its Wildlife Toxicology Program (see Mineau *et al.* 1984, Elliott 1985, Wakeford and Kasserra 1997). Also, the decrease in PCBs and chlorinated pesticides and the increase in mercury shown by Braune *et al.* (2001) for the Prince Leopold Island area are based on reanalyzing archived samples of seabird eggs collected between 1975 and 1998.

SPECIES AND COLONY LOCATIONS

During the early development of STAMP, specific seabird species were identified as ideal for collecting eggs routinely at nesting colonies in the AMNWR based on the species feeding strategies and prey types. They include:

- Deep-diving fish eaters - common and thick-billed murres
- Surface feeding fish eaters - black-legged kittiwakes
- Surface feeding plankton eaters - fork-tailed storm petrels (*Oceanodroma furcata*)
- Scavengers - glaucous and glaucous-winged gulls (*Larus hyperboreus* and *L. glaucescens*)

Black guillemots are also being considered by STAMP, since they are recommended by AMAP as a primary circumpolar monitoring species. If this species is added, the most logical location for egg collections is from the largest nesting colony in Alaska, Cooper Island in the Beaufort Sea near Barrow (Figure 1).

STAMP is currently collecting eggs from three widely distributed piscivorous species: common and thick-billed murres and black-legged kittiwakes (black-legged kittiwakes were integrated into project in 2002). These three species use different feeding strategies. Black-legged kittiwakes are surface-feeders preying on forage fish (e.g., Pacific sand lance, *Ammodytes hexapterus*; capelin, *Mallotus villosus*; small cod, gadidae) in the upper 0.5 meter of the water column (e.g., see Springer et al. 1984, 1986, 1987; Baird 1994). In contrast, murres are divers capable of reaching depths of 150 m or more (see Piatt and Nettleship 1985, Burger and Simpson 1986). Common and thick-billed murres also take sand lance, capelin, and cod; however, thick-billed murres tend to feed at greater depths than common murres and often prey on benthic species, including some invertebrates, that they catch on or near the bottom (e.g., pricklebacks, Stichaeidae, sculpins, Cottidae, and pandalid and crangonid shrimp), while common murres tend to feed closer to shore at shallower depths on mid-water fishes (e.g., see Springer et al. 1984, 1986, 1987). Murre eggs are harvested in many rural Alaskan coastal communities where they play a role in local subsistence diets (e.g., see Iknokinok and Georgette, 1997).

Both murres and kittiwakes spend most of their time at sea, coming ashore to breed in large colonies on precipitous sea cliffs and headlands. Commonly, the same colony locations support both kittiwakes and murres. Although the range of the thick-billed murre extends further north than that of the common murre and the range of the common murre extends further south, these closely related species overlap to a great degree in Alaska, with both species often nesting at the same location.

More than 95% of the seabirds breeding in the continental United States nest at colonies in the Bering and Chukchi seas and Gulf of Alaska (see USFWS 1992), and about 80% of these birds are found on Alaska Maritime National Wildlife Refuge (AMNWR) lands (G.V. Byrd, pers. comm.). The AMNWR consists of 4.5 million acres on more than 2,400 islands, headlands, rocks, islets, spires and reefs on the Alaskan coast. This refuge extends from Cape Lisburne in the Chukchi Sea to the tip of the Aleutian Islands and eastward to Forrester Island on the border of British Columbia. Due to the importance of the AMNWR to seabirds and the opportunity for

collecting eggs in the refuge through the USFWS observer program, STAMP has concentrated on AMNWR murre and kittiwake colonies.

Current STAMP sampling sites (Figure 1) are Cape Lisburne and Cape Thompson in the eastern Chukchi Sea; Little Diomede Island in Bering Strait; Bluff in Norton Sound; St. Lawrence and St. George islands in the Bering Sea; Bogoslof Island in the eastern Aleutians; Chiniak Bay near Kodiak Island; East Amatuli, Middleton, and St. Lazaria islands in the Gulf of Alaska; and Shoup Bay in Prince William Sound. Several more sampling locations may be added in the future, including Chamisso-Puffin islands and Cape Deceit in Kotzebue Sound; Buldir Island in the western Aleutian Islands; Aiktak Island in the eastern Aleutian Islands (Unimak Pass); Chowiet Island in the southwestern Gulf of Alaska; and Chisik-Duck and Gull islands in Cook Inlet and Kachemak Bay. Plans also call for adding glaucous-winged and glaucous gulls to the project in 2003-2004. The eggs of both species are important human subsistence resources in Alaska and, due to their scavenging nature, have the potential for having higher concentrations of bioaccumulative contaminants than murres or kittiwakes.

PROTOCOL DEVELOPMENT

Protocols for collecting, sampling, processing, transporting, and cryogenically banking murre eggs were developed and tested in 1998 – 1999, when murre eggs were obtained from Cape Lisburne, Little Diomede, St. George, Bogoslof, East Amatuli, and St. Lazaria islands (Figure 1). These protocols, which emphasize carefully documented standard procedures, the use of non-contaminating materials for handling specimens, adherence to chain of custody procedures, and storage under conditions that ensure long-term sample stability, were published in York *et al.* (2001). However, it became apparent after these protocols were published that the egg collectors needed more detailed field instructions. These instructions, which were produced as STAMP Field Collection Supplemental Instructions, are found in Appendix D of this report.

BASELINE CHEMICAL ANALYSIS

Egg samples from colonies at St. Lazaria, East Amatuli, Bogoslof, St. George, and Little Diomede islands were selected for analysis to begin establishing baseline contaminant values for use in long-term studies of POPs and mercury levels in Alaskan seabirds. After baseline data sets have been developed for the complete suite of STAMP colonies, eggs will be collected from these sampling locations on alternating schedules and checked for potentially harmful contaminants about every 5 to 10 years. Unanalyzed portions of the eggs will be cryogenically banked at the NBSB for future retrospective research.

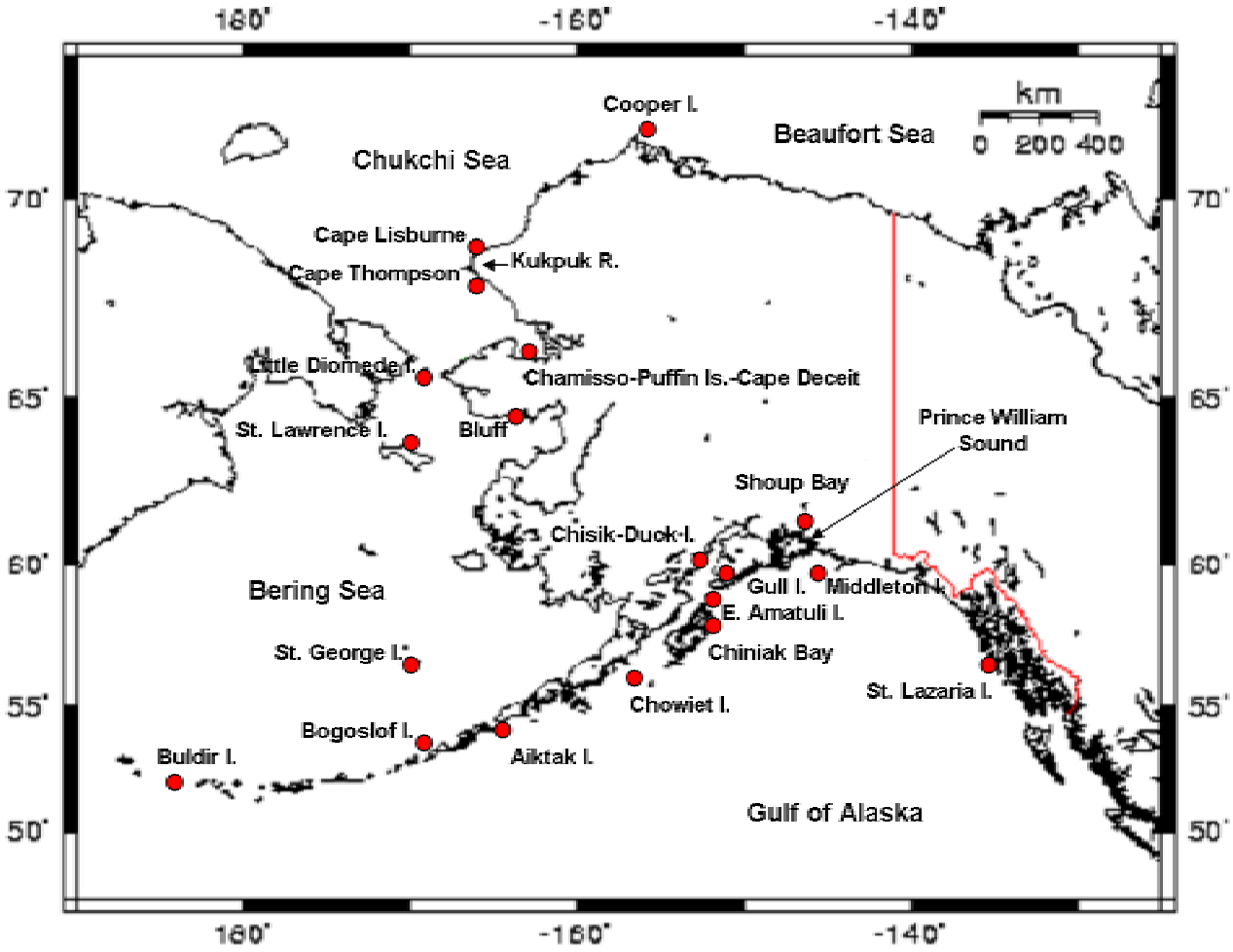

Figure 1. Locations of seabird colonies identified for egg collections.

METHODS

COLLECTING AND PROCESSING EGGS

Eggs were collected by AMNWR, USGS-BRD, USFWS Office of Migratory Bird Management (MBM), and University of Alaska Fairbanks (UAF) biologists and community residents using NIST-published protocols (see York *et al.* 2001) and additional supplemental guidelines that are found in the Appendix D of this report. Entire clutches were collected, which for murres consist of single eggs and for kittiwakes one or two eggs. These eggs were sent to the USGS-BRD Alaska Science Center in Anchorage, Alaska, where the contents were separated from the shells and frozen in clean Teflon containers. Two-egg clutches had their contents combined to form a single egg specimen representing the total clutch. The dried shells were shipped to the UAF Museum in Fairbanks, Alaska, and the frozen contents were sent to NIST's National Biomonitoring Specimen Bank (NBSB) at the Hollings Marine Laboratory in Charleston, South Carolina.

BANKING SPECIMENS

At the NBSB, the frozen egg contents were cryogenically homogenized, divided into 'A' and 'B' subsamples, and stored in permanently labeled, cataloged Teflon containers in liquid nitrogen vapor freezers at -150º C. The 'A' subsamples are specifically earmarked for long-term storage for future research projects that will explore new questions and concerns about persistent bioaccumulative contaminants using more advanced, yet-to-be developed techniques and methodologies, and the 'B' subsamples are available for immediate analysis. After baseline data sets have been developed for the complete suite of STAMP murre, kittiwake, and gull colonies, eggs will be collected from the sampling sites on alternating schedules and checked for potentially harmful contaminants about every 5 - 10 years.

PERSISTENT ORGANIC POLLUTANT ANALYSIS

Sample Extraction

Methods used to extract and analyze the samples were similar to methods reported by Kucklick *et al.* (2002). Approximately three grams of frozen material were removed from each storage vial and individually mixed with 30 g of Na_2SO_4 (batches 1-3; samples 1-30) or 8 g diatomaceous earth (batches 4 and 5; samples 31-67) that had been combusted at 700 ^{o}C for 24 h and then cooled in a desiccator prior to use. Diatomaceous earth was substituted for Na_2SO_4 in order to remove more water from the samples during extraction. The samples, including the associated Na_2SO_4 or diatomaceous earth, were transferred to 33 mL pressurized fluid extractor cells (PFE; Dionex, Sunnyvale, CA). Aliquots of SRM 1946 'Lake Superior Fish Tissue', six calibration solutions, and a blank were analyzed with each batch. Aliquots of frozen Lake Ontario herring gull egg homogenate reference material from the Canadian Wildlife Service (CWS; obtained from Bryan Wakeford) was analyzed with batches 4 and 5. Although this material has not been certified for organochlorine values, the CWS has used it for over ten years. The homogenate was prepared in 1989 from a batch of 138 herring gull eggs taken from a

nesting colony on Lake Ontario. The eggs were homogenized and several hundred 6 g aliquots were prepared and stored frozen at -35 ^{o}C at the main CWS freezer complex. To test the homogeneity of the murre egg samples, three aliquots from sample 42, a thick-billed murre egg from St. George Island, were analyzed in batch 5.

Calibration solutions were prepared by placing weighed portions of SRMs 2261 (Chlorinated Pesticides in Hexane), 2262 (Chlorinated Biphenyl Congeners in 2,2,4-trimethylpentane), 2274 (Chlorinated Biphenyl Congeners in Isooctane II), 2275 (Chlorinated Pesticides in Hexane II), and PCB solution 3 (Schantz, 2001) into a weighed portion of isooctane. From 0.3 ng to 300 ng of each analyte were gravimetrically added to the individual PFE cells that were packed with clean Na_2SO_4 or diatomaceous earth. A mixed internal standard solution containing 4,4'-DDT-d_8, 4,4'-DDE-d_8, 4,4'-DDD-d_8, endosulfan I-d_4, PCB 103 and PCB 198, and a coplanar PCB internal standard solution containing PCB 77, PCB 126, and PCB 169 (batches 1-3; samples 1-30), or combined PCB and coplanar PCB mixed internal standard solution containing all the above compounds except endosulfan I-d_4 (batches 4 and 5; samples 31-67) were also gravimetrically added to the PFE cells. Samples were extracted with CH_2Cl_2 using the PFE. Conditions were as follows: cell temperature 100 ^{o}C, equilibration 5 min, static time 5 min, cell pressure 2000 psi, and there were 3 cycles (one-third of the solvent each time, 35 mL total). To remove extra water, the sample extracts were mixed with clean Na_2SO_4 (batches 1-3; samples 1-30) or filtered by a 125 mm phase separation paper (Whatman, Ann Arbor, MI) funnel that had been sonicated in CH_2Cl_2 three times and dried (batches 4 and 5; samples 31-67). The phase separation paper funnel was filled with a scoop of clean Na_2SO_4 to enhance water removal. The extract (known weight) was transferred to Turbovap tubes (Zymark, Hopkinton, MA) and reduced to approximately 10 mL by evaporating it in a stream of purified N_2 using a Turbovap. Nonvolatile solvent extractable material ("lipid") analyses were run on the samples by gravimetrically weighing 2 mL of the extract into preweighed aluminum dishes and allowing the solvent to evaporate before reweighing to constant weight.

Samples 44, 46, and 48 (thick-billed murre eggs from St. George Island) all had strong odors and large amounts of water/protein and were analyzed for lipids by the phase separation paper method. Lipid values for these eggs were low (4.92, 3.75, and 5.20%, respectively). Due to a batch of samples that had to be discarded because of a bad lot of solvent, samples 46 and 48 were previously analyzed using the Na_2SO_4 method. Results were 9.24% and 11.1% lipid, respectively. All other samples that had lipid percentages determined by both methods did not vary by more than 15%.

Samples 44, 46, and 48, and sample 41, a common murre egg from East Amatuli Island that had a low lipid percentage and was only analyzed by the phase separation paper method, were analyzed by a third method for removing water that consisted of centrifuging the sample at 1500 rpm for 2 minutes and pipetting off the sample. The centrifuge technique produced values similar to the Na_2SO_4 analysis of samples 46 and 48, and to the phase separation paper analysis of sample 41. The percent lipid used for samples 41, 46, and 48 was the average of the percentages obtained by similar methods. The percent lipid obtained by the centrifuge method was used for sample 44.

After lipid percentages were determined for the samples, they were reduced to between 0.5-1 mL in the Turbovap. Lipids were separated from organochlorines by using a 600 mm x 25 mm (10 μm particle size with 100 Å diameter pores) PLGel column (Polymer Labs, Amherst, CA;

Schantz *et al.*, 1992). The solvent, CH_2Cl_2, was delivered at 10 mL/min. Absorbance was monitored at 254 nm using a UV/VIS detector (Linear, model 200, San Jose, CA). Samples were injected (0.5-1 mL) and the first 175 mL of CH_2Cl_2 containing high molecular mass material were discarded. The next 100 mL, containing the analytes of interest, were collected and retained. The CH_2Cl_2 fractions were reduced in volume using the Turbovap and the solvent was exchanged to hexane and then further reduced to 0.5 mL. The extract was fractionated into relatively lower and higher polarity fractions (F1 and F2, respectively) by using a semi-preparative aminopropylsilane column (μBonda Pak or YMC Pak; Waters, Milford, MA). The column was changed between batch 3 and 4. The F1 consisted of either 42 mL (batches 1-3; samples 1-30) or 52 mL (batches 4 and 5; samples 31-67) of hexane, and F2 consisted of 60 mL of 25% CH_2Cl_2:hexane. F1 compounds included PCBs, heptachlor, 2,4'-DDE, 4,4'-DDE, 2,4'-DDT, HCB, oxychlordane, and mirex. F2 analytes included 4,4'-DDT, *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, α-, β-, and γ-HCH, heptachlor epoxide, 2,4'-DDD, 4,4'-DDD, and dieldrin. However, β-HCH remained on the column in batches 4 and 5.

Sample Analysis

Amounts of organochlorine compounds in sample extracts were determined by injecting each of the samples twice into a gas chromatograph (GC) with dual micro-electron capture detectors (ECD) (Hewlett Packard 6890, Palo Alto, CA). Organochlorines in F1 and F2 from the aminopropylsilane column were separated using a 60 m DB-5 with 0.25 mm interior diameter and 0.25 μm film thickness (J&W Scientific, Folsom, CA) and a 60 m DB-XLB with 0.25 mm interior diameter and 0.25 μm film thickness (J&W Scientific). The GC was configured by installing a 5 m x 0.25 mm interior diameter retention gap to the inlet and attaching a glass Y connector to the free end. The columns connected to the Y splitter, then to the ECDs. The injector and detector temperatures were set at 220 ^oC and 325 ^oC, respectively, and the carrier and makeup gasses were H_2 (constant velocity of 30 cm/s) and N_2 (60 mL/min), respectively. Samples were injected into the GC (2 μL, splitless injection), and the oven was programmed to run from an initial 90 ^oC (1 min hold) to 170 ^oC at 18 ^oC/min, then increased in temperature to 260 ^oC at 1 ^oC/min, and then increased again to 300 ^oC at 15 ^oC/min (10 min hold; 107 min run time). Amounts of each compound in the unknowns were calculated by using the mass of internal standard that was added to the sample and the slope and intercept of the six-point calibration curve generated from the response of the calibration solutions. The same column was used for individual contaminants in all of the samples. If there was no known coelution, the average of the DB5 and DB-XLB columns was used if there was at least 75% agreement between the columns. If there was more than 25% non-agreement between the columns, the column with the lowest result was used because there may have been unknown coelution on the other column. In the F1, the average of the internal standards PCB 103, PCB 198, and 4,4'-DDE-d_8 was used to quantify all compounds on the DB-5 column and the average of the internal standards PCB 103 and PCB 198 was used to quantify all compounds on the DB-XLB column. The average of the DB-5 and DB-XLB columns was reported for PCB congeners 28, 66, 99, 118, 146, 153, 105, and 180, and HCB and 4,4'-DDE. The DB-5 column was used to quantify PCB congeners 56+60, 70+76, 82, 92+84+89, 101+90, 107, 151, 156+202+171, 157, 158,193, 194, and 201, and 2,4'-DDE. The DB-XLB column was used to quantify PCB congeners 8, 18, 31, 44, 45, 49, 52, 63, 74, 87, 95, 110, 128, 132, 138, 149, 163, 170, 174, 183, 187, 195, 206, and 209, and 2,4'DDT, heptachlor, mirex, and oxychlordane. In the F2, 4,4'-DDD-d_8 was used as the internal standard to quantify all compounds. Peak areas obtained from the DB-5 column

were used to quantify the F2 compounds. A detection limit of 0.100 ng/g wet mass was determined based on the lowest concentration of the calibration curve.

GC/mass spectrometry (MS; Hewlett Packard 6890/5973, Palo Alto, CA) was used to reanalyze oxychlordane from batch 2 and 4,4'-DDT from batch 3 due to these compounds splitting between the two aminopropylsilane LC fractions as determined from SRM 1946 results. The F1 and F2 fractions were recombined and reduced in volume to approximately 0.05 mL before GC/MS analysis. For oxychlordane, the GC/MS was operated in the negative chemical ionization (NCI) mode. Samples were injected (2 μL) into a 60 m DB-5 capillary column with 0.25 mm internal diameter x 0.25 μm film thickness (on-column mode; J&W Scientific, Folsom, CA). Helium was used as the carrier gas at a constant flow rate of 30 cm/s. Methane was used as the reagent gas. The source temperature was held at 136 ^{o}C. The initial column temperature was 60 ^{o}C; the temperature was then increased to 150 ^{o}C at 25 ^{o}C/min, then to 200 ^{o}C at 0.75 ^{o}C/min, then again to 240 ^{o}C at 2 ^{o}C/min, and finally to 300 ^{o}C at 10 ^{o}C/ min (10 min hold; 107 min run time). For 4,4'-DDT, the GC/MS was operated in the electron impact ionization (EI) mode. All conditions were similar to the oxychlordane analysis described above with the exception of the run conditions. From the initial column temperature of 60 ^{o}C; the temperature was increased to 170 ^{o}C at 25 ^{o}C/min, then to 200 ^{o}C at 1 ^{o}C/min, then again to 240 ^{o}C at 2 ^{o}C/min, and finally to 300 ^{o}C at 10 ^{o}C/min (10 min hold; 71.4 min run time.

MERCURY ANALYSIS

Sample Preparation and Spike Calibration

Samples were run in 12 analytical batches of six samples, each of which consisted of four eggs, one control sample and one method blank. The sample dissolution procedures used multiple iterations of microwave digestion. For each digestion batch, approximately 0.9 g sample aliquots of homogenized egg tissue were digested along with one approximately 0.6 g control sample aliquot of SRM 2976 Mussel Tissue (Trace Elements and Methylmercury) and a procedural blank. The certified value for total Hg in SRM 2976 is 0.0610 μg/g ± 0.0036 μg/g. Each analytical sample was spiked with a known quantity of isotopically enriched mercury (^{201}Hg enriched isotopic spike) prior to addition of the 5 mL nitric acid decomposition medium. The amount of spike delivered to the blank vessels was reduced to curtail errors due to overspiking. All samples were digested in a Perkin-Elmer (Shelton, CT) Multiwave® microwave oven at the highest possible temperatures (up to 300 °C) and pressures (up to 8 MPa) in order to equilibrate the spiked mercury with the natural mercury present in the samples. The resulting digests were vented and diluted with high purity water to a total volume of approximately 40 mL and non-quantitatively transferred into 60 mL polyethylene bottles. Further sample dilutions ranging from 1:3 to 1:40 were required prior to analysis.

SRM 3133 Mercury Spectrometric Solution was used to calibrate the isotopic spike solution prior to its use. First, an approximately 100 ng/g ^{201}Hg isotopic spike solution was prepared using 3 % (mass fraction) HNO_3 and 0.5 % (mass fraction) $K_2Cr_2O_7$ as the diluent to reduce loss of elemental mercury. Two approximately 100 ng/g natural mercury solutions were quantitatively prepared from SRM 3133 in 3 % (mass fraction) HNO_3 only. The natural and enriched Hg solutions were then mixed (by mass) to obtain four spike calibration solutions having a target ^{201}Hg/^{202}Hg ratio of 2:1. Thus, the mean spike concentration obtained from the

four spike calibration mixes was used as the working concentration for the spike solution. The spike solution was periodically re-calibrated with freshly prepared SRM 3133 as even the $K_2Cr_2O_7$ stabilizer could not indefinitely postpone the liberation of elemental Hg from the spike solution. The variability in the spike calibration (expressed as the percent relative standard deviation of the working spike concentration ± 1s) as calculated from four spike calibration mixes for n = 5 separate spike calibration experiments was 0.22 % ± 0.03 %.

ID-CV-ICPMS Measurements

The mercury reduction chemistry and sample introduction system has been described previously (Christopher et al., 2001) and is only briefly summarized here. The mercury in each sample solution was reduced to elemental Hg using a reductant solution of 10 % (mass fraction) $SnCl_2$ in 7 % (mass fraction) HCl in water. A gas-liquid separator was used to strip the Hg from the sample digest solutions using a stream of Ar gas (approximately 250 mL/min.). Delivery of Hg^0 to the mass spectrometer was achieved by plumbing the gas output of the gas-liquid separator into the ICPMS injector line. A mass flow controller (AALBORG Model GFC 171, Greenwich, CT), controlled with LabView™ software and National Instruments (Austin, TX) data acquisition hardware, regulated gas flow through the gas-liquid separator.

Numerous $^{201}Hg/^{202}Hg$ isotope ratio pairs were collected for all calibration and analytical samples using a Thermo Elemental PQ3 ICPMS operating in the time resolved analysis mode. The ICP power was maintained at 1350 W forward power and Ar gas flow rates were 13.5 L/min., 0.85L/min. and 0.81 L/min. for the coolant, auxiliary and injector lines, respectively. Each analytical run produced a temporal profile that consisted of a 240 s data collection window. Measurements during the first 20 s to 40 s of the profile when a 5 % (mass fraction) HNO_3 wash solution (and not a sample) was present in the gas-liquid separator established the reference baselines. A typical isotope-time profile is depicted in Fig. 2 for a spiked egg sample from East Amatuli Island. The mean of eight baseline-corrected 10 s integration windows was used to establish the measured $^{201}Hg/^{202}Hg$ isotope ratio for all spike calibration, blank, control and unknown samples. All data were corrected for detector dead time and mass discrimination using the methods outlined by Vanhaecke and coworkers (1998).

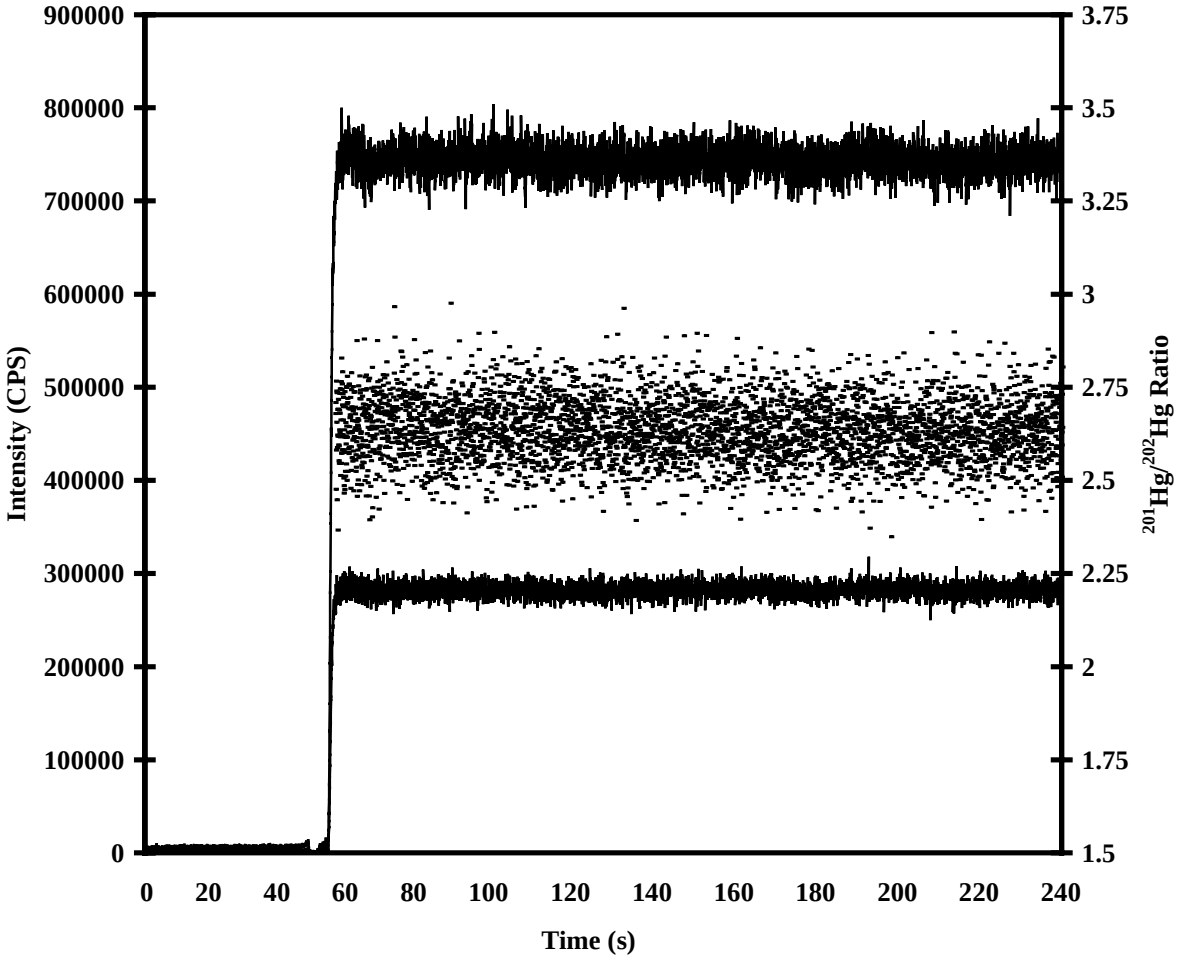

Figure 2. Transient profiles for ^{201}Hg (top trace) and ^{202}Hg (bottom trace) and overlay of corresponding ^{201}Hg/^{202}Hg isotope ratio pairs for a ^{201}Hg spiked common murre egg sample.

RESULTS AND DISCUSSION

EGG COLLECTIONS, 1999 – 2002

A total of 222 common and thick-billed murre and black-legged kittiwake egg clutches were collected between 1999 and 2002 from 12 different locations (Figure 3, Appendix A).

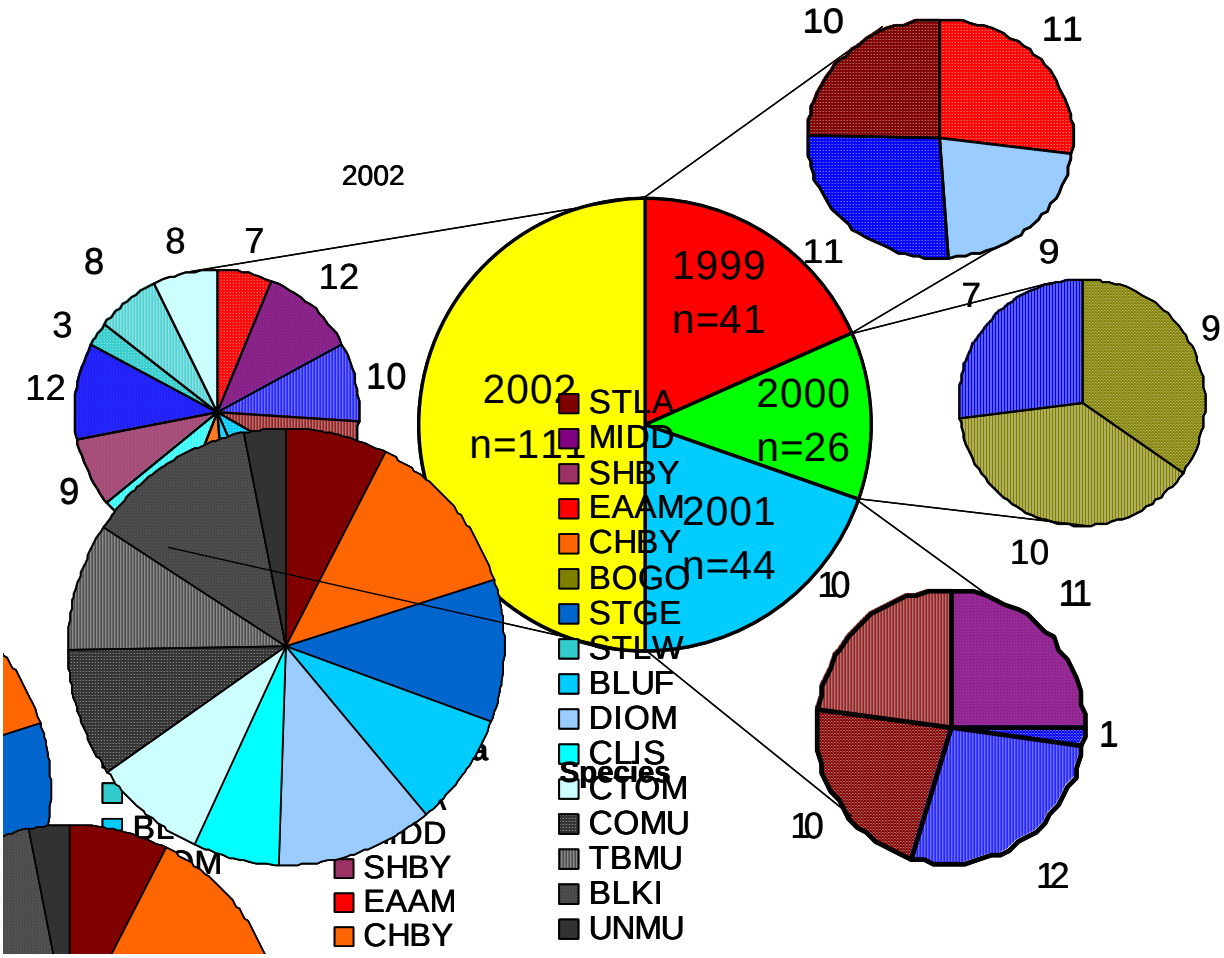

Figure 3. Number of STAMP egg clutches collected in 1999 – 2002. Colors indicate colony locations (see Figure 1) and patterns indicate species. Abbreviations are standard for the project (see Appendix D): BOGO = Bogoslof Island; STGE = St. George Island; STLW = St. Lawrence Island; BLUF = Bluff; DIOM = Little Diomede Island; CLIS = Cape Lisburne; CTOM = Cape Tompson; STLA = St. Lazaria Island, MIDD = Middleton Island; SHBY = Shoup Bay; EAAM = East Amatuli Island; CHBY = Chiniak Bay; COMU = common murre; TBMU = thick-billed murre; BLKI = black-legged kittiwake; UNMU = murre species.

PERSISTENT ORGANIC POLLUTANTS

Quality Control

SRM 1946 and the Canadian Wildlife Service herring gull egg homogenate reference material values were within the standard deviations of the mean reported values for most compounds. The exceptions were slightly higher values (within 10 %) in SRM 1946 for PCB congeners 105, 118, and 195 and slightly lower values (within 10 %) for *cis*- and *trans*-chlordane compared to the certified and reference values reported by Poster *et al.* (2003). For the herring gull egg homogenate, variances ranging from 6 % to 69 % were found for PCB congeners 44, 95, 66, 87, 149, 158, 157, and heptachlor, oxychlordane, mirex, *cis*-nonachlor and 4,4'-DDT. β-HCH was not quantified in East Amatuli Island eggs and in eggs collected in 2000. The three aliquots of a thick-billed murre egg from St. George Island varied by less than 12 % for all compounds (see Vander Pol 2002).

Analytical Results

The chlorinated hydrocarbon analytical data are presented in Appendix B. The major compounds in Alaskan murre eggs were 4,4'-DDE, ΣPCB (sum of the 46 congeners), HCB, β-HCH, and ΣCHL (sum of oxychlordane, *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor, *cis*-nonachlor, and heptachlor epoxide). All values are presented on a lipid mass basis unless otherwise noted. The range of values were 387 ng/g to 1,376 ng/g for 4,4'-DDE in the Bering Sea (BS) colonies of Little Diomede, St. George, and Bogoslof islands and 713 ng/g to 3,687 ng/g for 4,4'-DDE in the Gulf of Alaska (GoA) colonies of East Amatuli and St. Lazaria islands, for ΣPCB: 293 ng/g to 1,603 ng/g in the BS and 587ng/g to 2,966 ng/g in the GoA, for HCB: 196 ng/g to 677 ng/g in the BS and 321 ng/g to 1,057 ng/g in the GoA, for β-HCH: 73.3 ng/g to 283 ng/g in the BS and 59.0 ng/g to 225 ng/g in the GoA, and for ΣCHL: 34.1 ng/g to 276 ng/g in the BS and 50.3 ng/g to 321 ng/g in the GoA (Figure 4; Table 1). PCB congeners 153, 118, 138, 99, and 151 were major contributors to ΣPCBs, with ranges of 43.1 ng/g to 337 ng/g in the BS and 95.8 ng/g to 642 ng/g in the GoA for congener 153, 43.9 ng/g to 155 ng/g in the BS and 58.2 ng/g to 289 ng/g in the GoA for congener 118, 18.6 ng/g to 199 ng/g in the BS and 33.8 ng/g to 346 ng/g in the GoA for congener 138, 14.9 ng/g to 146 ng/g in the BS and 33.5 ng/g to 184, ng/g, in the GoA for congener 99, and <0.100 ng/g to 199 ng/g, in the BS and 9.16 ng/g to 183 ng/g in the GoA for congener 151 (Figure 5). On average, oxychlordane comprised 69.6 % of all chlordane compounds, ranging from 37.5 ng/g to 197 ng/g in the BS and 20.7 ng/g to 141 ng/g in the GoA.

Data Analysis

Due to significant differences in lipid concentrations of the eggs at two colonies (Table 1; Appendix B), statistical analyses were conducted on lipid corrected wet mass concentrations. To meet the assumptions of the parametric tests, all data were log + 1 transformed because several values were close to zero. To reduce type I errors, multivariate analyses of variances tests (MANOVAs; Profile type, Wilks' λ) were run on common murre eggs (including the samples from Little Diomede Island) to test for geographical differences among colonies. These tests were also run on the samples from Bogoslof and St. George islands to test for differences between species (two-factor MANOVA).

Analysis of variances (ANOVAs) with Tukey-Kramer HSD for geographical differences and two-factor ANOVAs for species differences were conducted post-hoc on individual POP compounds to determine which ones contributed to the significant MANOVAs. Only compounds that had less than half of the values below the detectable limit (<0.100 ng/g) were analyzed for geographic differences. Values below the detectable limit were assigned half the detection value (0.0500 ng/g). For the species comparison, only compounds with no values below detectable limit were used because of degree of freedom problems caused by small sample sizes. All statistical tests were conducted using JMP (SAS Institute, Cary, NC) software and plotted using SigmaPlot (SPSS Inc., Chicago, IL) software.

Principal components analyses (PCAs) were performed as described by Zitko (1989) and Kucklick *et al*. (1997) to help visualize the degree of geographical and species differences in three-dimensions. PCAs were conducted on the fractions of total PCBs and organochlorine pesticides for each egg based on lipid corrected wet mass concentrations. Compounds with values below the detectable limit were removed from the PCAs. The eigenvectors for each compound from the first three principal components were multiplied by the fraction of the total for that compound. The results from each egg sample were summed and the principal components were plotted.

Two-tailed t-tests were used to compare temporal changes between current concentrations of individual POPs in common murre eggs from Bogoslof and St. George islands with concentrations reported in the 1970s.

Geographic Comparisons

There were significant differences in chlorinated hydrocarbon concentrations observed among colonies (Wilks' $\lambda = 0.0157$, $F_{28,142} = 11.0$, $p < 0.0001$; Table 1). Except for HCB and β-HCH, contaminant concentrations tended to be significantly higher in eggs from St. Lazaria Island (Figure 4; Table 1). In addition, the pattern of contaminants varied among colonies as visualized by PCA. For the PCA of geographic differences in chlorinated hydrocarbon patterns among common murre egg colonies (including Little Diomede Island, Figures 6a and 6b), the first three principal components (PCs) accounted for 70 % of the total variation. Samples with high concentrations of HCB, 4,4'-DDE, and dieldrin had low loadings on PCs 1 to 3, respectively, while high concentrations of PCB congeners 170 and 180, congeners 99 and 188, and congeners 105 and 118 caused high loadings on PCs 1 to 3, respectively (Figure 6b). PC 1 appears to be related to vapor pressure. The PCA plot clearly shows the separation of the GoA colonies (upper right group consisting of East Amatuli and St. Lazaria islands) from the BS colonies (lower left group consisting Little Diomede and St. George islands), with Bogoslof Island (upright triangles) intermediate between the two areas (Figure 6a). The higher chlorinated hydrocarbon concentrations in the eggs from GoA colonies are similar to the pattern observed a quarter of a century ago in (Ohlendorf *et al.*, 1982).

The geographic difference in chlorinated hydrocarbon levels between the GoA and the BS colonies may be due to different foraging locations and concentration differences in the food webs. In addition, regionally specific differences in atmospheric and oceanic transport patterns, POPs source locations, and the role of over wintering areas for the individual colonies should also be considered.

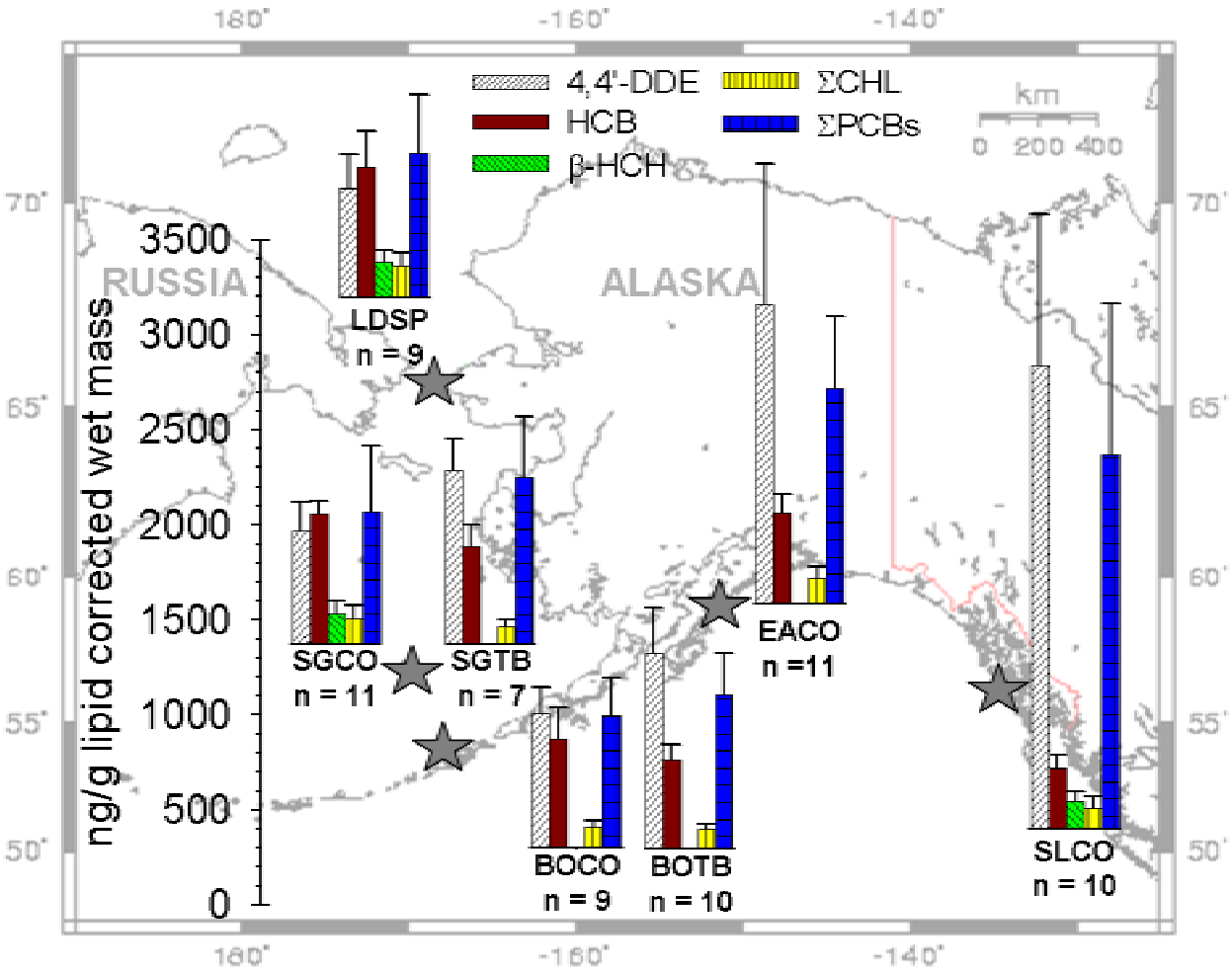

Figure 4. Concentrations (mean bars with 1 standard deviation error lines) of major persistent organic pollutants in eggs collected at murre (*Uria* spp.) colonies in 1999 and 2000. BO = Bogoslof Island, EA = East Amatuli Island, LD = Little Diomede Island, SG = St. George Island, and SL = St. Lazaria Island. CO = common murre eggs, TB = thick-billed murre eggs, and SP = murre species eggs.

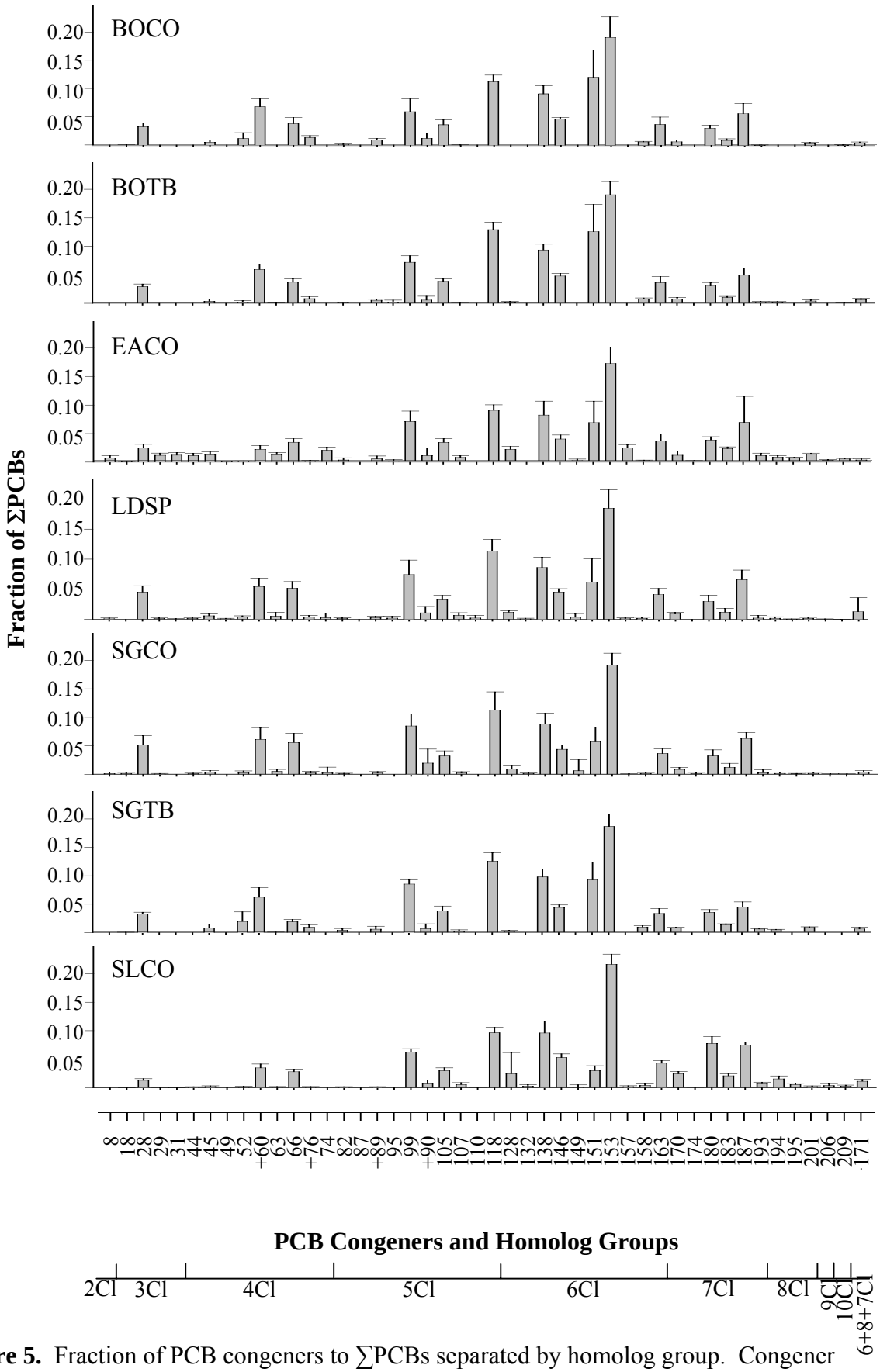

Figure 5. Fraction of PCB congeners to ∑PCBs separated by homolog group. Congener numbers based on IUPAC system. Abbreviations are the same as in Figure 4.

Table 1. Persistent organic pollutants in Alaska murre eggs. Values are means ± 1 SD in ng/g lipid corrected wet mass. ANOVAs with Tukey-Kramer HSD post-hoc tests were conducted to determine geographical differences. Colonies that do not share a common letter were significantly different ($p < 0.05$). Post-hoc 2-factor ANOVAs were conducted to compare species differences. Statistical tests were conducted on log + 1 transformed values to meet parametric assumptions. Abbreviations are the same as in Figure 4.

Compound	Lipid corrected wet mass means ± SD (ng/g)							Geographic	Species
	LDSP	SGCO	BOCO	EACO	SLCO	SGTB	BOTB	$F_{4,45}$	$F_{3,33}$
% lipid[1]	12.8 ± 2.3 ^{A}	12.3 ± 1.6 ^{A}	10.9 ± 1.5 ^{AB}	8.97 ± 1.4 ^{B}	12.3 ± 0.87 ^{A}	10.5 ± 1.4	11.0 ± 1.4	10.6 *	2.73
4,4'-DDE	572 ± 180 ^{C}	594 ± 150 ^{C}	712 ± 140 ^{C}	1570 ± 740 ^{B}	2440 ± 800 ^{A}	914 ± 170	1030 ± 240	38.0 *	13.1 *
dieldrin	40.2 ± 17 ^{A}	32.6 ± 26 ^{A}	21.5 ± 6.0 ^{A}	21.6 ± 12 ^{A}	35.7 ± 31 ^{A}	23.3 ± 18	38.3 ± 27	21.9 *2	
HCB	685 ± 190 ^{A}	679 ± 68 ^{A}	576 ± 170 ^{AB}	478 ± 98 ^{B}	316 ± 72 ^{C}	510 ± 120	466 ± 84	20.7 *	6.80 *
α-HCH	10.0 ± 5.5 ^{B}	11.0 ± 4.5 ^{B}	22.3 ± 7.2 ^{A}	16.2 ± 7.5 ^{AB}	9.51 ± 4.0 ^{B}	17.4 ± 9.1	17.3 ± 4.0	6.71 *	3.95 *
β-HCH[1]	183 ± 63	161 ± 64			143 ± 50			0.885	
γ-HCH	3.74 ± 3.1 ^{AB}	3.10 ± 2.5 ^{AB}	6.27 ± 1.3 ^{A}	15.9 ± 2.5 ^{B}	3.00 ± 1.3 ^{B}	5.9 ± 1.7	6.0 ± 1.6	19.7 *2	
mirex	22.6 ± 14 ^{A}	14.5 ± 6.0 ^{A}	6.30 ± 3.4 ^{B}	20.6 ± 11 ^{A}	25.2 ± 14 ^{A}	6.3 ± 2.9	8.5 ± 5.1	21.6 *2	
ΣCHL	165 ± 67	133 ± 66	113 ± 30	132 ± 64	106 ± 65	93.7 ± 36	102 ± 28	1.97	1.56
ΣPCBs	758 ± 310 ^{BC}	695 ± 340 ^{C}	699 ± 200 ^{BC}	1130 ± 380 ^{B}	1970 ± 800 ^{A}	876 ± 320	811 ± 220	12.3 *	1.26
DDE/PCB[1]	0.783 ± 0.14 ^{B}	0.937 ± 0.25 ^{B}	1.08 ± 0.34 ^{AB}	1.38 ± 0.42 ^{A}	1.33 ± 0.30 ^{A}	1.11 ± 0.26	1.30 ± 0.20	8.35 *	3.77 *
β-HCH/ΣHCH[1]	0.928 ± .053	0.910 ± 0.068			0.919 ± 0.049			0.743	

[1] Compound not included in MANOVAs

[2] Welch ANOVA used due to unequal variances.

* $p > 0.05$

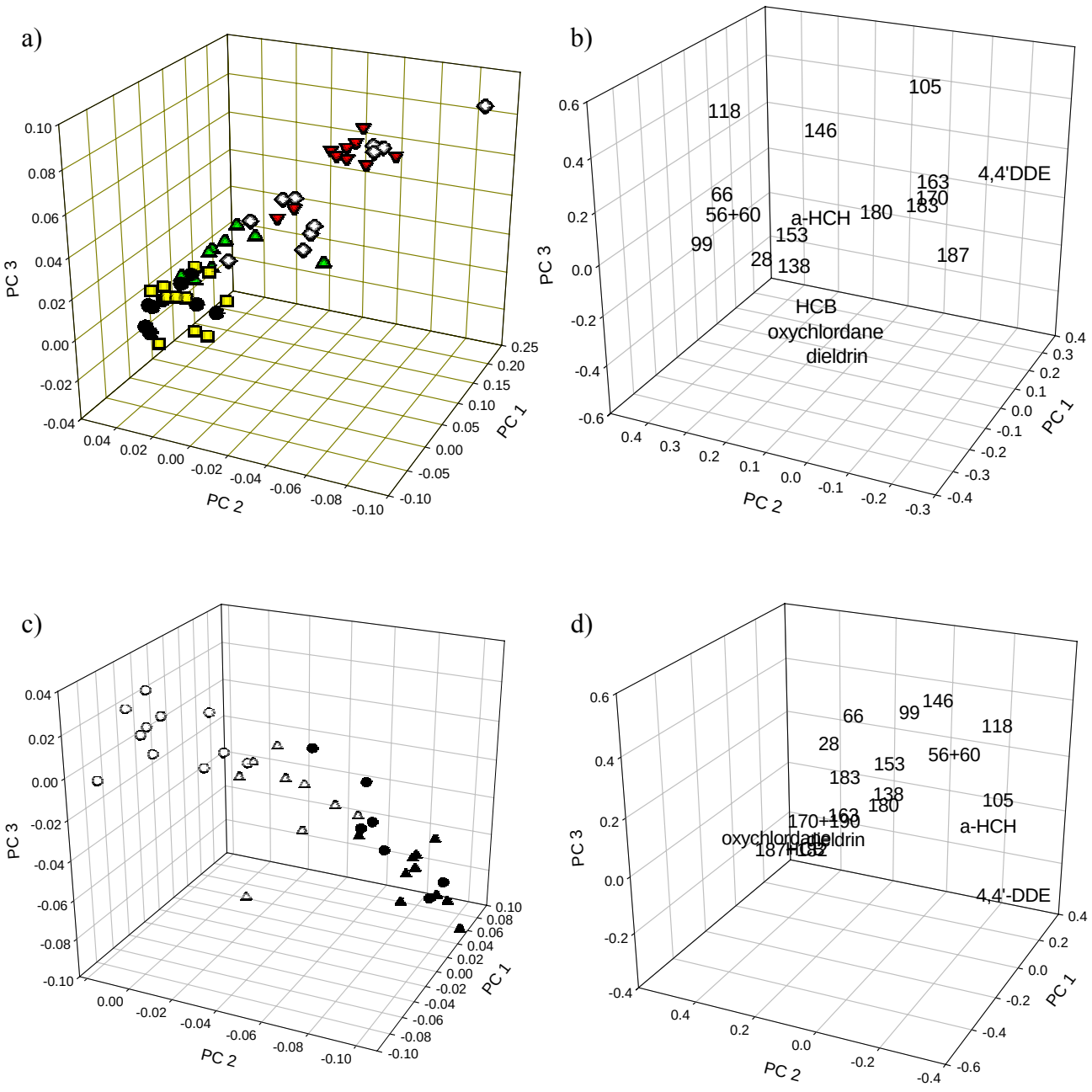

Figure 6. (a) Principle components analysis (PCA) showing geographical separation of Alaskan common murre (*Uria aalge*) eggs. Circles = Little Diomede Island (*U.* spp.), squares = St. George Island, triangles = Bogoslof Island, diamonds = East Amatuli Island, and upside-down triangles = St. Lazaria Island. (b) Geographical component loadings where numbers are PCB congeners based on IUPAC system. (c) PCA showing species separation of common murre (*U. aalge*, white) and thick-billed murre (*U. lomvia*, black) eggs from Bogoslof Island (triangles) St. George Island (circles). (d) Species component loadings where numbers are PCB congeners based on IUPAC system.

Species Comparisons

Significant differences in chlorinated hydrocarbon concentrations were observed between the two closely related murre species (Wilks' $\lambda = 0.0853$, approximate $F_{12,80} = 10.2$, $p = <0.0001$; Table 1). While it is difficult to see differences between species based on the concentrations (Figure 4, Table 1), the pattern of contaminants visualized by PCA shows much clearer separation (Figure 6c and 6d), with the first three PCs accounting for 71 % of the total variation. Samples with high concentrations of HCB loaded low on PC1 and high concentrations of 4,4'-DDE resulted in low loadings on PCs 2 and 3, while high concentrations of PCB congeners 180 and 138, 187+182 and 170+190, and 66 and 28 resulted in high loadings and PCs 1 to 3, respectively (Figure 6d). While the PCA was conducted between common and thick-billed murre eggs, the colony locations are included in the plot of the PCA for ease of interpretation (Figure 6c). There was some separation of the common and thick-billed murre eggs when combining data from both colony locations and both species. However, species separation became more evident when examining colonies from Bogoslof and St. George islands individually as there was some separation between colonies within the species groupings (Figure 6c).

The separation observed in chlorinated hydrocarbon levels between common and thick-billed murre eggs may be due to species differences in foraging diving depth, type of prey, foraging areas, and/or over-wintering locations. Although common and thick-billed murres are both pursuit diving piscivores, there can be diet differences as reported for murres in the Bering Sea in the early 1980's (Springer *et al.,* 1986). Both common and thick-billed murres feed on sand lance, capelin, and cod. However, thick-billed murres tend to feed farther from shore at greater depths (> 61 m; Cramp, 1985) compared to common murres (>45 m; Cramp, 1985) and often prey on benthic species, such as Stichaeidae pricklebacks, Cottidae sculpins, and pandalid and crangonid shrimp, while common murres tend to feed closer to shore at shallower depths on mid-water fishes (e.g., Springer *et al.*, 1984; Springer *et al.*, 1986; Springer *et al.*, 1987; Ehrlich *et al.,* 1988; Kaufman, 1996; Barrett *et al.,* 1997). More hydrophobic compounds, such as DDT, tend to sorb to particles that sink and accumulate in sediments and benthic food webs (Bard, 1999) possibly explaining the higher concentrations of these POPs in eggs of the deeper diving thick-billed murre eggs. The different food preferences and diving depths combined result in resource partitioning by the two species and may help explain the separation in chlorinated hydrocarbon levels in the eggs.

An additional factor that may be contributing to the differences observed in chlorinated hydrocarbon levels is over-wintering locations. However, since murres move into the breeding grounds several weeks prior to laying eggs (Ehrlich *et al.,* 1988; Gaston and Hipfner, 2000) and yolks are formed in 8-12 days (Roudybush *et al.,* 1979) eggs should be indicative of contaminant concentrations at the breeding location, but the female may offload to the egg some residual contaminants obtained while at the wintering location. More data is needed for murres to determine the energetics of egg production.

Temporal Comparisons

Common murre colonies on St. George and Bogoslof islands were also included in a survey of contaminants in seabird eggs collected from 1973 to 1976 (Ohlendorf *et al.,* 1982). Not all compounds we analyzed for were included in this earlier study. Also, the method for analyzing PCBs during the 1970s (packed column GC, Aroclor method) is such that direct comparisons of our PCB values with this older data is not recommended (Eganhouse and Gossett, 1991; Turle *et al.,* 1991). However, for other analytes that are common between the two datasets, comparisons can be made.

At Bogoslof Island, Ohlendorf *et al.* (1982) determined 4,4'-DDE, *cis*-nonachlor, dieldrin, HCB, heptachlor epoxide, and oxychlordane concentrations in common murre eggs. All concentrations are reported as mean ± 1 SD on a wet mass basis. While concentrations of dieldrin were lower in the current study and thus did appear to be declining (34 ng/g ± 49 ng/g to 2.28 ng/g ± 0.50 ng/g), only c*is*-nonachlor (8 ng/g ± 10 ng/g to 0.773 ng/g ± 0.43 ng/g) and 4,4'-DDE (119 ng/g ± 15 ng/g to 77.0 ng/g ± 18 ng/g) were significantly ($p < 0.05$) lower in the current dataset (Table 2). At St. George Island, the same compounds, except for *cis*-nonachlor were analyzed by Ohlendorf *et al.* (1982). The lower values of the current study suggest a significant decline for 4,4'-DDE (273 ng/g ± 270 ng/g to 73.5 ng/g ± 22 ng/g) and heptachlor epoxide (12 ng/g ± 5.1 ng/g to 2.89 ng/g ± 1.3 ng/g) concentrations (Table 2). The lower concentrations observed in common murre eggs from both Bogoslof and St. George islands compared to values reported for the same locations by Ohlendorf *et al.* (1982) mirrors the declining trend of ΣDDT from the early 1970's to late1980's reported for common murre eggs in the Baltic (Bignert *et al.,* 1995) and for thick-billed murre eggs from Prince Leopold Island in the eastern Canadian high Arctic (Braune *et al.,* 2001).

Table 2. Temporal comparisons of persistent organic pollutants in Alaska murre eggs: results (ng/g wet mass) from the study by Ohlendorf *et al.* (1982) compared to results from current study. Results in bold were significant ($p < 0.05$). Abbreviations are the same as in Figure 4.

	Ohlendorf *et al.*(1982)		**This Study**		**BOCO**		**SGCO**	
	BOCO	**SGCO**	**BOCO**	**SGCO**				
Collection Date	**1973-1976**	**1973-1976**	**2000**	**1999**				
Number of Eggs	**7**	**11**	**9**	**11**				
Compound	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**t_{14}**	**p**	**t_{20}**	**p**
4,4'- DDE	119 ± 15	273 ± 270	77.0 ± 18	73.5 ± 22	**4.90**	**0.0002**	**2.45**	**0.0240**
HCB	66 ± 43	79 ± 32	62.2 ± 20	83.7 ± 16	0.234	0.819	0.433	0.670
***cis*-nonachlor**	8 ± 10		0.773 ± 0.43		**2.21**	**0.0459**		
dieldrin	34 ± 49	9 ± 12	2.28 ± 0.50	4.16 ± 3.5	1.99	0.0677	1.28	0.214
heptachlor epoxide	4 ± 4.1	12 ± 5.1	1.63 ± 1.2	2.89 ± 1.3	1.67	0.124	**5.75**	**<0.001**
oxychlordane	5 ± 3.7	18 ± 10	7.74 ± 2.3	9.70 ± 2.5	1.77	0.100	1.95	0.0649

The concentration of HCB appears to have remained fairly constant (means ranged from 62.2 ng/g to 83.7 ng/g) for the past quarter century in common murre eggs at both Bogoslof and St. George islands (Table 2). This is likely due to continued HCB production as a by-product in the production of several industrial chemicals and waste incineration (ATSDR, 1996). While declining, the estimated global production of HCB from developed countries in the mid-1990's was still 23,000 kg/yr (Bailey, 2001). Oxychlordane was not significantly different at either colony, but only at St. George Island did it appear to have declining concentrations (18 ng/g ± 10 ng/g to 9.70 ng/g ± 2.5 ng/g; Table 2). Since chlordane compounds were banned for use in the U.S. in only 1988 (ATSDR, 1994), more time may be needed to observe a decrease in oxychlordane. All uses of aldrin and its breakdown product, dieldrin, were banned in the U.S. in 1987 (ATSDR, 1993a) and since levels of dieldrin have declined (Table 2), but not significantly, these compounds may slowly be degrading from the environment as may heptachlor epoxide, the metabolite of heptachlor that was banned in the U.S. in 1988 (ATSDR, 1993b). A decline in heptachlor epoxide was observed at both colonies (Table 2), but this decline was only statistically significant at St. George Island. There was a significant decline of *cis*-nonachlor at Bogoslof Island (Table 2), but this compound was not reported by Ohlendorf *et al*. (1982) for St. George Island.

Literature Comparisons

Due to changes in methods, it is very difficult to make direct comparisons with literature values for contaminants in murre eggs. This is especially true for PCBs, as many of the early values were obtained using Aroclor standards and now most values are based on the sum of PCB congeners. Turle *et al*. (1991) reported concentrations of Arclor 1254/1260 (1:1) were slightly more than twice the concentration of the sum of 41 PCB congeners in herring gull (*Larus aegentatus*) eggs. The sum of PCB congeners causes its own problems for comparison as different PCB congeners and different numbers of congeners are used to obtain the sum. However, several general observations for many contaminants can be made by comparing our data with literature values (Table 3). All values are reported on a wet mass basis. Concentrations of contaminants were generally higher in eggs from Scandinavia than those from eastern Canada and Alaska. For example, DDE means ranged from 510 ng/g to 1070 ng/g in common murre eggs collected from Norway in 1972 versus 119 ng/g to 273 ng/g in Alaskan common murre eggs collected from 1973-1976. ΣCHL concentrations in the Alaska murre eggs from the current study (means ranged from 9.55 ng/g to 19.6 ng/g) were generally lower than values from Canada or Norway in 1992 to 1998 (means ranged from 21 ng/g to 63 ng/g; Table 3). Similar results were found for ΣPCBs in polar bears and ringed seals where lower levels were found in Alaska and highest levels were found in Scandinavia (Muir and Norstrom, 2000). The percent lipid in murre eggs generally appeared to be consistent among studies at approximately 12 %, although the common murre eggs from East Amatuli Island in our study may be below average (8.97 % ± 1.4 %; Table 3). Thick-billed murre eggs in our study had concentrations of DDE (means were 94.6 ng/g and 115 ng/g) and HCB (means were 51.7 ng/g and 52.5 ng/g) that were similar to the 1998 northeastern Canadian thick-billed murre eggs (means ranged from 100 ng/g to 141 ng/g and 53 ng/g to 54 ng/g for DDE and HCB, respectively; Table 3). Values of ΣHCHs in eggs from the current study where β-HCH was measurable were similar to concentrations reported in Canadian murre eggs collected in 1993 and 1998 (means ranged from 19.1 ng/g to 25.0 ng/g versus 10 to 23 ng/g, respectively; Table 3).

Table 3. Literature values for POPs concentrations in murre (*Uria* spp.) eggs compared to current study. Methods to analyze PCBs were either not stated in the methods (NS), based on Aroclor standards 1254 or 1:1 1254/1260 (A), or reported as sum of PCB congeners (∑ followed by number of congeners used). All values are in ng/g wet mass. References: 1. Newton *et al.,* 1981, 2. Fimreite *et al.,* 1977, 3. Bignert *et al.,* 1995, 4. Barrett *et al.,* 1985, 5. Gabrielsen *et al.*, 1995, 6. Barrett *et al.,* 1996, 7. Pearce *et al.,* 1979, 8. Nettleship and Peakall, 1987, 9. Noble and Elliot, 1986, 10. Braune *et al.,* 2001, 11. Braune *et al.,* 2002, 12. Ohlendorf *et al.,* 1982.

Date Collected	Species	Location	% fat Mean	% fat SD	DDE Mean	DDE SD	PCB Mean	PCB SD	PCB Method	HCB Mean	HCB SD	ΣCHL Mean	ΣCHL SD	ΣHCH Mean	ΣHCH SD	N	Ref.
		Western Europe															
1969-1972	*U. aalge*	Skomer (SW Wales)			1570	170[1]	8500	1240[1]	NS							10	1
1969-1972	*U. aalge*	Scare Rocks (SW Scotland)			1710	215[1]	12520	2210[1]	NS							10	1
1969-1972	*U. aalge*	St. Kilda (NW Scotland)			600	50[1]	490	335[1]	NS							10	1
May 1972	*U. aalge*	71°05'N-Hjelmsoy, Norway	13[2]	8.5-25[3]	740	180	2010	760	NS							11	2
May 1972	*U. aalge*	70°20'N-Hornoy, Norway	13[2]	8.5-25[3]	1070	480	3230	1500	NS							10	2
May 1972	*U. aalge*	67°30'N- Rost, Norway	13[2]	8.5-25[3]	890	420	2080	1190	NS							10	2
May 1972	*U. aalge*	62°25'N-Runde, Norway	13[2]	8.5-25[3]	510	160	1450	510	NS							10	2
1974-76&79	*U. aalge*	Stora Karlso, Central Baltic	12.1	0.56	290	86	230	56	NS							20	3
1980	*U. aalge*	Skomer (SW Wales)			1010	225[1]	2350	1770[1]	NS							10	1
1980	*U. aalge*	Scare Rocks (SW Scotland)			1230	80[1]	5450	820[1]	NS							10	1
1980	*U. aalge*	St. Kilda (NW Scotland)			990	205[1]	1520	460[1]	NS							10	1
1983	*U. aalge*	E. Finnmark (Norway)	11	1	940	230	640	180	A	170	40			13[4]	2	10	4
1983	*U. aalge*	W. Finnmark (Norway)	12.2	3.6	690	240	700	290	A	130	40			7[4]	2	9	4
1983	*U. aalge*	S. Troms/N. Nordland (Norway)	10.5	1.4	490	90	360	120	A	90	10			6[4]	2	7	4
1983	*U. aalge*	Lofoten (Norway)	11.1	2.1	330	70	790	340	A	130	40			5[4]	6	8	4
1990	*U.* spp.	Bear I., Svalbard	14.30	2.69	229	54	465	210	Σ 21	83	21	23[5]	15	2	2	13	5
1992-1993	*U. aalge*	E. Finnmark (Norway)	11.77	1.28	250	30	480	60	Σ 21	90	10	40	10	2.27[4]	0.59	5	6
1992-1993	*U. lomvia*	E. Finnmark (Norway)	11.26	0.76	340	50	530	140	Σ 21	110	10	50	10	3.59[4]	1.03	5	6
1992-1993	*U. aalge*	Kola Pen. (Norway)	11.73	1.59	310	190	980	280	Σ 21	100	20	40	10	2.88[4]	1.29	5	6
1992-1993	*U. lomvia*	Kola Pen. (Norway)	11.39	1.24	290	40	920	80	Σ 21	100	10	40	0	4.11[4]	2.02	5	6
1992-1993	*U. lomvia*	Svalbard (Norway)	12.36	0.41	400	170	500	70	Σ 21	70	20	40	20	5.82[4]	2.14	5	6
		Eastern Canada															
1971	*U. aalge*	50°10'-60°N-Ile Ste-Marie, Quebec	17		2030		2210		A							4	7
1975	*U. lomvia*	Prince Leopold I.	12.6		310		720		A							12	8
1975	*U. lomvia*	Prince Leopold I.	12.6	0.65	297	152	708	267	A	97	39	18.4[5]	6.4	3.5[4]	9.7	12	9
1976	*U. lomvia*	Prince Leopold I.	12.4	1.2[1]	232[6]	28[1]	360	59[1]	Σ 67	142[7]	18[1]	36	3[1]	12	1[1]	3 pools of 3	10
1976	*U. lomvia*	Prince Leopold I.	14.3		440		1010		A							10 (pooled)	8
1976	*U. lomvia*	Prince Leopold I.	14.3		340		230		A	127		30[5]		10[4]		1	9
1977	*U. lomvia*	Prince Leopold I.	11.7	0.4[1]	232[6]	22[1]	346	45[1]	Σ 67	117[7]	21[1]	26	8[1]	11	2[1]	3 pools of 3	10
1977	*U. lomvia*	Prince Leopold I.	12.6		390		910		A							10	8

[1] SE [2] Mean for group [3] Range [4] β-HCH [5] Oxychlordane [6] ΣDDT [7] ΣChlorobenzenes

Table 3 (Cont.). Literature values for POPs concentrations in murre eggs compared to current study. Methods to analyze PCBs were either not stated in the methods (NS), based on Aroclor standards 1254 or 1:1 1254/1260 (A), or reported as sum of PCB congeners (∑ followed by number of congeners used). All values are in ng/g wet mass. References: 1. Newton *et al.,* 1981, 2. Fimreite *et al.,* 1977, 3. Bignert *et al.,* 1995, 4. Barrett *et al.,* 1985, 5. Gabrielsen *et al.*, 1995, 6. Barrett *et al.,* 1996, 7. Pearce *et al.,* 1979, 8. Nettleship and Peakall, 1987, 9. Noble and Elliot, 1986, 10. Braune *et al.,* 2001, 11. Braune *et al.,* 2002, 12. Ohlendorf *et al.,* 1982.

Date Collected	Species	Location	% fat		DDE		PCB		PCB Method	HCB		ΣCHL		ΣHCH		N	Ref.
			Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	Mean	SD		
		Eastern Canada (Cont.)															
1977	*U. lomvia*	Prince Leopold I.	12.64	1.43	377	152	854	434	A	109	35	24[5]	8.1	11[4]	3.2	10	9
1987	*U. lomvia*	Prince Leopold I.	11.4	0.9[1]	156[6]	19[1]	210	25[1]	Σ 67	85[7]	10[1]	33	2[1]	19	2[1]	3 pools of 3	10
1988	*U. lomvia*	Prince Leopold I.	10.8	0.5[1]	104[6]	16[1]	167	27[1]	Σ 67	85[7]	2[1]	33	3[1]	13	1[1]	3 pools of 3	10
1993	*U. lomvia*	Prince Leopold I.	11.4	0.4[1]	139[6]	21[1]	149	20[1]	Σ 67	54[7]	6[1]	24	3[1]	20	2[1]	5 pools of 3	10
1993	*U. lomvia*	Prince Leopold I.	13.5	0.5[1]	134[6]	14[1]	155	8[1]	Σ 42	49[7]	8[1]	21	2[1]	22	2[1]	5 pools of 3	10
1993	*U. lomvia*	Coburg I.	12.2	0.2[1]	309[6]	37[1]	420	18[1]	Σ 42	78[7]	8[1]	39	1[1]	18	1[1]	5 pools of 3	11
1993	*U. lomvia*	Digges I.	12.5	0.1[1]	311[6]	29[1]	434	38[1]	Σ 42	129[7]	7[1]	63	6[1]	18	2[1]	5 pools of 3	11
1993	*U. lomvia*	Coats I.	14.5	0.3[1]	326[6]	35[1]	360	39[1]	Σ 42	124[7]	9[1]	58	4[1]	23	1[1]	5 pools of 3	11
1998	*U. lomvia*	Coats I.	12.4	0.2[1]	141[6]	8[1]	172	11[1]	Σ 42	54[7]	5[1]	24	2[1]	10	1[1]	5 pools of 3	11
1998	*U. lomvia*	Prince Leopold I.	12.9	0.4[1]	100[6]	8[1]	129	8[1]	Σ 42	53[7]	3[1]	29	4[1]	17	1[1]	5 pools of 3	11
1998	*U. lomvia*	Prince Leopold I.	12.9	0.4[1]	100[6]	7[1]	130	9[1]	Σ 67	53[7]	2[1]	30	4[1]	17	1[1]	5 pools of 3	10
		Alaska															
1973	*U. aalge*	Bogoslof I. (Aleutian Islands)	9.31[2]	0.17	119	15	126	46	A	66	40	5[5]	4			7	12
1974&1976	*U. lomvia*	Ugaiushak I. (Gulf of Alaska)	9.08[2]	0.22	147	41	259	301	A			19[5]	18			6	12
1974	*U. aalge*	Ugaiushak I. (Gulf of Alaska)	9.31[2]	0.17	202	213	168	300	A	27	15	8[5]	7			7	12
1975	*U. aalge*	St. George I. (Bering Sea)	9.31[2]	0.17	273	266	270	85	A	79	32	18[5]	10			11	12
1975	*U. aalge*	St. Paul I. (Bering Sea)	9.31[2]	0.17	135	56	205	73	A	80	29	26[5]	11			10	12
1976	*U. aalge*	Middleton I. (Gulf of Alaska)	9.31[2]	0.17	649	518	1050	1371	A			42[5]	15			10	12
1976	*U. aalge*	Bluff (Seward Peninsula)	9.31[2]	0.17	141	63	182	77	A	111	49	23[5]	16			10	12
1976	*U. lomvia*	King I. (Bering Sea)	9.08[2]	0.22	166	74	307	124	A	98	54	21[5]	8			10	12
1999	*U. aalge*	St. Lazaria I. (Gulf of Alaska)	12.3	0.87	298	91	241	99	Σ 46	38.7	7.8	11.5	9.8	19.1	6.8	10	This study
1999	*U. aalge*	East Amatuli I. (Gulf of Alaska)	8.97	1.4	142	79	99.1	31	Σ 46	42.2	9.5	11.7	6.1	1.79	0.88	11	This study
1999	*U. aalge*	St. George I. (Bering Sea)	12.3	1.6	73.5	22	86.4	45	Σ 46	83.7	16	15.0	7.6	21.5	8.2	11	This study
1999	*U.* spp.	Little Diomede I. (Bering Sea)	12.8	2.3	70.3	12	92.8	25	Σ 46	85.5	19	19.6	5.6	25.0	9.3	9	This study
2000	*U. aalge*	Bogoslof I. (Aleutian Islands)	10.9	1.5	77.0	18	76.2	25	Σ 46	62.2	20	12.0	2.9	3.09	1.0	9	This study
2000	*U. lomvia*	Bogoslof I. (Aleutian Islands)	11.0	1.4	115	33	90.6	29	Σ 46	51.7	12	11.3	3.4	2.55	0.54	10	This study
2000	*U. lomvia*	St. George I. (Bering Sea)	10.5	1.4	94.6	14	88.8	22	Σ 46	52.5	10	9.55	2.5	2.31	1.1	7	This study

[1] SE [2] Mean for group [3] Range [4] β-HCH [5] Oxychlordane [6] ΣDDT [7] ΣChlorobenzenes

Human Health and Ecological Implications

Overall, the levels of POPs in the Alaskan murre eggs were relatively low. Many studies have documented the declines in eggshell thickness in birds exposed to DDE (e.g., Hickey and Anderson, 1968). Pyle *et al.* (1999) found that oxychlordane, but not DDE, was significantly correlated with eggshell thinning in common murre eggs at concentrations between 6-12 ng/g. Although concentrations of oxychlordane in murre eggs collected during this study were similar to these levels, neither oxychlordane nor DDE concentrations were correlated with shell thickness (R^2 = -0.11, p = 0.373 and R^2 = -0.13, p = 0.304, respectively). In addition, the concentrations of POPs found in murre eggs in this study are lower than concentrations found to affect birds (U.S. Department of the Interior, 1975; Gilman *et al.,* 1978; U.S. Department of the Interior, 1984; Barron *et al.,* 1995; Sanderson and Bellward, 1995; Fox *et al.*, 1998).

The risks to human health from consumption of murre eggs appear to be lower than marine mammals with respect to contaminant levels. Based on the Health Canada acceptable or tolerable daily intake (ADI/TDI) levels (Van Oostdam *et al.,* 1999), a 50-kg person could consume more than one murre egg per day from any colony without exceeding the recommendation for any compound (Table 4). The mass range of murre eggs are almost twice the average mass range of USDA classified "large" chicken eggs (Agriculture Marketing Service, 1995). For many POPs, a large mass (> 90 g based on mean egg content mass and lowest number of eggs safely consumed) of murre eggs must be consumed daily to exceed the ADI/TDI. These calculations consider murre eggs as the only source of POPs in the daily diet of a 50-kg person. If that person were also ingesting other sources of contaminants, such as marine mammal fat, which has much higher levels of many POPs, then the additional POPs consumed in murre eggs may cause concern for some pollutants such as chlordanes and HCB.

Table 4. Canadian acceptable or tolerable daily intakes (ADI/TDI) for several contaminants (Van Oostdam *et al.,* 1999). The ADI/TDIs have been extrapolated to determine the maximum number of murre eggs a 50-kg person could consume based on the mean concentration of contaminants from the colonies in this study and not exceed the ADI/TDI. Abbreviations are the same as in Figure 4.

Contaminant	Canada ADI/TDI (ng*kg body wt^{-1}*day^{-1})	max # eggs a 50-kg person can consume under Canada ADI/TDI						
		LDSP	SLCO	SGCO	EACO	SGTB	BOTB	BOCO
ΣDDT	20,000	144	38	135	76	116	96	148
ΣPCBs	1000	5	2	6	5	6	6	7
ΣHCH	300	6	9	7	63	71	67	57
ΣCHL	50	1	2	2	2	3	2	2
ΣHeptachlor	100	11	21	19	25	46	14	36
HCB	270	1	4	1	3	2	3	2
Aldrin/dieldrin	100	10	13	13	29	24	12	26
Mirex	70	14	13	21	21	63	41	62
Mercury	714	7	2	15	2			

MERCURY

Isotope Dilution Method

Isotope dilution techniques such as ID-CV-ICPMS for Hg determinations are often used at NIST for high-accuracy measurements needed for the certification of analytes in NIST Standard Reference Materials. Analytical uncertainties are robustly determined and the precision of the technique allows heterogeneity of reference material batches to be assessed. However, many laboratories view isotope dilution methods unsuited for routine environmental measurements that typically feature large sample numbers and wide-ranging differences in analyte concentration. For example, the natural variation of Hg mass fraction in the 41 common murre eggs studied here ranges from approximately 0.010 μg/g to 0.360 μg/g, making it challenging to design an optimal ID experiment for each "unique" sample. A discussion follows that considers the use of ID-CV-ICPMS under such conditions.

Error Magnification and ICPMS Isotope Ratio Measurements

The ID-CV-ICPMS experiments involve measuring $^{201}Hg/^{202}Hg$ isotopic ratios of spiked samples. The uncertainty in ratio measurement is propagated non-linearly in the calculated concentration; the sensitivity factor is called the "error magnification factor." Ideally, a sample should be spiked with the amount of ^{201}Hg that minimizes the error magnifaction factor. For the ^{201}Hg spike used here, the error magnification factor is plotted against isotope dilution $^{201}Hg/^{202}Hg$ ratios in Fig. 7. The error magnification blows up if the sample is either "underspiked" or "overspiked" (Fassett and Paulsen, 1989). The effective dynamic range for spiking and ratio measurement (where the error magnification factor is between 1.2 and 2) extends over roughly a range from 0.8 to 50. Practically, there are other considerations that favor ratio measurements of 1.00. Figure 8 shows the measured $^{201}Hg/^{202}Hg$ ratios collected for all batches of unknown, blank and control samples in the form of a radar plot. The experiment was designed so that most of the samples were spiked at a $^{201}Hg/^{202}Hg$ ratio between 1.5 and 10, coinciding with the lowest part of the error magnification curve in Fig. 7. Allowing for some variability in the measured ratios greatly improves the ability to automate the spiking process, using the same quantity of spike aliquot for each sample, with the exception of the blank, where the size of the aliquot is reduced to minimize the error magnification factor. Nonetheless, the blank samples remain overspiked indicating that there is only a small amount of contamination introduced from the analytical method. Blank corrections are on the order of approximately 1 % to 4 % for most of the egg samples, with a typical blank having an absolute value of approximately 0.3 ng. For some of the lowest Hg content eggs collected from Little Diomede and Saint George Islands, the typical uncertainty of the blank correction (approximately 0.17 ng/g) is on par with the uncertainty obtained from the ratio measurement, whereas for the higher Hg content eggs, the uncertainty due to the blank correction is nearly an order of magnitude lower than the ratio measurement uncertainty.

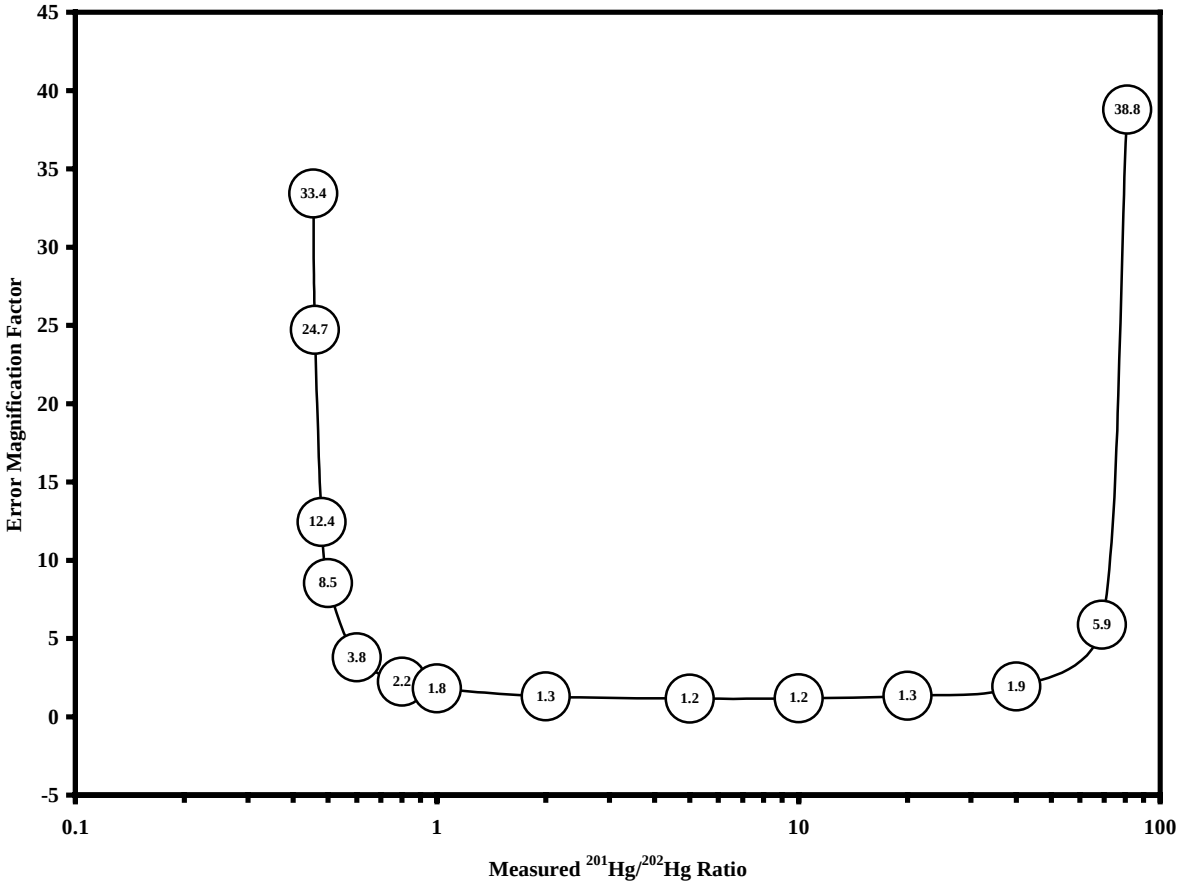

Figure 7. Error magnification factor as a function of measured $^{201}Hg/^{202}Hg$ ratio.

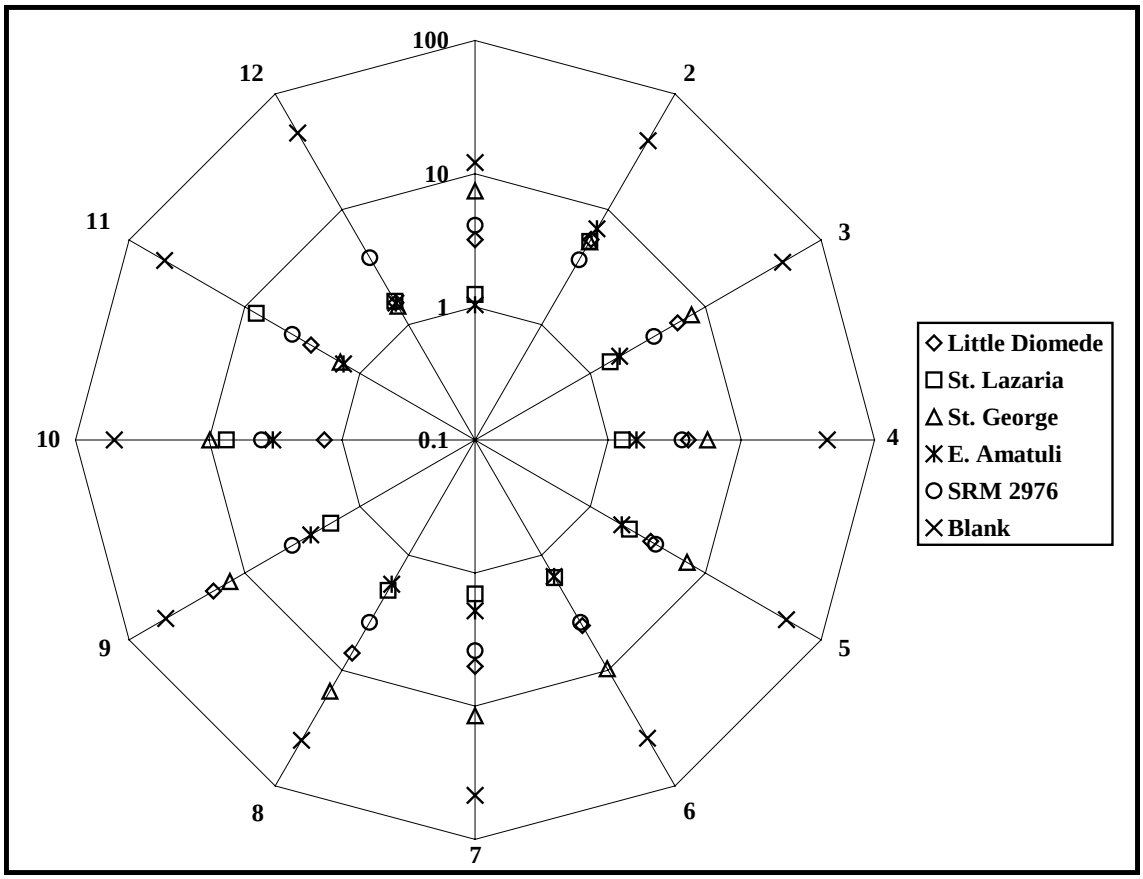

Figure 8. Radar plot showing all measured $^{201}Hg/^{202}Hg$ isotope dilution ratios (log axis) for each sample batch.

Method Accuracy, Reproducibility and Uncertainty

A control chart for SRM 2976 (Fig. 9) verifies the method accuracy across multiple analysis batches (project duration approximately 3 months). A method reproducibility study was conducted on two egg samples to help establish an uncertainty budget for the remaining eggs that were subjected to only a single determination. Method reproducibility results expressed as percent relative standard deviation (RSD) for single homogenized egg samples from Little Diomede Island (representing a low Hg concentration sample) and East Amatuli Island (representing a high Hg concentration sample) were 1.25 % and 0.64 %, respectively. Each result is based on four sample aliquots taken through the analytical spiking, weighing, digestion and measurement processes. The measurement reproducibility reflects the precision of ratio measurement, sample homogeneity, and other sources of variability in the isotope dilution method, including weighing precision and sample contamination.

The Hg mass fraction values and corresponding expanded uncertainties for each egg are presented in Fig. 10 and Appendix D. The individual components of uncertainty for Hg in each egg sample were determined according to ISO guidelines (Taylor and Kuyatt, 1994). Type A uncertainty components included sample measurement, spike calibration and blank correction. Type B uncertainty contributions included weighing measurements on a balance possessing 0.001 g resolution, uncertainty in concentration for the NIST SRM 3133 calibrant and instrument mass discrimination.

The Type A uncertainty contributions for each egg sample were first compiled in relative terms before conversion into absolute mass fraction terms. The reproducibility data presented in the previous paragraph were used to estimate the sample measurement repeatability for each egg sample where only a single measurement was collected (n = 1 measurement, 3 degrees of freedom). The RSD of 1.25 % was used to estimate the measurement reproducibility for all of the eggs collected on Little Diomede and Saint George Islands, i.e., the eggs from the islands in the Bering Sea that possessed low relative Hg content. Similarly, an RSD of 0.64 % was used to estimate the measurement reproducibility for all of the eggs collected on East Amatuli and Saint Lazaria Islands, i.e., the eggs from the islands in the Gulf of Alaska that possessed a high relative Hg content. The RSD obtained from the measurement of four spike calibration mixes was used to estimate the contribution of uncertainty from the spike concentration. Finally, the standard deviation for eleven blank measurements was ratioed to each egg's Hg concentration to obtain a blank uncertainty component based on a single measurement with 10 degrees of freedom for the blank correction.

The Type B uncertainty contributions for each egg sample were also compiled in relative terms before conversion into absolute mass fraction terms. The calibrant certification uncertainty is derived from the expanded uncertainty reported in the certificate of SRM 3133. The reported expanded uncertainty was converted to a standard uncertainty by dividing by 2 and expressed in relative terms by dividing by the concentration of Hg in the SRM. The uncertainty contribution from mass discrimination (0.34 % RSD) was derived from experimental biases observed over the course of the project while collecting dead time-corrected $^{201}Hg/^{202}Hg$ isotope ratios for approximately 1 ng/g solutions of SRM 3133.

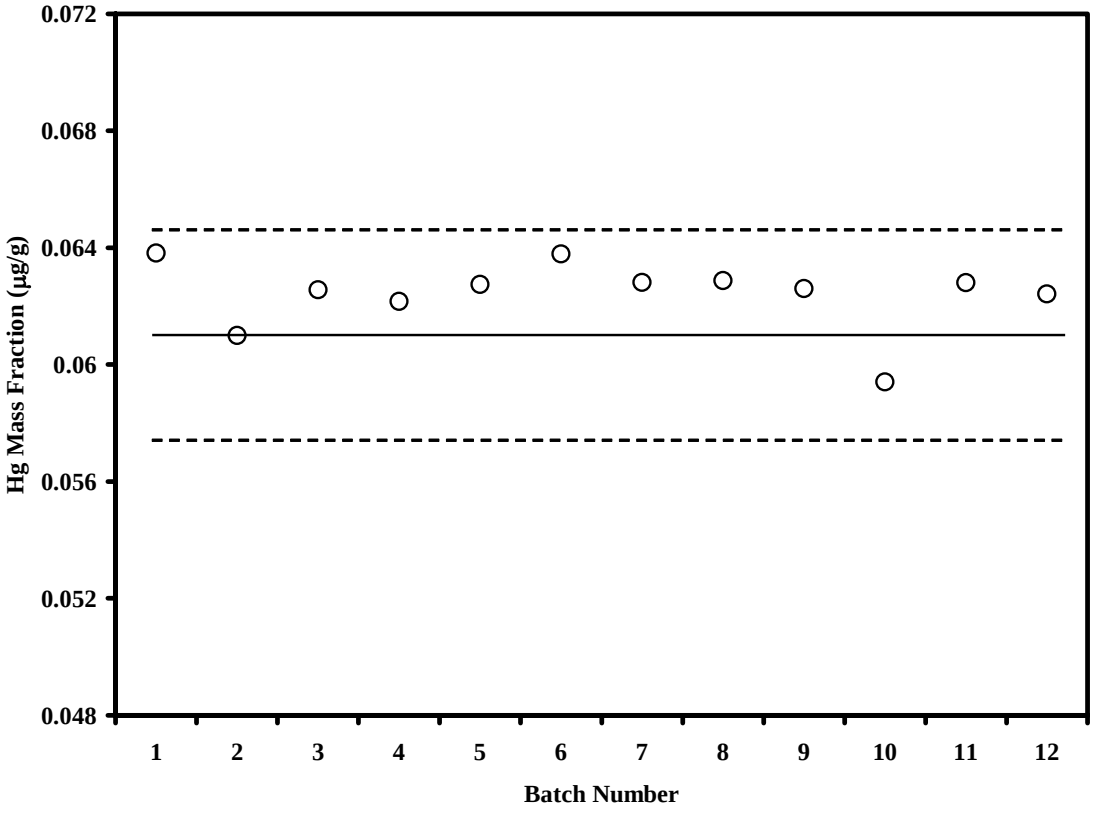

Figure 9. Control chart for mercury mass fraction (µg/g) in SRM 2976 Mussel Tissue (Trace Elements and Methylmercury), total mercury certified value = 0.0610 µg/g ± 0.0036 µg/g.

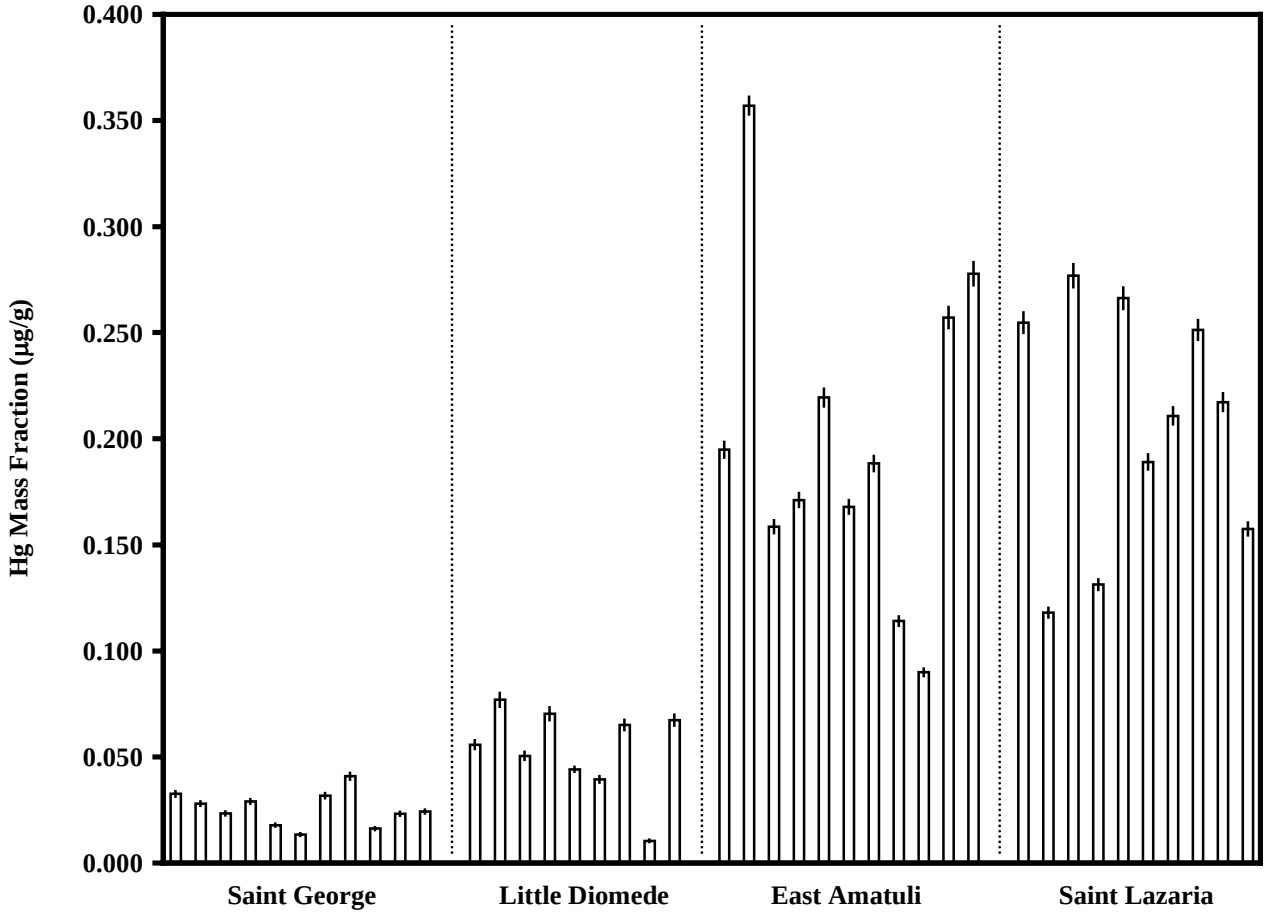

Figure 10. Mass fraction value (µg/g) and expanded uncertainty for each individual mercury wet mass fraction determination.

Data Analysis and Geographic Comparisons

The mercury analytical data are presented in Appendix C. The mercury mass fraction data plot for the eggs collected from each colony (Fig. 11) shows that the colony means and medians are similar. This suggests that the data are normally distributed, an atypical result for environmental contaminant data. Constructing normal plots (quartile vs. mercury mass fraction) for the data and applying the Shapiro-Wilk test for non-normality formally tested the normality assumption. For example, a normal plot generated for the 11 eggs collected from Saint George Island showed a high degree of linearity ($y = 121.06x - 3.06$, $R^2 = 0.975$). This indication of data normality was also confirmed by the output of the corresponding Shapiro-Wilk test (coefficient = 0.9748 and $p = 0.934$ at 95% confidence level). Applying normality tests to the remaining colonies produced similar results. A one-way analysis of variance ($F = 38.6$, $p < 0.0001$) and pair-wise comparisons across the four colonies indicate that the eggs collected from the two colonies in the Gulf of Alaska (Saint Lazaria and East Amatuli Islands) are significantly higher in mercury content than the eggs collected from the two colonies in the Bering Sea (Little Diomede and Saint George Islands). This pattern is similar to that of PCBs, 4,4'-DDE, and ΣCHL, with the eggs from the GoA having significantly higher concentrations than eggs from the BS (refer to the results presented previously in this report).

The normally distributed data of this study implies that the female birds (and eggs) of a particular colony are exposed to mercury that is ubiquitously incorporated in local food webs. However, the differences in common murre egg mercury content in the Bering Sea versus the Gulf of Alaska imply that either the quantity or bioavailability of regionally deposited mercury is significantly different in the two regions. One factor that may be influencing mercury uptake and deposition in common murre eggs is differences in rates of wet and dry deposition of mercury into coastal Alaska. Mercury deposition will be influenced by meteorology, gas phase chemistry and terrain. The Alaskan coast along the Bering Sea features a relatively flat, rocky coastline when compared to the coastline bordering the Gulf of Alaska, which possesses a more mountainous and heavily forested topography, with higher annual precipitation (Sugden, 1982; AMAP, 1998). Although the propensity for mercury to be deposited through wet and dry scavenging events and washed into Low Arctic wetlands and the coastal zone through precipitation and snowmelt events is necessarily higher in the Gulf of Alaska region, deposited mercury must become bioavailable through methylation processes before it can accumulate in the foodweb of seabirds. We speculate that mercury deposition and methylation rates are greater in the coastal area of the Gulf of Alaska than that of the Bering Sea. An increase in Hg methylation efficiency would presumably result from greater microbial activity in a more seasonally temperate climate with higher surface air (Parkinson *et al.,* 1987) and water (Wilson *et al.*, 1998) temperatures that possesses a higher percentage of organic matter at the forest soil-surface water interface (Schroeder and Munthe, 1998).

The migration patterns of both the birds and their prey must be considered as well. In the non-breeding season, common murres tend to stay north in their respective habitats (Cramp, 1985; Kaufman, 1996), so migration of the birds themselves is not likely to account for the differences in mercury content among the Bering Sea and Gulf of Alaska colonies. The roles that prey migration and food web effects have on contaminant uptake in Alaskan common murres need to be studied. Finally, the Alaska Coastal Current may also provide a waterborne influx of

nutrients and contaminants to the Gulf of Alaska region, which may indirectly impact mercury methylation efficiencies.

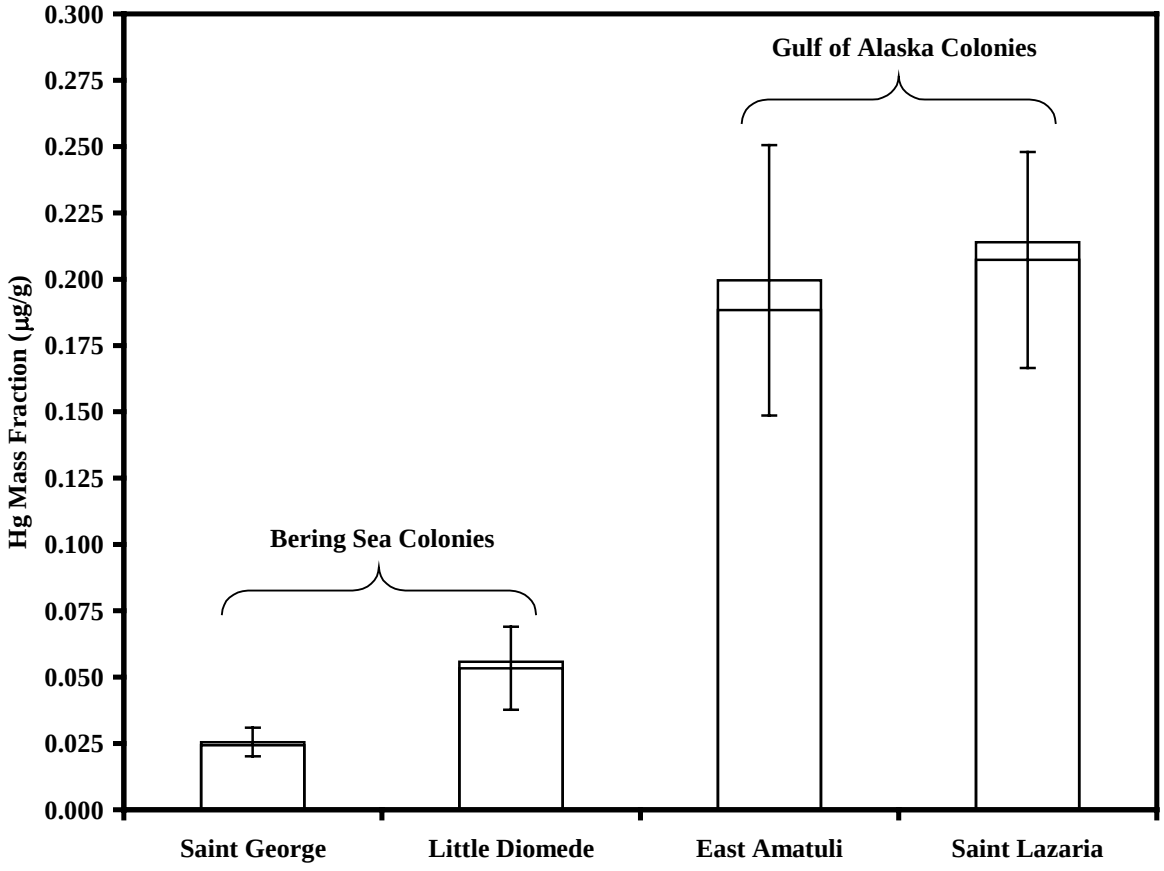

Figure 11. Mercury mass fraction data: mean ± 95% confidence interval and median plotted as a function of island location.

Literature Comparisons

The concentrations of mercury in common murre eggs from Alaska were compared with previously published data published (Table 5). The mean concentrations of mercury in the Gulf of Alaska common murres (the two colonies with the highest concentrations) were slightly lower but within the same order of magnitude as was most recently reported in murre eggs from Prince Leopold Island, Canada (Braune *et al.*, 2001 and 2002). The levels in the Gulf of Alaska common murres were the same as levels reported by Barrett et al. (1996) for thick-billed murre eggs collected in the early 1990s from Svalbard and in common murre eggs from Farrallon Islands off the coast of California in 1993 (Sydeman & Jarman, 1998).

Mercury levels in the thick-billed murre eggs, which have been monitored at Prince Leopold Island since the mid-1970s, indicate that a significant increase in this metal has occurred over the

last 30 years. In comparison, common and thick-billed murre eggs from the Barents Sea have been monitored since 1983; however, there has been little change in the level of mercury for these colonies (Barrett *et al.* 1996), while mercury concentrations decreased in common murre eggs from 1969-1972 to 1980 in Norway (Newton *et al.*, 1981). Additional monitoring of the Alaskan colonies will be required to determine which trend is occurring in the Bering Sea and Gulf of Alaska

Table 5. Literature values for total mercury (ng/g wet mass) in common (*U. aalge*) and thick-billed (*U. lomvia*) murre eggs compared to current study.

Date Collected	Species	Location	Hg Mean	Hg SD	Number of eggs	Reference
		Western Europe				
1969-1972	*U. aalge*	Skomer (SW Wales)	4370	350[1]	10	Newton *et al.* (1981)
1969-1972	*U. aalge*	Scare Rocks (SW Scotland)	8050	1265[1]	10	Newton *et al.* (1981)
1969-1972	*U. aalge*	St. Kilda (NW Scotland)	1500	200[1]	10	Newton *et al.* (1981)
1980	*U. aalge*	Skomer (SW Wales)	1040	195[1]	10	Newton *et al.* (1981)
1980	*U. aalge*	Scare Rocks (SW Scotland)	2940	220[1]	10	Newton *et al.* (1981)
1980	*U. aalge*	St. Kilda (NW Scotland)	760	75[1]	10	Newton *et al.* (1981)
1983	*U. aalge*	E. Finnmark (Norway)	120	40	10	Barrett *et al.* (1985)
1983	*U. aalge*	W. Finnmark (Norway)	110	60	9	Barrett *et al.* (1985)
1983	*U. aalge*	S. Troms/N. Nordland (Norway)	130	40	7	Barrett *et al.* (1985)
1983	*U. aalge*	Lofoten (Norway)	80	10	8	Barrett *et al.* (1985)
1992-1993	*U. aalge*	E. Finnmark (Norway)	100	40	5	Barrett *et al.* (1996)
1992-1993	*U. aalge*	Kola Pen. (Norway)	80	10	5	Barrett *et al.* (1996)
1992-1993	*U. lomvia*	Kola Pen. (Norway)	70	20	5	Barrett *et al.* (1996)
1992-1993	*U. lomvia*	Svalbard (Norway)	200	60	5	Barrett *et al.* (1996)
1992-1993	*U. lomvia*	E. Finnmark (Norway)	100	20	5	Barrett *et al.* (1996)
		Eastern Canada				
1971	*U. aalge*	Ile Ste-Marie (Quebec)	120	51	4	Pearce *et al.* (1979)
1977	*U. lomvia*	Prince Leopold I.[2]	150	13	3 pools of 3	Braune *et al.* (2001)
1987	*U. lomvia*	Prince Leopold I.[2]	269	16	3 pools of 3	Braune *et al.* (2001)
1988	*U. lomvia*	Prince Leopold I.[2]	268	8	3 pools of 3	Braune *et al.* (2001)
1993	*U. lomvia*	Prince Leopold I.[2]	303	27	5 pools of 3	Braune *et al.* (2001)
1993	*U. lomvia*	Prince Leopold I.[2]	295	27	5 pools of 3	Braune *et al.* (2002)
1993	*U. lomvia*	Coburg I.[2]	423	6	5 pools of 3	Braune *et al.* (2002)
1993	*U. lomvia*	Digges I.[2]	238	30	5 pools of 3	Braune *et al.* (2002)
1993	*U. lomvia*	Coats I.[2]	237	12	5 pools of 3	Braune *et al.* (2002)
1998	*U. lomvia*	Prince Leopold I.[2]	330	19	5 pools of 3	Braune *et al.* (2001)
1998	*U. lomvia*	Prince Leopold I.[2]	332	28	5 pools of 3	Braune *et al.* (2002)
1998	*U. lomvia*	Coats I.[2]	176	25	5 pools of 3	Braune *et al.* (2002)
		Western United States				
1993	*U. aalge*	Farrallon I. (California)[2]	154	62	12	Jarman *et al.* (1996)
1993	*U. aalge*	Farrallon I. (California)[2]	196	70	15	Sydeman & Jarman (1998)
1999	*U. aalge*	St. Lazaria I. (Alaska)	207	57	10	This study
1999	*U. aalge*	East Amatuli I. (Alaska)	200	76	11	This study
1999	*U. aalge*	St. George I. (Alaska)	26	8.1	11	This study
1999	*U.* spp.	Little Diomede I. (Alaska)	53	20	9	This study

[1]Standard Error

[2]Published dry mass concentrations converted to wet mass using mean moisture content published for colony

Human Health and Ecological Implications

Based on the Health Canada ADI/TDI for total mercury of 714 ng*kg body wt^{-1}*day^{-1} (Van Oostdam *et* al., 1999) a 50 kg person could safely consume at least two murre eggs per day (Table 4). The amount of safe consumption will most likely decrease after methylmercury values are assigned to the murre eggs. The Health Canda ADI/TDI for methylmercury is 470 ng*kg body wt^{-1}*day^{-1} (Van Oostdam *et* al., 1999) and large percentage (>85%) of total mercury is expected to be methylmercury based on other studies of methylmercury in northern aquatic bird species eggs (Paasivrta *et al.*, 1981; Scheuhammer *et al.*, 2001). Exposure to mercury may cause adverse effects to the nervous system, particularly brain function, digestive system, and kidneys, and exposure to fetuses and young children may cause developmental disabilities (ATSDR, 1999).

In birds, mercury causes reproductive problems including reduced egg weight, reduced hatchability, increased embryo and chick abnormalities, and reduced survival. Mercury levels of at least 500 ng/g wet weight in eggs are usually associated with these effects (see review by Burger & Gochfeld, 1997). The levels of mercury in murre eggs from this study ranged from 11 – 357 ng/g wet mass and thus should not have a reproductive effect on the population. In deed, the mercury concentration was not correlated with egg weight ($R^2 = 0.00$, $p = 0.995$).

CONCLUSIONS

In the three years since its inception, STAMP has collected 222 Alaskan seabird egg clutches from three species (common murres, thick-billed murres, and black-legged kittiwakes) over a large geographic area from southeast Alaska near Sitka to the Aleutian Islands in the west and to Cape Lisburne in the north. These specimens are available for research now and a portion of each is being banked for future researchers. Current analyses of murre eggs have shown significant geographical differences in concentrations of POPs and mercury. Analysis of eggs from mixed colonies of common and thick-billed murres eggs have also revealed species differences. Comparison of our results to data published on eggs collected from the same colonies in the 1970s, suggest that some compounds might be decreasing in the environment (i.e., DDE, some chlordane compounds, and possibly PCBs) This is consistent with what has been reported by Braune *et al.* (2001) for seabird colonies in the High Canadian Arctic.

The application of ID-CV-ICPMS to the measurement of mercury in seabird eggs had several benefits including: high accuracy, good method reproducibility, and the ability to estimate errors and uncertainty for a single analytical determination. The accuracy and uncertainty of critical environmental mercury measurements must be verified as this information may ultimately be used by wildlife health assessors to determine the impact of mercury contamination on colonial seabirds in the Alaska Maritime National Wildlife Refuge and by organizations concerned with identifying health issues that impact native Alaskan peoples.

A major factor in differences between murre species and geographic differences among the same species may be food web related. Determining carbon and nitrogen stable isotope ratios and fatty acid profiles should help to ascertain if trophic level differences exist between species and colonies. The effect of over-wintering locations and feeding during over-wintering on concentrations in eggs is also poorly understood. Gut content analysis of female murres, tagging or tracking of the female birds and their prey to determine winter distributions and analyzing prey items for POPs and mercury may help explain some of the geographical and species differences. Also, there is always some question regarding identifying the species of origin for a murre egg when it is collected from a mixed colony of both common and thick-billed murres. Genetic analysis of the eggshells would be helpful in verifying the species collected as eggs appear very similar. This would also be useful for determining if any hybrids were among the eggs we analyzed. As for the temporal changes, STAMP will continue to collect and bank eggs, while expanding the number of species and colonies, so future analyses can use the stored samples to eliminate methodological differences, thus enabling accurate temporal comparisons.

REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 1993a. Toxicological profile for aldrin and dieldrin. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 1993b. Toxicological profile for heptachlor and heptachlor epoxide. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. Toxicological profile for chlordane (update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 1996. Toxicological profile for hexachlorobenzene. Atlanta, GA; U.S. Department of Health and Human Services, Public Health Service.

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological profile for mercury. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Agricultural Marketing Service. 1995. "How to buy eggs" Home and Garden Bulletin No. 264. United States Department of Agriculture. http://www.ams.usda.gov/howtobuy/eggs.htm (March 4, 2002).

AMAP. 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

AMAP. 2002. *Arctic Pollution 2002*. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Bailey, R. E. 2001. Global hexachlorobenzene emissions. *Chemosphere*. 43:167-182.

Baird, P. H. 1994. Black-legged kittiwake (*Rissa tridactyla*). *In* The Birds of North America, No. 92 (A. Poole and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington D.C: The American Ornithologists' Union.

Bard, S. M. 1999. Global transport of anthropogenic contaminants and the consequences for the Arctic marine ecosystem. *Mar. Pollut. Bull.* 35(5):356-379.

Barrett, R. T., M. Asheim, and V. Bakken. 1997. Ecological relationships between two sympatric congeneric species, common murres and thick-billed murres, Uria aalge and U. lomvia, breeding in the Barents Sea. *Can. J. Zool*. 75:618-631.

Barrett, R. T., J. U. Skaare, and S. W. Gabrielsen. 1996. Recent changes in levels of persistent organochlorines and mercury in eggs of seabirds from the Barents Sea. *Environ. Poll.* 92:13-18.
Barrett, R. T., J. U. Skaare, G. Norheim, W. Vader, and A. Frøslie. 1985. Persistent organochlorines and mercury in eggs of Norwegian seabirds 1983. *Environ. Pollut. (Ser. A)*. 39:79-93.

Barron, M. G., H. Galbraith and D. Beltman. 1995. Comparative reproductive and developmental toxicology of PCBs in birds. *Comp. Biochem. Physiol.* 112C:1-14.

Bignert, A., K. Litzén, T. Odsjö, M. Olsson, W. Persson, and L. Reutergårdh. 1995. Time-related factors influence the concentrations of sDDT, PCBs and shell parameters in eggs of Baltic guillemot (*Uria aalge*), 1861-1989. *Environ. Poll.* 89:27-36.

Braune, B. M., G. M. Donaldson, K. A. Hobson. 2002. Contaminant residues in seabird eggs from the Canadian Arctic. II. Spatial trends and evidence from stable isotopes for intercolony differences. *Environ. Pollut.* 117:133-145.

Braune, B. M., G. M. Donaldson, and K. A. Hobson. 2001. Contaminant residues in seabird eggs from the Canadian Arctic. Part I. Temporal trends 1975-1998. *Environ. Pollut.* 114:39-54.

Braune, B. M., and R. J. Norstrom. 1989. Dynamics of organochlorine compounds in herring gulls: III Tissue distribution and bioaccumulation in Lake Ontario gulls. *Env. Toxicol. Chem.* 8:957-968.

Burger, A. E. and M. Simpson. 1986. Diving depths of Atlantic puffins and common murres. *Auk* 103:828-830.

Christopher, S. J., S. E. Long, M. S. Rearick, and J. D. Fassett. 2001. Development of Isotope Dilution Cold Vapor Inductively Coupled Plasma Mass Spectrometry and its application to the certification of mercury in NIST Standard Reference Materials. *Anal. Chem.* 73 (10):2190-2199.

Christopher, S. J., S. S. Vander Pol, R. S. Pugh, R. D. Day, and P. R. Becker. 2002. Determination of mercury in the eggs of common murres (*Uria aalge*) for the seabird tissue archival and monitoring project. *J. Anal. At. Spectrom.* 17:780-785.

Cramp, S. 1985. *Handbook of the Birds of Europe, the Middle East, and North Africa.* Oxford University Press: New York, NY, Vol. IV, p 170.

Eganhouse, R. P., and R. W. Gosset. 1991. Sources and Magnitude of Bias Associated with Determination of Polychlorinated Biphenyls in Environmental Samples. *Anal. Chem.*, 63:2130-2137.

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. *The birder's handbook: a field guide to the natural history of North American birds.* Simon & Schuster Inc: New York, p 196.

Elliott, J. E. 1985. Specimen banking in support of monitoring for toxic contaminants in Canadian wildlife. In: International Review of Environmental Specimen Banking, S.A. Wise and R. Zeisler (eds.). U.S. Dept. of Commerce, National Bureau of Standards. Spec. Publ. 706. 4-12.

Fassett, J. D. and P. J. Paulsen. 1989. Isotope Dilution Mass Spectrometry for accurate elemental analysis. *Anal. Chem.*, 61:643A-649A.

Fimreite, N., J. E. Bjerk, N. Kveseth, and E. Brun. 1977. DDE and PCBs in eggs of Norwegian seabirds. *Astarte*. 10(1):15-20.

Fox, G. A., S. Trudeau, H. Won, and K. A. Grasman. 1998. Monitoring the elimination of persistent toxic substances from the Great Lakes: Chemical and physiological evidence from adult herring gulls. *Environ. Monit. Assess.* 53:147-160.

Gabrielsen, G. W., J. U. Skaare, A. Polder, and V. Bakken. 1995. Chlorinated hydrocarbons in glaucous gulls (*Larus hyperboreus*) in the southern part of Svalbard. *Sci. Total Environ.* 160/161:337-346.

Gaston, A. J.and J. M. Hipfner. 2000. Thick-billed murre (*Uria lomvia*). *In*: The Birds of North America, No. 497; Poole. A; Gill, F; Eds; The Birds of North America, Inc.: Philadelphia, PA, p. 12.

Gilman, A. P., D. J. Hallett, G. A. Fox, L. J. Allan, D. B. Peakall. 1978. Effects of injected organochlorines on naturally incubated herring gull eggs. *J. Wildl. Manage.* 42(3):484-493.

Hickey, J. J. and D. W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. *Science*. 162:271-273.

Iknokinok, S. and S. Georgette. 1997. St. Lawrence Island's bounty of birds: More than 20,000 birds caught by hunters in 1996: a summary of the St. Lawrence Island migratory bird harvest survey by Kawerak, Inc. and the Alaska Department of Fish and Game (http://www.state.ak.us/adfg/subsist/download/sliwfowl.pdf).

Jarman, W. M., K. A. Hobson, W. J. Sydeman, C. E. Bacon, and E. B. McLaren. 1996. Influence of trophic position and feeding location on contaminant levels in the Gulf of the Faralllones food web revealed by stable isotope analysis. *Environ. Sci. Technol.* 30(2):654-660.

Kaufman, K. *Lives of North American Birds*, Houghton Mifflin: New York, NY, 1996, p. 269.

Kawano, M., T. Inoue, T. Wada, H. Hidaka, and R. Tatsukawa. 1988. Bioconcentration and residue patterns of chlordane compounds in marine mammals: invertebrates, fish, mammals and seabirds. *Environ. Sci. Technol.* 22:792-797.

Kucklick, J. R., S. S. Vander Pol, P. R. Becker, R. S. Pugh, K. Simac, G. W. York, and D. G. Roseneau. 2002. Persistent organic pollutants in murre eggs from the Gulf of Alaska and Bering Sea. 22nd International Symposium on Halogenated Environmental Organic Pollutants and Persistent Organic Pollutants (POPs), Barcelona, Spain, August 11-16, 2002. *Organohalogen Compounds* 59:13-16.

Li, Y.-F., R. W. Macdonald, L. M. M. Jantunen, T. Harner, T. F. Bidleman, and W. M. J. Strachan. 2002. The transport of β-hexachlorocyclohexane to the western Arctic Ocean: a contrast to α-HCH. *Sci. Total Environ.* 291:229-246.

Mineau, P., G. A. Fox, R. J. Nordstrom, D. V. Weseloh, D. J. Hallett, and J. A. Ellentonl. 1984. Using the Herring Gull to monitor levels of organochlorine contaminants in the Canadian Great Lakes. Chap. 19 in Toxic Contaminants in the Great Lakes, J.O. Nriagu and A.S. Simmon (eds.).

Muir, D., B. Braune, B. DeMarch, R. Norstrom, R. Wagemenn, L. Lockahart, B. Hargrave, D. Bright, R. Addison, J. Payne, and K. Reimer. 1999. Spatial and temporal trends and effects of contaminants in the Canadian Arctic marine ecosystem: a review. *Sci. Total Environ.* 230:83-144.

Muir, D. C. G. and R. J. Norstrom. 2000. Geographical differences and time trends of persistent organic pollutants in the Arctic. *Toxicol. Lett.* 112-113:93-101.

Nettleship, D. N. and D. B. Peakall. 1987. Organochlorine residue levels in three high Arctic species of colonially-breeding seabirds from Prince Leopold Island. *Mar. Pollut. Bull.* 18(8):434-438.

Newton, I., M. B. Haas, and A. A. Bell. 1981. Pollutants in guillemot eggs. Institute Of Terrestrial Ecology Annual Report 1981. 57-59.

Noble, D. G. and J. E. Elliott. 1986. Environmental contaminants in Canadian seabirds, 1968-1984: Trends and effects. Technical Report Series No. 13. Canadian Wildlife Service, Ottawa.

Ohlendorf, H. M., J. C. Bartonek, G. J. Divoky, E. E. Klaas, and A. J. Krynitsky. 1982. Organochlorine Residues in Eggs of Alaskan Seabirds. U.S. Fish and Wildlife Service. Spec. Scientific Rept.-Wildlife No. 245, Wash. D.C. 41 pp.

Parkinson, C. L., J. C. Comiso, H. J. Zwally, D. J. Cavalieri, P. Gloersen, and W. J. Campbell. 1987. *Arctic Sea Ice, 1973-1976: Satellite Passive-Microwave Observations*. NASA SP-489, pp. 32-33.

Paasivirta, J., J. Sarkka, J. Pellinen, Jukka;and T. Humppi. 1981. Biocides in eggs of aquatic birds. Completion of a food chain enrichment study for DDT, PCB and mercury. *Chemosphere.* 10(7):787-94.

Pearce, P. A., D. B. Peakall, and L. M. Reynolds. 1979. Shell thinning and residues of organochlorines and mercury in seabird eggs, Eastern Canada, 1970-76. *Pestic. Monit. J.* 15(2):61-68.

Piatt, J. F. and D. N. Nettleship. 1985. Diving depths of four alcids. *Auk* 102:293-297.

Poster, D. L., J. R. Kucklick, M. M. Schantz, B. J. Porter, S. D. Leigh, and S. A. Wise. 2003. Determination of polychlorinated biphenyl congeners and chlorinated pesticides in a fish tissue standard reference material. *Anal. Bioanal. Chem.* 375:223-241.

Pyle, P., W. J. Sydeman, and E. McLaren. 1999. Organochlorine concentrations, eggshell thickness, and hatchability in seabirds of central California. *Waterbirds.* 22(3):376-381.

Roudybush, T. E., C. R. Grau, M. R. Petersen, D. G. Ainley, K. V. Hirsch, A. P. Gilman, and S. M. Patten. 1979. Yolk formation in some Charadriiform birds. *Condor.* 81:293-298.

Sanderson J. T. and G. D. Bellward. 1995. Hepatic microsomal ethoxyresorufin O-deethylase-inducing potency in ovo and cytosolic Ah receptor binding affinity of 2,3,7,8-tetrachlorodibenzo-p-dioxin: comparison of four avian species. *Toxicol. Appl. Pharmacol.* 132: 131-145.

Schroeder, W. H. and J. Munthe. 1998. Atmospheric mercury-An overview. *Atmospheric Environ.* 32(5):809-822.

Scheuhammer, A. M., J. A. Perrault, and D. E. Bond. 2001. Mercury, methylmercury, and selenium concentrations in eggs of common loons (*Gavia immer*) from Canada. *Environ. Monit. Assess*. 72(1):79-94.

Springer, A. M., D. G. Roseneau, E. C. Murphy, and M. I. Springer. 1984. Environmental controls of marine food webs: food habits of seabirds in the eastern Chukchi Sea. *Can. J. Fish Aquat. Sci.* 41: 1202-1215.

Springer, A. M., D .G. Roseneau, D. S. Lloyd, C. P. McRoy, and E. C. Murphy. 1986. Seabird responses to fluctuating prey availability in the eastern Bering Sea. *Marine Ecol. Prog. Ser.* 32: 1-12.

Springer, A. M., E. C. Murphy, D. G. Roseneau, C. P. McRoy, and B. A. Cooper. 1987. Paradox of pelagic food webs in the northern Bering Sea - I. Seabird food habits. *Cont. Shelf Res*. 7: 895-911.

Stabeno, P.J., J.D. Schumacher, and K. Ohtani. 1999. The physical oceanography of the Bering Sea. In: *Dynamics of the Bering Sea*, T.R. Loughlin and K. Ohtani, Editors. University of Alaska Sea Grant, Fairbanks, AK. pages 1-28.

Sugden, D. 1982. *Arctic and Antarctic: A Modern Geographical Synthesis*. Basil Blackwell, Oxford.

Sydeman, W. J. and W. M. Jarman. 1998. Trace metals in seabirds, steller sea lion, and forage fish and zooplankton from central California. *Mar. Pollut. Bull*. 36(10):828-832.

Taylor. B. N. and C. E. Kuyatt. 1994. *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note 1297.

Thompson, D. R., R. W. Furness, R. W., and R. T. Barrett. 1992. Mercury concentrations in seabirds from colonies in the Northeast Atlantic. *Arch. Environ. Contam. Toxicol.* 23(3):383-389.

Turle, R., R. J. Norstrom and Collins, B. 1991. Comparison of PCB quantitation methods: Re-analysis of archived specimens of herring gull eggs from the Great Lakes. *Chemosphere*. 22(1-2):201-213

U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sports Fisheries and Wildlife. 1975. Lethal dietary toxicities of environmental pollutants to birds. Special Scientific Report - Wildlife No. 191. Washington, DC: U.S. Government Printing Office.

U.S. Department of the Interior, Fish and Wildlife Service. 1984. Handbook of toxicity of pesticides to wildlife. Resource Publication 153. Washington, DC: U.S. Government Printing Office.

U.S. Fish and Wildlife Service. 1992. Alaska Seabird Management Plan. U.S. Fish and Wildlife Service, Div. of Migratory Birds. Anchorage, AK.

Vander Pol, S. S. 2002. *Persistent Organic Pollutants (POPs) in Alaskan Murre (*Uira *spp.) Eggs.* M.S. Thesis, College of Charleston.

Vander Pol, S. S., P. R. Becker, J. R. Kucklick, R. S. Pugh, D. G. Roseneau, K. Simac, and G. W. York. 2002a. Trends in concentrations of persistent organic pollutants in eggs from Alaskan murre colonies. Second AMAP International Symposium on Environmental Pollution of the Arctic, Rovaniemi, Finland, October 1-4, 2002. Extended abstract 0-025. AMAP Rept. 2002.2, Arctic Monitoring and Assessment Program (AMAP), Oslo, Norway.

Vander Pol, S. S., S. J. Christopher, R. Day, R. S. Pugh, P. R. Becker, D. G. Roseneau, K. Simac, and G. W. York. 2002b. Trends in concentrations of mercury in eggs from Alaskan murre colonies. Second AMAP International Symposium on Environmental Pollution of the Arctic, Rovaniemi, Finland, October 1-4, 2002. Extended abstract P-M40. AMAP Rept. 2002.2, Arctic Monitoring and Assessment Program (AMAP), Oslo, Norway.

Vanhaecke, F., G. de Wannemacker, L. Moens, R. Dams, C. Latkoczy, T. Prohaska, and G. Stingeder. 1998. Dependence of detector deadtime on analyte mass number in Inductively Coupled Plasma Mass Spectrometry. *J. Anal. At. Spectrom.* 13(6):567-571.

Van Oostdam, J., A. Gilman, E. Dewailly, P. Usher, B. Wheatley, H. Kuhnlein, S. Neve, J. Walker, B. Tracy, M. Feeley, V. Jerome, and B. Kwavnick. 1999. Human health implications of environmental contaminants in Arctic Canada: a review. *Sci. Total Environ.* 230(1-3):1-82.

Wakeford, B. J. and M. T. Kasserra. 1997. The relationship between the Canadian Wildlife Service Specimen Bank and the Wildlife Toxicology Program: the effect on specimen collection. *Chemosphere*. 34(9/10): 1933-1938.

Wania F. and D. Mackay. 1996. Tracking the distribution of persistent organic pollutants. *Environ. Sci. Techn.* 30(0): 390A- 396A.

Wilson, S. J., J. L. Murray, and H. P. Huntington. 1998. AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme, Oslo, Norway, Chapter 2, pp. 9-23

York, G.W., B.J. Porter, R.S. Pugh, D.G. Roseneau, K. Simac, P.R. Becker, L.K. Thorsteinson, and S.A. Wise. 2001. Seabird Tissue Archival and Monitoring Project: Protocol for Collecting and Banking Seabird Eggs. NISTIR 6735, U.S. Dept. Commerce, NIST, Gaithersburg, MD. 25 pp.

APPENDIX A: EGG COLLECTION INVENTORY

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
1	ST01E001C	DIOM01COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*Uria* spp.	98.34	7.93	5.43	0.26	14.79
2	ST01E002C	DIOM02COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	98.11	8.61	5.31	0.26	15.53
3	ST01E003C	DIOM03COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	98.78	8.44	5.28	0.27	15.13
4	ST01E004C	DIOM04COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	88.14	7.94	5.13	0.28	15.25
5	ST01E005C	DIOM05COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	94.73	8.19	5.15	0.29	15.02
6	ST01E006C	DIOM06COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	83.00	8.43	5.12	0.26	14.72
7	ST01E007C	DIOM07COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	97.64	8.78	5.12	0.28	15.10
8	ST01E008C	DIOM08COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	79.01	8.26	4.97	0.26	11.93
9	ST01E009C	DIOM09COMU99	65°43.2'N/168°55.2'W	1-Jul-99	*U.* spp.	78.18	7.76	5.13	0.26	13.27
10	ST01E010C	STLA01COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	86.16	8.25	5.08	0.23	11.30
11	ST01E011C	STLA02COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	80.61	7.89	4.94	0.24	11.98
12	ST01E012C	STLA03COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	93.72	8.58	5.32	0.27	17.75
13	ST01E013C	STLA04COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	81.11	7.93	4.95	0.27	13.65
14	ST01E014C	STLA05COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	87.68	8.29	5.10	0.26	14.61
15	ST01E015C	STLA06COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	94.15	8.89	5.22	0.27	15.40
16	ST01E016C	STLA07COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	90.94	8.57	5.10	0.26	15.94
17	ST01E017C	STLA08COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	85.58	7.94	4.96	0.25	12.69
18	ST01E018C	STLA09COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	80.36	8.55	5.11	0.26	14.99
19	ST01E019C	STLA10COMU99	56°59.1'N/135°42.2'W	23-Jul-99	*U. aalge*	77.24	8.58	5.29	0.27	15.46
20	ST01E020C	STGE01COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	97.28	7.63	5.01	0.25	11.64
21	ST01E021C	STGE02COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	76.99	8.06	5.01	0.26	15.28
22	ST01E022C	STGE03COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	79.84	8.39	4.96	0.27	13.99
23	ST01E023C	STGE04COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	95.50	8.46	5.16	0.28	15.95
24	ST01E024C	STGE05COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	107.00	8.24	5.44	0.26	13.87
25	ST01E025C	STGE06COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	83.02	8.25	4.80	0.24	11.41
26	ST01E026C	STGE07COMU99	56°36.2'N/169°32.9'W	25-Jun-99	*U. aalge*	91.42	7.89	5.11	0.25	12.16
27	ST01E027C	STGE08COMU99	56°36.2'N/169°32.9'W	1-Jul-99	*U. aalge*	94.30	8.24	5.15	0.24	12.94
28	ST01E028C	STGE09COMU99	56°36.2'N/169°32.9'W	1-Jul-99	*U. aalge*	76.02	7.75	4.97	0.26	12.35
29	ST01E029C	STGE10COMU99	56°36.2'N/169°32.9'W	1-Jul-99	*U. aalge*	93.44	8.07	5.26	0.26	12.98
30	ST01E030C	STGE11COMU99	56°36.2'N/169°32.9'W	1-Jul-99	*U. aalge*	97.72	7.94	5.28	0.27	13.69
31	ST01E031C	EAAM01COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	94.06	8.58	5.31	0.26	15.36
32	ST01E032C	EAAM02COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	94.83	8.40	5.15	0.24	12.71
33	ST01E033C	EAAM03COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	83.55	8.43	4.98	0.29	15.17
34	ST01E034C	EAAM04COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	95.64	8.40	5.42	0.26	14.58
35	ST01E035C	EAAM05COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	91.47	8.39	5.14	0.26	12.82

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
36	ST01E036C	EAAM06COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	90.43	8.26	5.26	0.29	16.22
37	ST01E037C	EAAM07COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	92.08	8.28	5.14	0.27	15.10
38	ST01E038C	EAAM08COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	88.31	7.91	5.11	0.24	12.98
39	ST01E039C	EAAM09COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	70.90	7.61	4.66	0.24	12.24
40	ST01E040C	EAAM10COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	85.81	8.58	5.13	0.25	14.69
41	ST01E041C	EAAM11COMU99	58°55.05'N/152°00.21'W	7-Jul-99	*U. aalge*	80.61	7.93	5.13	0.28	15.01
42	ST02E42C	STGE01TBMU00	56°36.1'N/169°30.2'W	26-Jun-00	*U. lomvia*	102.54	8.32	5.33	0.51	12.28
43	ST02E43C	STGE02TBMU00	56°36.1'N/169°30.2'W	22-Jun-00	*U. lomvia*	88.17	8.10	5.20	0.50	11.59
44	ST02E44C	STGE03TBMU00	56°36.1'N/169°30.2'W	22-Jun-00	*U. lomvia*	83.60	7.85	5.08	0.47	9.82
45	ST02E45C	STGE05TBMU00	56°36.1'N/169°30.2'W	26-Jun-00	*U. lomvia*	89.77	7.50	5.30	0.50	11.34
46	ST02E46C	STGE06TBMU00	56°36.1'N/169°30.2'W	26-Jun-00	*U. lomvia*	81.58	8.05	5.15	0.52	12.14
47	ST02E47C	STGE08TBMU00	56°36.1'N/169°30.2'W	22-Jun-00	*U. lomvia*	92.46	8.05	5.21	0.48	10.72
48	ST02E48C	STGE10TBMU00	56°36.1'N/169°30.2'W	3-Jul-00	*U. lomvia*	76.80	8.19	5.07	0.51	12.09
49	ST02E49C	BOGO01TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	67.07	7.91	5.25	0.23	11.76
50	ST02E50C	BOGO02TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	84.79	7.60	5.13	0.24	11.28
51	ST02E51C	BOGO03TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	97.52	8.09	5.44	0.26	14.84
52	ST02E52C	BOGO04TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	88.68	8.24	5.10	0.25	13.37
53	ST02E53C	BOGO05TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	84.85	7.43	5.15	0.22	10.82
54	ST02E54C	BOGO06TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	85.81	7.91	5.14	0.23	12.69
55	ST02E55C	BOGO07TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	90.25	8.00	5.15	0.23	12.82
56	ST02E56C	BOGO08TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	91.86	7.91	5.25	0.23	13.08
57	ST02E57C	BOGO09TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	92.59	8.01	5.11	0.23	11.99
58	ST02E58C	BOGO10TBMU00	53°56.09'N/168°02.20'W	18-Jun-00	*U. lomvia*	85.29	7.44	5.13	0.23	11.22
59	ST02E59C	BOGO01COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	103.10	8.26	5.44	0.28	15.32
60	ST02E60C	BOGO02COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	88.84	8.05	5.30	0.26	14.60
61	ST02E61C	BOGO03COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	91.46	8.41	5.11	0.25	13.39
62	ST02E62C	BOGO04COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	50.54	7.60	4.93	0.26	11.69
63	ST02E63C	BOGO05COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	72.03	8.12	5.44	0.29	16.67
64	ST02E64C	BOGO07COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	88.13	7.91	5.12	0.24	12.18
65	ST02E65C	BOGO08COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	81.78	not measured		0.22	10.26
66	ST02E66C	BOGO09COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	86.68	7.92	4.96	0.26	12.65
67	ST02E67C	BOGO10COMU00	53°56.09'N/168°02.20'W	17-Jun-00	*U. aalge*	95.48	8.09	5.32	0.26	14.75
68	ST03E068C	STLA01COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	95.89	8.60	5.18	0.59	12.78
69	ST03E069C	STLA02COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	93.06	8.16	5.24	0.70	14.42
70	ST03E070C	STLA03COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	100.42	8.69	5.14	0.66	14.46

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
71	ST03E071C	STLA04COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	100.45	8.17	5.45	0.65	16.49
72	ST03E072C	STLA05COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	102.95	9.12	5.14	0.62	15.46
73	ST03E073C	STLA06COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	104.90	8.46	5.42	0.64	15.27
74	ST03E074C	STLA07COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	88.25	7.80	4.97	0.68	12.27
75	ST03E075C	STLA08COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	89.11	8.04	5.15	0.66	13.33
76	ST03E076C	STLA09COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	95.50	8.14	5.25	0.64	13.81
77	ST03E077C	STLA10COMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. aalge*	82.99	8.04	5.02	0.64	12.29
78	ST03E078C	STLA01TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	85.87	7.98	5.17	0.59	11.27
79	ST03E079C	STLA02TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	80.57	8.98	4.96	0.55	12.90
80	ST03E080C	STLA03TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	93.15	8.21	5.30	0.59	12.45
81	ST03E081C	STLA04TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	97.59	8.09	5.17	0.53	12.08
82	ST03E082C	STLA05TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	97.64	8.65	5.19	0.67	15.23
83	ST03E083C	STLA06TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	90.84	8.37	4.99	0.62	12.03
84	ST03E084C	STLA07TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	84.62	8.06	4.88	0.62	11.45
85	ST03E085C	STLA08TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	84.68	8.09	5.05	0.61	13.62
86	ST03E086C	STLA09TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	99.70	8.81	5.28	0.64	15.21
87	ST03E087C	STLA10TBMU01	56°59.1'N/135°42.2'W	10-Jul-01	*U. lomvia*	82.70	7.84	4.98	0.56	11.66
88	ST03E088C	STGE01TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	93.87	8.21	5.03	0.57	12.31
89	ST03E089C	STGE02TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	69.23	7.73	4.80	0.55	10.62
90	ST03E090C	STGE03TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	99.81	8.66	5.13	0.55	12.41
91	ST03E091C	STGE04TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	86.51	8.46	5.10	0.57	11.06
92	ST03E092C	STGE05TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	98.76	8.05	5.33	0.56	11.75
93	ST03E093C	STGE06TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	93.21	8.47	5.10	0.60	12.36
94	ST03E094C	STGE07TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	89.60	8.25	5.00	0.55	11.51
95	ST03E095C	STGE08TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	75.75	7.91	5.07	0.50	10.98
96	ST03E096C	STGE09TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	93.52	8.23	5.15	0.52	11.85
97	ST03E097C	STGE10TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	85.45	8.23	5.10	0.61	12.93
98	ST03E098C	STGE11TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	87.43	8.01	5.14	0.55	11.96
99	ST03E099C	MIDD02BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*Rissa tridactyla*	27.42	5.69	4.06	0.11	2.96
100	ST03E100C	MIDD03BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	22.2+14.83	5.23	4.02	0.11	2.68
101	ST03E101C	MIDD04BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	20.52+20.60	5.55	4.07	0.11	3.14
102	ST03E102C	MIDD05BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	28.09+12.44	5.45	4.18	0.10	2.88
103	ST03E103C	MIDD06BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	30.42	5.43	3.99	0.11	3.08
104	ST03E104C	MIDD07BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	35.98	5.68	4.27	0.11	3.53
105	ST03E105C	MIDD08BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	33.29	5.53	4.17	0.12	3.54

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
106	ST03E106C	MIDD09BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	39.44	5.74	4.24	0.11	3.32
107	ST03E107C	MIDD10BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	25.25+12.26	5.60	4.21	0.11	3.29
108	ST03E108C	MIDD11BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	20.13	5.53	4.02	0.10	2.72
109	ST03E109C	MIDD12BLKI01	59°26.1'N/146°19.4'W	5-Jun-01	*R. tridactyla*	41.39	5.38	4.19	0.10	3.13
110	ST03E110C	STGE01COMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	75.85	7.57	4.81	0.21	9.13
111	ST03E111C	STGE12TBMU01	56°36.1'N/169°30.2'W	28-Jun-01	*U. lomvia*	66.53	8.27	5.12	0.22	11.75
112	ST04E112C	BLUF01COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	89.49	8.15	4.95		
113	ST04E113C	BLUF02COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	83.87	8.10	5.12		
114	ST04E114C	BLUF03COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	101.00	8.45	5.20		
115	ST04E115C	BLUF04COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	86.59	7.95	4.97		
116	ST04E116C	BLUF05COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	96.30	8.41	5.08		
117	ST04E117C	BLUF06COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	82.77	7.82	4.92		
118	ST04E118C	BLUF07COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	95.29	8.23	5.11		
119	ST04E119C	BLUF08COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	103.49	8.35	5.23		
120	ST04E120C	BLUF09COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	92.76	7.76	5.13		
121	ST04E121C	BLUF10COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	56.07	8.65	5.12		
122	ST04E122C	BLUF11COMU02	64°34.22'N/163°45.15'W	18-Jun-02	*U. aalge*	87.82	4.85	8.40		
123	ST04E123C	STGE01TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	95.99	8.50	5.10		
124	ST04E124C	STGE02TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	85.15	7.97	4.87		
125	ST04E125C	STGE03TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	93.58	8.85	5.02		
126	ST04E126C	STGE04TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	79.78	7.87	4.88		
127	ST04E127C	STGE05TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	97.34	8.35	5.10		
128	ST04E128C	STGE06TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	99.67	8.23	5.27		
129	ST04E129C	STGE07TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	104.57	8.41	5.35		
130	ST04E130C	STGE08TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	77.43	7.95	5.27		
131	ST04E131C	STGE09TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	87.97	7.77	4.98		
132	ST04E132C	STGE11TBMU02	56°36.1'N/169°30.2'W	2-Jul-02	*U. lomvia*	81.32	7.69	4.95		
133	ST04E133C	STLA01TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	87.04	8.85	4.85		
134	ST04E134C	STLA02TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	91.55	8.40	5.05		
135	ST04E135C	STLA03TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	113.70	8.62	5.43		
136	ST04E136C	STLA04TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	97.01	8.40	5.18		
137	ST04E137C	STLA05TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	101.90	8.44	5.27		
138	ST04E138C	STLA06TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	93.47	8.41	4.93		
139	ST04E139C	STLA08TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	91.38	8.48	5.10		
140	ST04E140C	STLA09TBMU02	56°59.1'N/135°42.2'W	6-Jul-02	*U. lomvia*	87.65	8.08	5.07		

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
141	ST04E141C	STGE01BLKI02	56°36.1'N/169°30.2'W	11-Jun-02	*R. tridactyla*	40.93	5.78	3.94		
142	ST04E142C	STGE02BLKI02	56°36.1'N/169°30.2'W	11-Jun-02	*R. tridactyla*	40.60	5.86	3.88		
143	ST04E143C	STGE03BLKI02A	56°36.1'N/169°30.2'W	11-Jun-02	*R. tridactyla*	90.17	5.39	4.42		
		STGE03BLKI02B					5.50	4.21		
144	ST04E144C	STGE04BLKI02A	56°36.1'N/169°30.2'W	11-Jun-02	*R. tridactyla*	89.35	5.68	4.02		
		STGE04BLKI02B					5.52	4.13		
145	ST04E145C	STGE05BLKI02A	56°36.1'N/169°30.2'W	11-Jun-02	*R. tridactyla*	78.90	5.54	4.17		
		STGE05BLKI02B					5.47	4.03		
146	ST04E146C	STGE06BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	83.85	5.68	4.02		
		STGE06BLKI02B					5.90	4.02		
147	ST04E147C	STGE07BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	98.15	5.72	4.21		
		STGE07BLKI02B					5.71	4.29		
148	ST04E148C	STGE08BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	50.06	6.20	4.27		
149	ST04E149C	STGE09BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	112.46	6.19	4.27		
		STGE09BLKI02B					6.40	4.40		
150	ST04E150C	STGE10BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	100.08	5.70	4.23		
		STGE10BLKI02B					6.04	4.43		
151	ST04E151C	STGE11BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	92.29	5.56	4.20		
		STGE11BLKI02B					5.74	4.09		
152	ST04E152C	STGE12BLKI02A	56°36.1'N/169°30.2'W	13-Jun-02	*R. tridactyla*	101.78	6.02	4.32		
		STGE12BLKI02B					5.82	4.20		
153	ST04E153C	BLUF01BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	42.97	5.60	4.01		
154	ST04E154C	BLUF02BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	45.66	5.43	4.20		
155	ST04E155C	BLUF04BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	41.57	5.79	4.02		
156	ST04E156C	BLUF05BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	46.61	5.85	4.16		
157	ST04E157C	BLUF06BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	46.20	5.69	4.12		
158	ST04E158C	BLUF07BLKI02	64°34.22'N/163°45.15'W	18-Jun-02	*R. tridactyla*	51.61	6.21	4.26		
159	ST04E159C	MIDD01BLKI02	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	39.90	5.57	3.98		
160	ST04E160C	MIDD02BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	77.58	5.39	4.05		
		MIDD02BLKI02B					5.15	4.01		
161	ST04E161C	MIDD03BLKI02B	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	43.06	5.57	4.04		
162	ST04E162C	MIDD04BLKI02B	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	53.26	6.03	4.28		
163	ST04E163C	MIDD05BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	42.33	5.40	4.13		
		MIDD05BLKI02B				39.14	5.41	4.11		
164	ST04E164C	MIDD06BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	86.92	5.35	4.06		
		MIDD06BLKI02B					5.47	4.24		
165	ST04E165C	MIDD07BLKI02B	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	38.67	5.44	3.96		

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
166	ST04E166C	MIDD08BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	43.69	5.58	4.12		
167	ST04E167C	MIDD09BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	93.54	5.60	4.12		
		MIDD09BLKI02B					5.60	4.20		
168	ST04E168C	MIDD10BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	39.47	5.30	4.06		
		MIDD10BLKI02B				35.69	4.91	3.94		
169	ST04E169C	MIDD11BLKI02A	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*		5.62	4.09		
		MIDD11BLKI02B				84.55	5.55	4.07		
170	ST04E170C	MIDD12BLKI02	59°26.1'N/146°19.4'W	5-Jun-02	*R. tridactyla*	44.91	5.78	4.08		
171	ST04E171C	SHBY01BLKI02	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	39.61	5.68	4.00		
172	ST04E172C	SHBY02BLKI02A	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	94.97	6.12	4.11		
		SHBY02BLKI02B					6.05	4.10		
173	ST04E173C	SHBY04BLKI02B	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	42.07	5.39	4.14		
174	ST04E174C	SHBY05BLKI02A	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	83.79	5.80	4.07		
		SHBY05BLKI02B					5.48	3.92		
175	ST04E175C	SHBY06BLKI02B	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	46.01	5.84	4.11		
176	ST04E176C	SHBY07BLKI02B	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	38.78	5.30	3.98		
177	ST04E177C	SHBY08BLKI02	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	46.86	5.73	4.14		
178	ST04E178C	SHBY10BLKI02	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	44.22	5.43	4.30		
179	ST04E179C	SHBY11BLKI02	61°7.54'N/146°35.02'W	14-Jun-02	*R. tridactyla*	47.55	5.66	4.19		
180	ST04E180C	CLIS01TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	82.72	7.70	5.09		
181	ST04E181C	CLIS02TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	85.57	8.18	4.92		
182	ST04E182C	CLIS03TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	88.62	7.88	5.19		
183	ST04E183C	CLIS04TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	95.64	8.19	5.20		
184	ST04E184C	CLIS06TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	89.76	7.92	5.01		
185	ST04E185C	CLIS07TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	90.29	8.08	5.07		
186	ST04E186C	CLIS08TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	78.91	7.22	5.00		
187	ST04E187C	CLIS09TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	101.42	8.47	5.26		
188	ST04E188C	CLIS12TBMU02	68°52.3'N/166°6.36'W	7-Jul-02	*U. lomvia*	84.92	7.71	5.02		
189	ST04E189C	STLW01COMU02	63°40.01'N/170°15.27'W	22-Jun-02	*U. aalge*	84.76	8.03	4.96		
190	ST04E190C	STLW02COMU02	63°40.01'N/170°15.27'W	22-Jun-02	*U. aalge*	89.20	7.98	5.19		
191	ST04E191C	STLW03COMU02	63°40.01'N/170°15.27'W	22-Jun-02	*U. aalge*	79.67	7.82	5.14		
192	ST04E192C	STLW02TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	99.35	7.98	5.22		
193	ST04E193C	STLW03TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	91.21	7.56	5.13		
194	ST04E194C	STLW06TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	88.31	8.27	5.11		
195	ST04E195C	STLW08TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	82.70	7.66	4.99		
196	ST04E196C	STLW09TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	100.09	8.37	5.21		

Sample #	Storage ID	Field ID	Location	Collection Date	Species	Content Mass (g)	Height (cm)	Width (cm)	Eggshell Thickness (mm)	Shell Mass (g)
197	ST04E197C	STLW10TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	88.90	8.05	5.12		
198	ST04E198C	STLW11TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	115.41	8.91	5.44		
199	ST04E199C	STLW12TBMU02	63°40.01'N/170°15.27'W	20-Jun-02	*U. lomvia*	99.27	8.14	5.26		
200	ST04E200C	CHBY02BLKI02	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	43.45	NM	NM		
201	ST04E201C	CHBY03BLKI02	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	49.78	5.83	4.20		
202	ST04E202C	CHBY04BLKI02	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	44.05	5.42	4.29		
203	ST04E203C	CHBY05BLKI02A	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	39.65	5.57	3.96		
204	ST04E204C	CHBY06BLKI02A	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	47.87	5.97	4.20		
205	ST04E205C	CHBY08BLKI02A CHBY08BLKI02B	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	95.90	5.58 5.31	4.01 4.09		
206	ST04E206C	CHBY11BLKI02B	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	46.60	6.01	4.03		
207	ST04E207C	CHBY12BLKI02A CHBY12BLKI02B	57°45.27'N/152°19.34'W	22-Jun-02	*R. tridactyla*	89.60	5.86 5.90	4.12 4.15		
208	ST04E208C	CTOM02COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	89.77	8.08	5.16		
209	ST04E209C	CTOM04COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	99.90	8.03	5.39		
210	ST04E210C	CTOM05COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	75.76	7.34	4.86		
211	ST04E211C	CTOM06COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	89.05	8.37	4.96		
212	ST04E212C	CTOM08COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	89.51	8.14	5.01		
213	ST04E213C	CTOM10COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	92.21	8.38	5.10		
214	ST04E214C	CTOM11COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	84.48	7.72	5.15		
215	ST04E215C	CTOM12COMU02	68°08.38'N/165°58.40'W	12-Jul-02	*U.* spp.	88.22	7.84	5.13		
216	ST04E216C	EAAM01COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	77.62	7.78	5.05		
217	ST04E217C	EAAM02COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	88.28	7.98	5.14		
218	ST04E218C	EAAM03COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	89.74	8.33	5.26		
219	ST04E219C	EAAM06COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	67.05	8.10	4.94		
220	ST04E220C	EAAM07COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	82.80	8.30	5.00		
221	ST04E221C	EAAM12COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	83.69	8.20	5.01		
222	ST04E222C	EAAM13COMU02	58°55.05'N/152°00.21'W	31-Jul-02	*U. aalge*	62.99	7.51	4.69		

APPENDIX B: CHLORINATED HYDROCARBON DATA

Murre species eggs from Little Diomede Island											
	Egg Number										
Compound	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean**	**SD**
%lipid	8.98	11.1	12.9	12.2	14.4	11.2	13.0	16.0	15.5	12.8	2.3
PCB 8	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.350	<0.100	<0.100	0.128	0.083
PCB 18	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 29	0.480	<0.100	0.449	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.181	0.16
PCB 31	0.362	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.129	0.087
PCB 28	5.74	2.09	5.41	4.39	5.08	3.00	3.22	3.98	3.50	4.05	1.2
PCB 45	1.81	0.170	0.590	0.330	0.750	0.190	0.440	0.150	0.890	0.591	0.53
PCB 52	1.23	0.589	0.853	0.400	0.130	<0.100	0.157	<0.100	1.71	0.585	0.58
PCB 49	<0.100	0.210	<0.100	0.130	<0.100	<0.100	<0.100	<0.100	<0.100	0.116	0.037
PCB 44	0.290	0.320	<0.100	0.210	0.260	<0.100	<0.100	<0.100	<0.100	0.176	0.094
PCB 74	3.05	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.428	0.98
PCB 63	<0.100	0.218	<0.100	0.289	0.665	<0.100	0.493	1.31	0.405	0.409	0.39
PCB 70+76	1.12	0.530	0.290	0.278	0.372	<0.100	0.197	<0.100	0.258	0.361	0.31
PCB 95	1.11	<0.100	<0.100	<0.100	0.110	<0.100	0.230	<0.100	0.490	0.271	0.34
PCB 66	7.19	2.38	5.62	5.11	4.44	3.72	4.03	4.22	4.58	4.59	1.3
PCB 56+60	4.53	2.97	4.19	4.96	6.82	4.24	4.95	4.54	5.63	4.76	1.1
PCB 92+84+89	0.700	0.430	0.360	0.300	0.400	<0.100	0.160	<0.100	0.120	0.297	0.20
PCB 101+90	<0.100	1.81	<0.100	0.550	1.01	1.74	1.01	<0.100	1.63	0.894	0.72
PCB 99	9.23	3.95	9.44	9.14	12.0	6.63	8.05	5.18	8.13	7.97	2.4
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	0.960	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.500	0.240	0.30
PCB 82	0.420	0.180	<0.100	0.180	0.220	<0.100	<0.100	<0.100	<0.100	0.167	0.11
PCB 151	17.9	5.50	4.38	0.449	7.52	3.84	2.96	2.30	9.97	6.09	5.3
PCB 107	2.12	0.600	0.660	0.520	0.500	<0.100	0.500	0.600	0.230	0.648	0.58
PCB 149	0.590	1.29	<0.100	<0.100	<0.100	<0.100	0.147	<0.100	0.860	0.376	0.44
PCB 118	12.7	6.19	10.7	11.5	13.4	8.20	9.63	9.05	9.67	10.1	2.2
PCB 146	6.20	2.73	4.86	4.53	4.94	3.06	3.95	3.21	3.65	4.13	1.1
PCB 132	<0.100	<0.100	<0.100	<0.100	0.149	0.188	<0.100	<0.100	0.245	0.131	0.053
PCB 153	17.6	13.1	17.3	21.0	27.3	12.7	15.9	9.14	16.9	16.8	5.2
PCB 105	3.96	2.43	3.55	3.13	3.62	2.33	2.36	2.95	2.56	2.99	0.61
PCB 138	8.47	6.53	9.56	10.6	13.6	4.71	6.38	4.24	7.21	7.92	3.0
PCB 163	4.65	2.97	3.81	3.84	4.14	2.30	3.56	4.08	3.21	3.62	0.70
PCB 158	0.437	0.281	0.311	0.311	0.404	<0.100	<0.100	<0.100	0.125	0.241	0.14
PCB 187	5.74	6.38	5.08	6.33	7.37	3.60	5.88	5.53	6.05	5.77	1.0
PCB 183	2.44	1.37	2.03	1.01	1.13	0.750	0.605	0.590	1.14	1.23	0.63
PCB 128	8.17	2.97	1.27	1.58	1.82	0.664	1.98	1.74	2.16	2.48	2.2
PCB 174	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 201	0.379	0.368	0.230	0.295	0.338	<0.100	<0.100	<0.100	<0.100	0.223	0.12
PCB 156+202+171	1.00	0.700	0.900	0.600	0.700	0.300	0.200	0.300	0.200	0.544	0.30
PCB 157	0.280	0.320	0.170	0.300	0.330	<0.100	<0.100	<0.100	<0.100	0.200	0.11
PCB 180	2.94	4.03	2.88	2.75	3.92	1.67	2.26	0.937	2.86	2.69	0.98
PCB 193	0.460	0.414	0.370	0.370	0.412	<0.100	<0.100	<0.100	<0.100	0.270	0.16
PCB 170	1.28	1.14	0.970	0.770	0.810	0.500	0.750	0.550	0.610	0.820	0.27
PCB 195	0.277	<0.100	0.150	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.125	0.059
PCB 194	0.470	0.470	0.360	0.130	<0.100	<0.100	<0.100	<0.100	<0.100	0.214	0.17
PCB 206	0.160	<0.100	0.180	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.116	0.031
PCB 209	<0.100	<0.100	0.161	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.107	0.020
ΣPCBs	135	76.6	97.1	96.3	125	64.3	80.4	64.6	95.5	92.8	25

Common murre eggs from St. George Island													
	Egg Number												
Compound	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Mean**	**SD**
%lipid	11.6	14.1	12.9	12.8	12.7	12.3	13.6	10.8	14.4	11.0	9.05	12.3	1.6
PCB 8	0.960	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.178	0.26
PCB 18	0.897	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.172	0.24
PCB 29	0.406	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.128	0.092
PCB 31	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 28	4.42	3.65	2.67	3.93	4.77	3.53	3.74	3.52	5.86	4.11	2.12	3.85	1.0
PCB 45	0.760	0.230	0.310	0.530	0.500	<0.100	0.170	0.150	0.480	0.870	<0.100	0.382	0.27
PCB 52	<0.100	<0.100	3.12	<0.100	<0.100	<0.100	<0.100	0.340	0.526	0.720	<0.100	0.491	0.90
PCB 49	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 44	<0.100	0.220	0.310	0.280	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.146	0.082
PCB 74	<0.100	<0.100	6.40	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.673	1.9
PCB 63	0.520	0.156	0.390	0.150	0.390	0.310	0.199	<0.100	1.05	0.816	0.179	0.387	0.30
PCB 70+76	0.180	0.309	0.212	0.398	0.720	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.220	0.19
PCB 95	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 66	5.06	3.91	2.63	4.07	5.51	4.23	4.55	4.09	6.33	4.38	1.75	4.23	1.3
PCB 56+60	3.88	3.94	3.48	4.63	4.48	4.92	4.99	4.40	6.97	6.33	2.23	4.57	1.3
PCB 92+84+89	0.200	0.290	1.55	0.330	0.250	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.293	0.43
PCB 101+90	<0.100	0.130	3.60	0.200	<0.100	<0.100	1.46	2.44	1.71	2.71	2.14	1.34	1.3
PCB 99	8.73	6.25	16.1	7.93	7.44	6.60	7.52	6.78	9.16	6.13	1.35	7.64	3.5
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 82	<0.100	0.180	0.300	0.250	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.139	0.072
PCB 151	5.03	3.41	16.0	8.35	3.27	3.12	5.18	3.35	7.47	4.40	<0.100	5.43	4.2
PCB 107	0.550	0.210	0.900	0.310	0.390	<0.100	<0.100	<0.100	0.170	<0.100	<0.100	0.275	0.25
PCB 149	<0.100	<0.100	12.9	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	1.26	3.9
PCB 118	11.1	7.59	6.47	8.33	8.77	8.36	9.11	8.73	10.7	8.83	4.40	8.40	1.8
PCB 146	5.07	3.04	4.39	3.44	3.78	3.33	3.18	3.50	4.03	3.18	1.23	3.47	0.96
PCB 132	<0.100	<0.100	1.01	<0.100	<0.100	<0.100	<0.100	0.193	0.207	<0.100	<0.100	0.201	0.27
PCB 153	19.9	14.1	43.6	18.0	13.7	12.9	14.4	14.1	16.1	14.8	3.90	16.9	9.7
PCB 105	3.40	2.12	2.32	2.00	2.88	2.29	2.40	2.39	3.15	2.21	1.32	2.41	0.57
PCB 138	10.6	6.59	25.8	8.67	7.83	4.86	5.60	5.40	6.48	5.71	1.68	8.11	6.3
PCB 163	4.04	2.05	6.20	2.47	2.97	2.37	2.42	2.50	3.11	2.48	1.56	2.92	1.3
PCB 158	0.325	<0.100	1.06	<0.100	0.255	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.222	0.29
PCB 187	5.98	4.48	15.9	5.24	4.12	3.84	3.86	4.09	5.22	4.62	2.23	5.42	3.6
PCB 183	2.54	0.630	3.94	0.600	1.74	0.690	0.580	0.750	0.910	0.680	0.148	1.20	1.1
PCB 128	1.54	0.644	6.49	1.05	1.14	0.586	0.754	0.794	1.18	1.02	<0.100	1.39	1.7
PCB 174	<0.100	<0.100	1.60	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.236	0.45
PCB 201	0.240	0.261	0.572	0.330	0.160	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.197	0.15
PCB 156+202+171	0.900	0.400	<0.100	0.300	0.600	0.200	<0.100	0.300	0.400	<0.100	<0.100	0.318	0.25
PCB 157	0.190	0.260	0.360	0.280	0.150	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.167	0.093
PCB 180	4.27	2.02	11.3	2.75	2.54	2.00	2.11	2.33	2.44	2.30	0.150	3.11	2.9
PCB 193	0.370	0.328	0.720	0.369	0.280	<0.100	<0.100	<0.100	0.120	<0.100	<0.100	0.244	0.20
PCB 170	1.14	0.410	3.45	0.460	0.730	0.540	0.490	0.600	0.641	0.466	0.144	0.825	0.90
PCB 195	0.260	<0.100	0.230	<0.100	0.140	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.130	0.058
PCB 194	0.370	<0.100	1.15	<0.100	0.250	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.234	0.32
PCB 206	0.140	<0.100	<0.100	<0.100	0.120	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.105	0.013
PCB 209	0.108	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.101	0.0024
ΣPCBs	104	67.8	207	85.6	79.9	64.7	72.7	70.7	94.4	76.8	26.5	86.4	45

	Thick-billed murre eggs from St. George Island								
				Egg Number					
Compound	**42 mean**	**43**	**44**	**45**	**46**	**47**	**48**	**Mean**	**SD**
% lipid	10.9	12.9	8.25	11.0	9.72	9.92	10.6	10.5	1.4
PCB 8	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 18	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 29	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 31	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 28	1.58	3.64	3.68	2.00	3.33	2.65	2.90	2.83	0.81
PCB 45	<0.100	0.744	0.380	<0.100	<0.100	<0.100	<0.100	0.232	0.25
PCB 52	<0.100	1.20	4.16	<0.100	0.658	0.528	0.569	1.05	1.4
PCB 49	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 44	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 74	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 63	<0.100	<0.100	0.245	<0.100	0.127	<0.100	<0.100	0.125	0.054
PCB 70+76	0.376	0.885	1.43	0.160	1.88	0.687	0.423	0.834	0.62
PCB 95	<0.100	<0.100	0.194	<0.100	0.301	<0.100	<0.100	0.142	0.078
PCB 66	2.04	3.51	4.04	2.10	3.97	3.42	2.53	3.09	0.85
PCB 56+60	2.68	5.74	9.84	3.35	9.38	4.42	4.02	5.63	2.9
PCB 92+84+89	<0.100	0.464	1.67	0.150	1.32	0.231	0.197	0.590	0.64
PCB 101+90	<0.100	0.787	2.69	<0.100	1.52	<0.100	<0.100	0.771	1.0
PCB 99	5.71	9.59	12.0	6.22	10.2	8.71	6.50	8.42	2.4
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 82	<0.100	0.137	0.893	0.122	0.910	0.313	0.283	0.394	0.36
PCB 151	4.06	11.6	13.2	8.49	7.08	9.86	3.22	8.22	3.7
PCB 107	<0.100	<0.100	0.703	<0.100	0.566	0.118	<0.100	0.255	0.26
PCB 149	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 118	7.88	11.2	12.8	8.18	11.3	11.2	12.2	10.7	1.9
PCB 146	2.61	3.97	4.74	2.88	3.89	4.05	4.12	3.75	0.75
PCB 132	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 153	12.1	18.6	20.1	13.3	16.6	18.7	12.1	15.9	3.4
PCB 105	2.64	3.43	3.71	2.58	2.47	3.23	4.10	3.17	0.63
PCB 138	7.02	8.92	9.48	7.20	8.61	8.79	7.29	8.19	0.99
PCB 163	1.70	2.76	3.11	1.99	2.90	2.91	4.20	2.80	0.81
PCB 158	0.342	0.551	0.978	0.849	1.18	0.786	0.896	0.797	0.28
PCB 187	2.56	3.71	4.01	2.82	3.99	3.73	5.16	3.71	0.85
PCB 183	0.850	1.36	1.24	0.970	1.12	1.10	1.11	1.11	0.17
PCB 128	0.185	0.570	0.664	0.217	0.769	0.548	1.13	0.583	0.33
PCB 174	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 201	1.72	1.73	1.79	1.60	1.73	1.68	1.90	1.74	0.093
PCB 156+202+171	0.212	0.529	0.393	0.266	0.251	0.321	1.08	0.436	0.30
PCB 157	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 180	2.32	3.40	3.74	2.62	3.09	3.51	2.08	2.97	0.64
PCB 193	<0.100	0.105	<0.100	<0.100	<0.100	0.102	0.118	0.104	0.0066
PCB 170	0.309	0.785	0.808	0.450	0.643	0.632	0.806	0.633	0.19
PCB 195	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 194	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 206	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 209	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
ΣPCBs	58.9	99.9	123	68.5	100	92.2	78.9	88.8	22

Common murre eggs from Bogoslof Island											
	Egg Number										
Compound	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**Mean**	**SD**
%lipid	8.74	13.0	10.2	9.12	12.5	11.0	11.5	9.91	11.7	10.9	1.5
PCB 8	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 18	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.119	0.102	0.0063
PCB 29	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 31	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 28	1.68	3.14	1.47	1.63	2.41	1.94	2.79	1.86	3.80	2.30	0.79
PCB 45	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.179	<0.100	0.109	0.026
PCB 52	<0.100	0.443	<0.100	<0.100	0.224	<0.100	0.396	0.157	<0.100	0.191	0.14
PCB 49	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 44	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 74	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 63	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 70+76	0.659	1.29	0.748	0.706	1.07	0.568	1.60	0.836	0.733	0.912	0.34
PCB 95	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 66	1.94	4.08	2.73	1.25	2.89	2.34	4.03	2.31	2.56	2.68	0.91
PCB 56+60	2.96	6.65	3.77	2.65	5.68	3.75	7.22	3.91	7.69	4.92	1.9
PCB 92+84+89	0.284	1.15	0.455	0.423	0.859	0.401	1.09	0.387	0.802	0.650	0.33
PCB 101+90	<0.100	2.00	0.503	0.208	1.58	0.695	2.46	0.335	0.530	0.935	0.86
PCB 99	6.02	8.56	4.99	1.37	6.99	3.61	8.56	7.74	8.99	6.31	2.6
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 82	<0.100	0.322	<0.100	<0.100	0.158	<0.100	<0.100	<0.100	<0.100	0.131	0.074
PCB 151	7.26	10.5	5.01	6.80	9.20	1.72	6.26	16.4	19.5	9.18	5.6
PCB 107	<0.100	0.151	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.106	0.017
PCB 149	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 118	7.11	9.97	6.22	4.00	8.03	6.36	10.3	9.22	11.9	8.12	2.5
PCB 146	2.84	4.15	2.28	1.73	3.31	2.49	4.18	4.42	4.96	3.37	1.1
PCB 132	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 153	14.4	17.5	10.9	4.55	13.7	7.37	18.3	21.3	22.2	14.5	6.0
PCB 105	1.94	2.88	1.92	2.22	2.33	1.99	2.91	2.40	4.17	2.53	0.72
PCB 138	6.85	7.38	5.86	3.07	6.29	4.88	7.55	8.32	8.13	6.48	1.7
PCB 163	2.06	2.75	1.35	2.59	2.08	2.48	2.96	3.14	3.28	2.52	0.61
PCB 158	0.411	0.421	0.323	0.304	0.377	0.361	0.464	0.607	0.722	0.443	0.14
PCB 187	3.33	4.05	2.51	3.70	3.23	3.82	4.30	4.85	4.37	3.80	0.70
PCB 183	0.440	0.835	0.276	0.648	0.603	0.361	0.784	0.893	0.955	0.644	0.24
PCB 128	0.227	0.352	<0.100	0.232	0.221	0.132	0.353	0.479	0.447	0.283	0.13
PCB 174	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 201	1.69	1.71	1.84	1.68	1.63	1.66	1.74	1.77	1.74	1.72	0.063
PCB 156+202+171	0.128	0.440	<0.100	0.272	0.315	0.180	0.475	0.401	0.842	0.350	0.23
PCB 157	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 180	2.67	3.07	2.06	1.17	2.54	1.41	3.28	4.08	3.71	2.67	0.99
PCB 193	<0.100	0.129	<0.100	<0.100	<0.100	<0.100	0.130	0.146	0.230	0.126	0.043
PCB 170	0.316	0.541	0.142	0.459	0.379	0.315	0.608	0.723	0.914	0.489	0.24
PCB 195	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 194	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.303	0.123	0.068
PCB 206	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 209	<0.100	<0.100	<0.100	0.141	<0.100	0.128	0.162	<0.100	0.187	0.124	0.033
ΣPCBs	65.2	94.4	55.4	41.8	76.1	49.0	92.9	96.9	114	76.2	25

Thick-billed murre eggs from Bogoslof Island												
	Egg Number											
Compound	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**Mean**	**SD**
%lipid	13.4	10.2	11.1	13.2	9.50	11.8	10.5	9.71	11.3	9.74	11.0	1.4
PCB 8	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 18	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 29	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 31	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 28	2.67	2.68	1.53	4.13	2.26	2.75	2.27	1.63	3.42	1.72	2.51	0.82
PCB 45	<0.100	2.05	<0.100	0.815	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.367	0.63
PCB 52	<0.100	0.208	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.659	0.167	0.18
PCB 49	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 44	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 74	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 63	<0.100	0.166	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.107	0.021
PCB 70+76	1.15	1.09	0.108	0.726	0.732	0.984	0.694	0.625	0.635	0.332	0.708	0.32
PCB 95	<0.100	1.26	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.473	0.253	0.37
PCB 66	3.34	3.44	1.89	4.50	2.64	4.13	2.53	2.00	4.62	2.66	3.18	0.99
PCB 56+60	5.88	6.41	2.89	7.41	5.02	6.97	4.17	3.03	6.24	3.52	5.15	1.7
PCB 92+84+89	0.497	0.727	0.117	0.500	0.481	0.807	0.350	0.338	0.444	0.327	0.459	0.20
PCB 101+90	0.338	2.32	<0.100	0.566	0.725	1.45	<0.100	<0.100	0.293	<0.100	0.609	0.73
PCB 99	9.99	11.8	4.99	12.1	5.09	9.41	5.98	5.36	9.45	3.98	7.82	3.0
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 82	<0.100	0.273	<0.100	<0.100	<0.100	0.200	<0.100	<0.100	<0.100	0.244	0.142	0.069
PCB 151	15.8	17.9	7.14	18.9	3.30	8.02	6.78	7.58	10.2	14.3	11.0	5.3
PCB 107	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.153	0.105	0.017
PCB 149	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 118	13.2	13.7	7.53	15.7	9.97	13.7	8.60	7.10	13.5	8.02	11.1	3.2
PCB 146	4.87	4.92	2.91	5.86	3.55	5.00	3.14	2.62	5.15	2.95	4.10	1.2
PCB 132	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 153	23.1	24.6	12.3	25.2	10.0	16.2	13.1	12.2	21.2	9.34	16.7	6.2
PCB 105	3.81	3.86	2.20	4.52	3.03	3.99	2.61	2.10	4.09	2.42	3.26	0.89
PCB 138	10.2	11.2	6.09	10.8	6.03	8.59	6.64	6.45	8.88	5.19	8.01	2.2
PCB 163	3.61	3.67	1.77	4.39	3.72	5.04	2.05	1.76	3.69	1.57	3.13	1.2
PCB 158	0.574	0.718	0.402	1.27	0.428	1.10	0.350	0.360	0.807	0.366	0.638	0.33
PCB 187	4.74	4.93	2.87	5.26	4.96	6.29	2.96	2.70	4.71	2.28	4.17	1.3
PCB 183	1.39	1.39	0.702	1.25	0.526	0.994	0.602	0.384	1.11	0.447	0.880	0.39
PCB 128	0.734	1.07	0.179	0.700	0.368	0.705	0.222	0.202	0.505	<0.100	0.479	0.32
PCB 174	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 201	1.83	1.83	1.78	1.76	1.81	1.83	1.64	1.76	1.63	1.85	1.77	0.079
PCB 156+202+171	0.659	0.561	0.341	0.943	0.488	0.750	0.409	0.116	0.899	0.284	0.545	0.27
PCB 157	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 180	4.36	4.78	2.43	4.13	1.78	2.63	2.36	2.19	3.51	1.56	2.97	1.1
PCB 193	0.141	0.114	0.137	0.177	<0.100	0.152	<0.100	<0.100	0.177	<0.100	0.130	0.031
PCB 170	1.00	1.08	0.227	1.09	0.636	1.09	0.380	0.157	0.929	0.164	0.675	0.41
PCB 195	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 194	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.132	<0.100	0.103	0.010
PCB 206	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 209	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.106	<0.100	0.101	0.0019
ΣPCBs	114	129	60.5	133	67.5	103	67.8	60.7	106	64.8	90.6	29

Common murre eggs from East Amatuli Island													
	Egg Number												
Compound	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**Mean**	**SD**
%lipid	7.56	8.22	9.27	6.94	7.73	9.45	9.56	11.9	9.61	10.4	8.01	8.97	1.4
PCB 8	0.786	0.672	0.667	0.645	1.00	0.744	0.684	0.773	0.581	0.573	0.664	0.708	0.12
PCB 18	<0.100	<0.100	<0.100	0.145	0.118	<0.100	<0.100	0.125	<0.100	<0.100	<0.100	0.108	0.015
PCB 29	1.08	1.04	1.03	1.07	1.26	1.11	1.05	1.16	1.11	1.06	1.22	1.11	0.075
PCB 31	1.23	0.991	1.07	1.57	1.42	1.06	1.03	1.08	1.08	0.980	1.16	1.15	0.19
PCB 28	2.32	2.45	3.20	2.63	1.56	2.32	2.77	2.53	2.62	1.99	2.33	2.43	0.42
PCB 45	0.982	0.652	0.863	2.00	1.35	0.880	0.741	0.878	1.01	1.50	0.945	1.07	0.39
PCB 52	0.624	<0.100	0.220	0.789	3.59	<0.100	<0.100	<0.100	<0.100	<0.100	0.311	0.558	1.0
PCB 49	<0.100	<0.100	0.167	<0.100	0.172	<0.100	<0.100	<0.100	<0.100	<0.100	0.140	0.116	0.029
PCB 44	0.833	1.21	0.663	1.14	1.14	0.844	1.11	1.28	0.935	1.55	1.05	1.07	0.24
PCB 74	1.82	1.77	1.73	3.87	1.76	1.67	1.62	1.69	1.98	2.03	1.82	1.98	0.64
PCB 63	1.19	1.24	1.26	1.39	1.13	1.18	1.15	1.10	1.22	1.26	1.06	1.20	0.091
PCB 70+76	0.193	<0.100	0.115	0.758	<0.100	<0.100	<0.100	<0.100	0.145	0.146	<0.100	0.178	0.19
PCB 95	<0.100	<0.100	<0.100	1.18	<0.100	<0.100	<0.100	<0.100	0.233	<0.100	<0.100	0.210	0.32
PCB 66	3.50	2.34	4.73	4.62	2.39	4.08	4.55	2.26	3.18	3.62	3.05	3.48	0.93
PCB 56+60	2.16	1.93	4.01	2.93	0.761	3.19	2.93	1.48	2.04	2.04	1.70	2.29	0.91
PCB 92+84+89	1.57	0.312	0.694	0.860	0.110	0.128	0.240	0.193	0.214	0.410	0.297	0.457	0.44
PCB 101+90	0.867	0.586	1.01	6.94	0.366	0.454	0.449	0.254	0.614	1.64	0.479	1.24	1.9
PCB 99	7.13	8.14	9.94	12.2	3.31	9.02	8.92	3.99	8.10	5.35	7.79	7.63	2.6
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 82	0.688	<0.100	<0.100	0.952	0.659	<0.100	<0.100	<0.100	0.102	0.216	0.309	0.311	0.31
PCB 151	5.24	1.30	6.89	11.1	7.91	4.52	6.87	1.09	11.1	18.9	5.53	7.31	5.0
PCB 107	0.829	0.504	0.673	0.467	0.788	0.570	0.473	0.530	0.331	1.23	0.992	0.672	0.27
PCB 149	<0.100	<0.100	<0.100	1.33	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.212	0.37
PCB 118	7.25	6.91	12.2	10.2	4.92	11.4	11.0	6.93	8.17	14.9	8.48	9.31	2.9
PCB 146	2.27	2.48	5.54	4.63	1.97	5.61	4.77	2.89	3.77	8.41	3.75	4.19	1.9
PCB 132	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 153	14.0	9.44	25.7	24.5	7.63	24.1	21.5	11.4	19.0	24.5	17.9	18.2	6.6
PCB 105	2.58	2.64	4.31	3.06	2.31	4.25	3.86	2.82	2.56	7.27	2.81	3.50	1.4
PCB 138	7.21	5.68	11.7	15.8	2.61	11.2	10.1	5.33	9.12	5.41	8.77	8.45	3.7
PCB 163	2.07	3.07	4.19	3.06	1.92	4.21	3.32	3.09	2.70	11.2	2.62	3.77	2.6
PCB 158	0.234	<0.100	0.113	0.466	<0.100	<0.100	<0.100	<0.100	<0.100	1.04	<0.100	0.232	0.29
PCB 187	3.00	4.38	6.20	5.31	3.13	6.32	5.53	16.2	5.58	16.0	4.10	6.89	4.7
PCB 183	1.64	1.57	2.36	2.38	1.70	2.62	2.30	1.71	1.99	4.21	1.94	2.22	0.75
PCB 128	0.780	0.850	1.05	4.99	1.15	1.06	0.990	0.860	1.02	4.02	1.05	1.62	1.4
PCB 174	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.135	<0.100	<0.100	<0.100	0.103	0.011
PCB 201	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 156+202+171	<0.100	<0.100	0.293	<0.100	<0.100	0.371	0.131	<0.100	<0.100	1.25	<0.100	0.250	0.34
PCB 157	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 180	1.40	1.11	5.79	4.76	1.15	5.23	3.90	1.40	3.77	7.15	3.12	3.53	2.1
PCB 193	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 170	0.385	0.428	1.59	0.760	0.481	1.62	1.13	0.549	0.806	4.92	0.615	1.21	1.3
PCB 195	0.471	0.399	0.559	0.583	0.446	0.606	0.524	0.553	0.553	0.809	0.555	0.551	0.11
PCB 194	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.218	<0.100	0.111	0.036
PCB 206	<0.100	<0.100	0.227	<0.100	<0.100	0.133	<0.100	0.184	<0.100	0.591	<0.100	0.167	0.15
PCB 209	0.149	0.140	0.521	0.156	0.157	0.451	0.397	0.285	0.277	0.692	0.168	0.308	0.18
ΣPCBs	76.5	64.2	121	139	60.4	111	104	74.7	95.9	157	86.7	99.1	31

Common murre eggs from St. Lazaria Island												
	Egg Number											
Compound	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**Mean**	**SD**
%lipid	13.3	12.1	12.4	13.0	11.7	11.5	11.8	11.8	14.1	11.6	12.3	0.87
PCB 8	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 18	<0.100	<0.100	0.169	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.107	0.022
PCB 29	<0.100	<0.100	0.368	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.127	0.085
PCB 31	0.141	<0.100	0.141	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.108	0.017
PCB 28	3.15	1.30	4.73	2.10	2.95	3.44	2.95	4.19	2.15	2.57	2.95	1.0
PCB 45	1.59	<0.100	0.800	<0.100	0.600	<0.100	<0.100	<0.100	0.160	0.130	0.378	0.49
PCB 52	0.611	<0.100	0.300	<0.100	<0.100	<0.100	<0.100	<0.100	0.267	<0.100	0.188	0.17
PCB 49	0.620	0.103	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.152	0.16
PCB 44	0.400	0.250	0.300	<0.100	<0.100	<0.100	0.270	<0.100	<0.100	<0.100	0.182	0.11
PCB 74	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 63	0.828	<0.100	0.778	0.126	0.551	0.330	0.167	0.357	<0.100	0.170	0.351	0.28
PCB 70+76	0.804	0.208	0.284	0.325	<0.100	<0.100	0.326	<0.100	0.130	<0.100	0.248	0.22
PCB 95	0.842	<0.100	0.253	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.190	0.23
PCB 66	7.94	2.49	10.9	4.62	6.53	9.50	5.87	8.05	4.66	5.28	6.58	2.5
PCB 56+60	9.44	2.78	14.2	5.40	7.12	11.0	7.39	10.0	6.37	8.24	8.19	3.2
PCB 92+84+89	0.500	0.190	0.400	0.300	<0.100	<0.100	0.300	<0.100	<0.100	<0.100	0.219	0.15
PCB 101+90	8.50	<0.100	<0.100	0.920	2.50	<0.100	1.50	0.200	1.88	1.53	1.73	2.5
PCB 99	23.7	4.77	22.8	11.0	13.1	20.6	15.4	16.7	10.4	12.4	15.1	6.0
PCB 87	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
PCB 110	0.500	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.140	0.13
PCB 82	0.560	0.240	<0.100	0.200	<0.100	<0.100	0.210	<0.100	<0.100	<0.100	0.181	0.14
PCB 151	10.4	1.47	7.91	6.31	5.54	7.84	8.23	7.59	7.84	6.82	7.00	2.3
PCB 107	5.10	0.260	2.80	0.500	1.20	1.40	1.20	1.60	0.500	0.700	1.53	1.5
PCB 149	3.97	<0.100	0.570	0.150	<0.100	<0.100	0.330	<0.100	0.130	<0.100	0.565	1.2
PCB 118	28.7	7.65	35.4	18.0	23.3	33.3	22.0	26.1	15.6	18.3	22.8	8.4
PCB 146	15.0	3.97	19.8	9.88	14.9	18.7	12.4	14.3	7.36	9.83	12.6	4.9
PCB 132	0.610	<0.100	<0.100	<0.100	1.67	2.48	<0.100	1.34	0.280	0.290	0.707	0.84
PCB 153	85.1	16.3	71.9	45.5	48.9	64.6	64.7	53.3	31.1	39.6	52.1	20
PCB 105	7.88	2.40	12.2	5.31	8.04	11.1	6.11	8.28	4.46	5.42	7.12	3.0
PCB 138	44.0	7.73	43.0	21.5	16.9	23.5	32.1	20.3	12.2	14.7	23.6	12
PCB 163	13.4	2.70	17.5	7.79	11.5	14.6	11.1	11.9	6.00	8.15	10.5	4.4
PCB 158	3.23	<0.100	2.15	0.730	0.520	1.18	1.41	0.944	0.500	0.709	1.15	0.93
PCB 187	29.9	4.75	27.4	15.0	19.3	23.4	20.9	19.5	10.4	13.4	18.4	7.7
PCB 183	9.26	1.39	6.61	3.62	6.84	6.58	5.42	5.68	2.40	3.38	5.12	2.4
PCB 128	19.0	0.709	6.64	2.88	2.88	4.94	3.91	4.07	3.11	3.11	5.12	5.1
PCB 174	0.400	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.130	0.095
PCB 201	0.925	0.287	1.00	0.551	0.312	0.257	0.651	0.272	<0.100	0.170	0.453	0.32
PCB 156+202+171	3.00	1.00	5.00	2.00	4.00	5.00	2.00	3.00	1.00	2.00	2.80	1.5
PCB 157	0.680	0.290	1.36	0.510	0.350	0.600	0.520	0.270	0.170	0.200	0.495	0.35
PCB 180	34.1	4.71	26.9	14.9	21.0	19.9	23.5	22.8	8.97	15.4	19.2	8.6
PCB 193	1.41	0.541	2.97	1.05	1.06	1.13	1.31	0.825	0.350	0.567	1.12	0.74
PCB 170	8.60	1.35	9.54	4.19	7.63	7.63	7.39	6.90	2.89	4.33	6.05	2.7
PCB 195	1.49	0.220	2.15	1.00	2.29	2.25	1.45	1.73	0.280	0.740	1.36	0.78
PCB 194	4.15	0.911	5.70	2.93	6.42	5.89	4.17	4.35	1.22	2.38	3.81	1.9
PCB 206	0.150	<0.100	2.06	0.130	2.09	2.58	0.150	1.70	0.110	0.480	0.955	1.0
PCB 209	0.865	<0.100	1.27	0.763	1.16	1.43	0.756	0.824	<0.100	0.127	0.740	0.49
ΣPCBs	391	71.0	368	190	241	305	266	257	143	181	241	99

Murre species eggs from Little Diomede Island											
	Egg Number										
Compound	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean**	**SD**
%lipid	8.98	11.1	12.9	12.2	14.4	11.2	13.0	16.0	15.5	12.8	2.3
HCB	94.9	64.8	101	91.2	123	66.3	73.2	87.0	68.0	85.5	19
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	17.7	11.30	10.5	12.9	16.4	8.02	10.6	14.5	15.2	13.5	2.6
2,4'-DDE	0.233	0.286	<0.100	0.172	0.300	<0.100	0.104	<0.100	<0.100	0.166	0.085
4,4'-DDE	89.3	62.4	69.1	78.0	87.3	62.8	58.0	66.3	59.9	70.3	12
2,4'-DDT	<0.100	0.827	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.181	0.24
mirex	4.87	2.47	2.19	3.36	4.16	1.27	2.18	1.89	2.04	2.71	1.2
α-HCH	2.02	0.962	1.43	1.70	0.861	0.760	0.856	0.803	1.51	1.21	0.46
β-HCH	17.8	14.3	9.45	30.4	39.6	17.7	28.7	23.9	29.4	23.5	9.5
γ-HCH	0.842	0.307	0.618	0.323	0.296	<0.100	<0.100	<0.100	0.122	0.312	0.26
heptachlor epoxide	4.90	2.75	2.07	4.97	6.41	2.00	5.82	6.40	6.39	4.63	1.9
trans -chlordane	<0.100	0.466	<0.100	0.243	0.172	<0.100	<0.100	<0.100	<0.100	0.165	0.12
cis -chlordane	<0.100	1.02	<0.100	0.442	0.370	<0.100	0.300	0.198	0.345	0.331	0.29
trans -nonachlor	1.14	2.56	<0.100	0.696	0.434	<0.100	0.718	0.538	0.390	0.742	0.75
dieldrin	5.59	4.64	3.21	3.79	5.52	2.41	4.72	5.17	11.3	5.15	2.5
2,4'-DDD	<0.100	0.350	<0.100	0.186	<0.100	<0.100	<0.100	<0.100	<0.100	0.137	0.085
4,4'-DDD	3.38	0.742	3.39	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.901	1.4
cis- nonachlor	5.04	2.23	0.672	0.784	1.69	0.369	0.427	0.199	1.23	1.40	1.5
4,4'-DDT	1.70	2.44	1.06	2.84	2.44	<0.100[1]	<0.100[1]	<0.100[1]	0.928[1]	1.28	1.2
total toxaphene	225	119	66.4	60.5	49.3	NA	NA	85.2	NA	101	66
tox. congener 26	12.9	5.27	19.3	1.31	7.40	NA	NA	1.47	NA	7.94	7.0
tox. congener 50	10.4	4.16	3.07	0.942	1.14	NA	NA	1.79	NA	3.58	3.5
tox. congener 62	1.11	2.11	0.455	0.328	0.362	NA	NA	0.482	NA	0.808	0.70

[1] Values obtained using GC-MS

Common murre eggs from St. George Island													
	Egg Number												
Compound	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**Mean**	**SD**
%lipid	11.6	14.1	12.9	12.8	12.7	12.3	13.6	10.8	14.4	11.0	9.05	12.3	1.6
HCB	75.7	83.6	86.3	86.1	81.2	82.7	95.2	69.3	123	79.3	58.7	83.7	16
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	10.1	12.3	16.4	13.4	9.01	9.30	10.1	8.63	14.7	9.87	6.42	11.7	3.8
2,4'-DDE	<0.100	0.199	0.439	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.166	<0.100	0.146	0.10
4,4'-DDE	72.2	71.6	129	65.5	58.8	76.3	70.5	68.5	93.1	63.0	40.0	73.5	22
2,4'-DDT	<0.100	<0.100	2.27	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.297	0.65
mirex	2.57	2.20	3.08	2.79	1.62	1.48	1.17	1.52	1.65	1.42	0.393	1.81	0.78
α-HCH	1.99	0.757	1.22	0.589	1.77	1.15	2.08	1.11	2.12	1.67	0.503	1.36	0.60
β-HCH	9.80	15.1	20.3	18.5	9.34	23.7	23.6	20.1	34.4	31.1	11.8	19.8	8.2
γ-HCH	0.927	0.295	0.407	0.324	0.865	0.127	0.189	<0.100	0.243	0.141	<0.100	0.338	0.29
heptachlor epoxide	2.59	2.30	5.30	4.28	1.74	1.87	2.49	1.71	3.57	4.22	1.70	2.89	1.3
trans -chlordane	<0.100	0.115	0.234	0.143	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.117	0.041
cis -chlordane	<0.100	0.268	1.41	0.310	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.149	0.258	0.39
trans -nonachlor	<0.100	0.288	13.9	0.366	<0.100	0.176	<0.100	<0.100	0.201	0.125	0.727	1.47	4.1
dieldrin	3.84	10.2	9.02	9.01	0.879	1.33	2.21	1.27	3.48	3.39	1.08	4.16	3.5
2,4'-DDD	<0.100	<0.100	0.484	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.135	0.12
4,4'-DDD	<0.100	<0.100	7.85	<0.100	3.16	<0.100	<0.100	<0.100	<0.100	<0.100	0.152	1.09	2.4
cis- nonachlor	0.606	0.619	2.93	1.29	0.321	0.120	0.213	0.163	0.328	0.479	0.102	0.652	0.83
4,4'-DDT	1.33	1.90	4.61	0.881	1.17	<0.100[1]	<0.100[1]	<0.100[1]	<0.100[1]	<0.100[1]	<0.100[1]	0.926	1.4
total toxaphene	89.1	50.8	133	78.0	56.2	NA	NA	NA	NA	106	NA	85.6	31
tox. congener 26	22.9	4.39	11.6	9.32	12.7	NA	NA	NA	NA	3.40	NA	10.7	7.1
tox. congener 50	3.71	0.749	5.77	1.23	1.43	NA	NA	NA	NA	0.811	NA	2.28	2.0
tox. congener 62	1.18	0.306	1.26	0.385	0.710	NA	NA	NA	NA	0.391	NA	0.705	0.42

[1] Values obtained using GC-MS

	Thick-billed murre eggs from St. George Island								
		Egg Number							
Compound	**42 mean**	**43**	**44**	**45**	**46**	**47**	**48**	**Mean**	**SD**
% lipid	10.9	12.9	8.25	11.0	9.48	9.92	10.8	10.5	1.4
HCB	35.1	67.1	57.7	45.7	57.0	54.3	50.4	52.5	10
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	4.10	8.03	8.69	5.95	7.12	8.23	7.93	7.15	1.6
2,4'-DDE	<0.100	0.467	1.46	<0.100	0.857	<0.100	<0.100	0.455	0.53
4,4'-DDE	81.5	110	99.6	82.4	77.6	96.8	114	94.6	14
2,4'-DDT	1.81	1.70	1.79	1.67	1.84	1.83	1.96	1.80	0.096
mirex	<0.100	0.573	0.813	0.205	0.685	0.837	0.636	0.550	0.29
α-HCH	1.55	2.61	2.72	1.88	1.84	0.214	1.69	1.79	0.83
γ-HCH	0.530	0.710	0.766	0.526	0.547	<0.100	0.539	0.531	0.21
heptachlor epoxide	<0.100	<0.100	0.709	<0.100	2.25	<0.100	0.697	0.579	0.79
trans -chlordane	0.295	0.366	0.389	0.253	0.341	<0.100	0.346	0.299	0.099
cis -chlordane	0.218	0.260	0.424	0.258	0.421	<0.100	0.256	0.277	0.11
trans -nonachlor	0.621	0.667	0.809	0.869	0.989	<0.100	0.547	0.657	0.29
dieldrin	1.29	2.23	3.74	0.570	4.37	0.289	3.72	2.32	1.7
2,4'-DDD	0.845	0.825	1.01	1.23	1.07	<0.100	0.905	0.855	0.36
4,4'-DDD	<0.100	<0.100	0.180	<0.100	0.105	<0.100	0.151	0.119	0.033
cis- nonachlor	0.271	0.643	1.43	0.507	1.49	<0.100	<0.100	0.649	0.59
4,4'-DDT	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	

Common murre eggs from Bogoslof Island											
	Egg Number										
Compound	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**Mean**	**SD**
%lipid	8.74	13.0	10.2	9.12	12.5	11.0	11.5	9.91	11.7	10.9	1.5
HCB	53.0	74.2	39.6	68.2	53.2	47.9	61.0	53.8	109	62.2	20
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	6.64	8.38	4.67	8.99	7.08	5.33	7.63	8.42	12.5	7.74	2.3
2,4'-DDE	<0.100	0.653	0.398	0.145	0.472	0.445	0.736	<0.100	0.339	0.376	0.23
4,4'-DDE	58.0	89.0	58.4	78.5	70.6	62.1	99.7	68.0	109	77.0	18
2,4'-DDT	1.83	1.79	1.97	1.76	1.73	1.80	1.82	1.92	1.35	1.77	0.18
mirex	0.393	0.649	<0.100	0.724	0.221	<0.100	0.990	1.19	0.497	0.540	0.38
α-HCH	2.26	3.47	2.16	1.22	1.42	2.00	2.66	2.53	4.06	2.42	0.91
γ-HCH	0.669	0.796	0.638	0.561	0.475	0.643	0.646	0.658	0.974	0.673	0.14
heptachlor epoxide	1.75	1.34	<0.100	1.20	<0.100	<0.100	0.279	3.58	<0.100	0.950	1.2
trans -chlordane	0.484	1.20	0.679	0.690	0.790	0.535	0.797	0.562	0.970	0.745	0.23
cis -chlordane	0.413	0.516	0.442	0.349	0.489	0.481	0.394	0.323	0.706	0.457	0.11
trans -nonachlor	0.961	1.16	1.30	1.21	1.10	3.46	0.988	0.869	1.54	1.40	0.80
dieldrin	2.29	2.63	1.95	2.37	2.30	1.51	2.10	3.33	2.07	2.28	0.50
2,4'-DDD	0.844	0.975	0.997	0.854	0.883	0.920	1.41	0.856	0.887	0.958	0.18
4,4'-DDD	<0.100	<0.100	<0.100	0.198	<0.100	0.264	0.384	<0.100	<0.100	0.161	0.10
cis- nonachlor	0.882	0.781	0.393	0.597	0.627	0.213	0.727	1.70	1.04	0.773	0.43
4,4'-DDT	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	

Common murre eggs from East Amatuli Island													
	Egg Number												
Compound	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**Mean**	**SD**
%lipid	7.56	8.22	9.27	6.94	7.73	9.45	9.56	11.9	9.61	10.4	7.60	8.97	1.4
HCB	35.7	55.7	44.1	35.6	40.4	32.4	38.5	60.4	50.9	33.2	37.6	42.2	9.5
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	4.05	11.6	7.40	9.23	7.22	5.81	7.71	4.79	8.40	14.4	5.80	7.86	3.0
2,4'-DDE	0.663	<0.100	0.177	0.191	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.166	0.17
4,4'-DDE	85.5	102	209	115	69.7	185	189	84.9	82.5	330	105	142	79
2,4'-DDT	2.64	2.52	2.41	2.76	2.68	2.54	2.52	2.73	2.66	2.65	2.72	2.62	0.11
mirex	1.20	1.12	1.71	1.63	1.50	0.980	1.80	1.18	1.93	5.34	1.87	1.84	1.2
α-HCH	0.966	0.598	1.62	0.979	2.35	1.62	1.20	0.963	1.96	1.06	2.10	1.40	0.56
γ-HCH	1.27	<0.100	1.21	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	1.36	0.422	0.55
heptachlor epoxide	1.06	3.13	1.57	1.95	2.60	0.645	1.27	1.61	3.09	6.02	1.30	2.20	1.5
trans -chlordane	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
cis -chlordane	<0.100	<0.100	<0.100	<0.100	0.102	<0.100	<0.100	<0.100	<0.100	0.179	<0.100	0.107	0.024
trans -nonachlor	0.108	0.455	<0.100	0.814	0.127	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.200	0.23
dieldrin	0.937	3.01	1.44	1.26	2.69	1.23	1.18	0.642	3.13	4.17	1.27	1.91	1.1
2,4'-DDD	0.620	0.694	0.620	0.295	0.681	0.595	0.605	0.670	0.700	0.916	0.689	0.644	0.15
4,4'-DDD	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
cis- nonachlor	0.233	<0.100	0.540	2.98	1.10	0.703	0.856	0.512	1.35	6.47	0.620	1.41	1.9
4,4'-DDT	4.70	1.80	1.66	4.15	2.51	1.67	2.01	2.31	2.87	4.31	1.61	2.69	1.2

Common murre eggs from St. Lazaria Island												
	Egg Number											
Compound	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**Mean**	**SD**
%lipid	13.3	12.1	12.4	13.0	11.7	11.5	11.8	11.8	14.1	11.6	12.3	0.87
HCB	38.4	23.7	45.2	35.1	37.9	41.2	44.9	52.0	34.5	33.9	38.7	7.8
heptachlor	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	
oxychlordane	13.4	2.50	9.04	6.63	7.95	9.88	9.87	7.15	7.97	8.26	8.10	3.6
2,4'-DDE	0.258	<0.100	<0.100	0.191	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.125	0.055
4,4'-DDE	333	141	433	285	305	425	276	340	206	234	298	91
2,4'-DDT	0.147	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.105	0.015
mirex	7.49	1.03	3.43	3.06	2.13	2.91	4.21	3.31	1.63	1.92	3.11	1.8
α-HCH	2.01	0.818	1.47	1.38	0.663	0.985	1.19	0.875	2.21	0.377	1.20	0.58
β-HCH	29.8	7.13	9.30	16.6	13.5	20.2	21.0	19.2	21.7	17.8	17.6	6.5
γ-HCH	0.494	0.263	0.647	0.340	<0.100	<0.100	0.341	<0.100	0.191	<0.100	0.268	0.19
heptachlor epoxide	9.85	0.685	1.93	2.19	1.05	1.88	2.98	1.88	2.76	1.96	2.72	2.6
trans -chlordane	0.312	0.127	<0.100	0.167	<0.100	<0.100	0.302	<0.100	<0.100	<0.100	0.151	0.085
cis -chlordane	0.394	0.213	<0.100	0.255	<0.100	<0.100	0.294	<0.100	<0.100	<0.100	0.176	0.11
trans -nonachlor	2.49	0.217	<0.100	0.266	<0.100	<0.100	0.299	0.124	<0.100	<0.100	0.390	0.74
dieldrin	13.5	5.14	1.18	6.34	1.30	1.90	8.39	1.67	3.95	1.51	4.49	4.0
2,4'-DDD	0.255	0.198	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.125	0.055
4,4'-DDD	0.144	<0.100	2.81	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	0.375	0.86
cis- nonachlor	10.1	0.381	0.621	0.748	0.157	0.302	1.09	0.251	0.488	0.291	1.44	3.1
4,4'-DDT	6.54	3.77	2.36	0.181	<0.100[1]	<0.100[1]	1.97	<0.100[1]	<0.100[1]	<0.100[1]	1.51	2.2
total toxaphene	415	37.2	101	72.1	NA	NA	81.6	98.4	NA	NA	134	150
tox. congener 26	9.36	1.72	7.96	7.79	NA	NA	10.2	7.41	NA	NA	7.41	3.0
tox. congener 50	28.8	0.663	1.67	1.83	NA	NA	2.45	1.49	NA	NA	6.15	11
tox. congener 62	3.69	0.358	0.648	0.726	NA	NA	0.758	0.912	NA	NA	1.18	1.2

[1] Values obtained using GC-MS

APPENDIX C: MERCURY DATA

Table 1. Summary of Batch Measurements for Murre Egg Samples ST01E001C-ST01E041C.

Batch No.	Sample ID	Island Location	Measured [Hg] µg/g	Blank Correction	SRM 2976 Measurement Bias (µg/g)
1	ST01E004C	L. Diomede	0.0704	3.64%	
1	ST01E010C	St. Lazaria	0.2547	1.00%	
1	ST01E030C	St. George	0.0243	10.31%	SRM 2976 Certified Value
1	ST01E032C	E. Amatuli	0.3481	0.74%	[Hg] = 0.061 ± 0.0036 µg/g
1	**SRM 2976**	-	**0.0638**	6.87%	**0.0028**
2	ST01E005C-1	L. Diomede	0.0442	1.68%	
2	ST01E005C-2	L. Diomede	0.0448	1.61%	
2	ST01E005C-3	L. Diomede	0.0444	1.59%	SRM 2976 Certified Value
2	ST01E005C-4	L. Diomede	0.0435	2.65%	[Hg] = 0.061 ± 0.0036 µg/g
2	**SRM 2976**	-	**0.0610**	1.04%	**0.0000**
3	ST01E006C	L. Diomede	0.0395	0.69%	
3	ST01E016C	St. Lazaria	0.2108	0.13%	
3	ST01E021C	St. George	0.0280	0.95%	SRM 2976 Certified Value
3	ST01E034C	E. Amatuli	0.1711	0.17%	[Hg] = 0.061 ± 0.0036 µg/g
3	**SRM 2976**	-	**0.0626**	0.65%	**0.0016**
4	ST01E009C	L. Diomede	0.0673	0.50%	
4	ST01E014C	St. Lazaria	0.2662	0.11%	
4	ST01E027C	St. George	0.0410	0.72%	SRM 2976 Certified Value
4	ST01E031C	E. Amatuli	0.1948	0.16%	[Hg] = 0.061 ± 0.0036 µg/g
4	**SRM 2976**	-	**0.0622**	0.71%	**0.0012**
5	ST01E002C	L. Diomede	0.0770	0.30%	
5	ST01E013C	St. Lazaria	0.1312	0.18%	
5	ST01E020C	St. George	0.0326	0.70%	SRM 2976 Certified Value
5	ST01E033C	E. Amatuli	0.1585	0.15%	[Hg] = 0.061 ± 0.0036 µg/g
5	**SRM 2976**	-	**0.0627**	0.56%	**0.0017**
6	ST01E007C	L. Diomede	0.0652	0.71%	
6	ST01E018C	St. Lazaria	0.2172	0.21%	
6	ST01E022C	St. George	0.0234	1.95%	SRM 2976 Certified Value
6	ST01E035C	E. Amatuli	0.2194	0.20%	[Hg] = 0.061 ± 0.0036 µg/g
6	**SRM 2976**	-	**0.0638**	1.07%	**0.0028**

Table 1 (continued).

Batch No.	Sample ID	Island Location	Measured [Hg] µg/g	Blank Correction	SRM 2976 Measurement Bias (µg/g)
7	ST01E003C	L. Diomede	0.0505	1.71%	
7	ST01E017C	St. Lazaria	0.2513	0.34%	
7	ST01E024C	St. George	0.0179	4.79%	SRM 2976 Certified Value
7	ST01E036C	E. Amatuli	0.1678	0.49%	[Hg] = 0.061 ± 0.0036 µg/g
7	**SRM 2976**	-	0.0628	2.03%	**0.0018**
8	ST01E001C	L. Diomede	0.0558	1.71%	
8	ST01E019C	St. Lazaria	0.1575	0.26%	
8	ST01E025C	St. George	0.0134	3.13%	SRM 2976 Certified Value
8	ST01E037C	E. Amatuli	0.1883	0.22%	[Hg] = 0.061 ± 0.0036 µg/g
8	**SRM 2976**	-	0.0629	0.99%	**0.0019**
9	ST01E008C	L. Diomede	0.0105	2.63%	
9	ST01E015C	St. Lazaria	0.1891	0.14%	
9	ST01E028C	St. George	0.0162	1.71%	SRM 2976 Certified Value
9	ST01E038C	E. Amatuli	0.1141	0.24%	[Hg] = 0.061 ± 0.0036 µg/g
9	**SRM 2976**	-	0.0626	0.64%	**0.0016**
10	ST01E012C	St. Lazaria	0.2769	0.08%	
10	ST01E026C	St. George	0.0318	0.75%	
10	ST01E029C	St. George	0.0232	1.04%	SRM 2976 Certified Value
10	ST01E039C	E. Amatuli	0.0900	0.27%	[Hg] = 0.061 ± 0.0036 µg/g
10	**SRM 2976**	-	0.0594	0.60%	**-0.0016**
11	ST01E011C	St. Lazaria	0.1180	0.23%	
11	ST01E023C	St. George	0.0291	0.90%	
11	ST01E040C	E. Amatuli	0.2572	0.10%	SRM 2976 Certified Value
11	ST01E041C	E. Amatuli	0.2778	0.09%	[Hg] = 0.061 ± 0.0036 µg/g
11	**SRM 2976**	-	0.0628	0.63%	**0.0018**
12	ST01E032C-1	E. Amatuli	0.3549	0.09%	
12	ST01E032C-2	E. Amatuli	0.3600	0.09%	
12	ST01E032C-3	E. Amatuli	0.3573	0.08%	SRM 2976 Certified Value
12	ST01E032C-4	E. Amatuli	0.3555	0.09%	[Hg] = 0.061 ± 0.0036 µg/g
12	**SRM 2976**	-	-*	-*	-*

* SRM 2976 control not measured due to sample breech in microwave

Table 2. Summary of Results for Mercury (μg/g) in Murre Egg Samples ST01E001C-ST01E041C.

NBSB Sample ID	Recommended Value	Combined Type A Uncertainty	Combined Type B Uncertainty	Combined Uncertainty	Effective DF	Coverage Factor	Expanded Uncertainty
ST01E001C	**0.0558**	0.00081	0.00023	0.00084	6.16	2.45	**0.0021**
ST01E002C	**0.0770**	0.00098	0.00031	0.00103	3.96	3.18	**0.0033**
ST01E003C	**0.0505**	0.00066	0.00021	0.00069	4.28	2.78	**0.0019**
ST01E004C	**0.0704**	0.00089	0.00029	0.00094	3.94	3.18	**0.0030**
ST01E005C	**0.0442**	0.00047	0.00018	0.00050	16.94	2.12	**0.0011**
ST01E006C	**0.0395**	0.00052	0.00016	0.00055	4.56	2.78	**0.0015**
ST01E007C	**0.0652**	0.00084	0.00027	0.00088	4.06	2.78	**0.0024**
ST01E008C	**0.0105**	0.00022	0.00004	0.00023	13.07	2.16	**0.0005**
ST01E009C	**0.0673**	0.00087	0.00027	0.00091	4.10	2.78	**0.0025**
ST01E010C	**0.2547**	0.00165	0.00104	0.00195	6.18	2.45	**0.0048**
ST01E011C	**0.1180**	0.00082	0.00048	0.00095	7.36	2.36	**0.0022**
ST01E012C	**0.2769**	0.00188	0.00113	0.00219	6.93	2.45	**0.0054**
ST01E013C	**0.1312**	0.00087	0.00053	0.00102	6.58	2.45	**0.0025**
ST01E014C	**0.2662**	0.00174	0.00108	0.00205	6.28	2.45	**0.0050**
ST01E015C	**0.1891**	0.00125	0.00077	0.00146	6.42	2.45	**0.0036**
ST01E016C	**0.2108**	0.00138	0.00086	0.00163	6.34	2.45	**0.0040**
ST01E017C	**0.2513**	0.00164	0.00102	0.00193	6.28	2.45	**0.0047**
ST01E018C	**0.2172**	0.00142	0.00088	0.00167	6.32	2.45	**0.0041**
ST01E019C	**0.1575**	0.00104	0.00064	0.00122	6.51	2.45	**0.0030**
ST01E020C	**0.0326**	0.00044	0.00013	0.00046	4.99	2.78	**0.0013**
ST01E021C	**0.0280**	0.00039	0.00011	0.00041	5.35	2.57	**0.0010**
ST01E022C	**0.0234**	0.00034	0.00010	0.00036	6.39	2.45	**0.0009**
ST01E023C	**0.0291**	0.00041	0.00012	0.00042	5.49	2.57	**0.0011**
ST01E024C	**0.0179**	0.00029	0.00007	0.00029	8.21	2.31	**0.0007**
ST01E025C	**0.0134**	0.00025	0.00005	0.00025	11.02	2.20	**0.0006**
ST01E026C	**0.0318**	0.00044	0.00013	0.00046	5.29	2.57	**0.0012**
ST01E027C	**0.0410**	0.00054	0.00017	0.00057	4.49	2.78	**0.0016**
ST01E028C	**0.0162**	0.00027	0.00007	0.00028	9.21	2.26	**0.0006**
ST01E029C	**0.0232**	0.00034	0.00009	0.00036	6.68	2.45	**0.0009**
ST01E030C	**0.0243**	0.00034	0.00010	0.00036	5.63	2.57	**0.0009**
ST01E031C	**0.1948**	0.00128	0.00079	0.00151	6.37	2.45	**0.0037**
ST01E032C	**0.3569**	0.00139	0.00145	0.00201	23.80	2.07	**0.0042**
ST01E033C	**0.1585**	0.00105	0.00065	0.00123	6.45	2.45	**0.0030**
ST01E034C	**0.1711**	0.00113	0.00070	0.00133	6.43	2.45	**0.0032**
ST01E035C	**0.2194**	0.00144	0.00089	0.00169	6.30	2.45	**0.0041**
ST01E036C	**0.1678**	0.00110	0.00068	0.00130	6.40	2.45	**0.0032**
ST01E037C	**0.1883**	0.00124	0.00077	0.00146	6.43	2.45	**0.0036**
ST01E038C	**0.1141**	0.00076	0.00046	0.00089	6.76	2.45	**0.0022**
ST01E039C	**0.0900**	0.00063	0.00037	0.00073	7.74	2.36	**0.0017**
ST01E040C	**0.2572**	0.00175	0.00105	0.00204	6.96	2.45	**0.0050**
ST01E041C	**0.2778**	0.00189	0.00113	0.00220	6.94	2.45	**0.0054**

INSTRUCTIONS FOR COLLECTING THICK-BILLED MURRE, COMMON MURRE, AND BLACK-LEGGED KITTIWAKE EGGS FOR THE STAMP PROGRAM IN 2002

(A Supplement to the Published NISTIR 6735 Egg Collecting and Banking Protocol)

Each STAMP collecting kit consists of a plastic tote containing materials and protocols for collecting thick-billed murre *(Uria lomvia*), common murre *(U. aalge)*, and black-legged kittiwake *(Rissa tridactyla)* eggs for contaminant analyses and long-term banking of tissue samples for future research on pollutant levels. Please read the enclosed protocol (NIST Report NISTIR 6735) in addition to the supplementary information presented below before collecting and shipping eggs (particularly pages 15-17; for egg collections made in 2002, ignore all references to white plastic buckets with o-ring sealing lids in the NISTIR 6735 document —totes similar to the one you have just opened are now being used as shipping containers instead).

Some totes have been set up for collecting murre eggs and some for collecting kittiwake eggs (e.g., "Murre 1", "Kittiwake 1"). Murre egg totes contain the following items packaged in Ziploc bags: 16 Teflon bags, 35 quart-size Ziploc bags, and a supply of printed labels (extra Teflon and Ziploc bags have been included in case seams tear or closures fail). These totes also contain a large amount of shredded paper, 1 role of duct tape, 1 box of clean disposable gloves, 1 black Sharpie marker, 1 pencil, copies of the appropriate USFWS and ADF&G collecting permits, and 1 coat hanger or length of heavy wire (see below). Kittiwake egg totes are similar; however, because they have been set up to handle larger sample sizes, they contain 30 Teflon bags and 55 quart-size Ziploc bags (again, extra bags have been provided in case seams tear or closures fail).

Collecting Eggs: In 2002, eggs will be needed in the following numbers from the following colonies and species:

- Cape Lisburne: 12 thick-billed murre eggs and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- Cape Thompson: 12 common murre eggs, 12 thick-billed murre eggs, and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- Bluff: 12 common murre eggs and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- St. Lawrence Island: 12 common murre eggs, 12 thick-billed murre eggs, and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- St. George Island: 12 common murre eggs, 12 thick-billed murre eggs, and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- Chowiet Island: 12 common murre eggs and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- East Amatuli Island: 12 common murre eggs and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).

- Kodiak Island: 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- Middleton Island: 12 common murre eggs and 12 complete clutches of black-legged kittiwake eggs (only collect clutches containing 1-2 eggs; see below).
- Shoup Bay: 12 complete clutches of black-legged kittiwake egg (only collect clutches containing 1-2 eggs; see below).
- St. Larzaria Island: 12 thick-billed murre eggs.

Note: If you cannot obtain more than 10 common murre or 10 thick-billed murre eggs, or more than 10 clutches of kittiwake eggs, these are still adequate samples; however, if this is the case, please be particularly careful when packing the eggs to minimize their chances of breaking during shipping.

The eggs should be obtained within 14 days of being laid to avoid collecting relays, and in the case of kittiwakes, complete clutches should be taken to avoid the problem of only collecting second or third eggs laid, which typically contain smaller amounts of contaminants (all kittiwake eggs taken from the same nest must be clearly labeled as coming from that nest because they will be pooled prior to analysis—see below). Only collect complete kittiwake clutches that contain 1 or 2 eggs— please do not take 3-egg clutches. When you collect eggs, always try to use the gloves provided in the tote (i.e., put one of the gloves on before you pick up an egg—whenever possible, avoid touching the eggs with your bare hands, and if you do, please note this on the label made for that egg—see below). In some cases, eggs can be collected from hard to reach places by using the following technique. First, thread one of the small Ziploc bags onto an open-ended loop of heavy wire or coat hanger, duct tape it in place, and then close the loop by bending the two free ends of the wire together. Next, firmly duct tape the free ends of the wire to a long pole. The free ends of the wire should extend at least 6 inches beyond the loop to help support it when they are taped to the pole (taping the free ends of the wire to opposite sides of the pole may provide the best support). Don't make the loop too large, because the bigger you make it, the easier it will bend. The wire loop can be adjusted to help scoop up eggs (e.g., you can flatten one side). If necessary, you can strengthen the Ziploc bag by applying strips of duct tape to the outside. When you attempt to scoop up an egg with the wire loop on the pole, try moving the loop back and forth in a gentle "sawing" motion as you slide it under the egg. If you use the pole technique, remember to put on a glove before taking any eggs out of the bag.

Bagging the Eggs: Using a gloved hand, put the eggs in the enclosed Teflon bags (1 per bag) as soon as you can. Be careful when you do this, because the seams of the bags are not particularly strong. Close the bags by folding the open ends over several times while gently squeezing most of the air out, and then seal them shut with duct tape. When you seal the bags, apply tape along the full length of the folded ends and let the tape-ends overlap around the backs of the bags so that if the eggs break during shipment, the contents will not leak out. Next, put the Teflon-bagged eggs into the enclosed Ziploc bags (1 egg per bag) and gently squeeze most of the air out before sealing them. After preparing labels for the eggs (see below), put the doubled-bagged eggs and their respective labels into the remaining Ziploc bags (1 label and egg per bag; again, squeeze most of the air out before sealing them). Finally, write the appropriate colony names and egg identification numbers on the outsides of these last Ziploc bags with the enclosed Sharpie before packing them for shipping.

Labeling the Eggs: Complete one of the enclosed blank labels for each of the eggs that you have collected and put it in the last Ziploc bag used to protect that egg (i.e., the second Ziploc; see above). Print the following information on the labels in pencil (please print clearly and don't write too small).

Collected By: _____(your full name with middle initial)_____
Date and Time of Collection: _____(e.g., 28 June 02, 1500 hrs_____
Species: _____(write "thick-billed murre", etc.)_____
Sample Type: _____(write "egg")_____
Colony Name: _____(e.g., St. George, East Amatuli, etc.)_____
Site ID No./Name: _____(see below)_____
Egg ID No.: _____(see below)_____
Note: Use the same sample number (e.g., 01) and add "A" or "B" to the end of the Egg ID number (e.g., …2002A, …2002B), as needed, for eggs belonging to 2-egg kittiwake clutches taken from the same nest—see below.

Temporary Storage Notes: _____(how stored; e.g., "in tote in snow bank"_____

Other Notes: _____(e.g., "egg handled with bare ungloved hand")_____

Date and Time Shipped from Study Site: _____(e.g., 5 July 02, about 1200 hrs)_____
Note: Fill this part of the label out just before packing and shipping the eggs, or write the information on a piece of paper and put it on top of the eggs in the tote so that the recipient can complete it out later.

Use the Site ID No./Name to identify what general part of the colony the eggs came from. If no name or number exists, create one and record it in your notes (e.g., "West Arch", "Spire Rock"). In most cases, existing study plot numbers can be used at most colonies. For example, if the colony has been divided into population census plots and an egg came from one of them, you can use the plot number with CP in front of it for that egg (e.g., "CP10", if the egg came from population census plot 10). Sections of some colonies may have names that have been coined and used over the years. For example, some parts of the Cape Lisburne colony have been named "First Beach", "Tiny Beach", "East Kittiwake Beach", West Kittiwake Beach", and Grizzly Bear Beach" on plot photos and figures in past reports. If you collect eggs from one of these subsections of the colony, the existing name can be used (e.g., "Tiny Beach"). However, you do it, the point of the Site ID No./Name is to more closely identify the general locations in the colony where the eggs came from so that samples can be collected from these same general areas in future years.

Use the following 14 digit alphanumeric codes for the Egg ID Nos. The first 4 letters indicate the colony (CLIS = Cape Lisburne, CTOM = Cape Thompson, DIOM – Little Diomede Island, STLW = St. Lawrence Island, BLUF = Bluff, STGE = St. George Island, BOGO = Bogoslof Island, CHOW = Chowiet Island, KODK = Kodiak Island, EAAM = East Amatuli Island, MIDD = Middleton Island, SHBY = Shoup Bay, and STLA = St. Lazaria Island), the first 2 numbers indicate the sample number (01 through 12, if 12 eggs are obtained), the next 4 letters indicate the species (COMU = common murre, TBMU = thick-billed murre, and BLKI = black-legged kittiwake), and the last 4 numbers indicate the year (2002)—also see page 9 in NIST Report NISTIR 6735). Examples of the Egg ID Nos. that should be used for the 11 study colonies where pollutant levels in eggs will be monitored as part of the long-term STAMP program are listed below (see the first paragraph under "Collecting Eggs" for specific 2002 sample needs).

- For Cape Lisburne: "CLIS01TBMU2002.....….....CLIS12TBMU2002"

For Cape Lisburne: “CLIS01BLKI2002.....CLIS15BLKI2002”

- For Cape Thompson: “CTOM01COMU2002.....CTOM12COMU2002”
  For Cape Thompson: “CTOM01TBMU2002.....CTOM12TBMU2002”
  For Cape Thompson: “CTOM01BLKI2002.....CTOM15BLKI2002”
- For Little Diomede Island: “DIOM01COMU2002.....DIOM12COMU2002”
  For Little Diomede Island: “DIOM01TBMU2002.....DIOM12TBMU2002”
  For Little Diomede Island: “DIOM01BLKI2002.....DIOM15BLKI2002”
- For St. Lawrence Island: “STLW01COMU2002.....STLW12COMU2002”
  For St. Lawrence Island: “STLW01TBMU2002.....STLW12TBMU2002”
  For St. Lawrence Island: “STLW01BLKI2002.....STLW15BLKI2002”
- For Bluff: “BLUF01COMU2002.....BLUF12COMU2002”
  For Bluff: “BLUF01BLKI2002.....BLUF15BLKI2002”
- For St. George Island: “STGE01COMU2002.....STGE15COMU2002”
  For St. George Island: “STGE01TBMU2002.....STGE15TBMU2002”
  For St. George Island: “STGE01BLKI2002.....STGE15BLKI2002”
- For Bogoslof Island: “BOGO01COMU2002.....BOGO12COMU2002”
  For Bogoslof Island: “BOGO01TBMU2002.....BOGO12TBMU2002”
  For Bogoslof Island: “BOGO01BLKI2002.....BOGO15BLKI2002”
- For Chowiet Island: “CHOW01COMU2002.....CHOW12COMU2002”
  For Chowiet Island: “CHOW01BLKI2002.....CHOW15BLKI2002”
- For Kodiak Island: “KODK01BLKI2002..... KODK15BLKI2002”
- For East Amatuli Island: “EAAM01COMU2002.....EAAM12COMU2002”
  For East Amatuli Island: “EAAM01BLKI2002.....EAAM15BLKI2002”
- For Middleton Island: “MIDD01COMU2002.....MIDD12COMU2002”
  For Middleton Island: “MIDD01BLKI2002.....MIDD15BLKI2002”
- For Shoup Bay: “SHBY01BLKI2002.....SHBY15BLKI2002”
- For St. Lazaria Island: “STLA01COMU2002.....STLA12COMU2002”
  For St. Lazaria Island: “STLA01TBMU2002..... .....STLA12TBMU2002”

Also, when labeling eggs from kittiwake nests containing two eggs, use the same sample number for both eggs in the clutch and add A and B to the end of the respective Egg ID Nos. to clearly link the eggs to the same nest (e.g., eggs from a 2-egg clutch collected from the 5th nest sampled at Shoup Bay would be labeled SHBY05BLKI2002A and SHBY05BLKI2002B).

Storage in the Field: If you don’t have access to a refrigerator (the ideal temporary storage method), try to keep the eggs as cool as possible until you can ship them to Anchorage or send them to Homer (see below). For example, you can temporarily store the bagged samples in containers that have been buried in snow banks or placed under boards in holes in the ground (the totes don’t necessarily have to be used as temporary storage containers—plastic buckets and ammo cans with lids can also be used for this purpose). You can also partially submerge containers in cold water or keep them in the shade under a tarp. If you opt to put containers in cool streams or ponds, try to keep them in the shade and make sure that they are securely anchored to the shore to prevent them from floating away during periods of high water. If you put the containers in cool shady places and put light colored canvas tarps over them and keep the

tarps wet, the evaporating water will help keep the temperature down. If canvas tarps aren't available, wet moss or grass placed around the sides and over the top of containers will serve almost as well. Standard blue field tarps or other types of plastic coated tarps won't absorb water, but they can be used for shade.

Shipping: Try to ship the eggs to Anchorage or Homer via aircraft or boat as soon as possible after collecting them. Only ship eggs to Homer if you can't ship them directly to Geoff York in Anchorage (see below).

- Cape Lisburne field crews should ship their eggs to Anchorage on Bering Air and Alaska Airlines.
- Cape Thompson collectors should take their eggs to Point Hope when they return to the village by boat and then ship them to Anchorage on Bering Air and Alaska Airlines.
- Little Diomede Island field crews may be able to send their eggs to Wales on a local boat and then have them forwarded to Anchorage on Bering Air and Alaska Airlines. They also may be able to send them to Nome via helicopter, where they can be transferred to Alaska Airlines.
- St. Lawrence Island researchers should ship their eggs to Anchorage on Bering Air and Alaska Airlines.
- Bluff field crews should take their eggs to Nome on their chartered aircraft and then ship them to Anchorage on Alaska Airlines.
- St. George Island researchers should ship their eggs to Anchorage on Penn Air or Northern Air Cargo.
- Bogoslof Island personnel may be able to send their eggs to Homer via the R/V *Tiglax* (if so, have the vessel crew store the egg containers in cool, shady places).
- Chowiet Island field crews may be able to send their eggs to Homer on the R/V *Tiglax* (if so, have the vessel crew store the egg containers in cool, shady places).
- Kodiak Island researchers can bring their eggs to Kodiak and ship them to Anchorage on Alaska Airlines.
- East Amatuli Island field crews can bring their eggs to Homer on their contract vessel when they return from their first field trip.
- Middleton Island researchers can probably send their eggs to Anchorage on a chartered aircraft.
- Shoup Bay personnel can probably send their eggs to Valdez via boat and then have them shipped to Anchorage on ERA Airlines.
- St. Lazaria Island researchers can probably send their eggs to Sitka on a charter-boat and then have them shipped to Anchorage via Alaska Airlines.

Use the plastic totes for shipping containers (one tote per 12 murre eggs or per 12 clutches of kittiwake eggs). To prepare the bagged and labeled eggs for transport, wrap them individually in several layers of the shredded paper that came with the tote (if more packing material is needed, crumpled paper, clean rags, or even dry moss or grass can be used). Next, pad the bottom of the tote with several inches of shredded paper and then arrange several bags containing eggs firmly in it so that they can't shift around during shipping. Add another layer of shredded paper to the tote and arrange more bags containing eggs in it. Try to avoid stacking the bagged samples

directly on top of one another as you build up the layers of eggs. Also, push paper down between the bags and the sides of the tote, as needed, when building up the layers of eggs. Always use enough paper around the samples to make sure they can't shift around inside the tote during handling (you don't necessarily have to use large quantities of packing material to protect the eggs—the real secret is to use enough material to keep them spread apart and firmly in place during shipping). Also, don't put too much shredded paper or other packing material on top of the last layer of eggs—cramming in too much packing material just to get rid of it might put undue pressure on the eggs when the tote lid is closed (again, you just want to use enough material to keep the eggs firmly in place and protect them from direct contact with the hard inside surfaces of the container). After closing the fully packed tote, tape it securely shut by wrapping at least three layers of duct tape around it in at least two places in both directions (i.e., run the tape completely around the container several times in several places both length-wise and cross-wise). Next, apply the enclosed pre-addressed self-sticking shipping label and "FRAGILE" and "THIS SIDE UP" stickers to the duct tape bands sealing the tote (they will not stick as good if applied directly to the plastic surfaces of the container). Also, you should find the USFWS federal permit number preprinted on the address label—if it is not, write it on one of the bands of duct tape sealing the tote with the enclosed Sharpie. If the pre-addressed shipping label and "FRAGILE" and "THIS SIDE UP" stickers are missing, also print this information on the duct tape sealing the container (shipping addresses are listed below). Left over paper packing material can be burned or used for other shipping purposes.

Eggs collected at the Cape Lisburne, Cape Thompson, Little Diomede, St. Lawrence, Bluff, St. George, Kodiak, Middleton, Shoup, and St. Lazaria colonies should be sent to Geoff York in Anchorage (address the tote to Geoff York, Alaska Science Center, USGS Biological Research Division, 1011 East Tudor Road, Anchorage, Alaska 99503-6199; phone 907/786-3928). East Amatuli, Chowiet, and Bogoslof eggs should be delivered to Dave Roseneau or Vern Byrd at the Alaska Maritime National Wildlife Refuge office in Homer (address the tote to Dave Roseneau & Vern Byrd, USFWS, 2355 Kachemak Bay Drive, Homer, Alaska 99603-8021; phone 907/235-6546). Dave or Vern will forward them to Geoff. **REMEMBER, FOR THOSE OF YOU SHIPPING EGGS BY AIR TO GEOFF YORK IN ANCHORAGE—PLEASE CONTACT HIM AT (907) 786-3928 BEFORE SHIPPING THEM. If Geoff is not available, contact Dave Roseneau or Vern Byrd (phone 907/235-6546) or radio (KOD654 Homer on 5907.5 or 3215.0 upper side-band) Also, Geoff will pay transportation costs for eggs shipped via airlines (e.g., using his Fed-X and airline account numbers, or asking you to ship freight collect). This will save you the problem of having to pay at your end and getting reimbursed later.**