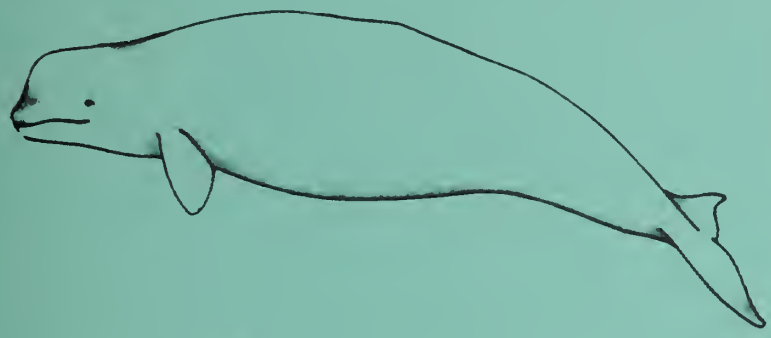
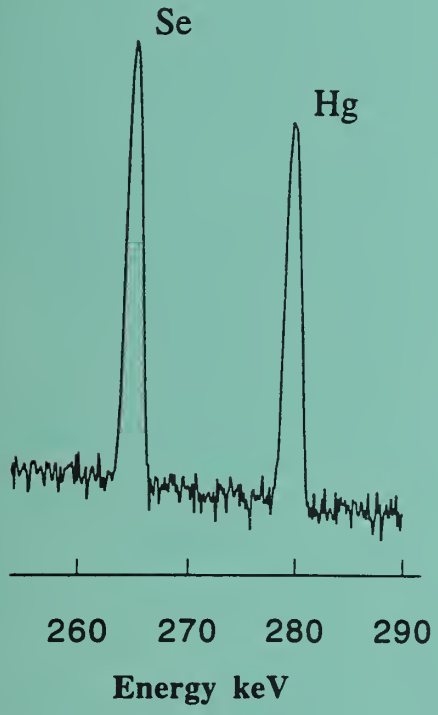
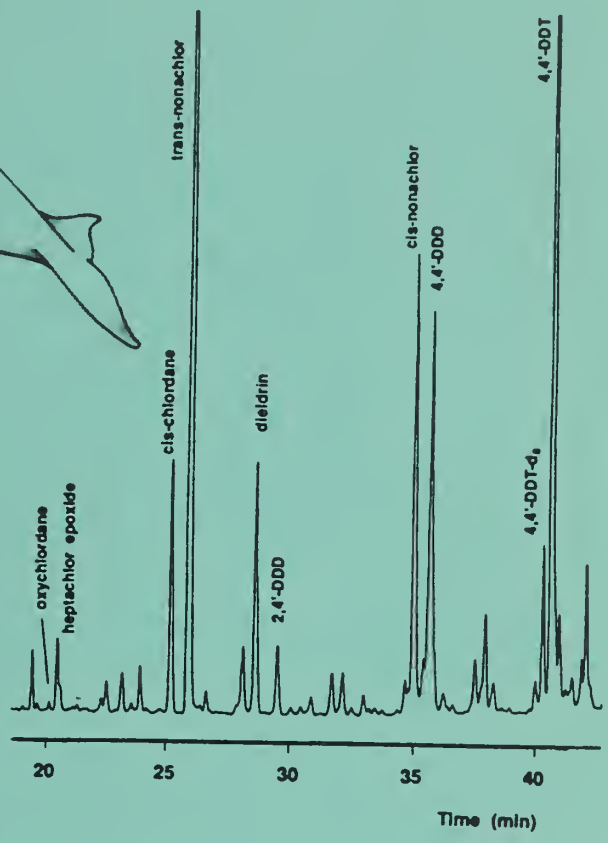
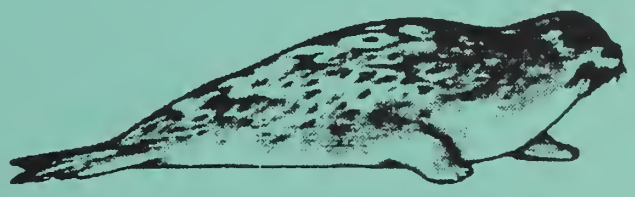
NISTIR 5620

Concentrations of Chlorinated Hydrocarbons, Heavy Metals and Other Elements in Tissues Banked by the Alaska Marine Mammal Tissue Archival Project









NIST

U.S. DEPARTMENT OF COMMERCE
TECHNOLOGY ADMINISTRATION
NATIONAL INSTITUTE OF STANDARDS
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March 1995

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PREFACE

This is the second report in the NIST Interagency Report Series that presents analytical data on samples collected and banked as part of the Alaska Marine Mammal Tissue Archival Project (AMMTAP). The first report, *Alaska Marine Mammal Tissue Archival Project: Sample Inventory and Results of Analyses of Selected Samples for Organic Compounds and Trace Elements, NISTIR-4731, 1992*, contained the specimen inventory as well as analytical results. The present report represents a departure from that format in that it contains only the analytical data. A separate report, *Alaska Marine Mammal Tissue Archival Project: Specimen Inventory, NISTR-5462, 1994* is devoted exclusively to the specimen inventory with all associated collection data and information.

The AMMTAP database on organic and inorganic materials in Alaska marine mammals is still relatively small. The interpretation of the data presented in this report should be considered as preliminary.

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TABLES

FIGURES

ACKNOWLEDGMENTS

The following individuals provided their time, effort, and expertise in the field collections and processing of tissue specimens included in this report:

Bowhead whales: Dr. L. Michael Philo, DVM, North Slope Borough Department of Wildlife Management (NSB/DWM), Barrow, Alaska; Dr. Kathy Burek, DVM, University of California-Davis; Dr. Peggy Barnes, DVM, Seattle, Washington; Dr. Dan Mulcahy, DVM, Anchorage, Alaska

Belukha whales: Robert Suydam, NSB/DWM, Barrow, Alaska; Geoff Carroll, Alaska Department of Fish and Game (ADF&G), Barrow Alaska; Rex Tuzroyluk, Point Hope, Alaska; Ron Morris, National Marine Fisheries Service (NMFS), Anchorage, Alaska; Matthew Eagleton, NMFS, Anchorage, Alaska; Brad Smith, NMFS, Anchorage, Alaska; Laurie E. Jarvela, Minerals Management Service (MMS), Anchorage, Alaska; Steve Treacy, MMS, Anchorage, Alaska; Dr. Cleveland Cowles, MMS, Anchorage, Alaska.

Pinnipeds: Matthew Iya (deceased) and Roy Ashenfelter, Kawerak, Inc.; Aaron (Luke) Jackson and Timothy Gologergen, Sr., Nome, Alaska; and from the Natural Resources Department, Kawerak, Inc. - Charlie Johnson, Director, Albert Johnson, Jake Olanna, and Art Nelson.

In addition to the above, the AMMTAP would like to express its appreciation to the following people for providing advice and support: Benjamin Nageak, former Director, Warren Matumeak, Director, Charlie Brower, Subsistence Research Specialist, Harry Brower, and Dr. Thomas Albert, Senior Scientist, NSB/DWM; Dr. Henry Huntington, Special Projects Coordinator, Alaska Eskimo Whaling Commission; Ron Morris, Supervisor, Western Alaska Field Office, NMFS; Jerry Imm, Director, Division of Environmental Quality, Alaska Department of Environmental Conservation, Juneau, Alaska. We would also like to thank Dr. R. Wagemann (DFO, Canada) for his careful review of the inorganic data and the corresponding discussion. Special acknowledgments are extended to Robert Suydam, NSB/DWM, who provided the relative age data on the belukha whales and to Mark Segstro, Department of Fisheries and Oceans (DFO), Winnipeg, who performed the analytical work provided by DFO. We also gratefully acknowledge Dr. Peter Ostapczuk from Nuclear Research Center, Jülich, Germany, who provided additional trace element data and Dr. Karlheinz Ballschmiter from the Department of Analytical and Environmental Chemistry, University of Ulm, Ulm, Germany, who provided organic analyses for quality assurance.

This study was funded by the MMS, U.S. Department of the Interior, through an Inter-Agency Agreement with the National Oceanic and Atmospheric Administration, as part of the MMS Environmental Studies Program.

DISCLAIMER

Certain commercial equipment or instruments are identified in this paper to specify adequately the experimental procedures. Such identification does not imply recommendation 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

Marine mammals are long-lived and most are considered to be top predators in the marine environment. Chemical analysis of their tissues can be particularly useful in determining whether bioaccumulation of contaminants and potential biological effects associated with human industrial activities are occurring in marine food webs. In the case of Alaska, the major industrial activities that might affect the marine environment consist of offshore petroleum and mineral extraction, marine transportation of petroleum and petroleum products, and the shore-based facilities associated with the petroleum and mining industries. Considering the large marine regions associated with Alaska, these industrial activities are relatively few and widely scattered. A more pervasive source of anthropogenic contaminants for Alaska and the Arctic may be industrial and agricultural activities occurring at lower latitudes. The general world-wide patterns of oceanic and atmospheric circulation, the semi-enclosed nature of the Arctic Ocean, and the climatically driven exchange between atmosphere, Arctic Ocean, polar ice cap, and land areas are conducive to transport of anthropogenic contaminants from the lower latitudes and their incorporation in the ecosystems of the Arctic. Important sources of anthropogenic contaminants for Arctic marine ecosystems include: atmospheric transport of semivolatile organic compounds (such as PCBs, chlordanes, and toxaphene) from industrial and agricultural areas and circumpolar runoffs, particularly from north-flowing rivers of Siberia (Barrie et al., 1992). These rivers discharge large volumes of freshwater containing suspended sediments and contaminants derived from the several large drainage basins.

In 1987, the Department of the Interior, Minerals Management Service (MMS) provided funds to NOAA's National Ocean Service (NOS), Ocean Assessments Division (OAD), Alaska Office to establish and conduct a program for the collection and long-term storage of tissues from Alaska marine mammals for future contaminants analysis. This program, the Alaska Marine Mammal Tissue Archival Project (AMMTAP), has been conducted as a collaborative effort between OAD and the National Institute of Standards and Technology (NIST). The collection and archival of such tissue samples over a period of several years will provide a resource that can be used to determine baseline contaminant levels against which future contaminant measures can be compared using improved analytical techniques to address questions that may arise in the future.

With the closure of the OAD Alaska Office in early 1992, principal management of the AMMTAP was transferred from NOS to the National Marine Fisheries Service (NMFS), Office of Protected Resources (OPR). The OPR manages the Marine Mammal Health and Stranding Response Program (MMHSRP). This program was established in 1992 by Public Law No. 102-587 to facilitate the collection and dissemination of data on the health of marine mammals and health trends in marine mammal populations in the wild, to correlate these trends with available data on physical, chemical, and biological environmental parameters, and to coordinate effective responses to unusual marine mammal mortalities. One component of the MMHSRP is the National Marine Mammal Tissue Bank (NMMTB). The NMMTB is similar to the AMMTAP, using basically the same collection and archival protocols and the same specimen bank facility (at NIST), but is directed toward the study of marine mammals of the contiguous 48 states of the USA.

The objectives of the AMMTAP are:

(1) to collect Alaska marine mammal tissues suitable for determining levels of organic and inorganic toxic substances;

(2) to transport, catalog, and curate the tissues in a condition suitable for long-term storage and eventual analysis; and

(3) to monitor the condition of the archived samples over time.

In 1987, NOAA and NIST conducted a pilot project to test the use of standard procedures for collecting tissues for long-term cryogenic archival and contaminant analysis from Alaska marine mammals. Based on the results of this pilot project, which involved the collection of liver, kidney, muscle and blubber tissues from northern fur seals taken in subsistence hunts on St. Paul Island, a formal program was established and subsequently described in Becker et al. (1991). This initial report presents the rationale for the tissue types and marine mammal species selected for routine collections, and describes the standard collection and archival protocols that are used by the AMMTAP.

The Alaska Marine Mammal Tissue Archive is maintained by NIST in the National Biomonitoring Specimen Bank (NBSB), Gaithersburg, Maryland. The NBSB has been in operation for about 15 years, providing environmental specimen banking for numerous agencies and conducting cooperative development activities with similar facilities in Europe and Canada. Samples are stored at the NBSB above liquid nitrogen, in nitrogen vapor (at -150 °C) to minimize sample degradation over time. The NBSB maintains an inventory of archived samples identified by type, date of collection, collection site, weight, identification numbers and other information provided by the collector. Additional information on archival procedures are provided in Becker et al. (1991), Becker et al. (1992), Wise and Zeisler (1984) and Wise et al. (1989). The current status of the NBSB has been recently reviewed by Wise et al. (1994).

From 1987 through 1994, the AMMTAP collected tissue samples from marine mammals of the Arctic Ocean, Bering Sea, and Gulf of Alaska, emphasizing species of subsistence value. The current inventory of AMMTAP samples maintained by the National Biomonitoring Specimen Bank, including the individual animal data recorded during field sampling, is presented in a separate report: *NISTIR-5462, Alaska Marine Mammal Tissue Archival Project: Specimen Inventory* (Koster et al., 1994). There are 329 duplicate samples of liver (n = 113), kidney (n = 92), blubber (n = 119), and muscle (n = 5) banked from 119 individual animals collected from nine species: bowhead whale, *Balaena mysticetus*; belukha whale, *Delphinapterus leucas*; ringed seal, *Phoca hispida*; spotted seal, *Phoca largha*; harbor seal, *Phoca vitulina*; bearded seal, *Erignathus barbatus*; northern fur seal, *Callorhinus ursinus*; Steller sea lion, *Eumatopias jubatus*; and Pacific walrus, *Odobenus rosmarus rosmarus*. Arrangements for routine collections of samples have been made with several institutions (Table 1). In some cases these collections have been intermittent activities, occurring once or twice over the five-year period, and in other cases they have been continuous.

To evaluate the stability of the archived tissues, the NIST monitors the concentrations of selected trace elements and organic compounds in 10 - 15 % of the tissue specimens. Aliquots of those specimens selected for monitoring are initially analyzed to establish the baseline levels. Re-analyses of aliquots of these tissues on a regular basis (every 5 - 10 years) will provide a measure of any change from the initial baseline concentrations. These analyses also provide some real-time measure of contaminant concentrations for monitoring purposes and provide a baseline for comparing contaminant levels using present analytical techniques with new or different methods in the future.

In addition to the analyses performed routinely at NIST, some collaborative analytical work with other research laboratories has been performed. For example, aliquots from all blubber samples collected from belukha whales were analyzed by Derek Muir, Department of Fisheries and Oceans (DFO) Winnipeg, Canada, for chlorinated hydrocarbons in order to expand the database on this species from eastern Canada through western Alaska. Aliquots of selected blubber samples were also analyzed by DFO, NIST and Karlheinz Ballschmiter of the University of Ulm, Germany, as part of an intercomparison exercise. Aliquots of liver samples have been analyzed by Peter Ostapczuk, Nuclear Research Center, Jülich, Germany, for elements not routinely measured by the INAA technique employed at NIST (e.g., lead and nickel) and for selected elements for comparison of analytical techniques (e.g., cadmium, cobalt, copper, and zinc).

Table 1. Locations of arrangements for routine sample collections for the AMMTAP

Cooperating Institution	Region/Area	Species	Status
NMFS, Alaska Region Juneau, AK and Marine Mammal Lab. Seattle, WA	Bering Sea Pribilof Islands	Northern Fur Seal	Intermittent
NMFS, Western Alaska Field Office, Anchorage, AK MMS, Anchorage, AK	Gulf of Alaska Cook Inlet	Belukha Whale	Ongoing
Marine Advisory Program Alaska Sea Grant Kodiak, AK	Gulf of Alaska Kodiak Island	Steller Sea Lion Harbor Seal	Planned Planned
NSB, Dept. of Wildlife Management, Barrow, AK	Arctic Ocean North Slope Area	Bowhead Whale Belukha Whale Ringed Seal Bearded Seal	Ongoing Ongoing Ongoing Intermittent
Kawerak, Inc. and Eskimo Walrus Commission Nome, AK	Bering Sea Norton Sound	Ringed Seal Bearded Seal Walrus	Ongoing Ongoing Ongoing
USFWS, Marine Mammals Management Office Anchorage, AK	Arctic Sea and Bering Sea	Walrus	Planned

Previous AMMTAP analytical results which have been presented in project reports (Becker et al., 1989, 1992) and journal papers (Becker et al., 1990; Schantz et al., 1993; Zeisler et al., 1993), have been restricted to comparisons of a very limited number of subsamples from northern fur seals, ringed seals and belukha whales with published literature values (Table 2). Additional analyses have now been completed for the belukha whales from Point Hope, Point Lay and Cook Inlet, bowhead whales from Barrow and pinnipeds from Norton Sound. The results of these analyses are presented in this report.

METHODS

Sample Collections

Samples of blubber and liver were collected from belukha whales taken in Alaska Native subsistence hunts at two villages on the Chukchi Sea coast of Alaska. Four animals were sampled at Point Hope in May 1989, and ten at Point Lay in July 1990. Blubber samples were taken from three belukha whales from Cook Inlet during subsistence hunts in 1994; these have not yet been analyzed. In addition, one liver sample was collected from a belukha whale that stranded in Cook Inlet, Gulf of Alaska, in October 1992. Samples of blubber and liver were collected from 11 bowhead whales taken at Barrow (Chukchi/Beaufort seas) in the 1992 subsistence hunt. Only three of the bowhead whale liver samples have been analyzed at this time. Samples of liver were collected from pinnipeds in Barrow in 1988 and in Norton Sound during 1989, 1991, and 1993. These include samples from fourteen ringed seals, one spotted seal, and one bearded seal. Samples were also collected from two bearded seals from Nome in spring of 1993.

Sampling was conducted using the standard AMMTAP protocols designed to preserve sample integrity and minimize sample contamination from handling (Becker et al., 1988, 1991). The sex of each animal was recorded and measurements were made of standard length and blubber thickness. Weights of pinnipeds were recorded and axillary girth was recorded for pinnipeds and bowhead whales. Fluke widths of the cetaceans were measured. Lower jaws with teeth were collected from the pinnipeds and belukha whales in order to determine the age of each animal. The ages of the belukha whales sampled at Point Hope and Point Lay were determined by Robert Suydam (North Slope Borough Department of Wildlife Management) based on the number of growth layer groups counted in a thin longitudinal section taken from the middle of the mandibular tooth (Sergeant, 1959; Brodie, 1969). Removal, cutting, and reading of the teeth have been described by Burns and Seaman (1986). Ages of the single belukha from Cook Inlet and the pinnipeds from Norton Sound have yet to be determined.

Additional specimens that were collected and analyzed as part of the NMMTB are described in this report for comparison with samples from the AMMTAP. Samples of pilot whale liver were collected on Cape Cod, Massachusetts, from five animals that stranded in December 1990, and from four that stranded in September 1991. In addition, kilogram amounts of liver tissue were taken from two animals stranded in December 1990. These tissues were homogenized and pooled to form a fresh frozen quality assurance (QA) material for use in interlaboratory comparisons (Wise et al., 1993). A complete description and inventory of the NMMTB will be published elsewhere.

Tissue Sample Preparation

Each liver and blubber sample to be analyzed [derived from "Subsample B" of each archived specimen - refer to AMMTAP protocols as described in Becker et al. (1991)] was homogenized

Table 2. Aliquots of AMMTAP tissue samples that have been analyzed. O = organic analysis; T= trace element analysis. Data previously reported in Becker et al. (1992), Schantz et al. (1993), or Zeisler et al. (1993) are indicated by an asterisk (*)

Species	Animal Number	Sample	Sample Number	Results	
N. fur seal	692-FRSL-004	liver	MM1L013	*O	*T
N. fur seal	692-FRSL-004	kidney	MM1K014	*O	*T
N. fur seal	692-FRSL-004	muscle	MM1M015	*O	*T
N. fur seal	692-FRSL-004	blubber	MM1B016	*O	
N. fur seal	692-FRSL-005	liver	MM1L017	*O	*T
N. fur seal	692-FRSL-005	kidney	MM1K018	*O	*T
N. fur seal	692-FRSL-005	muscle	MM1M019	*O	*T
N. fur seal	692-FRSL-005	blubber	MM1B020	*O	
Ringed seal	692-RGSL-004	liver	MM2L030	*O	*T
Ringed seal	692-RGSL-004	kidney	MM2K031	*O	*T
Ringed seal	692-RGSL-004	blubber	MM2B032	*O	
Ringed seal	692-RGSL-008	liver	MM2L042	*O	*T
Ringed seal	692-RGSL-008	kidney	MM2K043	*O	*T
Ringed seal	692-RGSL-008	blubber	MM2B044	*O	
Ringed seal	692-RGSL-011	liver	MM3L054	*O	*T
Ringed seal	692-RGSL-011	blubber	MM3B056	*O	
Ringed seal	692-RGSL-012	liver	MM3L057		T
Ringed seal	692-RGSL-013	liver	MM3L060	*O	*T
Ringed seal	692-RGSL-013	blubber	MM3B062	*O	
Ringed seal	692-RGSL-014	liver	MM3L063		T
Ringed seal	692-RGSL-015	liver	MM3L066		T
Ringed seal	692-RGSL-016	liver	MM5L155		T
Ringed seal	692-RGSL-017	liver	MM5L158		T
Ringed seal	692-RGSL-018	liver	MM5L161		T
Bearded seal	692-BDSL-001	liver	MM3L051		T
Spotted seal	692-SPSL-001	liver	MM5L164		T
Belukha whale	692-BLKA-001	liver	MM3L069		T
Belukha whale	692-BLKA-001	blubber	MM3B071	*O	
Belukha whale	692-BLKA-002	liver	MM3L072		*T
Belukha whale	692-BLKA-002	blubber	MM3B074	*O	
Belukha whale	692-BLKA-003	liver	MM3L075		*T
Belukha whale	692-BLKA-004	liver	MM3L077		*T
Belukha whale	692-BLKA-005	liver	MM4L125		T
Belukha whale	692-BLKA-005	blubber	MM4B127	O	
Belukha whale	692-BLKA-006	liver	MM4L128		T
Belukha whale	692-BLKA-006	blubber	MM4B130	O	
Belukha whale	692-BLKA-007	liver	MM4L131		*T
Belukha whale	692-BLKA-007	blubber	MM4B133	*O	
Belukha whale	692-BLKA-008	liver	MM4L134		T
Belukha whale	692-BLKA-008	blubber	MM4B136	O	
Belukha whale	692-BLKA-009	liver	MM4L137		T
Belukha whale	692-BLKA-009	blubber	MM4B139	O	
Belukha whale	692-BLKA-010	liver	MM4L140		T
Belukha whale	692-BLKA-010	blubber	MM4B142	O	

using a cryogenic procedure designed to reduce the likelihood of changes in sample composition due to thawing and re-freezing (Zeisler et al., 1983). The sample homogenate, a frozen powder, was then aliquoted into Teflon jars (10 mL and 90 mL) for analysis and for storage as the homogenate. A summary of specimens from the AMMTAP that have been homogenized for organic and inorganic analyses is provided in Table 2.

Chlorinated Hydrocarbon Analysis

Measurements for the determination of chlorinated hydrocarbons were performed in the Analytical Chemistry Division at NIST and at two other laboratories. Results from the analysis of four belukha whale blubber samples (BLKA-001 and 002 from Point Hope and BLKA-007 and 012 from Point Lay) have been reported previously (Becker et al., 1992 and Schantz et al. 1993). Two additional belukha whale blubber samples (BLKA-002 and BLKA-005) were analyzed at NIST. Subsamples of 12 belukha whale blubber specimens from the AMMTAP (BLKA-001 through 014) were provided to Derek Muir at the Department of Fisheries and Oceans, Winnipeg, Canada as part of a collaborative effort to compare contaminant data for belukha whales from both Alaska and Canada. Subsamples of four of the same belukha whale blubber specimens were also sent to Professor Karlheinz Ballschmiter at the Department of Analytical and Environmental Chemistry, University of Ulm in Ulm Germany. The analyses of subsamples of the same specimens at NIST, the University of Ulm, and the Department of Fisheries and Oceans provided a three way intercomparison exercise.

Methods--NIST

Four belukha whale blubber samples were analyzed at NIST using the methodology described in a previous report (Becker et al., 1992). Briefly, 2 - 3 g of the blubber homogenate were mixed with approximately 100 g of pre-extracted sodium sulfate. These mixtures were spiked with an internal standard solution containing perdeuterated 4,4'-DDT, PCB 103, and PCB 198 and Soxhlet extracted for 18 h using methylene chloride. The extracts were concentrated and about 1 mL was used for size exclusion chromatography (SEC). The SEC step was used to remove the majority of the lipid and biogenic material. Following the SEC step, normal-phase liquid chromatography (LC) on a semi-preparative-scale aminopropylsilane column was used to isolate two fractions containing: (1) the PCB congeners and lower polarity chlorinated pesticides and (2) the more polar chlorinated pesticides.

Extracts were analyzed by capillary gas chromatography with electron capture detection (GC-ECD) using a 60 m x 0.25 mm i.d. 5% phenylmethylpolysiloxane capillary column with helium carrier gas. PCB congeners and pesticides were quantified using a series of mixtures obtained from NIST. NIST SRM 1588 (Organics in Cod Liver Oil) was analyzed with each set of blubber samples as a control material.

The quality and comparability of the analytical data generated for the AMMTAP is assured by participation in the quality assurance component of the NMFS's Marine Mammal Health and Stranding Response Program. This Quality Assurance Program is described in Wise (1993) and Wise et al. (1993).

Methods--Department of Fisheries and Oceans

Analyses of blubber specimens were performed at the Department of Fisheries and Oceans (DFO) using methods described in Muir et al. (1988a, 1988b, 1990) and Stern et al. (1994). In summary, samples of blubber (2 - 5 g) were mixed with anhydrous sodium sulfate (heated 6 h at 600 °C prior to use) and extracted by ball-milling (30 min) with hexane. The extract was allowed

to stand for 4 h before being centrifuged. Internal standards of aldrin and octachloro-naphthalene (OCN) were added at the extraction step. Extractable lipid was determined gravimetrically using 1/10 of the extract. Following evaporation of the solvent, a portion of the sample extract equivalent to 1 g of lipid was chromatographed on an automated gel permeation column to separate chlorinated hydrocarbons from co-extracted lipids, and then fractionated on Florisil into three eluates: hexane (F1); hexane:dichloromethane (85:15) (F2); hexane:dichloro-methane (1:1) (F3) (Norstrom and Won 1985). The chromatography on Florisil separates PCB congeners, chlorobenzenes, 4,4'-DDE, and mirex in F1 from most toxaphene, chlordane-related compounds, and 4,4'-DDT in F2. F3 contains heptachlor epoxide and dieldrin.

Extracts were analyzed by capillary gas chromatography with electron capture detection (GC-ECD) using a 60 m x 0.25 mm i.d. 5% phenylmethylpolysiloxane capillary column with hydrogen carrier gas. A volume correction standard (PCB 30) was added to samples prior to GC analysis. PCB congeners were quantified using a series of congener mixtures obtained from NIST or purchased from Ultra Scientific (North Kingston, RI). Where congeners were not available, response factors (RFs) were estimated from other congeners with the same number of chlorines. NIST SRM 1588 (Organics in Cod Liver Oil) was analyzed every 20 samples as a control sample.

Chlordane-related compounds were quantified with individual standards excluding nonachlor III for which the RF for trans-nonachlor was used. Minor chlordane components, "C", C1, C2, and C4 were quantified using the RF for heptachlor while C5 was quantified using the RF of trans-nonachlor. (See Dearth and Hites, 1992, for a discussion of chlordane components.) Total chlordane was the sum of all chlordane-related compounds including heptachlor epoxide.

Toxaphene was quantified by a modification of previous procedures described by Muir et al. (1988b) and Stern et al. (1994). RFs for individual toxaphene peaks were calculated from the weight percent of each peak in the total ion chromatogram of a toxaphene standard as determined by electron-impact mass spectrometry on a GC-mass selective detector. Total toxaphene was the sum of the concentrations of 19 peaks (14 major peaks were generally observed).

Methods--University of Ulm

Four belukha whale blubber samples were analyzed at the University of Ulm. Samples of blubber (0.4 - 5 g) were mixed with sodium sulfate and coarse sand and extracted by a column technique using hexane/acetone (7/4) [Ernst et al., 1974]. Prior to extraction, tetrachloronaphthalene and ε-HCH were added as internal standards. The extractable lipid content was determined gravimetrically. To remove the majority of the lipids from the extracts, two different clean-up steps were used: gel permeation and concentrated sulfuric acid. After removal of the lipids, the eluants were concentrated to 500 µL. Liquid chromatography on a self-made column was used to separate the organic residues into three fractions. The first fraction contains the PCB congeners and lower polarity pesticides, such as HCB, 4,4'-DDE, and mirex. The second fraction contains the more polar pesticides, such as the HCHs, DDDs, DDTs, chlordane compounds, and toxaphene. The third fraction contains dieldrin which is destroyed in the sulfuric acid clean-up. The three fractions were each concentrated to 200 - 600 µL, then spiked with internal standard solutions, PCB 103 for the first fraction and tetrachloronaphthalene for the second and third fractions.

Extracts were analyzed by GC-ECD using a 100 m x 0.32 mm i.d. 50% octylmethylpolysiloxane capillary column with hydrogen as carrier gas. PCB congeners and pesticides were quantified using a series of solutions obtained from NIST. NIST SRM 1588 was analyzed with each set of blubber samples as a control material.

Element Analysis

Major and trace element analyses were performed on aliquots of liver samples collected from ringed seals taken in Norton Sound in 1989, 1991, and 1993 (RGSL-011 - 018, RGSL-029 - 032); one bearded seal from Norton Sound in 1989 (BDSL-001); two bearded seals taken in Nome in 1993 (BDSL-004 - 005); one spotted seal taken in Norton Sound in 1991 (SPSL-001); three bowhead whales taken at Barrow in 1992 (BWHD-001, -006, -007); and belukha whales taken at Point Hope in 1989 (BLKA-001 - 004), Point Lay in 1990 (BLKA-005 - 014), and Cook Inlet in 1992 (BLKA-015). These analyses were performed in the Analytical Chemistry Division at NIST.

The analytical approach for the determination of elements focuses on the use of a multi-element analytical technique, instrumental neutron activation analysis (INAA), to provide data on a large number of trace elements using only a limited amount of sample. This method consists of exposing samples and standards to a neutron field to produce radioactivity and measuring the energy and amount of the resulting radiation. In the neutron field, many of the stable nuclides of elements comprising the sample undergo neutron capture which, for many elements, results in the formation of radioactive product nuclides. The gamma ray emissions from the resulting product nuclides are collected using a germanium detector. The energy of the gamma ray indicates from which element the product nuclide was formed and the amount of radiation emitted is proportional to the concentration of that element.

In preparation for INAA, the frozen homogenate from each sample was lyophilized and two 200-mg portions of the resulting powder were formed into disk-shaped pellets, each packaged in acid-washed linear polyethylene (LPE) film. Duplicate portions of standard reference materials (SRMs) were prepared in the same manner and included in the analysis scheme for quality control purposes. Standards consisted of known amounts of each element deposited onto filter papers. These filter papers were also formed into disks so that counting geometry was consistent between samples, controls, and standards.

The irradiation and counting times for INAA were chosen to optimize the number of elements that could be determined and the detection limits for each. The samples, standards and controls were subjected to two irradiations, the first for 120 s and the second for 16 h. Approximately 90 s after the first irradiation, the samples were counted for 5 min to determine elements for which the product nuclides possess very short half-lives (magnesium, aluminum, chlorine, calcium, vanadium, copper, iodine, bromine). After several hours of decay, samples are counted again for 20 min to determine nuclides that possess half-lives on the order of a few hours (sodium, potassium, manganese). Each sample and control material was then repackaged in clean LPE film in preparation for the second irradiation. After the second irradiation and a decay time of approximately 6 days, each sample was counted for 4 h to determine concentrations of molybdenum, arsenic, cadmium, antimony, lanthanum, samarium, gold, and uranium; after a decay time of 1 - 2 months, samples were counted for 8 h to determine scandium, iron, zinc, cobalt, selenium, rubidium, strontium, molybdenum, silver, antimony, cesium, barium, cerium, europium, terbium, hafnium, tantalum, and thorium concentrations. All irradiations were done at the NIST Reactor, at a reactor power of 15 MW which corresponds to a neutron fluence rate of approximately 2.0×10^{13} $cm^{-2} \cdot s^{-1}$. Quantitation was based on comparison with standards. The ratio of the amount of activity induced in the standard at the end of the irradiation per unit mass of element (A_o/g) is calculated and this value or standard constant is used to determine the amount of element present in the sample based on the amount of activity measured in the sample. Spectral and data reduction for all samples were performed using a μVAX 3400 computer with Nuclear Data software.

For mercury analyses, additional portions of lyophilized liver tissue were packaged in acid-washed quartz vials. Mercury analysis could not be performed on the subsamples that were packaged in

LPE film because during irradiation, the samples are heated and volatile elemental mercury and mercury compounds may permeate the film. These samples in quartz vials were irradiated for 5 h and allowed to decay for about two months after which gamma spectroscopy was performed.

For the determination of all trace elements except mercury, SRM 1577a Bovine Liver was analyzed and, for the determination of mercury, SRM 1572 Citrus Leaves and SRM 2710 Montana Soil I were analyzed. The results of these analyses are shown together with the certified values in Appendix D, Table D-1. Results of INAA generally agree with certified values within the analytical uncertainty of the method. The uncertainty of the method includes the uncertainties associated with counting statistics, uncertainty in the concentrations of the standards, differences between standards and uncertainties due to differences in counting geometry. The magnitude of the uncertainty associated with counting statistics varies greatly from element to element and from animal to animal depending on the levels present. The magnitude of uncertainty in the concentration of the standards is estimated to be <1% at the 1s level. The uncertainty associated with differences in counting geometry between samples and standards is estimated based on experience to be approximately 1% for the disk-shaped samples and approximately 2% for the powdered samples contained in quartz vials. For many elements, the uncertainty associated with counting statistics is the largest source of uncertainty.

Analyses of liver samples for six of the fourteen belukha whales and two of the Norton Sound ringed seals were performed during 1990 -1991; these results have been published elsewhere (Becker et al., 1992 and Zeisler et al., 1993) but are included here for completeness. Similar INAA procedures were used for the analysis of these samples for the determination of all elements except nickel, lead, and mercury which were determined using other techniques as described below.

Additional analytical techniques were used to provide data on elements of high priority that are not routinely measured by INAA (e.g., lead and nickel) and to provide quality control data for selected elements (copper, zinc, and mercury) by comparing data from two different analytical techniques. Nickel and lead were determined using differential pulse and square wave voltammetry using previously published procedures for biological and environmental samples (Ostapczuk et al., 1986) after high pressure ashing digestion with nitric acid (Würfels et al., 1989). Mercury concentrations were determined using cold vapor atomic absorption spectrometry (CVAAS). Methodological details are presented in May and Stoeppler (1984), and Zeisler et al. (1993).

RESULTS AND DISCUSSION

Information including relative age, sex, date and location sampled, and morphometric measurements made on the individual animals is presented in Table 3. Complete information on each sample in the AMMTAP inventory is provided in Koster et al. (1994). Age estimates are not yet available for the pinnipeds and the single belukha whale from Cook Inlet. For the belukha whales, the numbers reported as "age indicator" are not absolute ages, but are the number of growth layer groups in longitudinal tooth sections. Belukha whales most likely lay down two growth layer groups per year (Brodie, 1982; Goren et al., 1987).

Table 3. Individual animal data. The numbers reported as "age indicator" for the belukha whales are not absolute ages but are the number of growth layer groups in longitudinal tooth sections.

Species	Animal No.	Sex	Age Indicator	Standard Length (cm)	Weight (kg)	Blubber Thickness (cm)	Date	Location
Ringed seal	RGSL-011	M	---	119.5	33.6	4.0	5/89	Norton S.
Ringed seal	RGSL-012	F	---	124.5	36.3	3.5	5/89	Norton S.
Ringed seal	RGSL-013	M	---	103.5	31.8	4.5	5/89	Norton S.
Ringed seal	RGSL-014	M	---	101.0	29.5	3.0	5/89	Norton S.
Ringed seal	RGSL-015	F	immature	83.2	20.0	3.3	5/89	Norton S.
Ringed seal	RGSL-016	M	immature	81.5	13.6	4.0	5/91	Norton S.
Ringed seal	RGSL-017	F	---	113	40.8	7.0	5/91	Norton S.
Ringed seal	RGSL-018	F	---	87	21.8	2.0	5/91	Norton S.
Bearded seal	BDSL-001	M	---	166.7	---	4.5	5/89	Norton S.
Spotted seal	SPSL-001	F	---	157.5	---	8.5	5/91	Norton S.
Belukha whale	BLKA-001	F	16	343	---	---	5/89	Pt. Hope
Belukha whale	BLKA-002	F	9	310	---	7.6	5/89	Pt. Hope
Belukha whale	BLKA-003	F	20	348	---	---	5/89	Pt. Hope
Belukha whale	BLKA-004	M	11	348	---	7.0	5/89	Pt. Hope
Belukha whale	BLKA-005	M	30	394	---	3.7	7/90	Pt. Lay
Belukha whale	BLKA-006	M	---	430	---	6.5	7/90	Pt. Lay
Belukha whale	BLKA-007	F	43	363	---	7.7	7/90	Pt. Lay
Belukha whale	BLKA-008	M	13	364	---	---	7/90	Pt. Lay
Belukha whale	BLKA-009	M	13	348	---	3.7	7/90	Pt. Lay
Belukha whale	BLKA-010	M	23	400	---	---	7/90	Pt. Lay
Belukha whale	BLKA-011	M	28	433	---	---	7/90	Pt. Lay
Belukha whale	BLKA-012	F	55	375	---	---	7/90	Pt. Lay
Belukha whale	BLKA-013	M	26	434	---	8.4	7/90	Pt. Lay
Belukha whale	BLKA-014	F	23	351	---	---	7/90	Pt. Lay
Belukha whale	BLKA-015	M	---	373	---	15.5	10/92	Cook Inlet
Bowhead	BWHD-001	F	immature	853	---	---	5/92	Barrow
Bowhead	BWHD-006	F	---	1495	---	25	9/92	Barrow
Bowhead	BWHD-007	M	---	1450	---	20.5	9/92	Barrow

Chlorinated Hydrocarbons

Analytical data for chlorinated hydrocarbons in twelve belukha whale blubber samples are presented in Appendix A, Table A-1. These analyses were performed at the DFO for the determination of 120 chlorinated hydrocarbon compounds: 85 PCB congeners and 35 pesticide compounds including four chlorobenzenes, three HCH isomers, 15 chlordane compounds, six DDT compounds, mirex, dieldrin, and toxaphene. For most samples PCB 128 was below the detection limit; however, this may have been due to incomplete separation from nonachlorobornane (T12), a toxaphene compound, on Florisil. The co-elution of an octachlorobornane (T2) with PCB 144/135 was also possible.

For comparison with previously published data generated by the use of electron-capture negative ion mass spectrometry, the TOXSRF values presented in Table A-1 are used to represent the sum of toxaphene. The TOXSRF values were calculated using a single response factor based on the area of 20 peaks in the standard, and the same peaks in the sample as described by Muir et al. (1990).

The sum of PCBs, toxaphene, DDTs, and chlordanes contributed the largest fractions to the total chlorinated hydrocarbon concentrations. The relatively large contribution of chlordane and toxaphene is similar to that reported for other Arctic marine mammals and appears to be characteristic of North American Arctic marine ecosystems (Muir et al., 1992a). The values for the major components are quite similar to the values reported for belukha whales from the Canadian Arctic (Muir et al., 1990) and western Greenland (Stern et al., 1994), particularly for belukha whales sampled from the Mackenzie River region, and major congeners contributing to the total PCB values are basically the same.

The following were the ranges of the major chlorinated hydrocarbon components (in μg/g wet weight) for all belukha whale blubber samples from the AMMTAP: ΣPCBs = 0.6 - 5.0; ΣTOXSRF = 0.5 - 5.4; ΣDDTs = 0.3 - 3.8; Σchlordane = 0.3 - 2.4; HCB = 0.08 - 0.95; and ΣHCH = 0.08 - 0.48. Oxychlordane and trans-nonachlor contributed the most to the total chlordane concentration. β-HCH and α-HCH contributed the most to the total HCH, while the γ-HCH isomer (lindane), contributed only a relatively small proportion. Major PCB congeners were 153, 138, 149, 118, 101, 99, 180, 187, 52, and 66/ 95.

In Table 4, concentration values for ΣPCBs (85 congeners), Σtoxaphene (TOXSRF), ΣDDTs (six compounds), Σchlordanes (15 compounds), Σchlorobenzenes, HCB, ΣHCH, trans-nonachlor, dieldrin, and mirex in (AMMTAP) belukha whale blubber tissues collected from animals in the Chukchi and western Beaufort seas are compared to values reported by Muir et al. (1990) for belukha whales from the Mackenzie Bay, which lies in the eastern Beaufort Sea. The values for the animals from the three locations are very similar. Males consistently had higher levels of PCBs, toxaphene, DDTs, and chlordanes than the females. Based on the present understanding of populations of belukha whales inhabiting the Chukchi, Beaufort, and Bering Seas, the Mackenzie Bay animals are probably from the same population as those sampled by AMMTAP at Point Hope. However, the degree of genetic and geographic separation of the Point Lay animals from the Point Hope/Mackenzie Bay group is presently unknown. The belukha whales that were sampled at Point Hope summer in the eastern Beaufort Sea, while those from Point Lay summer in the Chukchi Sea. It is not known if they winter together, although all of the belukha whales in the Alaska Arctic apparently winter in various ice-free areas of the Bering and possibly Chukchi seas (Hazard, 1988). Even if the AMMTAP belukha whales represent two different groups or populations, the source of exposure to chlorinated hydrocarbons (atmospheric input) may be the same, since it appears from these data that there is no difference in the chlorinated hydrocarbon levels in the animals from Point Lay as compared to those from Point Hope/Mackenzie Bay.

Table 4. Concentration (μg/g wet weight) of selected chlorinated hydrocarbons measured in blubber of belukha whales from the Chukchi/Beaufort seas. Values are mean ± 1 standard deviation, with the range shown below the mean. Standard deviation is not given for n = 2. Mackenzie Bay values are from Muir et al. (1990).

	POINT HOPE 1989	POINT LAY 1990		MACKENZIE BAY 1983, 1987	
	females n = 2	females n = 3	males n = 7	females n = 2	males n = 10
ΣPCB	2.37 2.08 - 2.66	2.64 ± 1.73 0.65 - 4.41	4.59 ± 0.64 3.56 - 5.23	1.23 0.83 - 1.64	3.33 ± 0.85 2.32 - 4.94
ΣTOXSRF	3.06 2.64 - 3.48	2.62 ± 2.07 0.50 - 4.64	3.93 ± 1.16 2.16 - 5.38	1.38 1.12 - 1.63	3.83 ± 1.16 2.55 - 6.62
ΣDDT	1.24 1.14 - 1.33	1.92 ± 1.42 0.33 - 3.31	3.25 ± 0.69 2.09 - 3.82	0.67 0.46 - 0.88	2.20 ± 0.83 1.47 - 3.73
ΣCHLOR	1.32 1.09 - 1.55	1.38 ± 0.87 0.33 - 2.17	2.22 ± 0.21 1.95 - 2.42	0.67 0.44 - 0.89	1.75 ± 0.41 1.28 - 2.56
ΣCBZ	0.62 0.25 - 0.99	0.58 ± 0.39 0.09 - 0.92	0.87 ± 0.10 0.78 - 1.04	0.33 0.19 - 0.47	0.65 ± 0.15 0.43 - 0.85
HCB	0.78 0.67 - 0.90	0.56 ± 0.38 0.08 - 0.89	0.81 ± 0.09 0.74 - 0.95	0.29 0.16 - 0.41	0.59 ± 0.13 0.40 - 0.78
ΣHCH	0.38 0.29 - 0.46	0.25 ± 0.12 0.08 - 0.36	0.32 ± 0.08 0.26 - 0.48	0.17 0.17 - 0.17	0.23 ± 0.06 0.14 - 0.32
t-nonachlor	0.58 0.50- 0.66	0.67 ± 0.43 0.18 - 1.08	1.06 _ 0.12 0.88 - 1.27	0.21 0.11 - 0.31	0.53 ± 0.12 0.32 - 0.72
Dieldrin	0.21 0.14 - 0.28	0.24 ± 0.16 0.05 - 0.41	0.34 ± 0.06 0.28 - 0.42	0.10 0.07 - 0.14	0.23 ± 0.05 0.16 - 0.34
Mirex	0.02 0.01 - 0.02	0.04 ± 0.02 0.02 - 0.07	0.05 ± 0.02 0.03 - 0.07	0.02 0.01 - 0.03	0.04 ± 0.01 0.02 - 0.06

In Figures 1 and 2, ΣPCB and ΣDDT concentrations in belukha whale blubber are compared to values that have been published since 1980 for other Arctic marine mammal species. The values for the Alaska belukha whales were similar to those reported for belukha whales from the Canadian Arctic and western Greenland (≤5 μg/g wet weight), narwhals and polar bears, but an order of magnitude less than those reported for belukha whales from the St. Lawrence River estuary.

DDE is a metabolite of the parent compound, DDT. Since DDE is relatively stable and tends to persist, it accumulates readily in tissues. A large DDE/∑DDT value suggests that the DDT has been in the system for a relatively long time, while a small ratio suggests relatively recent input of DDT into the system. For a more thorough discussion of DDT and its metabolites refer to Becker et al. (1992). In Table 5, the ratio of the concentrations of 4,4'-DDE to ∑DDT in the blubber of the belukha whales from Point Hope and Point Lay are compared to results reported for this species from Canada (Muir et al., 1990), western Greenland (Stern et al., 1994) and results previously reported for AMMTAP pinnipeds (Becker et al., 1992; Schantz et al., 1993). The 4,4'-DDE/∑DDT in blubber of male and female belukha whales from the same locations are similar and there appears to be little difference between locations, even when including the non-Arctic animals from the St. Lawrence River Estuary. As one might expect, the open-ocean northern fur seals have 4,4'-DDE/∑DDT values approaching 1, as do the ringed seals from Barrow, which may be year-round residents. The ratios for the ringed seals from Norton Sound (Nome) varied more widely; however, as there are data for only two northern fur seals and two ringed seals, it is difficult to draw any conclusions.

In Figures 3 and 4, Σchlordane and Σtoxaphene concentrations in blubber of the AMMTAP belukha whales are compared to post-1980 published values for other Arctic marine mammal species. The levels in the AMMTAP animals are similar to those reported for belukha whales and narwhals from the Canadian Arctic (Muir et al., 1992a), for belukha whales from western Greenland (Stern et al., 1994), and for polar bears (Norstrom et al., 1988). Concentrations of ∑chlordane and Σtoxaphene in Arctic ringed seals appear to be an order of magnitude lower (Muir et al., 1992b). Although the concentrations of both compounds are somewhat higher in male belukha whales from the Gulf of St. Lawrence than those from the Arctic, the number of males from St. Lawrence is relatively small (n = 4) and the differences appear to be slight. The levels in the females from St. Lawrence are also the same order of magnitude as the other belukha whales.

Most of the animals sampled at Point Lay had higher levels of total DDTs, PCBs, chlordanes and toxaphene than the two animals from Point Hope. However, the two Point Hope animals were relatively young females (see Table 3). Combining the Point Hope with the Point Lay data (Figure 5a), one can see that the concentrations of these chlorinated hydrocarbons are lower in the females than in the males, and vary more widely for females. The latter might be due to the relatively small number of animals sampled, the wider range of ages for females (Figure 5b), and the ability of reproductive females to eliminate lipophilic contaminants through lactation and parturition. The differences between males and females in total concentrations of DDTs, PCBs, chlordanes and toxaphene are similar to differences reported by Muir et al. (1990) and Stern et al. (1994) for belukha whales from Canada and western Greenland (see Figure 5a).

Both toxaphene and chlordane contribute a greater fraction to the total chlorinated hydrocarbon levels in Arctic biota (including marine mammals) than appears to be the case for temperate regions of the northern hemisphere (Muir et al., 1992b). This is shown in Table 6, where the Σchlordane/ΣPCB of AMMTAP belukha whale blubber is compared to that reported for belukha whales from three regions of Arctic Canada and the St. Lawrence River estuary and from western Greenland. The ratios for the animals from Point Lay and Point Hope are basically the same as those reported for belukha whales sampled at the mouth of the Mackenzie River (Beaufort Sea). This should not be surprising since the animals from the Mackenzie River area are probably from the same population as those sampled at Point Hope and may also be exposed to the same

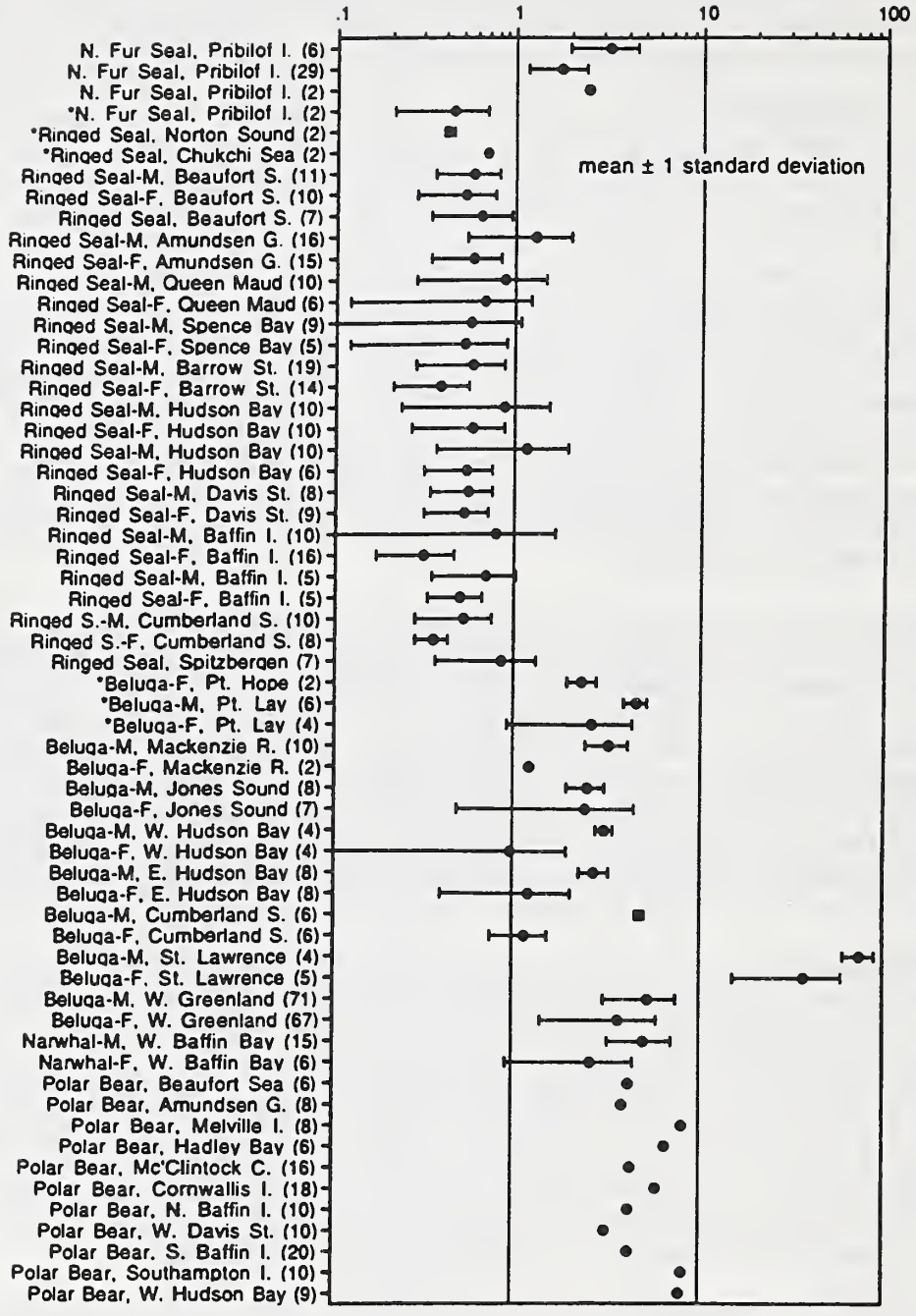


Figure 1. ∑PCB concentration (µg/g wet weight) in blubber of Arctic marine mammals. Numbers of animals are in parentheses; male and female animals are designated by M and F. AMMTAP data are indicated by an asterisk (*). Other values are from: Kurtz (1987), Calambokidis and Peard (1985), Muir et al. (1990), Muir et al (1992a&b), Muir et al. (1988a), Addison et al. (1986), Thomas and Hamilton (1988), Oehme et al. (1988), and Stern et al. (1994). Polar bear data are pooled samples (Norstrom et al., 1988). No data published prior to 1980 are included.

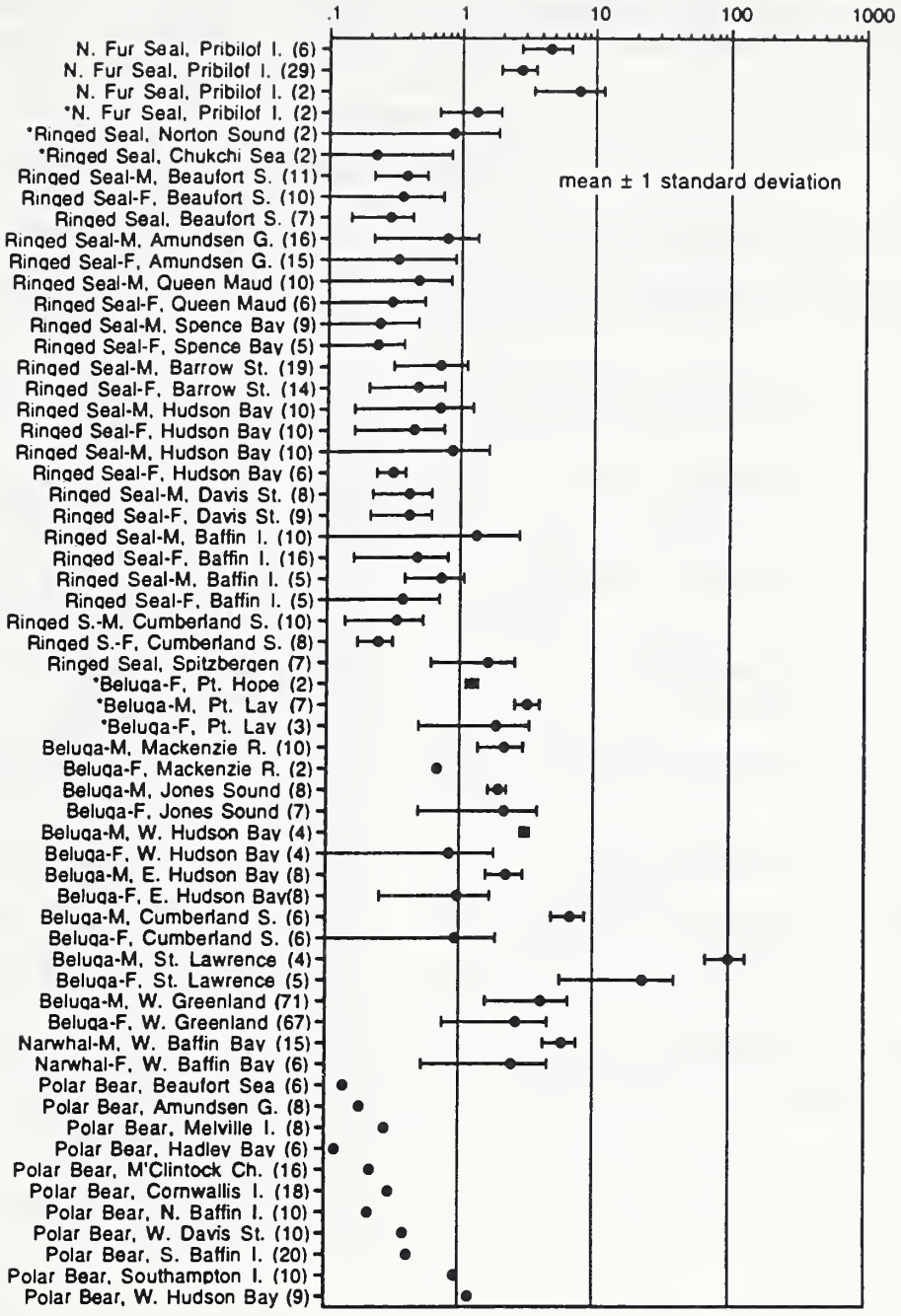


Figure 2. ΣDDT concentration (µg/g wet weight) in blubber of Arctic marine mammals. Numbers of animals are in parentheses; male and female animals are designated by M and F. AMMTAP data are indicated by an asterisk (*). Other values are from: Kurtz (1987), Calambokidis and Peard (1985), Muir et al. (1990), Muir et al (1992a, b), Muir et al. (1988a), Addison et al. (1986), Thomas and Hamilton (1988) Oehme et al. (1988), and Stern et al. (1994). Polar bear data are pooled samples (Norstrom et al., 1988). No data published prior to 1980 are included.

Table 5. Ratios of 4,4'DDE to ΣDDT in blubber of belukha whales from Point Hope and Point Lay as compared to values reported for belukha whales from Canada, for pinnipeds (AMMTAP data previously reported). Data sources are: 1- Stern et al. (1994); 2 - Muir et al. (1990); 3 - Becker et al. (1992) and Schantz et al. (1993). Values are expressed as the mean ± 1 standard deviation.

Species	Location (Date)	Sex	Number	4,4'DDE/ΣDDT	Data Source
Belukha whale	W. Greenland (1989-90)	M	71	0.56 ± 0.05	1
		F	67	0.52 ± 0.05	1
	St. Lawrence (1986-87)	M	4	0.66 ± 0.06	2
		F	5	0.56 ± 0.09	2
	Hudson Bay (1986)	M	4	0.57 ± 0.04	2
		F	4	0.57 ± 0.04	2
	Jones Sound (1986)	M	8	0.55 ± 0.04	2
		F	7	0.56 ± 0.05	2
	Mackenzie Bay	M	10	0.47 ± 0.15	2
	(1983, 87)	F	2	0.50	2
	Point Lay (1990)	M	7	0.58 ± 0.02	
		F	3	0.48 ± 0.18	
	Point Hope (1989)	F	2	0.53 ± 0.01	
Ringed Seal	Barrow, AK (1988)	M	2	0.85 ± 0.10	3
	Nome, AK (1989)	M	2	0.34 ± 0.25	3
N. Fur Seal	St. Paul I., AK (1987)	M	2	0.93 ± 0.06	3

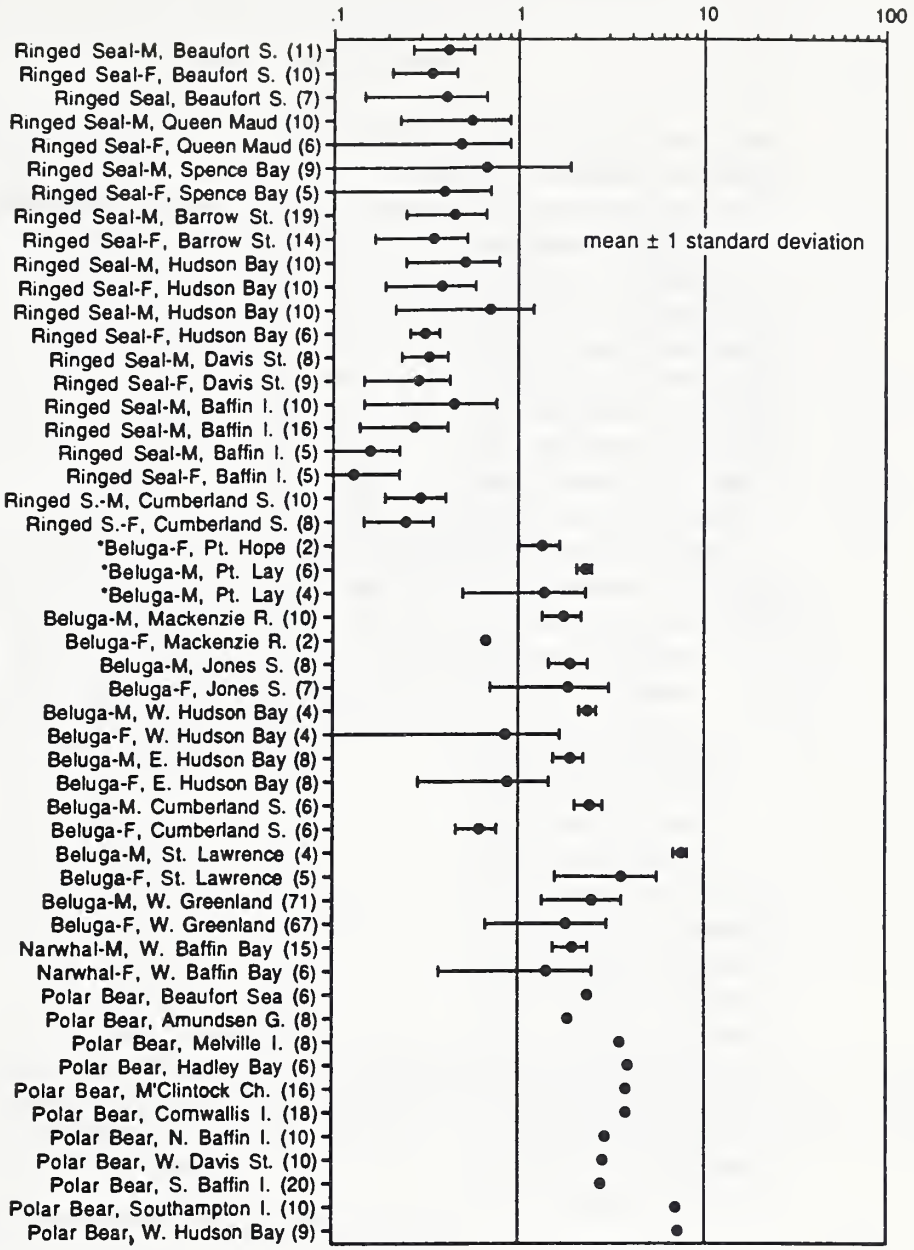


Figure 3. ΣChlordane concentration (µg/g wet weight) in blubber of Arctic marine mammals. Numbers of animals are in parentheses; male and female animals are designated by M and F. AMMTAP data are indicated by an asterisk (*). Ringed seal data is from Muir et al. (1992b) and Thomas and Hamilton (1988); additional belukha and narwhal data is from Muir et al. (1992a) and Stern et al. (1994); polar bear data is from pooled samples (Norstrom et al., 1988). No data published prior to 1980 are included.

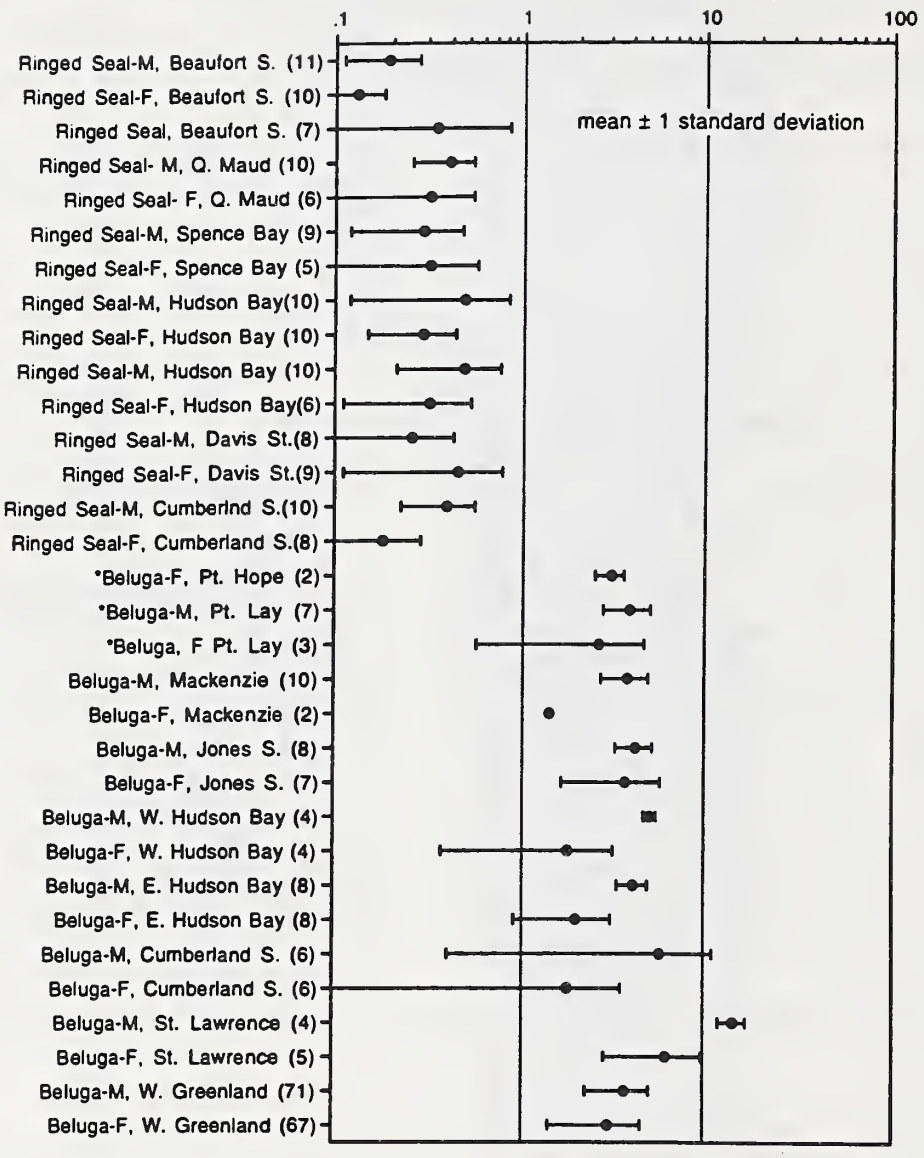
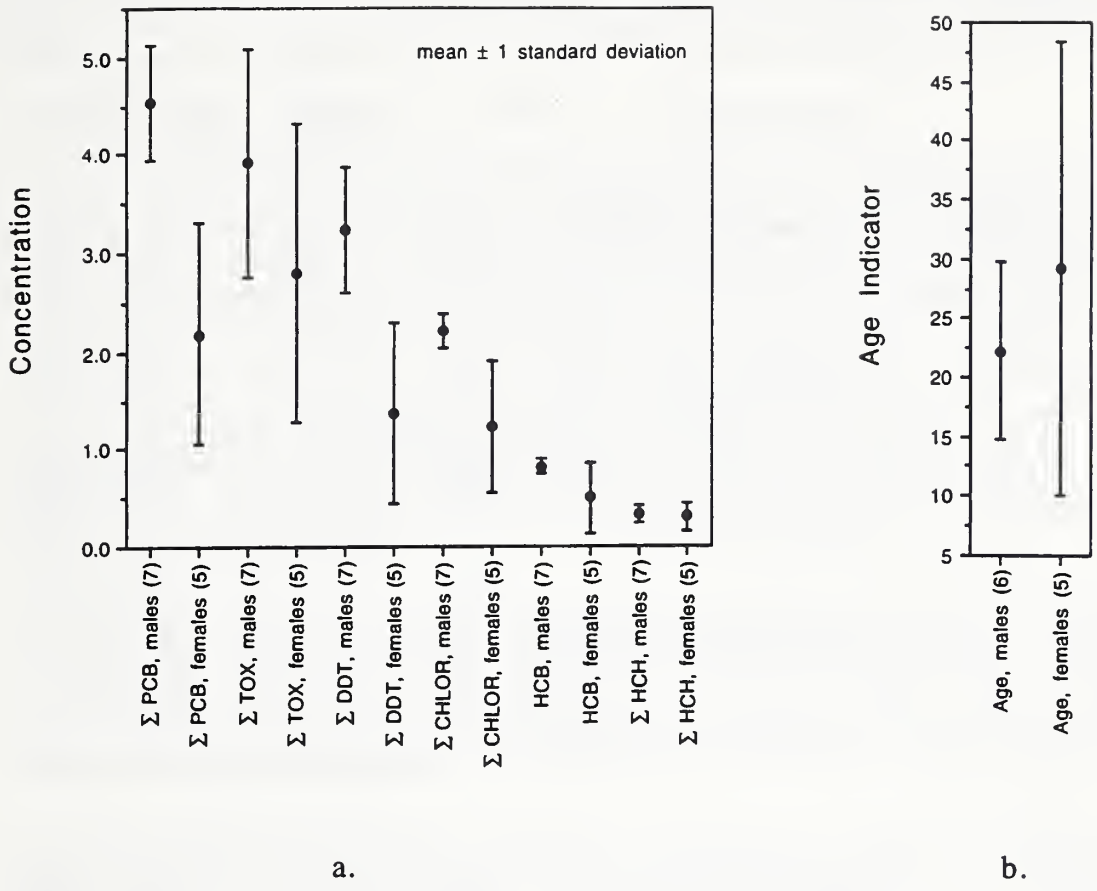


Figure 4. Toxaphene concentration (µg/g wet weight) in blubber of Arctic marine mammals. Numbers of animals are in parentheses; male and female animals are designated by M and F. AMMTAP data are indicated by an asterisk (*). Ringed seal data is from Muir et al. (1992b); additional belukha and narwhal data is from Muir et al. (1992a). No data published prior to 1980 are included.



a. b.

Figure 5. Concentration of PCBs and chlorinated pesticides in blubber and relative age distribution of male and female belukhas sampled by the AMMTAP. Concentrations are in µg/g wet weight. Age indicator is the number of growth layer groups in longitudinal tooth sections. It is believed that two layers are laid down annually.

Table 6. Ratios of Σchlordane to ΣPCBs in blubber of belukha whales from Point Hope and Point Lay as compared to values reported in Muir et al. (1990) for belukha whales from Canada and in Stern et al. (1994) for belukha whales from West Greenland. Values are expressed as the mean ± 1 standard deviation.

Species	Location (Date)	Sex	Number	ΣCHLOR/ΣPCB
From Stern et al. (1994):	W. Greenland (1989-90)	M	71	0.45
		F	67	0.48
From Muir et al. (1990):	St. Lawrence (1986-1987)	M	4	0.10 ± 0.01
		F	5	0.10 ± 0.02
	Hudson Bay (1986)	M	4	0.70 ± 0.11
		F	4	0.82 ± 0.19
	Jones Sound (1986)	M	8	0.76 ± 0.22
		F	7	0.84 ± 0.28
	Beaufort Sea (1983, 1987)	M	10	0.53 ± 0.04
		F	1	0.55
This report:				
	Point Lay (1990)	M	7	0.50 ± 0.05
		F	3	0.53 ± 0.06
	Point Hope (1989)	F	2	0.55 ± 0.04

environment as the Point Lay animals during the winter in the Bering Sea. Although the Arctic animals from Hudson Bay and Jones Sound had much higher ratios, belukha whales from western Greenland had ratios similar to belukha whales from Alaska and the Western Arctic of Canada. The lowest ratios were observed for animals from the lower latitudes of the St. Lawrence River estuary reflecting the larger contribution of chlordane to the chlorinated hydrocarbon burden for Arctic animals.

Intercomparison Data

Since NIST, DFO, and the University of Ulm provided results for chlorinated hydrocarbons in belukha whale blubber samples from the AMMTAP, an intercomparison exercise was conducted to determine the comparability of results from these three laboratories. DFO also participates in the quality assurance component of the Marine Mammal Health and Stranding Response Program sponsored by the National Marine Fisheries Service (Wise, 1993; Wise et al., 1993).

A pilot whale blubber QA material (Wise et al., 1993) was distributed as an intercomparison exercise among the three laboratories, and SRM 1588 Organics in Cod Liver Oil was analyzed as a control sample by each laboratory. The results from each of the three laboratories for the analyses of SRM 1588 and the QA whale blubber are shown in Tables B-1 and B-2, respectively. The agreement of the results among the laboratories is very good as is the agreement with the certified concentrations for SRM 1588.

Subsamples of four belukha whale blubber samples were analyzed at NIST, DFO, and the University of Ulm. The results of this three-laboratory intercomparison exercise are summarized in Appendix B, Table B-3. Four of the samples in this first intercomparison exercise were those previously analyzed at NIST and reported in Becker et al. (1992), and these results are denoted as NIST-I in Table B-3. Two of these four samples were re-analyzed at NIST in 1992 and the results are denoted as NIST-II in Table B-3.

In general the results among the three laboratories are within 25%. The largest differences are for the NIST-I results which were often higher suggesting possible coelution of compounds of interest. For example, PCB 28 and PCB 31, as well as PCB 105 and PCB 132, coeluted in the NIST-I data set but not in the more recent NIST-II or the DFO and Ulm results. PCB 66 and PCB 95 coelute in the NIST-I and DFO results but not in the NIST-II and Ulm data. When only the NIST-II results are compared, the agreement among the three laboratories is very good, particularly for the major PCB congeners and chlorinated pesticides.

Inorganic Constituents

Results of the inorganic analyses of liver tissue specimens collected from the Norton Sound pinnipeds, belukha whales, and bowhead whales are presented in Appendix C. These results include many elements that are not determined routinely in marine mammal tissues. Concentration values for 35 elements are given, including several trace elements that are considered to be potentially toxic at elevated levels and in the appropriate chemical forms. The following elements were at or below detection limit: gold, barium, cerium, europium, hafnium, lanthanum, scandium, tin, strontium, tantalum, terbium, thorium, and uranium. (See Appendix C, Table C-1.)

For direct comparison of concentration values obtained using the same analytical techniques on similar matrices, the Project has available results of element analyses by NIST of liver tissue from four harbor porpoise and eight pilot whales sampled for the NMMTB, plus the values previously reported by AMMTAP for northern fur seals and ringed seals (Becker et al., 1992; Zeisler et al., 1993). In addition, Wagemann et al. (1990) have recently published trace element data on belukha

whales from five locations in the Canadian Arctic and the St. Lawrence Estuary, which allows for a comparison with different populations of this species across the northern part of North America. Results for arsenic, cadmium, copper, mercury, selenium, silver, vanadium, and zinc are discussed below.

Arsenic

Arsenic concentrations in liver tissue of animals sampled by AMMTAP and NMMTB are compared in Figure 6. Both the pilot whales and harbor porpoise contain somewhat higher levels than the belukha whales and basically the same concentrations as the bowhead whales, while the ringed seals from Norton Sound show substantially elevated levels (six of the fourteen animals have levels > 1 μg/g and two have levels >2 μg/g wet weight). Although the database for arsenic concentration in marine mammals is limited, the hepatic arsenic concentrations for these two ringed seals are an order of magnitude higher than levels reported for walrus, northern fur seal, other Arctic ringed seals, belukha whales, bowhead whales, pilot whales, gray whales, and harbor porpoise (see Figure 7). Excluding one pilot whale, whose liver contained slightly above 1.0 μg/g wet weight, all other values for the NMMTB pilot whales and harbor porpoise were ≤ 0.5 μg/g.

Thompson (1990) indicates that concentrations of arsenic in liver tissue of birds and mammals rarely exceed 1.0 μg/g wet weight. Marine mammal tissues, however, may potentially contain higher levels. Marine organisms generally contain higher amounts of arsenic than terrestrial or freshwater organisms and the majority of this arsenic is in organic rather than inorganic form. Tissues with high lipid content generally have the highest concentrations. These include liver, fat, and muscle. It appears that organic forms of arsenic in marine food webs are derived from *in vivo* synthesis by primary producers and are efficiently transferred along the marine food chain (Wrench et al., 1979; Maher, 1985). Organic forms include the tetramethylarsonium ion, dimethylarsinyl-ethanol, trimethylarsoniumlactate, arsenic-containing sugars and phospholipids, arsenocholine, and arsenobetaine, [$(CH_3)_3AsCH_2OOH$] the dominant form in marine animals (Edmonds and Francesconi, 1993).

The toxicity of both the organic and inorganic forms of arsenic is highly valence state dependent: trivalent arsenic is much more toxic than pentavalent arsenic. For example, Eisler (1988) gives the following order of toxicity for arsenic compounds, from greatest to least toxic: arsines > inorganic arsenites > organic trivalent compounds (arsenoxides) > inorganic arsenates > organic pentavalent compounds (such as arsenobetaine) > arsonium compounds > elemental arsenic. Although Vahter and Envall (1983) have shown that arsenate may be reduced to the more toxic arsenite in mice and rabbits, it appears that organoarsenicals are not converted metabolically to the more toxic inorganic species during their passage through animal systems (Soto et al., 1993). Due to the valence state of the arsenic and its organic nature, one would expect arsenobetaine to be of little toxic concern and this seems to be the case. The potential risks associated with consumption of seafood containing arsenobetaine are very minor (Edmonds and Francesconi, 1993). It is relatively non-toxic, rapidly absorbed by the gastrointestinal tract and rapidly excreted in urine, without metabolism (Kaise et al., 1985). It is not mutagenic in the Ames test, has no mutagenic action, and shows no synergism or antagonism with other contaminants (Jongen et al., 1985).

Crustacean tissues sold for food and taken in U.S. coastal waters usually contain total arsenic levels of 3 - 10 μg/g wet weight (Hall et al., 1978) or 1 - 100 μg/g dry weight (Fowler and Unlu 1978), and somewhat higher levels have been reported in finfish and mollusks. Arsenic levels in finfish range from about 2 - 5 μg/g wet weight (Eisler, 1988). The highest arsenic values in marine mammals were reported for fin whale blubber oil, 1.8 μg/g wet weight (Jenkins, 1980), and for cetaceans, 0.6 - 2.8 μg/g wet weight (Eisler, 1981). However, of all the values for arsenic in liver tissue published, none were as high as the levels found in the livers of the ringed seals from Norton Sound.

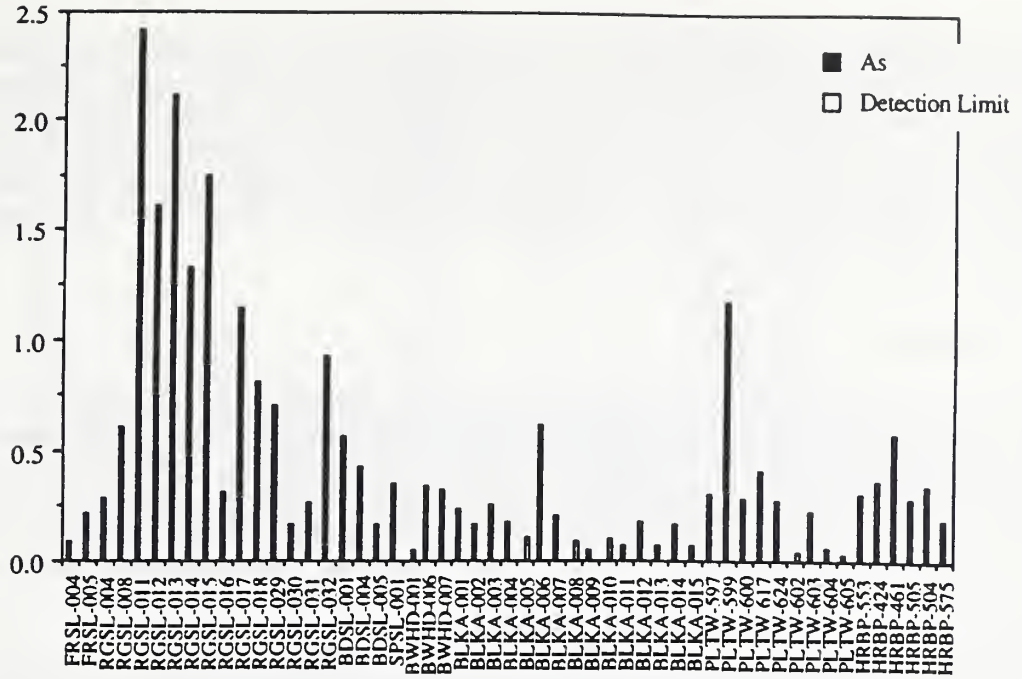


Figure 6. Arsenic concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

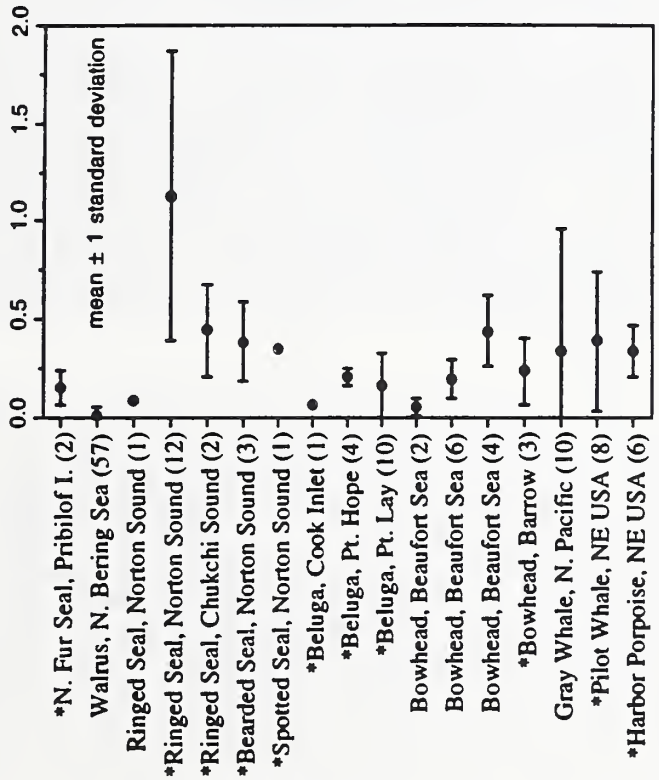


Figure 7. Comparison of arsenic concentrations (µg/g dry weight) in marine mammal liver. AMMTAP and NMMTB data are indicated by an asterisk (*). Other values are: walrus from Taylor et al. (1989), ringed seal from AT (1988), bowhead from Byrne et al. (1985) and Bratton et al. (1993), and gray whale from Varanasi et al. (1993). Numbers of animals are in parentheses.

We do not know how much of the arsenic in the ringed seal liver was present as arsenobetaine, since we did not analyze for this compound. Bratton et al. (1993) in their study of bowhead whales found that in the animal with the highest liver concentration of arsenic (0.44 µg/g wet weight), 98% was in the form of arsenobetaine. Edmonds and Francesconi (1993) in their review of the data on arsenic levels in fish, crustaceans, and mollusks reported that the proportion of inorganic arsenic ranged from about 1% at very low total arsenic concentrations to about 0.5 % at total arsenic levels of about 20 µg/g wet weight.

Cadmium

Cadmium is not easily regulated metabolically and may increase in animal tissues with age. It is not eliminated by females during lactation so that little difference is observed between the levels found in males and females. The highest cadmium concentrations in liver tissue from the AMMTAP and NMMTB animals were for northern fur seals, bowhead whales, and pilot whales, with two of the ringed seals from Norton Sound having somewhat elevated levels (Figure 8). Levels in the harbor porpoise were particularly low. The pilot whale and harbor porpoise data are consistent with cadmium concentration values reported by other researchers for these species (Falconer et al., 1983 and Meador et al., 1993).

Cadmium values for the belukha liver tissue (Figure 8) were relatively low and comparable to those previously reported for ringed seals from the Chukchi Sea (Becker et al., 1992; Zeisler et al., 1993). In order to compare the AMMTAP belukha whale data with those reported for this species by Wagemann et al. (1990), wet weight values were converted to µg/g of dry weight. These comparisons are shown in Figure 9. The single whale from Cook Inlet had lower hepatic cadmium concentrations than the hepatic concentrations of whales from Point Hope and Point Lay and than levels reported for the other whales from the Canadian Arctic. The cadmium data from the Point Hope and Point Lay animals are similar to values reported by Wagemann et al. (1990) for belukha whales sampled at the mouth of the Mackenzie River. This is expected as the Point Hope and Mackenzie River whales are probably from the same population. A much wider variation in hepatic cadmium concentrations was observed for the whales from the eastern Canadian Arctic (Pangnirtung and Eskimo Point). Norstrom et al. (1986) and Wagemann (1993) found that hepatic Cd concentrations were higher in animals from the western Arctic as compared with those from the eastern Arctic. This may also be the case for belukha whales, as indicated by the data shown in Figure 9. The belukha whales from the Gulf of St. Lawrence, which are highly contaminated with organochlorines and have elevated mercury levels, had very low cadmium levels, as low as that for the belukha whale from Cook Inlet.

Although we only have data from three bowhead whales, the cadmium concentrations in the livers of these animals ranged from below the detection limit of 0.34 µg/g (wet weight) for a small immature female to a value of 19.7 µg/g wet weight for a large mature male. The high values are similar to those reported for northern fur seal and are comparable with values reported by USFWS for walrus from the Bering and Chukchi seas (Warburton and Seagars, 1993). The USFWS has been monitoring heavy metals in walrus because of elevated levels of cadmium in liver and kidney of these animals. The USFWS recently reported hepatic cadmium concentrations for walrus ranging from 0.96 - 86.7 µg/g dry weight, with a mean of 27.6 ± 16.9 µg/g (one standard deviation). The cadmium concentrations for the three bowhead whale livers expressed on the basis of dry weight are: ≤1.41, 68.2, and 81.7 µg/g. Elevated levels of cadmium in the liver and kidney tissue of bowhead whales were previously reported by Byrne et al. (1985) and Bratton et al. (1993).

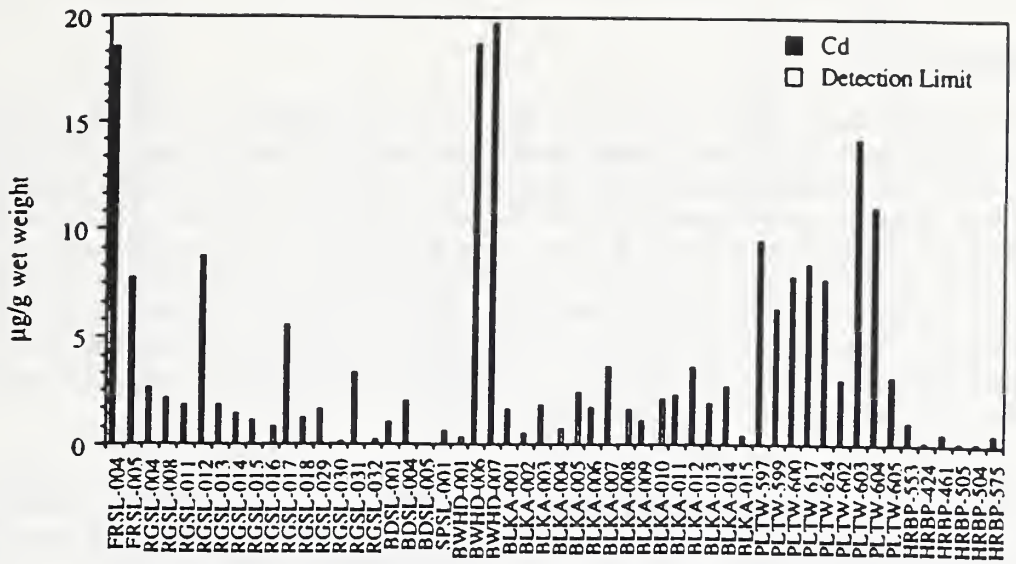


Figure 8. Cadmium concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

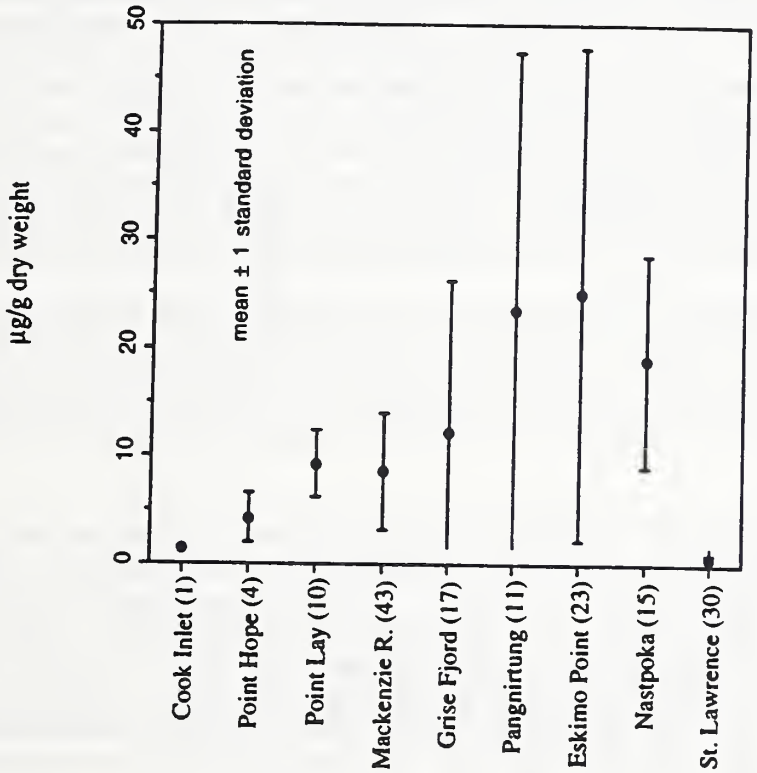


Figure 9. Comparison of cadmium concentrations (µg/g dry weight) in liver of belukha whales from Alaska and Canada. Locations are presented from west to east (left to right); numbers of animals are in parentheses. Data for the six Canadian locations are from Wagemann et al. (1990).

Copper

Copper is an essential element that is regulated metabolically in vertebrates. The highest levels in mammals are usually found in the liver. Most marine mammal liver tissues contain <20 µg/g wet weight. Hepatic copper concentrations were higher for belukha whales, northern fur seals, ringed seals, and harbor porpoise as compared with the concentrations for bowhead whales and pilot whales (see Figure 10). McClurg (1984) reported very high copper levels in liver of Ross seal from the Antarctic and related this to the seal's prey; this may also be the case for the belukha whales and harbor porpoise. Since copper is metabolically regulated, accumulation with age may not occur. In fact, the highest copper levels reported have been for young animals. Wagemann et al. (1983) reported that copper concentration was negatively correlated with length for narwhals and Honda et al. (1983) found the same for striped dolphin.

In Figure 11 the copper concentrations in liver tissue of the AMMTAP belukha whales are compared with those reported by Wagemann et al. (1990) for animals from six locations in Canada. The one belukha whale from Cook Inlet had a relatively high hepatic copper concentration while the whales from Point Hope and Point Lay had concentrations similar to those for whales from the western Canadian Arctic.

Mercury

Similar to cadmium, mercury accumulates with age. Females can eliminate some forms of this element through lactation and parturition; therefore, mature males often have higher levels of mercury than females. The highest levels of mercury are usually found in the liver, with a large proportion in the relatively non-toxic inorganic form. The percentage of the more toxic organic mercury (methylmercury) varies based on age and the amount of total mercury. Methylmercury is probably the form acquired from the food web. The highest percentage of organic mercury in liver is generally associated with the lowest total mercury levels, and the lowest percentage of organic mercury (≤ 3%) is usually associated with the highest total levels. The highest concentrations of organic mercury in marine mammal liver tissue are rarely above 2 µg/g wet weight. Some marine mammals may have the ability to demethylate the organic form and sequester it in the liver in a non-toxic form. However, the ability of new-born and young animals to do this is probably limited.

The highest values of total mercury in liver were found in the belukha whale and pilot whale liver (see Figure 12). The one belukha whale from Cook Inlet had a relatively low hepatic mercury concentration of 2.82 µg/g wet weight. The range for the Point Hope animals was 1.40 - 10.2 µg/g wet weight (mean = 4.73), and for the Point Lay animals, 17.7 - 72.9 µg/g wet weight (mean = 36.5). The whales from Point Lay were somewhat older that those from Point Hope which may account for this difference.

The total mercury levels in the Point Lay belukha whales were relatively high as compared to those for belukha whales from the Canadian Arctic and are comparable to levels reported by Wagemann et al. (1990) for belukha whales from the Gulf of St. Lawrence (see Figure 13). Comparing animals from five Canadian Arctic locations, Wagemann et al. (1990) reported average hepatic mercury concentrations (in µg/g dry weight) for belukha whales of 8.27 ± 7.71 µg/g for animals from Grise Fjord, 44.1 ± 45.5 µg/g for those from Mackenzie Delta, and 126 ± 161 µg/g for those from the St. Lawrence area. For comparison, average hepatic mercury concentrations for the AMMTAP belukha whales were 17.1 ± 13.3 and 191 ± 93.2 µg/g dry weight for animals from Point Hope and Point Lay, respectively.

The methylmercury fraction was measured in liver specimens of four belukha whales from Point Hope and two from Point Lay (Becker et al. 1992 and Zeisler et al. 1993). The two animals from Point Lay (BLKA-007 and BLKA-012) had methylmercury values of 2.15 and 0.68 µg/g wet weight, which composed 3% of the total mercury concentration in the livers of these animals,

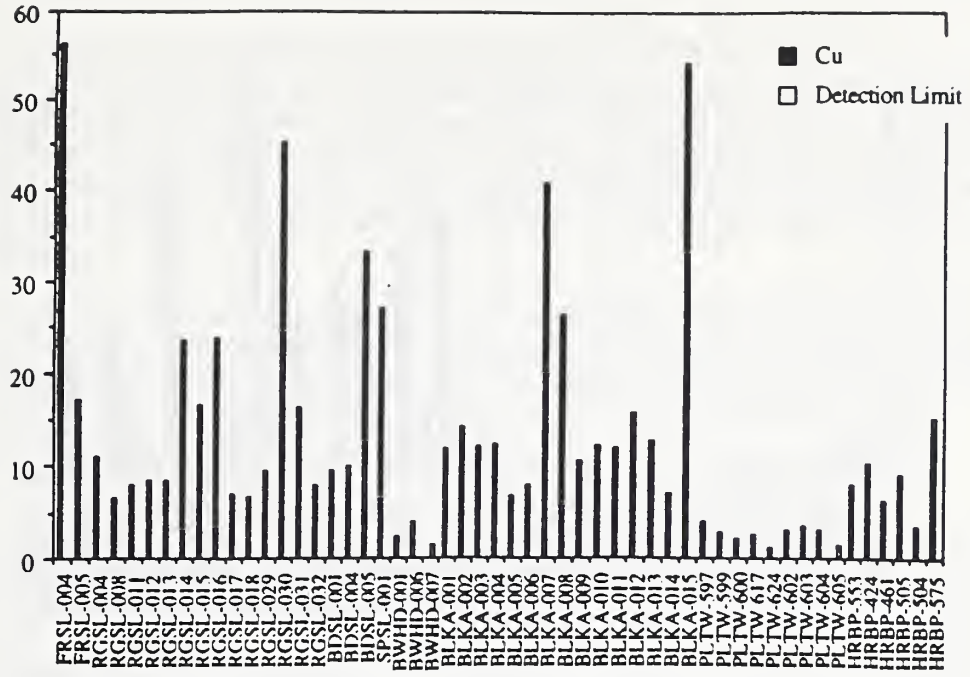


Figure 10. Copper concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

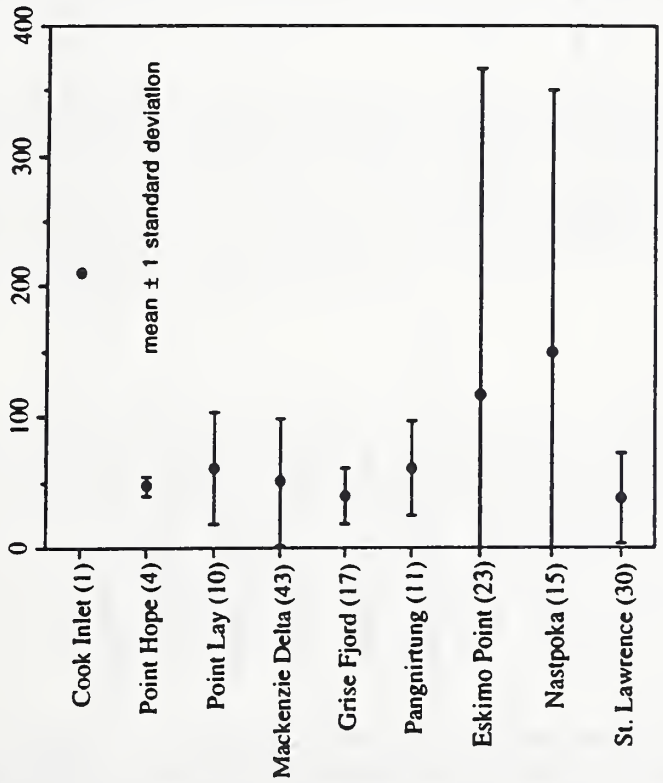


Figure 11. Comparison of copper concentrations (µg/g dry weight) in liver of belukha whales from Alaska and Canada. Locations are presented from west to east (left to right); Numbers of animals are in parentheses. Data for the six Canadian locations are from Wagemann et al. (1990).

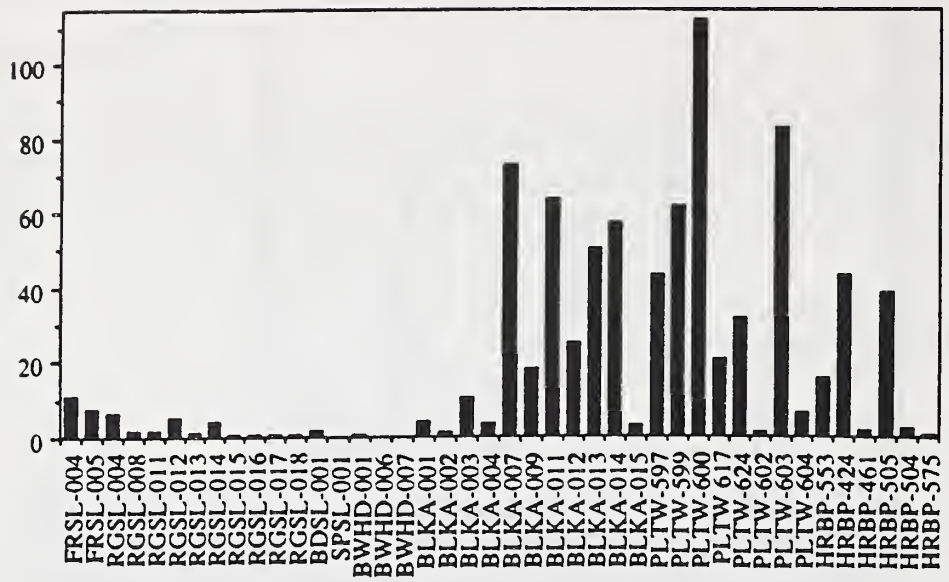


Figure 12. Total mercury concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

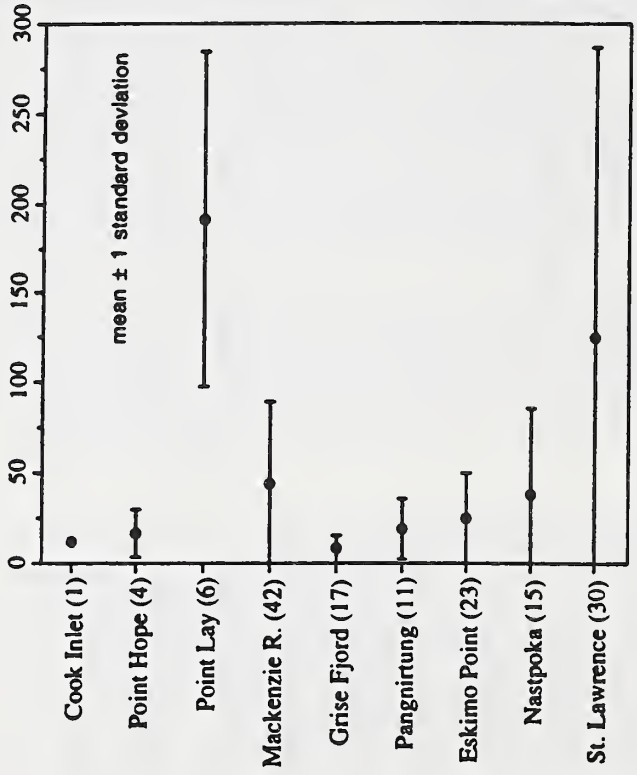


Figure 13. Comparison of total mercury concentrations (µg/g dry weight) in liver of belukha whales from Alaska and Canada. Locations are presented from west to east (left to right); numbers of animals are in parentheses. Data for the six Canadian locations are from Wagemann et al. (1990).

while the younger animals from Point Hope had methylmercury values ranging from 0.36 to 0.75 µg/g wet weight, which composed from 7% to 29% of the total mercury in liver tissue. For comparison, Dietz et al. (1990) reported organic mercury concentrations in liver tissues of belukha whales from Greenland (n = 6) ranging from 0.33 µg/g wet weight (39%) to 1.63 µg/g wet weight (18%). They also reported an organic mercury value of 2.15 µg/g wet weight (6%) for one ringed seal from Greenland.

The lowest total mercury level was found in the single bowhead whale for which mercury determinations have been made. This value, 0.325 µg/g wet weight, is probably low because this animal was a small immature female, but it is still two orders of magnitude higher than the mercury values reported by Byrne et al. (1985) and Bratton et al. (1993) for bowhead whales.

Selenium

Selenium is an essential element which has an antidotal action on the toxic effects of mercury, cadmium, arsenic, copper, and thallium either through the formation of insoluble selenide compounds or by simultaneous binding to the toxic metal and to a high molecular weight protein. The presence of metal selenide compounds in cetacean liver has been reported by Martoja and Viale (1977). Selenium is also an integral part of glutathione peroxidase, a mammalian enzyme that, like vitamin E, functions as an antioxidant by preventing lipid peroxidation in tissues, a biochemical path common for many toxic substances and diseases (Rotruck, 1973; Ridlington and Whanger, 1981).

Selenium concentrations in liver tissues of AMMTAP and NMMBT animals are shown in Figure 14 and the average values found in belukha whales from AMMTAP are shown together with the average values found in belukha whales from six Canadian locations are shown in Figure 15. Most values are ≤ 30 µg/g with the exception of the value for one animal (BLKA-007) from Point Lay.

As has been reported by numerous researchers for many animals (both invertebrates and vertebrates), hepatic selenium is positively correlated with hepatic mercury. One would, therefore, expect to find the highest selenium levels in the pilot whale and belukha whale livers, since these contain the highest mercury levels. Results plotted in Figure 18 show that this is the case. The relationship between selenium and mercury can be seen clearly in the data for belukha whales from Cook Inlet, Point Hope, and Point Lay and for the belukha whales described by Wagemann et al. (1990) from the Canadian Arctic (Figures 13 and 15).

Silver

Silver concentrations in liver tissue of belukha whales (from Cook Inlet, Point Hope and Point Lay) are compared in Figure 16 with values for other AMMTAP and NMMTB animals. In Figure 17, we present an additional comparison with literature values (Byrne et al., 1985; Norstrom et al., 1986; Smith, 1986; Varanasi et al., 1993). The concentrations of silver in the belukha whale livers were usually two orders of magnitude higher than those values reported for other marine mammal species from both the Arctic and sub-Arctic. Whereas all other values are <1 µg/g wet weight, values for the belukha whales are generally >10 µg/g wet weight. In an additional comparison, the belukha whale liver wet weight values were converted to dry weight concentrations and compared to the data reported by Warburton and Seagars (1993) for walrus from the Bering and Chukchi seas. The mean silver concentration, based on dry weight, in liver tissue of 53 walrus was reported to be 1.49 µg/g, with a standard deviation of 1.11 µg/g and values ranging from 0.70 to 5.11 µg/g. For the belukha whale livers, the mean silver concentration was 103.1 µg/g, with a standard deviation of 98.8 µg/g and values ranged from 23.1 - 431 µg/g, two orders of magnitude higher than those for walrus.

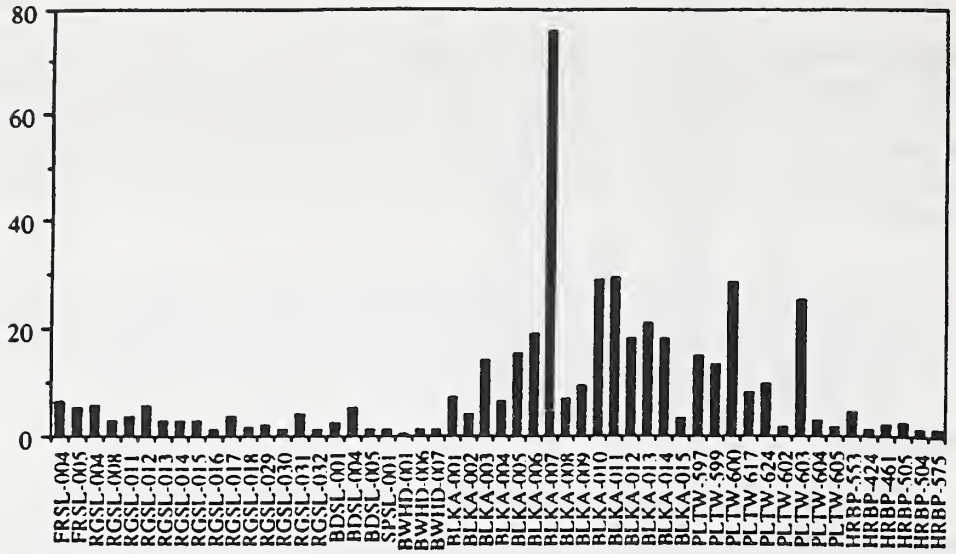


Figure 14. Selenium concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

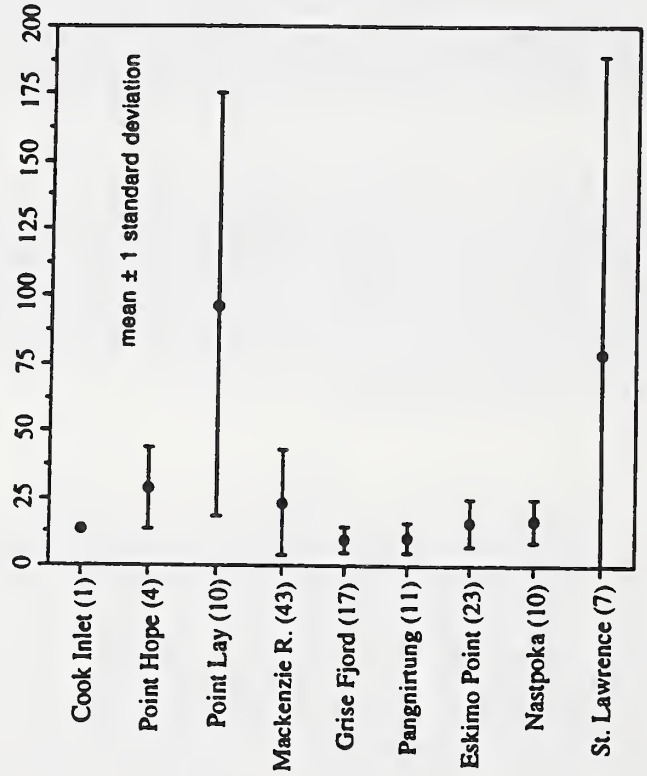


Figure 15. Comparison of selenium concentrations (µg/g dry weight) in liver of belukha whales from Alaska and Canada. Locations are presented from west to east (left to right); numbers of animals are in parentheses. Data for the six Canadian locations are from Wagemann et al. 1990.

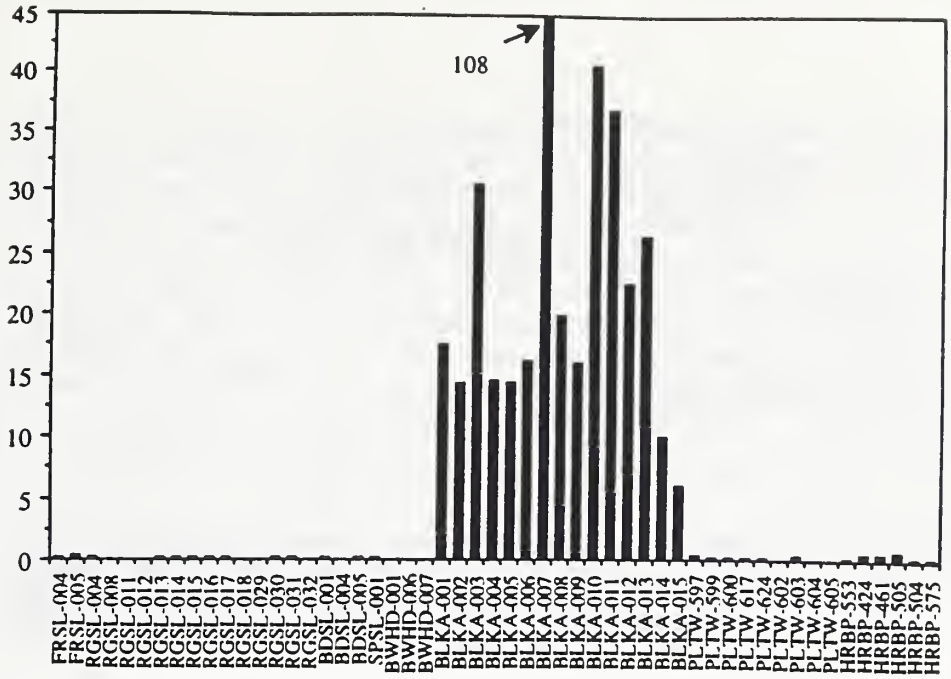


Figure 16. Silver concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

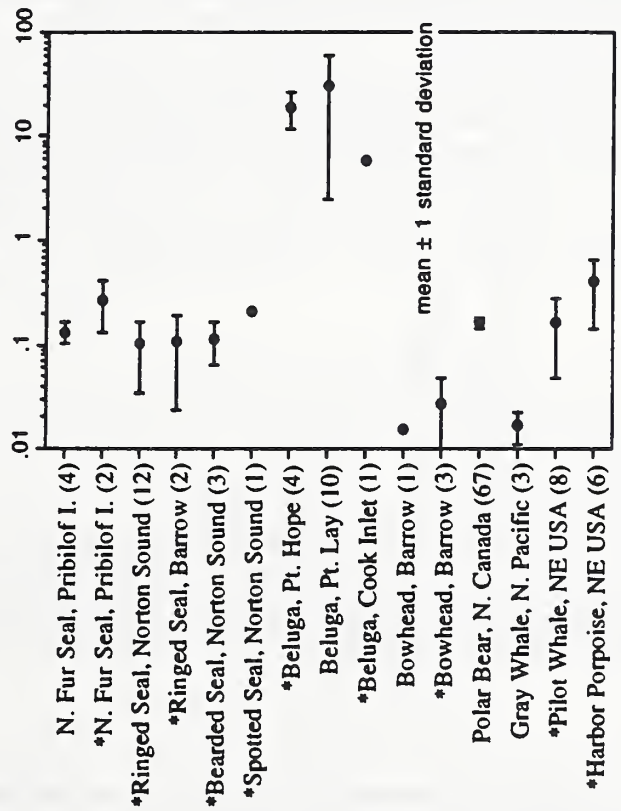


Figure 17. Comparison of silver concentrations (µg/g wet weight) in marine mammal liver tissue. AMMTAP and NMMTB data are indicated by an asterisk (*). Other values are: fur seal from Smith (1986), bowhead from Byrne et al. (1985), polar bear from Norstrom et al. (1986), and gray whale from Varanasi et al. (1993). Numbers of animals are in parentheses.

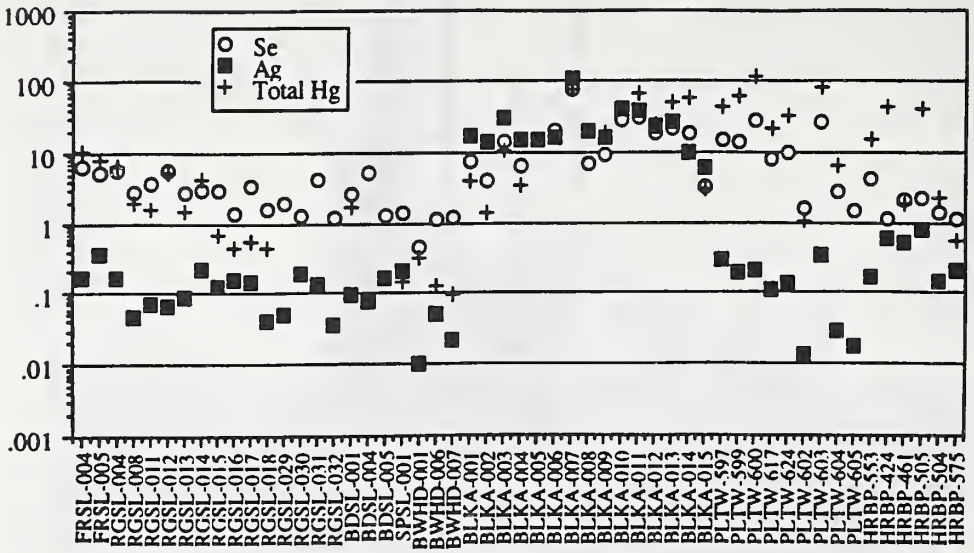


Figure 18. Comparison of the total mercury, selenium, and silver concentrations (µg/g wet weight) in the liver tissue of animals sampled by AMMTAP and NMMTB.

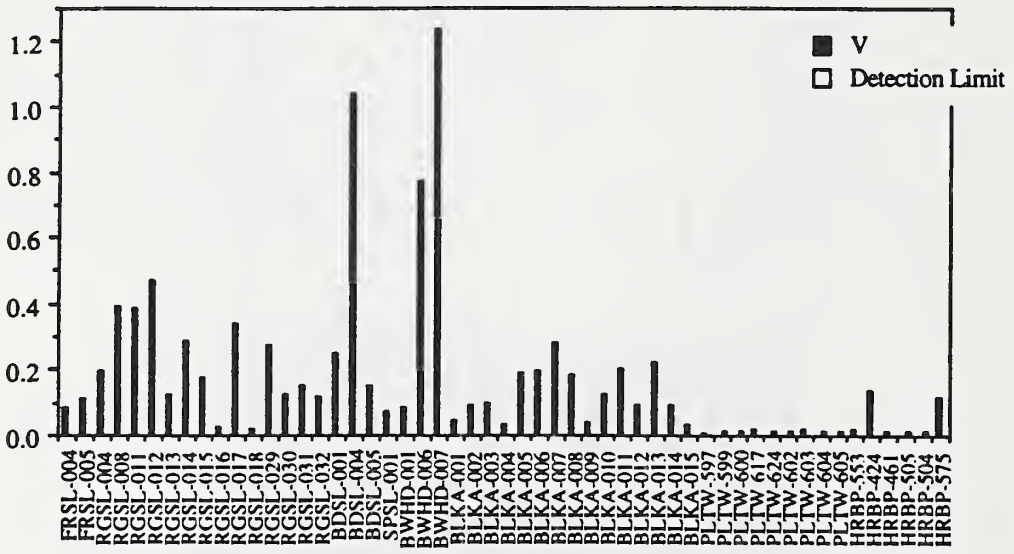


Figure 19. Vanadium concentration (µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

In all other cetaceans and pinnipeds from the AMMTAP and NMMTB, the levels of mercury and selenium are about the same order of magnitude and silver concentrations are substantially lower, but correlated with selenium to some degree. The linear correlation coefficient for hepatic silver versus hepatic selenium for pilot whales was 0.819, significant at the 5% level, and for belukha whales 0.952, significant at the 1% level. For the belukha whale livers, silver levels are comparable to those for selenium and mercury, and in some cases exceed the levels of these two elements (see Figure 18). The apparent correlation of silver with selenium does not necessarily indicate a direct relationship between the two elements but might be due to independent factors such as accumulation with age. However, physiological mechanisms involving the interaction of silver and selenium have been shown for other species of mammals and might also function in these marine mammals. These physiological mechanisms appear to be linked to the anti-oxidative functions of glutathione peroxidase and vitamin E (Ridlington and Whanger (1981). The interaction of silver with selenium differs from other selenium-metal interactions in mammals in that silver can induce symptoms of selenium deficiency in vitamin E-deficient animals by forming a silver-selenium complex that reduces the pool of available selenium used for normal cellular processes (Hammond and Beliles, 1980). The possible relationship between silver, mercury, and selenium in the belukha whale liver tissues from the AMMTAP has been discussed recently by Becker et al. (in press).

Vanadium

Vanadium concentrations in the liver of ringed seal, bowhead whales, and belukha whales varied widely (Figure 19). The highest values were found in two of the bowhead whales (0.77 and 1.23 μg/g wet weight). The lowest concentration was found in the pilot whales, which had liver values as low as those reported for human liver tissue, e.g., ≤0.02 μg/g wet weight (Zeisler et al., 1983). Vanadium values were reported by Norstrom et al. (1986) for pooled liver samples from polar bears (n = 7) and by Warburton and Seagars (1993) for walrus (n = 53). The value reported by Norstrom et al. (1986) was 0.07 μg/g wet weight, which is in the low end of the range found in the AMMTAP belukha whale liver tissues. The values reported by Warburton and Seagars (1993) for walrus were higher than those found in the AMMTAP animals. Levels of vanadium in liver of walrus from the Bering and Chukchi seas ranged from 0.96 to 14.55 μg/g dry weight, with a mean of 6.04 ± 3.12 SD. Converting the AMMTAP values to dry weight, the belukha whale liver concentrations of vanadium ranged from 0.122 - 1.119 μg/g and the bowhead liver concentrations ranged from 0.344 - 5.12 μg/g.

Although the levels present in these tissues vary widely, vanadium is present at measurable levels in all of the Alaska marine mammal livers whereas for most of the east coast marine mammals, vanadium concentrations are at or below detection limits. Vanadium is used as an environmental indicator for the presence of crude oil. Although absolute vanadium concentrations vary for different oils, it is possible that the presence of vanadium in these whale liver tissues indicates the presence of oil in the Alaska marine environment.

Zinc

Like copper, zinc is an essential element regulated metabolically by vertebrates. Hepatic concentrations vary little between species, generally ranging from 20 - 60 μg/g wet weight (Thompson, 1990). Values for the AMMTAP and NMMTB animals are within this range (Figure 20). The range of hepatic zinc concentrations for the belukha whales was quite narrow (20 - 40 μg/g). A comparison with values reported by Wagemann et al. (1990) for belukha whales sampled from several locations in Canada shows that the range of hepatic zinc concentrations is very consistent for belukha whales throughout the Arctic and eastern Canada (Figure 21). Hepatic zinc concentrations for ringed seals are more variable. The liver of one seal, a relatively small male less than a year old (RGSL-016), from the Norton Sound, contained about 90 μg/g wet weight. Some of the highest zinc levels, far above the 20 - 60 μg/g range, were reported for pinnipeds from the

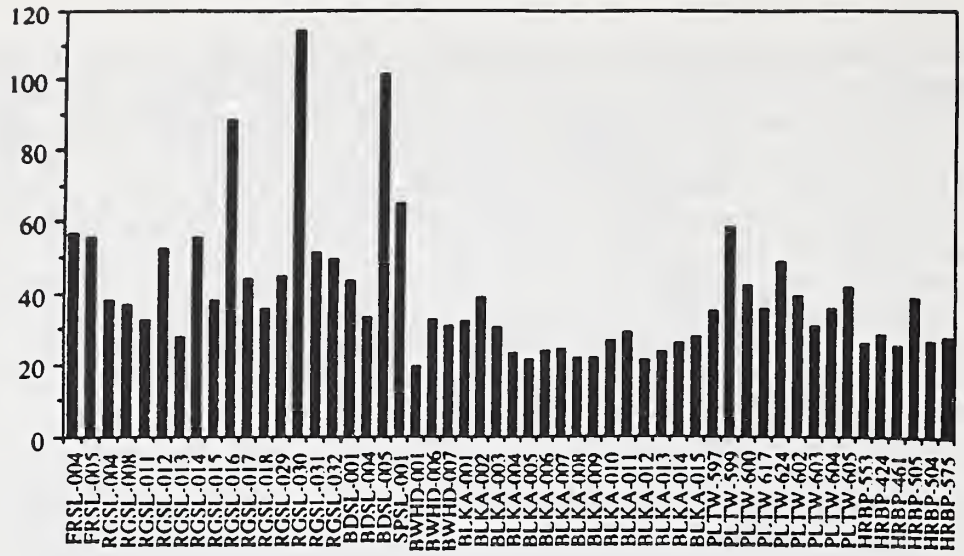


Figure 20. Zinc concentration µg/g wet weight) in AMMTAP and NMMTB liver samples. AMMTAP animals: FRSL = northern fur seal; RGSL = ringed seal; BDSL = bearded seal; SPSL = spotted seal; BWHD = bowhead whale; BLKA = belukha whale. NMMTB animals: PLTW = pilot whale and HRBP = harbor porpoise.

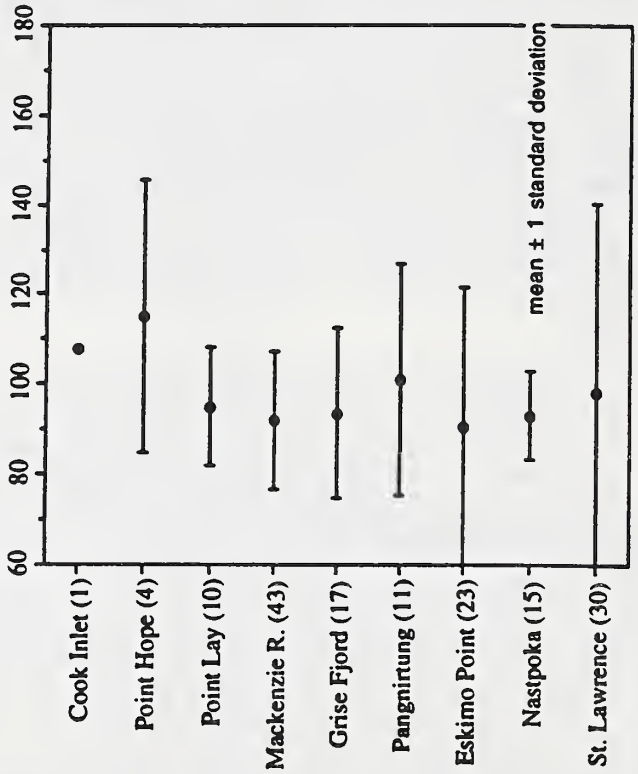


Figure 21. Comparison of zinc concentrations (µg/g dry weight) in liver of belukha whales from Alaska and Canada. Locations are presented from west to east (left to right); numbers of animals are in parentheses. Data for the six Canadian locations are from Wagemann et al. (1990).

Antarctic. Thompson (1990) suggests that the higher hepatic zinc levels might reflect a natural dietary source that is high in zinc.

Bioaccumulation

For many trace elements in marine mammal tissues, little is known of baseline concentrations or what concentrations are within the normal range for a particular species. This information would be helpful in determining whether concentrations are increasing for a given population over time or whether bioaccumulation is occurring for a given species within a given organ. One measure of bioaccumulation is to determine whether concentrations increase with age. Concentrations in belukha whale liver were plotted versus age or length for each element. Positive correlations with age were observed for vanadium, selenium, silver, and mercury. These elements accumulate in liver tissue with age. The correlation between mercury and selenium and between selenium and silver may simply reflect that both elements accumulate with age or may also indicate a biochemical relationship between these elements. These biochemical relationships have been discussed in previous sections of this report as well as in Becker et al. (in press).

No correlation with age was observed for cadmium or for several other toxic elements. It is possible that some toxic elements do not accumulate in the same manner as others because of the existence of regulatory biochemical mechanisms that serve to prevent harmful bioaccumulation. For example, metallothioneins are known to protect mammalian bodies from the toxic effects of many trace elements, including cadmium and mercury. However, it still remains to be determined whether the concentration levels observed reflect levels that would be present naturally or whether the levels reflect the influence of anthropogenic inputs into the marine environment. Although most trace elements are acquired from diet rather than the surrounding water a comparison with levels present in seawater could indicate the presence of excessive amounts of a particular element in the marine environment. The relative amount of bioaccumulation was assessed by calculating enrichment factors, the amount of a given element present in the liver tissue relative to concentrations in sea water, normalized to sodium. Enrichment factor is defined in the following equation:

$$EF = [x]_l/[Na]_l//[x]_S/[Na]_S$$

where $[x]_l$ is the concentration of element x in the liver tissue and $[x]_S$ is the concentration of that same element in sea water (Drever, 1982). The enrichment factors for belukha whale liver tissue fall roughly into three categories: electrolytes, essential trace elements, and toxic (or potentially toxic) elements with the electrolytes showing the least enrichment and toxic trace elements the most (Figure 22). Cadmium and mercury fall into the last category and selenium is on the border between the last two categories. Similar trends are evident in the enrichment factors for ringed seal liver tissue. These results may indicate that bioaccumulation occurs for cadmium in liver tissue even without a linear correlation with animal age.

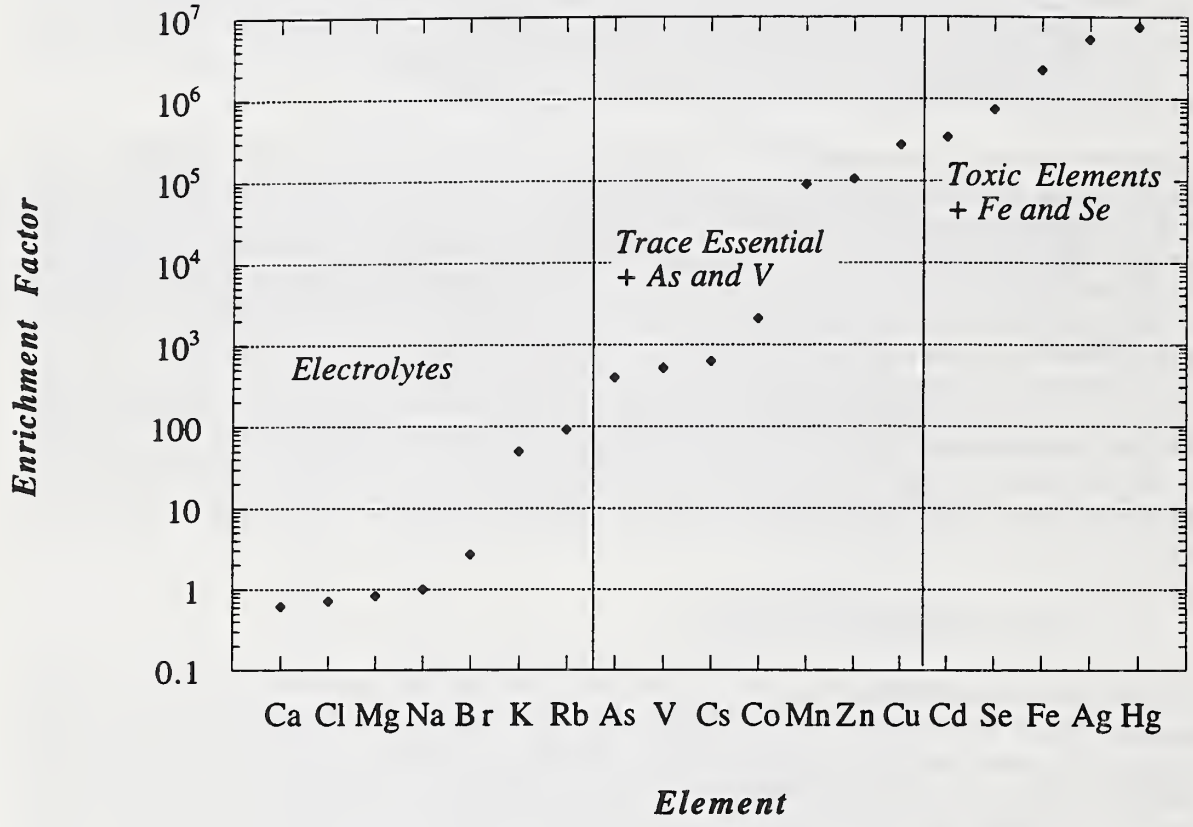


Figure 22. Enrichment factors for belukha whale liver.

SUMMARY AND CONCLUSIONS

It is very common to find PCBs and chlorinated pesticides such as DDT, HCH, HCB, dieldrin, mirex, chlordane, and toxaphene in Alaska marine mammals. Such contaminants are found throughout the world, including the most remote regions of the Arctic and Antarctic. Since these chemicals are lipophilic, the highest levels are found in the blubber. Of the species that the AMMTAP has sampled so far and for which chemical data are available, the highest levels of PCBs and chlorinated pesticides were found in the blubber of belukha whales sampled at Point Lay and Point Hope. Levels were somewhat higher in males than in the females, which is consistent with results reported for belukha whales from the Canadian Arctic, and closely resemble concentration levels reported for belukha whales sampled recently in Mackenzie Bay (eastern Beaufort Sea). The levels of PCBs are generally the same for the Arctic belukha whales as those for narwhal and polar bears, but an order of magnitude lower than levels for belukha whales from the St. Lawrence River Estuary, a population that is highly contaminated with organochlorine pesticides. The ratios of 4,4'-DDE to ΣDDT were quite similar for all belukha whales, including those from the St. Lawrence River Estuary.

Two groups of chlorinated pesticides that may be very important in the study of Arctic animals are the chlordanes and toxaphene. When one compares animals from lower latitudes with those from the northern latitudes and the Arctic, concentration levels of PCBs and most chlorinated pesticides generally decrease from south to north. However, in the case of chlordanes and toxaphene, there is much less difference between animals from the north and the south, and these two groups of chlorinated hydrocarbons contribute a relatively large fraction to the total amount of organochlorine compounds. The ratio of Σchlordane to ΣPCBs, which reflects the relative contribution of chlordanes to the total organochlorines, appears to be much lower for belukha whales from the St. Lawrence River Estuary than for those from the Arctic.

The interpretation of heavy metal data in marine mammals is very difficult. Unlike PCBs and chlorinated pesticides, heavy metals occur naturally and levels can vary quite widely in the environment depending upon the regional geology. Alaska is highly mineralized with localized elevated levels of many heavy metals in rock and sediments. Cadmium and mercury are two heavy metals that are commonly present at high levels in marine mammal tissues (particularly in kidney and liver). Both elements are transferred to vertebrates through the food web and both may be present at relatively high levels in many kinds of seafood (shellfish, finfish, etc.). Both elements are non-essential; once taken up by a vertebrate, they are not easily eliminated and therefore bioaccumulate. One might expect that species from higher trophic levels would contain higher concentrations of cadmium and mercury. However, this is not always the case. Relatively high concentrations of mercury were found in the liver tissues of belukha whales sampled by the AMMTAP; however, cadmium concentrations for this species were very low. The bowhead whale, which feeds much lower in the food web than the belukha whale and which has very low levels of mercury, PCBs, and chlorinated hydrocarbons, had much higher hepatic cadmium concentrations. Cadmium in bowhead whale liver and kidney warrants further investigation, since the levels that we found and that have been previously reported by other investigators are quite high, approaching the levels found in northern fur seals from the Pribilof Islands and walrus from the Bering Sea.

The mercury concentrations in belukha whale livers were relatively high for the animals sampled at Point Lay (18 - 73 μg/g wet weight) as compared with the levels in the liver tissue of the animals sampled at Point Hope (1.4 - 10.2 μg/g). The single whale from Cook Inlet, an older animal, had a relatively low concentration of mercury in its liver. Marine mammals accumulate mercury in a relatively non-toxic form. The toxic portion, methylmercury, is usually less than 2 μg/g wet weight liver. Although methylmercury was not determined in all of the belukha whale livers, for the specimens analyzed the values ranged from 0.36 to 2.15 μg/g wet weight. For the animals

with the highest total mercury, methylmercury accounted for 3% of the total. The ability of some marine mammals to concentrate mercury to high levels in liver tissue is probably a protective mechanism by which the animals convert the toxic methyl form, which they ingest, into a non-toxic inorganic form which is then stored in the liver. Generally, hepatic selenium concentration is positively correlated with hepatic mercury. For many species, it has been shown that selenium combines with the mercury in liver to form a mercury selenide compound, a non-toxic form that is stored in the liver.

Arsenic levels in ringed seals from Norton Sound were quite high for marine mammals with six out of fourteen animals having levels over 1 μg/g wet weight. Although this might reflect a localized natural arsenic source (from the food web) for these animals, these arsenic levels are probably of no concern with regard to toxicity. Most seafoods have elevated arsenic levels and the liver tissue of the Norton Sound ringed seals had comparable levels of this trace element. The arsenic in marine biota are generally in an organic form, mostly arsenobetaine, which is essentially non-toxic and of no concern to humans consuming such biota. Bratton et al. (1993) measured organic arsenic in the liver tissue of one bowhead whale and found that approximately 98% of the total arsenic was in the form of arsenobetaine. Although we did not determine the form of arsenic, it is likely that most of it is in the organic form. However, until analyses for organic arsenic are performed, this can not be confirmed. The amount of arsenic in the liver tissues of the ringed seals does not pose a health risk for the seals or for the humans consuming these animals. However, the presence of these relatively high levels is of interest as this may represent an anomaly specific to the Norton Sound region and may be an example of a case in which a localized trace element source is reflected in a marine mammal species. The Norton Sound region is, historically, an important mining area and soil arsenic levels are normally elevated near arseniferous deposits and in mineralized zones containing gold, silver, and sulfides of lead and zinc (Dudas, 1984).

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APPENDIX A

CHLORINATED HYDROCARBON DATA: BELUKHA WHALE BLUBBER

A list of the abbreviations used in Appendices A and B are shown below in Table A-1. NA indicates that there was no analysis; ND indicates that the substance was not detected, e.g., below minimum detection limit (MDL). Chlordane related compounds, "C", C1A, C2/U5, C3, C5, U3, are U1 are defined according to Dearth and Hites, 1991. Concentration values are expressed as $ng \cdot g^{-1}$, wet weight (ppb, wet weight).

Table A-1. List of abbreviations.

TCB = tetrachlorobenzene
P5CBZ = pentachlorobenzene
HCBZ - hexachlorobenzene
ΣCBZ = sum of chlorobenzenes
HCH = hexachlorocyclohexane
α-HCH = alpha hexachlorocyclohexane
β-HCH = beta hexachlorocyclohexane
γ-HCH= gamma hexachlorocyclohexane
"C"= chlordane "C"
HCHLOR = heptachlor
OCSTYR = octachlorostyrene
C1A = chlordane-C1A
C2/U-5= chlordane-C2/U5
C3 = chlordane-C3
C5 = chlordane-C5
U3 = nonachlor III
U1= cphotoheptachlor
U1= cphotoheptachlor
OXYCLR = oxychlordane
T-CHLOR = trans-chlordane
C-CHLOR = cis-chlordane
T-NONA = trans-nonachlor
C-NONA = cis-nonachlor
H.EPOX = heptachlor epoxide
ΣCHLOR = sum of chlordane compounds
ΣTOX = sum of chlorobornane congeners
ΣTOXSRF = Toxaphene; single response factor calculation
MONO/DI = mono- and dichlorobiphenyl
TETRA = tetrachlorobiphenyls
PENTA = pentachlorobiphenyls
HEXA = hexachlorobiphenyls
HEPTA = heptachlorobiphenyls
OCTA = octachlorobiphenyls
NONA = nonachlorobiphenyls
DECA = decachlorobiphenyls

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number	% Lipid	PCB 1	PCB 4/10	PCB 7	PCB 6	PCB 8/5	PCB 19	PCB 18	PCB 17	PCB 24/27	PCB 16/32	PCB 26
692-BLKA-001	Point Hope	MM3B071	89.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	30.5
692-BLKA-002	Point Hope	MM3B074	94.4	ND	ND	ND	ND	ND	ND	18.9	ND	ND	ND	46.6
692-BLKA-005	Point Lay	MM4B127	81.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
692-BLKA-006	Point Lay	MM4B130	93.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	62.2
692-BLKA-007	Point Lay	MM4B133	84.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	56.2
692-BLKA-008	Point Lay	MM4B136	83.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	54.1
692-BLKA-009	Point Lay	MM4B139	89.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	64.4
692-BLKA-009	Point Lay	MM4B139	89.8	ND	ND	ND	ND	ND	ND	14.5	ND	ND	ND	62.2
692-BLKA-009	Point Lay	MM4B139	89.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
692-BLKA-010	Point Lay	MM4B142	90.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
692-BLKA-011	Point Lay	MM4B145	85.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	58.0
692-BLKA-012	Point Lay	MM4B148	87.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	23.7
692-BLKA-013	Point Lay	MM4B151	91.7	ND	ND	ND	ND	ND	ND	9.7	ND	ND	ND	73.6
692-BLKA-014	Point Lay	MM4B154	97.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MDL				46.0	5.0	3.3	5.4	4.5	7.1	5.1	5.1	2.4	3.8	0.4

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 2)

NIST Identification Number	PCB 25	PCB 31	PCB 28	PCB 33	PCB 22	PCB 45	PCB 46	PCB 52	PCB 49	PCB 48	PCB 44	PCB 42	PCB 41/71
MM3B071	ND	NA	ND	ND	NA	ND	ND	103.0	22.0	46.6	18.4	4.7	ND
MM3B074	ND	NA	ND	ND	NA	ND	ND	178.0	48.8	52.6	43.1	12.3	ND
MM4B127	ND	88.1	34.1	ND	ND	ND	ND	242.4	97.8	19.4	38.5	12.7	ND
MM4B130	ND	NA	ND	ND	NA	ND	ND	261.1	57.3	65.9	64.5	ND	ND
MM4B133	ND	NA	7.4	ND	NA	ND	ND	230.5	38.4	56.0	55.7	ND	ND
MM4B136	ND	NA	ND	ND	NA	ND	ND	224.9	56.2	54.3	53.6	ND	ND
MM4B139	ND	NA	4.5	ND	NA	ND	ND	252.4	75.6	67.6	40.6	7.6	3.5
MM4B139	ND	NA	6.2	ND	NA	ND	ND	247.8	73.3	65.1	42.0	7.2	ND
MM4B139	ND	77.7	88.4	ND	6.6	ND	ND	222.6	141.0	17.4	66.2	19.2	ND
MM4B142	ND	95.8	71.8	ND	6.4	9.2	ND	243.6	139.0	23.7	78.1	21.3	ND
MM4B145	ND	NA	ND	ND	NA	ND	ND	242.5	65.6	59.9	60.5	5.8	ND
MM4B148	ND	NA	ND	ND	NA	ND	ND	89.9	18.3	25.2	19.6	4.6	ND
MM4B151	ND	NA	8.7	ND	NA	ND	ND	274.7	55.8	72.3	51.6	2.6	ND
MM4B154	ND	14.0	28.2	ND	ND	ND	ND	14.1	33.7	ND	6.6	ND	ND
MDL	2.2	2.4	1.7	2.9	1.9	1.9	1.9	3.6	2.4	2.9	2.2	2.2	2.2

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 3)

NIST Identification Number	PCB 64	PCB 40	PCB 74	PCB 70/78	PCB 95/66	PCB 56/60	PCB 91	PCB 84/89	PCB 101	PCB 99	PCB 83
MM3B071	15.1	ND	28.8	11.5	110.7	NA	12.5	9.1	144.0	100.8	52.5
MM3B074	24.6	ND	51.4	20.8	180.3	NA	14.7	8.3	218.7	153.1	105.8
MM4B127	ND	ND	ND	5.0	355.4	43.9	22.6	ND	310.4	248.3	26.9
MM4B130	ND	ND	74.6	15.4	286.2	NA	24.9	33.5	358.7	251.1	42.3
MM4B133	ND	ND	66.1	9.6	256.0	NA	19.2	24.3	252.1	176.4	39.0
MM4B136	ND	ND	79.8	14.0	253.1	NA	18.5	20.8	284.1	198.9	38.1
MM4B139	13.0	ND	49.5	16.8	253.5	NA	23.7	24.9	342.8	240.0	30.3
MM4B139	13.1	ND	56.7	16.2	254.4	NA	22.2	23.0	333.0	233.1	76.4
MM4B139	ND	ND	ND	ND	320.5	36.4	22.5	ND	351.7	264.7	28.7
MM4B142	16.8	ND	ND	ND	334.8	38.3	38.1	ND	391.1	312.9	26.6
MM4B145	ND	ND	80.3	20.2	295.8	NA	21.0	24.1	312.2	218.6	39.0
MM4B148	ND	ND	30.0	9.6	126.7	NA	9.0	6.7	113.0	79.1	56.2
MM4B151	ND	ND	131.3	9.3	298.2	NA	25.0	5.0	336.8	235.8	82.7
MM4B154	ND	ND	ND	ND	27.7	ND	ND	ND	36.3	29.1	ND
MDL	2.2	2.2	2.0	2.3	2.2	1.1	2.4	1.1	2.2	1.8	2.6

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 4)

NIST Identification Number	PCB 97	PCB 87	PCB 85	PCB 136	PCB 110	PCB 151	PCB 144/135	PCB 149	PCB 118	PCB 134	PCB 114	PCB 131
MM3B071	62.0	NA	42.8	22.1	62.9	54.8	ND	117.0	78.5	15.3	28.6	28.6
MM3B074	71.8	NA	67.0	20.9	106.5	66.4	ND	135.3	106.0	13.4	21.1	21.1
MM4B127	43.6	47.2	34.6	ND	58.1	127.2	ND	367.5	270.9	ND	ND	ND
MM4B130	10.3	NA	128.	43.4	107.8	145.6	54.3	286.0	240.6	30.2	36.6	36.6
MM4B133	6.7	NA	92.7	38.9	60.2	116.8	ND	229.0	191.9	19.8	24.9	24.9
MM4B136	16.1	NA	85.1	36.7	90.7	98.7	37.4	209.0	166.1	19.2	21.7	21.7
MM4B139	110.0	NA	83.8	37.7	149.4	122.1	ND	249.7	190.3	25.1	22.0	22.0
MM4B139	108.5	NA	83.5	34.5	148.0	126.2	ND	248.1	186.9	24.6	20.5	20.5
MM4B139	67.9	70.6	32.9	ND	134.1	130.4	ND	362.7	239.8	ND	ND	ND
MM4B142	80.2	106.5	49.0	ND	135.9	146.8	ND	400.0	306.7	ND	ND	ND
MM4B145	22.3	NA	94.1	40.3	134.5	116.0	ND	234.7	211.6	22.9	37.0	37.0
MM4B148	52.1	NA	52.2	14.9	52.7	43.1	2.5	85.8	79.3	11.5	24.8	24.8
MM4B151	56.3	NA	105.	42.5	85.1	150.4	57.3	302.7	264.4	87.2	48.6	48.6
MM4B154	ND	8.3	11.6	ND	10.3	12.3	ND	55.7	31.3	ND	ND	ND
MDL	2.3	1.2	1.2	0.3	1.2	1.4	1.2	1.8	1.3	2.5	0.9	1.6

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 5)

NIST Identification Number	PCB 146	PCB 153	PCB 132	PCB 105	PCB 141	PCB 130/176	PCB 179	PCB 137	PCB 138	PCB 158	PCB 178/129
MM3B071	53.3	215.8	45.5	18.0	25.3	6.9	15.3	50.6	166.9	17.0	31.1
MM3B074	56.5	217.0	57.4	25.5	29.0	5.2	9.4	22.0	179.5	23.8	23.0
MM4B127	74.0	467.4	47.8	68.7	24.0	ND	14.7	26.6	373.3	ND	42.9
MM4B130	138.7	527.1	104.1	69.2	49.0	ND	16.0	39.1	460.1	60.5	69.6
MM4B133	95.7	402.5	69.3	44.5	17.9	10.5	14.4	30.8	341.5	44.2	46.0
MM4B136	86.7	349.6	63.6	39.9	29.1	7.8	11.8	28.2	299.5	39.3	37.5
MM4B139	109.4	421.7	71.5	41.8	51.6	4.9	14.0	30.2	365.9	45.9	49.7
MM4B139	105.3	422.5	70.1	46.0	50.5	5.9	14.3	31.6	360.7	44.4	53.2
MM4B139	72.7	414.2	46.0	58.9	51.4	ND	13.9	24.6	352.0	ND	43.5
MM4B142	95.7	511.9	54.8	88.7	66.5	ND	19.9	32.1	408.7	ND	49.1
MM4B145	95.6	417.2	72.2	51.3	43.9	7.0	12.9	32.7	361.5	48.6	49.6
MM4B148	42.1	162.5	33.9	24.1	18.0	4.7	3.4	16.2	144.6	18.7	20.2
MM4B151	128.2	538.7	89.0	62.1	27.4	ND	11.2	41.1	458.6	56.7	56.8
MM4B154	11.2	72.6	10.0	11.3	ND	ND	ND	ND	50.8	ND	8.2
MDL	1.6	1.3	1.3	1.0	1.0	1.1	1.1	1.1	1.1	0.9	1.2

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 6)

NIST Identification Number	PCB 175	PCB 187	PCB 183	PCB 128[a]	PCB 185	PCB 174	PCB 177	PCB 171	PCB 156	PCB 201/157
MM3B071	ND	25.2	21.0	ND	ND	34.0	26.9	ND	9.3	ND
MM3B074	ND	59.7	24.7	ND	ND	24.5	12.5	ND	12.4	ND
MM4B127	7.6	189.5	72.4	50.5	4.3	45.3	33.7	ND	33.2	14.4
MM4B130	9.7	163.5	65.2	ND	5.9	85.8	28.3	ND	32.9	14.3
MM4B133	ND	118.2	45.4	ND	4.9	53.3	21.5	ND	23.9	9.9
MM4B136	ND	103.5	46.2	ND	3.9	43.3	25.2	ND	20.8	9.0
MM4B139	7.0	128.9	50.0	ND	6.2	48.3	24.4	ND	27.2	10.2
MM4B139	6.7	128.3	53.3	ND	5.2	49.2	22.9	ND	27.5	10.4
MM4B139	7.4	182.5	67.1	51.5	4.6	40.5	19.6	ND	35.3	14.4
MM4B142	8.1	205.9	80.2	56.0	5.0	50.6	24.2	ND	40.2	16.4
MM4B145	ND	124.6	59.3	ND	4.3	59.5	24.7	ND	25.7	11.3
MM4B148	ND	57.7	23.9	ND	ND	26.8	16.0	ND	10.7	ND
MM4B151	8.6	158.7	61.0	ND	5.3	64.0	27.0	ND	29.1	12.3
MM4B154	ND	42.4	21.2	5.3	ND	13.5	ND	ND	6.2	4.3
MDL	1.2	0.9	0.9	0.9	0.6	1.0	1.5	0.6	0.6	0.9

[a] - Incomplete separation in some samples from nonachlorobornene (T12) on Florisil

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 7)

NIST Identification Sample ID	PCB 172/197	PCB 180	PCB 193	PCB 191	PCB 200	PCB 170	PCB 198	PCB 199	PCB 196/203	PCB189
MM3B071	9.9	42.9	6.3	ND	ND	17.6	8.4	11.7	ND	ND
MM3B074	5.5	38.7	ND	ND	ND	15.5	ND	15.6	ND	ND
MM4B127	14.1	128.3	11.3	ND	17.6	38.5	ND	34.3	29.7	ND
MM4B130	18.7	139.1	14.5	ND	ND	55.6	ND	45.6	37.4	ND
MM4B133	12.9	97.4	11.4	ND	ND	39.0	ND	31.2	27.0	ND
MM4B136	9.6	80.0	8.8	ND	ND	32.0	ND	24.4	12.6	ND
MM4B139	13.9	102.1	10.9	ND	ND	40.0	ND	29.8	23.9	ND
MM4B139	15.0	101.7	10.3	ND	ND	39.7	ND	30.9	23.7	ND
MM4B139	14.2	119.8	10.9	ND	24.8	35.9	ND	29.5	32.1	ND
MM4B142	15.4	137.1	12.7	ND	19.5	41.1	ND	31.5	33.1	ND
MM4B145	13.7	98.1	9.3	ND	ND	39.3	ND	28.7	24.8	ND
MM4B148	7.1	40.8	4.6	ND	ND	16.3	ND	19.1	13.0	ND
MM4B151	16.4	130.4	13.9	1.8	ND	53.5	ND	43.4	34.4	ND
MM4B154	2.5	34.4	4.3	ND	ND	10.3	ND	16.1	ND	ND
MDL	1.1	0.6	0.8	0.8	0.8	0.7	0.7	0.9	0.7	0.7

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 8)

NIST Identification Number	PCB 195	PCB 207	PCB 194	PCB 205	PCB 206	PCB 209	Σ-CBZ	Σ-HCH	Σ-CHLOR	Σ-DDT	Σ-PCB
MM3B071	ND	ND	ND	ND	ND	ND	253.3	294.4	1091.5	1143.3	2081.3
MM3B074	ND	ND	ND	ND	ND	ND	986.2	464.4	1548.3	1330.7	2664.7
MM4B127	2.2	ND	9.1	ND	ND	ND	919.5	259.6	2008.8	3313.1	4411.9
MM4B130	ND	ND	11.1	ND	ND	ND	793.5	288.6	2366.3	3778.7	4978.5
MM4B133	ND	ND	ND	ND	ND	ND	874.2	297.2	2173.9	2890.6	3705.9
MM4B136	ND	ND	ND	ND	ND	ND	778.3	478.3	1981.5	2086.6	3564.9
MM4B139	ND	ND	7.2	ND	ND	ND	880.8	318.4	2175.4	2626.4	4259.0
MM4B139	ND	ND	8.1	ND	ND	ND	890.0	345.8	2247.9	2645.0	4284.7
MM4B139	4.5	ND	9.7	ND	3.7	ND	856.7	265.3	1947.6	2782.0	4528.0
MM4B142	ND	ND	9.4	ND	ND	ND	1040.9	346.5	2418.4	3816.1	5233.3
MM4B145	ND	ND	ND	ND	ND	ND	807.3	308.5	2285.6	3405.1	4169.6
MM4B148	ND	ND	ND	ND	ND	ND	454.6	364.4	1004.7	1126.6	1779.5
MM4B151	ND	ND	10.0	ND	ND	ND	927.7	265.5	2350.3	3617.9	5061.0
MM4B154	ND	ND	4.4	ND	ND	ND	92.1	77.7	326.4	332.4	648.4
MDL	0.6	0.9	0.5	0.9	0.7	0.9					

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 9)

NIST Identification Number	Σ-TOX	Σ-TOXSRF	Σ-MON/DI	Σ-TRI	Σ-TETRA	Σ-PENTA	Σ-HEXA	Σ-HEPTA	Σ-OCTO	Σ-NONA	Σ-DECA
MM3B071	964.8	2643.1	ND	30.5	250.1	722.3	812.1	290.0	20.0	ND	ND
MM3B074	1252.2	3481.9	ND	65.5	431.5	1078.8	842.4	247.6	15.6	ND	ND
MM4B127	935.5	2312.8	ND	122.2	501.8	1486.5	1558.2	662.4	107.3	ND	ND
MM4B130	2121.4	5382.7	ND	62.2	538.9	1589.9	1974.6	743.7	108.4	ND	ND
MM4B133	1802.9	4644.2	ND	63.5	456.3	1187.9	1431.4	519.0	68.1	ND	ND
MM4B136	1315.1	3615.9	ND	54.1	482.7	1233.1	1318.8	450.7	46.0	ND	ND
MM4B139	1488.2	3928.5	ND	68.9	526.5	1512.5	1552.8	552.7	71.1	ND	ND
MM4B139	1555.2	4079.9	ND	82.9	521.2	1535.4	1539.0	558.7	73.1	ND	ND
MM4B139	871.6	2160.6	ND	172.6	543.9	1592.2	1505.5	619.9	115.0	3.7	ND
MM4B142	1248.3	3090.4	ND	173.9	617.3	1870.3	1772.4	721.4	110.0	ND	ND
MM4B145	2090.9	5363.1	ND	58.0	534.8	1461.3	1522.7	553.7	64.8	ND	ND
MM4B148	1094.0	2723.9	ND	23.7	197.1	675.8	618.5	243.8	32.1	ND	ND
MM4B151	1669.8	4363.5	ND	91.9	597.7	1605.3	2028.2	679.0	100.0	ND	ND
MM4B154	202.7	499.4	ND	42.1	54.4	165.9	218.0	143.1	24.8	ND	ND

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 10)

NIST Identification Number	1245TCB	1234TCB	P5CBZ	HCBZ	α-HCH	ß-HCH	γ-HCH	C	heptachlor	OCSTYR	C1A	C2/U-5	C3
MM3B071	ND	5.3	17.3	230.8	162.0	99.1	33.3	NA	ND	6.4	NA	ND	1.5
MM3B074	ND	8.4	76.6	901.2	180.3	188.2	95.9	NA	ND	10.1	NA	ND	2.1
MM4B127	8.0	ND	25.6	885.8	79.2	130.3	50.2	NA	2.4	30.8	40.4	18.2	4.3
MM4B130	8.7	5.8	32.1	747.0	129.0	120.0	39.6	NA	ND	13.3	NA	ND	1.8
MM4B133	6.5	ND	28.1	839.6	103.9	144.1	49.2	NA	ND	11.9	NA	ND	3.5
MM4B136	ND	5.7	34.4	738.2	196.3	221.1	60.9	NA	5.6	9.1	NA	ND	3.2
MM4B139	19.1	9.4	60.2	792.2	106.2	166.2	46.0	NA	ND	10.3	NA	ND	1.5
MM4B139	10.1	8.1	59.1	812.7	115.3	180.8	49.8	NA	ND	10.9	NA	ND	2.8
MM4B139	15.4	7.9	63.3	770.1	82.4	136.6	46.3	16.7	ND	6.4	35.1	25.7	4.6
MM4B142	12.1	5.6	70.8	952.4	154.1	127.4	64.9	20.6	ND	29.3	46.3	34.7	8.1
MM4B145	ND	6.8	46.9	753.6	70.8	187.8	49.9	NA	ND	11.8	NA	ND	2.6
MM4B148	ND	5.5	33.2	415.9	186.9	128.7	48.7	NA	ND	7.0	NA	ND	0.9
MM4B151	14.6	8.2	28.9	876.0	89.0	126.9	49.7	NA	ND	17.0	NA	ND	2.7
MM4B154	ND	5.0	5.2	81.9	43.9	22.3	11.5	3.0	ND	17.4	ND	6.7	ND
MDL	2.7	1.2	0.6	0.5	0.5	1.3	0.5	0.5	0.5	0.4	0.5	0.5	0.5

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 11)

NIST Identification Sample ID	C5	U3	U1	oxychlordane	trans-chlordane	cis-chlordane	trans-nonachlor	cis-nonachlor	heptachlor epoxide	dieldrin
MM3B071	5.7	172.7	ND	222.8	5.6	21.8	503.9	78.9	72.1	136.4
MM3B074	6.7	214.6	ND	366.2	8.7	19.0	662.5	103.4	155.1	275.6
MM4B127	10.2	22.4	ND	347.9	31.6	58.9	1081.6	137.1	215.1	411.7
MM4B130	9.3	343.4	ND	485.4	11.0	38.8	1087.1	222.8	153.4	362.7
MM4B133	8.7	303.8	ND	462.1	8.0	29.0	971.2	195.9	179.8	318.8
MM4B136	8.0	281.5	ND	434.8	8.8	28.9	881.7	146.8	173.4	330.1
MM4B139	9.4	310.2	0.9	493.4	11.4	25.7	1000.2	157.6	154.8	276.1
MM4B139	8.4	305.8	ND	527.2	12.2	27.7	1032.4	168.0	152.6	284.3
MM4B139	9.6	9.3	ND	379.8	37.6	52.5	1067.2	128.9	166.8	332.9
MM4B142	15.4	20.3	ND	480.0	55.2	74.8	1262.1	182.4	179.4	419.7
MM4B145	10.8	303.1	ND	433.4	12.1	46.0	1058.1	232.4	175.4	392.7
MM4B148	6.1	96.8	ND	186.9	7.1	32.1	454.2	125.5	88.1	191.9
MM4B151	6.8	341.1	ND	536.1	7.8	37.8	1081.4	175.8	144.0	276.8
MM4B154	3.0	ND	ND	32.3	3.7	28.3	175.6	37.2	19.4	45.9
MDL	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.6	0.5

Table A-2. Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber determined by Department of Fisheries and Oceans (Page 12)

NIST Identification Number	2,4'-DDE	4,4'-DDE	2,4'-DDD	4,4'-DDD	2,4'-DDT	4,4'-DDT	mirex	T.SRF-1	T.SRF-2
MM3B071	19.2	607.5	9.7	86.9	231.4	188.7	14.0	1370.9	1272.2
MM3B074	24.7	692.9	9.8	140.3	258.6	204.5	20.1	1711.8	1770.1
MM4B127	44.9	1940.6	57.7	204.1	480.6	585.6	70.8	1402.6	910.2
MM4B130	26.4	2180.6	65.1	217.7	562.7	726.2	55.3	2548.9	2833.8
MM4B133	14.8	1640.8	54.9	205.7	446.5	527.9	35.4	2007.2	2636.9
MM4B136	21.4	1244.7	19.6	155.5	323.5	321.9	27.6	1830.5	1785.4
MM4B139	9.6	1567.8	9.6	200.8	387.3	451.2	41.6	1869.4	2059.2
MM4B139	25.4	1484.7	12.9	218.6	412.2	491.2	43.4	1872.2	2207.7
MM4B139	38.1	1515.2	57.4	212.6	398.6	560.1	65.6	1366.9	793.7
MM4B142	52.7	2066.6	88.6	236.4	600.4	771.4	71.4	1796.6	1293.8
MM4B145	25.2	1984.1	77.5	235.5	504.9	577.9	37.0	2470.7	2892.5
MM4B148	8.9	511.3	39.6	109.8	177.1	279.9	18.6	1145.2	1578.7
MM4B151	8.1	2228.2	52.7	216.4	505.1	607.4	56.7	2280.7	2082.8
MM4B154	1.9	142.4	11.9	28.4	49.5	98.4	27.6	270.6	228.8
MDL	0.9	0.5	1.0	0.7	0.8	0.7	1.0	2.6	2.6

APPENDIX B

QUALITY CONTROL IN ORGANIC ANALYSIS: INTERLABORATORY COMPARISON OF ANALYSIS OF BELUKHA WHALE BLUBBER, SRM 1588, AND QA WHALE BLUBBER HOMOGENATE

Table B-1. Results (ng/g) of the Interlaboratory Comparison Exercise for Selected PCB Congeners and Selected Chlorinated Pesticides in SRM 1588, Organics in Cod Liver Oil (Page 1)

Congener		Certified Value[a]	Recommended Value[b]	NIST[c]	DFO[d]	Ulm[e] (GPC)	Ulm[e] (Sulphuric)
PCB 18	(2,2',5-Trichlorobiphenyl)		<10	<10	23.1	NA[f]	NA
PCB 28	(2,4,4'-Trichlorobiphenyl)		28.3 ± 0.6	27.6 (0.7)	34.1	31	26
PCB 31	(2,4',5-Trichlorobiphenyl)		8.3 ± 0.3	7.9 (0.1)	11.1	(26)	(24)
PCB 44	(2,2',3,5'-Tetrachlorobiphenyl)		35.1 ± 1.4	35.4 (3.4)	29	39	36
PCB 49	(2,2',4,5'-Tetrachlorobiphenyl)		29.8 ± 1.0	29.8 (0.5)	41.6	40	36
PCB 52	(2,2',5,5'-Tetrachlorobiphenyl)		83.3 ± 1.3	80.4 (5.8)	74.7	87	83
PCB 66	(2,3',4,4'-Tetrachlorobiphenyl)		54.8 ± 2.5	52.3 (1.8)	[88.9][g]	56	55
PCB 87	(2,2',3,4,5'-Pentachlorobiphenyl)		56.3 ± 0.6	56.0 (0.8)	63.9	NA	NA
PCB 95	(2,2',3,5',6-Pentachlorobiphenyl)		36.5 ± 0.8	36.1 (0.8)	[88.9][g]	60	59
PCB 99	(2,2',4,4',5-Pentachlorobiphenyl)		213 ± 2	212 (4)	96.6	89	86
PCB 101	(2,2',4,5,5'-Pentachlorobiphenyl)	129 ± 5	127 ± 2	126 (7)	135	125	130
PCB 105	(2,3,3',4,4'-Pentachlorobiphenyl)		60.2 ± 2.3	53.1 (4.5)	80	59	61
PCB 110	(2,3,3',4',6-Pentachlorobiphenyl)		75.8 ± 1.9	75.1 (2.7)	67.6	71	72
PCB 118	(2,3',4,4',5-Pentachlorobiphenyl)		176 ± 2	179 (10)	226	155	164
PCB 128	(2,2',3,3',4,4'-Hexachlorobiphenyl)		47.1 ± 2.6	47.9 (1.0)	<0.1	37	39
PCB 138	(2,2',3,4,4',5'-Hexachlorobiphenyl)	261 ± 29	263 ± 5	267 (18)	237	209	226
PCB 149	(2,2',3,4',5',6-Hexachlorobiphenyl)		105 ± 2	105 (4)	86.7	80	91
PCB 151	(2,2',3,5,5',6-Hexachlorobiphenyl)		55.2 ± 2.2	53.4 (3.8)	46.9	52	48
PCB 153	(2,2',4,4',5,5'-Hexachlorobiphenyl)	276 ± 40	277 ± 5	283 (17)	269	230	249
PCB 156	(2,3,3',4,4',5-Hexachlorobiphenyl)		27.3 ± 2.0	27.8 (8.9)	28.4	23	25
PCB 170	(2,2',3,3',4,4',5-Heptachlorobiphenyl)	45 ± 5	46.4 ± 1.2	49.1 (2.6)	47	37	42
PCB 180	(2,2',3,4,4',5,5'-Heptachlorobiphenyl)	107 ± 4	106 ± 1	108 (4)	95	96	105
PCB 183	(2,2',3,4,4',5',6-Heptachlorobiphenyl)		30.8 ± 0.7	29.8 (1.7)	27.2	37	35
PCB 187	(2,2'3,4,5,5',6-Heptachlorobiphenyl)		35.3 ± 0.9	36.1 (3.3)	60.8	NA	NA
PCB 194	(2,2',3,3',4,4',5,5'-Octachlorobiphenyl)		15.7 ± 0.8	15.2 (0.4)	12.8	NA	NA
PCB 195	(2,2',3,3',4,4',5,6-Octachlorobiphenyl)		<10	<10	<0.1	5	6
PCB 201	(2,2',3,3',4,5',6,6'-Octachlorobiphenyl)		12.2 ± 0.5	11.5 (0.3)	<0.1	NA	NA
PCB 206	(2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl)		<10	<10	<0.1	NA	NA
PCB 209	(Decachlorobiphenyl)		<10	<10	<0.1	NA	NA

[a] Values from the SRM Certificate of Analysis (issued 1989); uncertainties are expressed as two standard deviations of the certified values.

[b] Recommended values are the means of the results from recent analyses of SRM 1588 using four methods with uncertainties expressed as 95% confidence intervals.

[c] NIST results from intercomparison exercise using DB-5 column excluding PCB 66, PCB 95, and PCB 110 for which results using the C-18 column are reported; two subsamples analyzed in duplicate.

[d] One subsample analyzed.

[e] One subsample analyzed for each of two clean-up methods, gel permeation and sulphuric acid.

[f] NA = not analyzed.

[g] PCB 66 and PCB 95 coeluted under the conditions used.

Table B-1. Results (ng/g) of the Interlaboratory Comparison Exercise for Selected PCB congeners and Selected Chlorinated Pesticides in SRM 1588, Organics in Cod Liver Oil (Page 2)

Compound	Certified Value[a]	Recommended Value[b]	NIST[c]	DFO[d]	Ulm[e] (GPC)	Ulm[e] (Sulphuric)
2,4'-DDE		22.0 ± 1.1	20.0 (2.3)	8.1	10	14
4,4'-DDE	641 ± 62	651 ± 4	647 (8)	552	NA[f]	NA
2,4'-DDD		36.3 ± 1.4	35.2 (6.3)	47.8	37	34
4,4'-DDD	277 ± 15	253 ± 13	228 (23)	242	239	232
2,4'-DDT	154 ± 5	156 ± 3	151 (6)	167	153	149
4,4'-DDT	529 ± 45	521 ± 6	521 (20)	503	565	486
Hexachlorobenzene	148 ± 21	158 ± 3	158 (6)	156	115	126
γ-HCH		25.5 ± 1.7	25.1 (6.4)	22.4	19	19
α-HCH	86 ± 19	85.6 ± 1.7	87.9 (1.9)	101	87	96
6-HCH			NA	5.1	<10	<10
Heptachlor epoxide		35.5 ± 1.5	31.9 (3.1)	26.7	NA	NA
Oxychlordane			31.0 (3.1)	42.5	46	43
cis-Chlordane	158 ± 8	167 ± 6	159 (6)	179	158	174
cis-Nonachlor		94.5 ± 1.4	93.6 (4.9)	97.1	86	83
trans-Nonachlor	209 ± 11	215 ± 4	212 (7)	205	220	230
Dieldrin	150 ± 12	156 ± 3	152 (8)	145	126	NA
Mirex		<10	<10	3.1	14	34

[a] Values from the SRM Certificate of Analysis (issued 1989); uncertainties are expressed as two standard deviations of the certified values.
[b] Recommended values are the means of the results from recent analyses of SRM 1588 using four methods with uncertainties expressed as 95% confidence intervals (see Tables 1 and 2).
[c] NIST results obtained during intercomparison exercise using DB-5 column; two subsamples analyzed in duplicate.
[d] One subsample analyzed.
[e] One subsample analyzed for each of two clean-up methods, gel permeation and sulphuric acid.
[f] NA = not analyzed.

Table B-2. Results (ng/g wet weight) of the Interlaboratory Comparison Exercise for Selected PCB Congeners and Selected Chlorinated Pesticides in Whale Blubber QA Material (Page 1)

Congener		NIST[a]	DFO[b]	Ulm[c]
PCB 18	(2,2',5-Trichlorobiphenyl)	6.12 ± 0.86	<5.1	NA[d]
PCB 28	(2,4,4'-Trichlorobiphenyl)	20.2 ± 0.5	29.9 (8.6)	26 (2)
PCB 31	(2,4',5-Trichlorobiphenyl)	2.59 ± 0.14	NA[d]	25 (1)
PCB 44	(2,2',3,5'-Tetrachlorobiphenyl)	17.8 ± 1.9	19.9 (2.2)	35 (1)
PCB 49	(2,2',4,5'-Tetrachlorobiphenyl)	34.8 ± 0.5	48.2 (12.9)	57 (2)
PCB 52	(2,2',5,5'-Tetrachlorobiphenyl)	103 ± 10	86.5 (5.9)	120 (1)
PCB 66	(2,3',4,4'-Tetrachlorobiphenyl)	50.4 ± 8.5	[202 (12)][e]	61 (2)
PCB 87	(2,2',3,4,5'-Pentachlorobiphenyl)	66.7 ± 0.7	NA	NA
PCB 95	(2,2',3,5',6-Pentachlorobiphenyl)	50.1 ± 0.1	[202 (12)][e]	143 (2)
PCB 99	(2,2',4,4',5-Pentachlorobiphenyl)	254 ± 4	162 (11)	159 (2)
PCB 101	(2,2',4,5,5'-Pentachlorobiphenyl)	261 ± 17	231 (15)	248 (3)
PCB 105	(2,3,3',4,4'-Pentachlorobiphenyl)	88.9 ± 13.0	61.5 (3.0)	82 (2)
PCB 110	(2,3,3',4',6-Pentachlorobiphenyl)	[91.2 ± 0.8][f]	52.8 (3.7)	47 (3)
PCB 118	(2,3',4,4',5-Pentachlorobiphenyl)	267 ± 25	217 (9)	217 (4)
PCB 128	(2,2',3,3',4,4'-Hexachlorobiphenyl)	99.0 ± 0.7	4.77(3.36)	77 (2)
PCB 138	(2,2',3,4,4',5'-Hexachlorobiphenyl)	664 ± 8	489 (24)	506 (8)
PCB 149	(2,2',3,4',5',6-Hexachlorobiphenyl)	372 ± 6	274 (14)	288 (5)
PCB 151	(2,2',3,5,5',6-Hexachlorobiphenyl)	111 ± 2	94.7 (5.4)	107 (2)
PCB 153	(2,2',4,4',5,5'-Hexachlorobiphenyl)	870 ± 9	582 (33)	618 (8)
PCB 156	(2,3,3',4,4',5-Hexachlorobiphenyl)	38.2 ± 0.7	47.9 (3.2)	39 (2)
PCB 170	(2,2',3,3',4,4',5-Heptachlorobiphenyl)	156 ± 1	129 (6)	118 (4)
PCB 180	(2,2',3,4,4',5,5'-Heptachlorobiphenyl)	483 ± 9	322 (17)	372 (4)
PCB 183	(2,2',3,4,4',5',6-Heptachlorobiphenyl)	147 ± 1	109 (3)	117 (0)
PCB 187	(2,2'3,4,5,5',6-Heptachlorobiphenyl)	357 ± 8	317 (17)	NA
PCB 194	(2,2',3,3',4,4',5,5'-Octachlorobiphenyl)	69.8 ± 2.6	59.2 (3.5)	NA
PCB 195	(2,2',3,3',4,4',5,6-Octachlorobiphenyl)	16.3 ± 0.8	17.1 (6.9)	20 (1)
PCB 201	(2,2',3,3',4,5',6,6'-Octachlorobiphenyl)	22.7 ± 0.7	25.4 (16.2)	NA
PCB 206	(2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl)	29.0 ± 0.4	23.6 (1.1)	NA
PCB 209	(Decachlorobiphenyl)	7.98 ± 0.10	<0.9	NA

[a] NIST values are the means of the results from all three methods with uncertainties expressed as 95% confidence intervals.
[b] Five subsmples analyzed, one from each of three bottles and two from one bottle.
[c] Subsamples from each of three bottles analyzed.
[d] NA = not analyzed.
[e] Values in [] indicate known coelution of two or more congeners; PCB 66 coeluted with PCB 95.
[f] Values in [] indicate known coelution of two or more congeners; PCB 77 (3,3',4,4'-tetrachlorobiphenyl) coeluted with PCB 110.

Table B-2. Results (ng/g wet weight) of the Interlaboratory Comparison Exercise for PCB Congeners and Selected Chlorinated Pesticides in Whale Blubber QA Material (Page 2)

Compound	NIST[a]	DFO[b]	Ulm[c]
2,4'-DDE	53.4 ± 7.4	49.4 (1.4)	62 (4)
4,4'-DDE	2032 ± 46	2076 (92)	1993(20)
2,4'-DDD	58.4 ± 3.5	63.2 (3.1)	63 (2)
4,4'-DDD	260 ± 31	313 (7)	346 (18)
2,4'-DDT	222 ± 11	293 (16)	363 (12)
4,4'-DDT	651 ± 26	494 (19)	800 (55)
Hexachlorobenzene	36.9 ± 1.1	40.1 (3.3)	41 (3)
γ-HCH	3.58 ± 0.35	3.7 (0.2)	<10
α-HCH	20.8 ± 2.6	22.9 (1.5)	22 (0.5)
δ-HCH	NA[d]	6.5 (1.6)	<10
Heptachlor epoxide	32.5 ± 2.7	28.3 (1.5)	NA
Oxychlordane	73.5 ± 0.8	66.2 (1.4)	72 (2)
cis-Chlordane	107 ± 2	81.8 (2.7)	82 (1)
cis-Nonachlor	111 ± 3	150 (5)	137 (5)
trans-Nonachlor	648 ± 25	503 (19)	600 (9)
Dieldrin	115 ± 3	95.1 (3.6)	90 (4)
Mirex	74.5 ± 0.9	33.0 (9.9)	83 (4)

[a] NIST values are the means of the results from all three methods with uncertainties expressed as 95% confidence intervals.
[b] Five subsmples analyzed, one from each of three bottles and two from one bottle.
[c] Subsamples from each of three bottles analyzed.
[d] NA = not analyzed.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 1)

Animal Identification Number	NIST Identification Number	PCB 18	PCB 28	PCB 31	PCB 44	PCB 49	PCB 52	PCB 66	PCB 87	PCB 95	PCB 99
692-BLKA-001	MM3B071										
NIST-I[a]		11(1)	[14(2)][d]	[14(2)]	31(2)	NA[e]	119(8)	[86(3)][f]	NA	[86(3)]	NA
NIST-II[b]		6.8	3.6	8.8	25	33	103	13	44	91	105
DFO[c]		≤5.1	≤1.7	NA	18	22	103	[111][f]	NA	[111][e]	101
Ulm[c]		NA	≤10	61	37	47	111	16	NA	102	91
692-BLKA-002	MM3B074										
NIST-I		≤7	[151(16)]	[151(16)]	54(1)	NA	170(4)	[102(3)]	-	[102(3)]	NA
DFO		19	≤1.7	NA	43	49	178	[180]	-	180	153
Ulm		NA	≤10	118	80	83	193	36	-	152	132
692-BLKA-007	MM4B133										
NIST-I		≤5	[82(6)]	NA	46(3)	NA	230(13)	[128(10)]	-	[128(10)]	NA
DFO		≤5.1	7.4	NA	56	38	231	[256]	-	[256]	176
Ulm		NA	12	67	75	63	239	45	-	192	207

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] Values in [] indicate known coelution of two or more congeners; PCB 23 coeluted with PCB 31.
[e] NA = not analyzed.
[f] Values in [] indicate known coelution of two or more congeners; PCB 66 coeluted with PCB 95.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 2)

Animal Identification Number	NIST Identification Number	PCB 18	PCB 28	PCB 31	PCB 44	PCB 49	PCB 52	PCB 66	PCB 87	PCB 95	PCB 99
692-BLKA-008	MM4B136										
NIST-II[b]		11	9.3	10	51	59	209	21	81	192	206
DFO		≤5.1	≤1.7	NA[e]	54	56	225	[253][f]	NA	[253]	199
692-BLKA-012	MM4B148										
NIST-II		7.6	6.3	5.5	25	26	87	19	43	66	79
NIST-I[a]		≤6	[≤8][d]	NA	30(4)	NA	92(3)	[83(2)][f]	NA	[83(2)][f]	NA
DFO[c]		≤5.1	≤1.7	NA	20	18	90	[127]	NA	[127]	79
Ulm[c]		NA	17	72	44	38	90	32	NA	79	76
692-BLKA-013	MM4B151										
NIST-II		9.8	4.8	2.3	50	56	268	28	71	209	308
DFO		9.7	8.7	NA	52	56	275	[298]	NA	[298]	236

[a] NIST-I[a] data fron Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] Values in [] indicate known coelution of two or more congeners; PCB 28 coeluted with PCB 31.
[e] NA = not analyzed.
[f] Values in [] indicate known coelution of two or more congeners; PCB 66 coeluted with PCB 95.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concentrations (ng/g wet weight) of PCB congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 3)

NIST Identification Number	PCB 101	PCB 105	PCB 110	PCB 118	PCB 128	PCB 138	PCB 149	PCB 151	PCB 153	PCB 156	PCB 170
MM3B071											
NIST-I[a]	189(5)	[32(4)][d]	NA[e]	94(2)	NA	194(6)	NA	NA	229(6)	NA	14(1)
NIST-II[b]	146	18	52	72	19	180	111	64	240	9.9	16
DFO[c]	144	18	63	79	≤0.9[f]	167	117	55	216	9.3	18
Ulm[c]	144	26	68	75	22	156	112	59	195	10	18
MM3B074											
NIST-I	235(8)	[57(3)]	NA	111(17)	NA	211(7)	NA	NA	259(14)	NA	13(1)
DFO	219	26	107	106	≤0.9[f]	180	135	66	217	12	16
Ulm	227	43	126	121	31	186	150	74	230	10	24
MM4B133											
NIST-I	239(6)	[94(4)]	NA	226(17)	NA	426(17)	NA	NA	583(11)	NA	43(1)
DFO	252	45	60	192	≤0.9[f]	341	229	117	403	24	39
Ulm	246	70	57	205	54	356	225	117	435	19	41

[a] NIST-I[a] data from Becker et al., (1993)
[a] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] Values in [] ondicate known coelution of two or more congeners; PCB 132 coeluted with PCB 105.
[e] NA = not analyzed.
[f] PCB 128 was possibly fractionated into F2 fraction.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concetnrations (ng/g wet weight) of PCB congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 4)

NIST Identification Number	PCB 101	PCB 105	PCB 110	PCB 118	PCB 128	PCB 138	PCB 149	PCB 151	PCB 153	PCB 156	PCB 170
MM4B136											
NIST-II[b]	282	38	58	158	42	339	218	91	442	9.9	29
DFO[c]	284	40	91	166	≤0.9	300	209	99	350	21	32
MM4B148											
NIST-I[a]	197(3)	[35(7)][d]	NA[e]	122(4)	NA	241(20)	NA	NA	269(11)	NA	18(2)
NIST-II	120	22	42	94	22	193	107	42	211	6.0	18
DFO	113	24	53	79	≤0.9[f]	145	86	43	163	11	16
Ulm[c]	113	31	54	83	24	145	90	46	166	10	21
MM4B151											
NIST-II	331	59	40	262	58	556	305	152	752	11	50
DFO	336	62	85	264	≤0.9	459	303	150	539	29	54

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] Values in [] indicate known coelution of two or more congeners; PCB 28 coeluted with PCB 31.
[e] NA = not analyzed.
[f] PCB 128 was possibly fractionated into F2 fraction.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 5)

NIST Identification Number	PCB 180	PCB 183	PCB 187	PCB194	PCB195	2,4'-DDE	4,4'-DDE	2,4'-DDD	4,4'-DDD	2,4'-DDT
MM3B071										
NIST-I[a]	64(3)	NA[d]	72(4)	NA	≤5	20(1)	762(33)	≤10	73(3)	199(7)
NIST-II[b]	54	21	70	3.3	≤5	19	654	12	75	262
DFO[c]	43	21	25	≤0.5	≤0.6	19	608	9.7	87	231
Ulm[c]	50	29	NA	NA	≤10	24	565	21	82	238
MM3B074										
NIST-I	55(3)	NA	66(4)	-	≤5	61(2)	607(21)	43(3)	94(3)	268(7)
DFO	39	25	60	-	≤0.6	25	693	9.8	140	259
Ulm	54	46	NA	-	≤10	47	640	30	139	287
MM4B133										
NIST	164(2)	NA	156(9)	-	≤5	64(2)	1912(38)	40(3)	213(4)	105(6)
DFO	97	45	118	-	≤0.6	15	1641	55	206	447
Ulm	109	106	NA	-	≤10	47	1290	40	192	556

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] NA = not analyzed.

Table B-3. Results of the Interlaboratory Comparison Excerise for Concentrations (ng/g wet weight) of PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 6)

NIST Identification Number	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	2,4'-DDE	4,4'-DDE	2,4'-DDD	4,4'-DDD	2,4'-DDT
MM4B136										
NIST-II[b]	88	38	107	3.5	-	27	1236	25	146	397
DFO[c]	80	46	104	≤0.5	-	21	1245	20	156	323
MM4B148										
NIST-I[a]	63(3)	NA[d]	71(3)	NA	≤5	17(1)	757(8)	48(4)	196(6)	142(8)
NIST-II	52	21	66	4.2	1.3	8.8	595	35	144	234
DFO	41	24	58	≤0.5	≤0.6	8.9	511	40	110	177
Ulm[c]	51	41	NA	NA	≤10	24	424	27	106	220
MM4B151										
NIST-II	150	58	146	11	8.6	29	2284	27	218	693
DFO	130	61	159	10	≤0.6	8.1	2228	53	216	505

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] NA = not analyzed.

Table B-3. Results of the Interlaboratory Comparison Exercise for Concentrations (ng/g wet weight) of Selected PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 7)

NIST Identification Number	4,4'-DDT	HCB	γ-HCH	α-HCH	ß-HCH	heptachlor epoxide	oxychlordane	cis-chlordane	cis-nonachlor	trans-nonachlor	dieldrin	mirex
MM3B071												
NIST-I[a]	217(5)	354(7)	23(3)	NA[d]	NA	45(3)	NA	13(1)	NA	497(5)	120(1)	NA
NIST-II[b]	185	241	29	202	NA	61	202	22	64	668	136	25
DFO[c]	189	231	33	162	99	72	223	22	79	504	136	14
Ulm[c]	246	192	30	138	92	NA	218	20	70	505	111	27
MM3B074												
NIST-I	312(13)	257(11)	62(1)	NA	NA	16(2)	NA	15(1)	NA	592(9)	229(1)	NA
DFO	205	901	96	180	188	155	366	19	103	663	276	20
Ulm	270	78	83	181	183	NA	385	18	93	700	315	25
MM4B133												
NIST-I	699(5)	253(14)	355(7)[e]	NA	NA	117(4)	NA	35(2)	NA	899(8)	350(4)	
DFO	528	840	49	104	144	180	462	29	196	971	319	35
Ulm	192	664	47	104	118	NA	516	29	187	1010	373	53

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] NA = not analyzed.
[e] Unknown interference

Table B-3. Results of the Interlaboratory Comparison Exercise for Concentrations (ng/g wet weight) of Selected PCB Congeners and Chlorinated Pesticides in Belukha Whale Blubber (Page 8)

NIST Identification Number	4,4'-DDT	HCB	γ-HCH	α-HCH	ß-HCH	heptachlor epoxide	oxychlordane	cis-chlordane	cis-nonachlor	trans-nonachlor	dieldrin	mirex
MM4B136												
NIST-II[b]	312	762	70	213	NA[d]	181	484	33	126	1008	344	34
DFO[c]	322	738	61	196	221	173	435	29	147	882	330	28
MM4B148												
NIST-I	267(4)	218(10)	1095(8)	NA	NA	117(4)	NA	35(2)	NA	599(8)	250(4)	NA
NIST-II	245	425	61	223	NA	96	183	34	92	659	239	23
DFO	280	416	49	187	129	88	187	32	126	454	192	19
Ulm	353	307	46	192	126	NA	194	31	115	506	204	26
MM4B151												
NIST-II	610	924	61	125	NA	166	653	34	205	1628	331	52
DFO	607	876	50	89	126	144	536	37	176	1081	277	57

[a] NIST-I[a] data from Becker et al., (1993)
[b] NIST-II[b] reanalysis of one subsample in March 1992.
[c] Analysis of one subsample.
[d] NA = not analyzed.

APPENDIX C

ELEMENT DATA:
LIVER TISSUE OF PINNIPEDS FROM NORTON SOUND, BELUKHA WHALES AND BOWHEAD WHALES

Typical detection limits for these elements in marine mammal liver tissue are listed in Table C-1. Element concentration data for duplicate subsamples of the liver specimens are presented in Tables C-2 - C-6. Table C-2 presents data from ringed seals sampled in Norton Sound in 1989 and 1991. The concentration values for RGSL-011 and RGSL-012 have been previously reported in Becker et al. (1992) and Zeisler et al. (1993). Table C-3 presents data from a bearded seal and Table C-4 presents data from a spotted seal sampled in Norton Sound in 1989 and 1991, respectively. Table C-5 presents data from belukha whales sampled at Point Hope in 1989, Point Lay in 1990 and Cook Inlet in 1992. The concentration values for BLKA-001, -002, -003, -004, -007 and -012 have been previously reported by Becker et al. (1992) and Zeisler et al. (1993). Table C-6 presents data from bowhead whales sampled at Barrow in 1992.

Concentration values are expressed as μg/g, wet weight, and dry weight conversion factors for each sample are listed in Table C-7; NA indicates that there was no analysis.

Table C-1. Range of INAA detection limits for elements in marine mammal liver tissues.

ELEMENTS	LIMITS OF DETECTION (μg/g)
Sc	0.00007 - 0.0002
Sr	0.5 - 2
Mo	0.13 - 1.1
Sn	1 - 2
Ba	3 - 25
La	0.002 - 0.01
Ce	0.01 - 0.03
Sm	0.0005 - 0.03
Eu	0.0002 - 0.001
Tb	0.0006 - 0.001
Hf	0.0003 - 0.005
Ta	0.0002 - 0.002
Au	0.0002 - 0.1
Th	0.001 - 0.02
U	0.03 - 0.7

Table C-2. Concentrations (μg/g wet weight) of Inorganic Constituents in Bearded Seal (*Erignathus barbatus*) Liver[a] (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number	Na	Mg	Al	Cl	K	Ca	Sc	V
692-BDSL-001	Nome	MM3L051	811 ± 7	220 ± 7	≤0.13	1185 ± 15	3102 ± 44	48 ± 5	≤0.00008	0.206 ± 0.006
			776 ± 7	238 ± 9	≤0.18	1136 ± 14	2987 ± 46	51 ± 4	≤0.00008	0.288 ± 0.009
692-BDSL-004	Nome	MM7L223	1377 ± 6	163 ± 13	0.73 ± 0.090	1382 ± 16	2271 ± 47	≤13	≤0.0002	1.041 ± 0.013
			1359 ± 6	169 ± 13	0.74 ± 0.084	1369 ± 11	2138 ± 43	≤14	≤0.0002	1.032 ± 0.013
692-BDSL-005	Nome	MM7L250	1021 ± 5	227 ± 12	≤0.14	733 ± 10	3154 ± 52	54 ± 5	≤0.0002	0.150 ± 0.004
			1010 ± 5	236 ± 11	≤0.13	733 ± 10	3099 ± 45	50 ± 4	≤0.0008	0.148 ± 0.007

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

Table C-2. Concentrations (μg/g wet weight) of Inorganic Constituents in Bearded Seal (*Erignathus barbatus*) Liver[a] (Page 2)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-BDSL-001	MM3L051	7.31 ± 0.27	231 ± 2	0.1096 ± 0.0010		10.22 ± 0.57	44.17 ± 0.37
		7.02 ± 0.28	225 ± 2	0.1064 ± 0.0011		9.07 ± 0.66	42.91 ± 0.36
					0.02150 ± 0.00020[b]	6.82 ± 0.20[b]	43.80 ± 2.9[b]
					0.01734 ± 0.00089[b]	9.31 ± 0.029[b]	42.40 ± 1.2[b]
692-BDSL-004	MM7L223	3.09 ± 0.06	252 ± 3	0.0996 ± 0.0012		10.97 ± 0.89	32.60 ± 0.1
		3.11 ± 0.04	259 ± 4	0.1039 ± 0.0013		9.11 ± 0.75	33.30 ± 0.1
692-BDSL-005	MM7L250	4.18 ± 0.06	1274 ± 11	0.0526 ± 0.0011		34.44 ± 0.93	103.70 ± 0.3
		4.29 ± 0.04	1226 ± 10	0.0521 ± 0.0010		32.24 ± 0.86	99.50 ± 0.3

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.
[b] Sample analyzed by Voltammetry

Table C-2. Concentrations (µg/g wet weight) of Inorganic Constituents in Bearded Seal (*Erignathus barbatus*) Liver[a] (Page 3)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-BDSL-001	MM3L051	0.547 ± 0.010	2.605 ± 0.030	16.9 ± 0.6	1.985 ± 0.047	≤1.421	≤0.39	0.097 ± 0.004	0.64 ± 0.19
		0.577 ± 0.022	2.560 ± 0.030	16.0 ± 0.7	1.995 ± 0.046	≤1.485	≤0.50	0.095 ± 0.004	1.33 ± 0.15
									1.16 ± 0.11[b]
									1.18 ± 0.043[b]
692-BDSL-004	MM7L223	0.428 ± 0.009	5.234 ± 0.061	14.1 ± 0.4	≤1.37	≤0.9	0.247 ± 0.048	0.078 ± 0.004	2.03 ± 0.088
		0.432 ± 0.009	5.376 ± 0.062	14.7 ± 0.4	≤1.18	≤0.9	0.206 ± 0.043	0.072 ± 0.005	2.05 ± 0.090
692-BDSL-005	MM7L250	0.170 ± 0.008	1.363 ± 0.023	18.5 ± 0.4	≤2.11	≤0.8	0.233 ± 0.045	0.173 ± 0.008	≤0.14
		0.161 ± 0.007	1.265 ± 0.021	18.2 ± 0.5	≤2.96	≤0.7	0.233 ± 0.042	0.171 ± 0.007	≤0.14

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] Samples analyzed by Voltammetry

Table C-2. Concentrations (μg/g wet weight) of Inorganic Constituents in Bearded Seal (*Erignathus barbatus*) Liver[a] (Page 4)

Animal Identification Number	NIST Identification Number	Sn	Sb	I	Cs	Ba	La	Ce	Sm	Eu
692-BDSL-001	MM3L051	≤2.13	0.0062 ± 0.0009	1.23 ± 0.22	0.0039 ± 0.0004	≤13	≤0.006	≤0.0084	≤0.002	≤0.0004
		≤2.21	0.0060 ± 0.0009	1.62 ± 0.24	0.0035 ± 0.0003	≤4	0.0080 ± 0.0010	≤0.0090	≤0.003	≤0.0002
692-BDSL-004	MM7L223	≤1.9	≤0.004	1.34 ± 0.30	0.0083 ± 0.0011	≤3	0.0660 ± 0.0020	0.070 ± 0.013	0.0058 ± 0.0003	0.0019 ± 0.0002
		≤1.9	≤0.004	0.84 ± 0.20	0.0078 ± 0.0010	≤3	0.0700 ± 0.0020	0.067 ± 0.011	0.0058 ± 0.0003	0.0018 ± 0.0001
692-BDSL-005	MM7L250	≤2.0	≤0.004	≤0.92	≤0.0033	≤2	0.0073 ± 0.0009	≤0.029	≤0.002	≤0.0010
		≤2.7	≤0.004	≤0.50	0.0059 ± 0.0013	≤2	0.0089 ± 0.0009	≤0.025	≤0.002	≤0.0008

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

Table C-2. Concentrations (μg/g wet weight) of Inorganic Constituents in Bearded Seal (*Erignathus barbatus*) Liver[a] (Page 5)

Animal Identification Number	NIST Identification Number	Tb	Hf	Ta	Au	Hg	Pb	Th	U
692-BDSL-001	MM3L051	≤0.0012	≤0.0013	≤0.0010	≤0.003	1.72 ± 0.11		≤0.0022	≤0.07
		≤0.0013	≤0.0014	≤0.0010	≤0.002	1.72 ± 0.11		≤0.0023	≤0.08
							0.0321 ± 0.0020[b]		
							0.0301 ± 0.0003[b]		
692-BDSL-004	MM7L223	≤0.0006	≤0.003	≤0.0017	≤0.00076	9.43 ± 0.06		≤0.009	≤0.07
		≤0.0013	≤0.003	≤0.0015	≤0.00077	9.44 ± 0.06		≤0.009	≤0.07
692-BDSL-005	MM7L250	≤0.0019	≤0.006	≤0.0018	≤0.00073	1.30 ± 0.03		≤0.015	≤0.07
		≤0.0017	≤0.005	≤0.0017	≤0.00069	1.40 ± 0.04		≤0.013	≤0.06

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] Samples analyzed by Voltammetry.

Table C-3. Concentrations (μg/g wet weight) of Inorganic Constituents in Spotted Seal (*Phoca largha*) Liver[a] (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number	Na	Mg	Al	Cl	K	Ca	Sc	V
692-SPSL-001	Nome	MM5L164	978 ± 8	233 ± 8	0.25 ± 0.05	1246 ± 15	2971 ± 44	51 ± 4	≤0.00027	0.078 ± 0.006
			968 ± 8	246 ± 8	0.51 ± 0.06	1223 ± 15	2914 ± 47	50 ± 4	≤0.00012	0.065 ± 0.005

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

Table C-3. Concentrations (μg/g wet weight) of Inorganic Constituents in Spotted Seal (*Phoca largha*) Liver[a] (Page 2)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-SPSL-001	MM5L164	5.69 ± 0.24	1422 ± 13	0.0570 ± 0.0007		27.23 ± 0.76	65.50 ± 0.55
		5.40 ± 0.26	1415 ± 12	0.0586 ± 0.0008		26.93 ± 0.69	65.10 ± 0.55
					0.01631 ± 0.00053[b]	24.94 ± 0.20[b]	68.10 ± 2.5[b]
						24.83 ± 0.65[b]	68.6 ± 3.4[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] Samples analyzed by Voltammetry.

Table C-3. Concentrations (μg/g wet weight) of Inorganic Constituents in Spotted Seal (*Phoca largha*) Liver[a] (Page 3)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-SPSL-001	MM5L164	0.359 ± 0.011	1.376 ± 0.018	14.3 ± 0.6	≤4.067	≤3.749	≤0.45	0.221 ± 0.005	≤0.55
		0.335 ± 0.019	1.356 ± 0.021	14.1 ± 0.6	3.049 ± 0.086	≤1.851	0.47 ± 0.15	0.203 ± 0.006	≤0.59
									≤0.014[b]
									≤0.014[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.
[b] Samples analyzed by Voltammetry.

Table C-3. Concentrations (μg/g wet weight) of Inorganic Constituents in Spotted Seal (*Phoca largha*) Liver[a] (Page 4)

Animal Identification Number	NIST Identification Number	Sn	Sb	I	Cs	Ba	La	Ce	Sm	Eu	Tb
692-SPSL-001	MM5L164	≤1.86	≤0.0056	≤0.74	0.0021 ± 0.0003	≤13	≤0.006	≤0.020	≤0.002	≤0.0002	≤0.0013
		≤2.52	≤0.0026	1.43 ± 0.24	0.0025 ± 0.0004	≤3	≤0.003	≤0.0090	≤0.003	≤0.0002	≤0.0014

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics , propagated for standards and samples.

Table C-3. Concentrations (μg/g wet weight) of Inorganic Constituents in Spotted Seal (*Phoca largha*) Liver[a] (Page 5)

Animal Identification Number	NIST Identification Number	Hf	Ta	Au	Hg	Pb	Th	U
692-SPSL-001	MM5L164	≤0.0049	≤0.0014	≤0.003	0.13 ± 0.02		≤0.0018	≤0.08
		≤0.0017	≤0.0016	≤0.002	0.16 ± 0.02		≤0.0026	≤0.03
						0.0427 ± 0.0025[b]		
						0.0430 ± 0.0014[b]		

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted, the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] Samples analyzed by Voltammetry.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispada*) Liver and Kidney[a] (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number[b]	Na	Mg	Al	Cl	K	Ca
692-RGSL-004	Barrow	MM2L030	842 ± 5	231 ± 8	≤0.07	1047 ± 6	3114 ± 61	42 ± 3
			822 ± 5	202 ± 8	≤0.07	1032 ± 6	2947 ± 67	≤8.7
		MM2K031	1912 ± 11	125 ± 9	≤0.10	2584 ± 14	1196 ± 44	47 ± 5
			1922 ± 11	158 ± 9	≤0.11	2555 ± 14	2166 ± 78	53 ± 4
692-RGSL-008	Barrow	MM2L042	833 ± 5	224 ± 8	≤0.07	933 ± 6	3110 ± 60	41 ± 3
			816 ± 5	250 ± 9	≤0.07	908 ± 6	3131 ± 71	45 ± 3
		MM2K043	2120 ± 11	169 ± 10	≤0.12	2939 ± 15	1930 ± 74	≤12
			2095 ± 11	173 ± 12	≤0.12	2893 ± 15	1852 ± 62	≤13
692-RGSL-011	Nome	MM3L054	870 ± 7	220 ± 5	0.88 ± 0.09	810 ± 7	2568 ± 85	30 ± 3
			880 ± 7	230 ± 4	0.74 ± 0.06	828 ± 7	2761 ± 85	30 ± 4
692-RGSL-012	Nome	MM3L057	704 ± 6	253 ± 8	0.28 ± 0.06	938 ± 12	3104 ± 47	43 ± 4
			694 ± 6	254 ± 8	0.28 ± 0.06	929 ± 12	2985 ± 44	37 ± 4
692-RGSL-013	Nome	MM3L060	880 ± 7	192 ± 4	0.98 ± 0.06	1108 ± 8	2559 ± 91	31 ± 3
			878 ± 7	175 ± 4	0.61 ± 0.06	1100 ± 8	2663 ± 70	31 ± 3
692-RGSL-014	Nome	MM3L063	938 ± 8	260 ± 8	0.26 ± 0.06	1236 ± 16	3340 ± 51	49 ± 4
			906 ± 8	267 ± 9	≤0.15	1205 ± 15	3304 ± 47	42 ± 4
692-RGSL-015	Nome	MM3L066	975 ± 8	356 ± 10	≤0.19	1229 ± 15	2805 ± 43	32 ± 4
			958 ± 8	305 ± 11	0.46 ± 0.08	1203 ± 15	2725 ± 43	32 ± 3
692-RGSL-016	Nome	MM5L155	770 ± 6	240 ± 7	0.71 ± 0.07	1040 ± 13	3433 ± 47	54 ± 5
			753 ± 6	264 ± 8	0.62 ± 0.03	1012 ± 13	3346 ± 48	48 ± 4

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispada*) Liver and Kidney[a] (Page 2)

Animal Identification Number	Sampling Site	NIST Identification Number[b]	Na	Mg	Al	Cl	K	Ca
692-RGSL-017	Nome	MM5L158	839 ± 7	240 ± 7	0.13 ± 0.04	1003 ± 13	3229 ± 44	49 ± 5
			826 ± 7	233 ± 7	0.13 ± 0.05	986 ± 13	3211 ± 49	45 ± 4
692-RGSL-018	Nome	MM5L161	1035 ± 8	239 ± 7	0.17 ± 0.04	1132 ± 14	2838 ± 46	39 ± 4
			1027 ± 9	242 ± 8	≤0.15	1120 ± 14	2937 ± 46	31 ± 4
692-RGSL-029	Nome	MM7L226	815 ± 4	217 ± 6	≤0.15	1102 ± 13	3121 ± 49	39 ± 4
			821 ± 4	233 ± 11	≤0.14	1111 ± 9	3082 ± 44	48 ± 4
692-RGSL-030	Nome	MM7L229	921 ± 4	148 ± 10	≤0.14	733 ± 10	3095 ± 47	63 ± 5
			920 ± 4	178 ± 15	≤0.13	733 ± 9	3202 ± 50	56 ± 5
692-RGSL-031	Nome	MM7L232	904 ± 4	235 ± 12	≤0.14	964 ± 11	3086 ± 46	53 ± 5
			903 ± 4	223 ± 12	≤0.14	971 ± 11	3096 ± 49	42 ± 5
692-RGSL-032	Nome	MM7L247	820 ± 4	230 ± 12	≤0.14	1004 ± 12	3279 ± 44	54 ± 5
			823 ± 4	246 ± 12	≤0.14	995 ± 12	3281 ± 50	60 ± 5

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 3)

Animal Identification Number	NIST Identification Number[b]	Sc	V	Mn	Fe	Co
692-RGSL-004	MM2L030	≤0.000058	0.200 ± 0.004	3.73 ± 0.04	729 ± 10	0.0184 ± 0.0002
		≤0.000097	0.196 ± 0.004	3.66 ± 0.04	722 ± 7	0.0178 ± 0.0003
						0.0221 ± 0.0020[c]
	MM2K031	≤0.000031	≤0.077	1.34 ± 0.03	124 ± 2	0.0207 ± 0.0002
		≤0.000053	≤0.082	1.03 ± 0.02	121 ± 1	0.0207 ± 0.0002
692-RGSL-008	MM2L042	0.000084 ± 0.000018	0.404 ± 0.005	3.85 ± 0.04	889 ± 12	0.0338 ± 0.0003
		≤0.000040	0.386 ± 0.005	3.68 ± 0.04	884 ± 12	0.0335 ± 0.0003
						0.0472 ± 0.0023[c]
	MM2K043	≤0.000034	0.073 ± 0.004	1.02 ± 0.02	115 ± 2	0.0557 ± 0.0005
		≤0.000041	0.056 ± 0.004	0.70 ± 0.02	114 ± 1	0.0551 ± 0.0005
692-RGSL-011	MM3L054	0.000196 ± 0.000044	0.380 ± 0.007	4.22 ± 0.04	573 ± 5	0.0448 ± 0.0007
		0.000323 ± 0.000050	0.395 ± 0.007	4.28 ± 0.04	582 ± 5	0.0461 ± 0.0007
						0.0458 ± 0.0022[c]
692-RGSL-012	MM3L057	0.000520 ± 0.000040	0.472 ± 0.010	5.59 ± 0.22	619 ± 5	0.0725 ± 0.0009
		0.000490 ± 0.000050	0.472 ± 0.010	5.69 ± 0.21	637 ± 5	0.0735 ± 0.0009
692-RGSL-013	MM3L060	0.000206 ± 0.000045	0.126 ± 0.005	2.86 ± 0.04	314 ± 3	0.0239 ± 0.0005
		0.000123 ± 0.000033	0.124 ± 0.006	3.02 ± 0.03	315 ± 3	0.0235 ± 0.0005
						0.0430 ± 0.0011[c]
692-RGSL-014	MM5L063	0.000370 ± 0.000040	0.297 ± 0.009	6.31 ± 0.23	382 ± 3	0.0320 ± 0.0007
		0.000320 ± 0.000040	0.280 ± 0.008	5.82 ± 0.24	374 ± 3	0.0322 ± 0.0008
692-RGSL-015	MM5L066	≤0.00010	0.172 ± 0.008	5.02 ± 0.19	1183 ± 9	0.0312 ± 0.0007
		≤0.00011	0.177 ± 0.007	4.97 ± 0.22	1172 ± 9	0.0311 ± 0.0006

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

[c] Samples analyzed by voltammetry

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 4)

Animal Identification Number	NIST Identification Number[b]	Sc	V	Mn	Fe	Co
692-RGSL-016	MM5L155	≤0.00020	0.032 ± 0.007	4.32 ± 0.18	5159 ± 40	0.0122 ± 0.0009
		≤0.00021	0.020 ± 0.004	4.04 ± 0.19	5127 ± 40	0.0146 ± 0.0009
692-RGSL-017	MM5L158	0.000280 ± 0.000050	0.333 ± 0.007	4.25 ± 0.20	1830 ± 15	0.0388 ± 0.0008
		0.000180 ± 0.000060	0.344 ± 0.008	4.39 ± 0.23	1909 ± 15	0.0403 ± 0.0008
692-RGSL-018	MM5L161	0.000170 ± 0.000030	0.019 ± 0.004	4.90 ± 0.20	209 ± 2	0.0236 ± 0.0005
		0.000130 ± 0.000030	0.019 ± 0.003	5.10 ± 0.25	207 ± 2	0.0249 ± 0.0005
692-RGSL-029	MM7L226	≤0.0003	0.279 ± 0.007	3.97 ± 0.06	623 ± 6	0.0457 ± 0.0010
		≤0.0003	0.264 ± 0.003	3.99 ± 0.04	639 ± 6	0.0430 ± 0.0010
692-RGSL-030	MM7L229	≤0.0005	0.136 ± 0.005	3.32 ± 0.06	622 ± 8	0.0376 ± 0.0009
		≤0.0004	0.107 ± 0.007	3.28 ± 0.04	632 ± 7	0.0386 ± 0.0009
692-RGSL-031	MM7L232	≤0.0003	0.143 ± 0.006	4.24 ± 0.04	950 ± 9	0.1256 ± 0.0016
		≤0.0003	0.163 ± 0.006	4.18 ± 0.05	912 ± 9	0.1207 ± 0.0015
692-RGSL-032	MM7L247	≤0.0004	0.113 ± 0.003	3.04 ± 0.04	5288 ± 38	0.0355 ± 0.0014
		≤0.0004	0.121 ± 0.006	3.01 ± 0.04	5134 ± 38	0.0288 ± 0.0013

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 5)

Animal Identification Number	NIST Identification Number[b]	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Mo
692-RGSL-004	MM2L030		11.21 ± 0.37	38.06 ± 0.49	0.263 ± 0.012	5.712 ± 0.075	NA	2.418 ± 0.053	≤0.31	0.253 ± 0.061
			10.92 ± 0.35	37.61 ± 0.49	0.300 ± 0.022	5.628 ± 0.053	NA	2.267 ± 0.051	≤0.56	0.244 ± 0.073
		0.0508 ± 0.0006[c]	9.45 ± 0.03[c]	37.9 ± 2.0[c]						
	MM2K031		≤0.85	26.29 ± 0.34	0.175 ± 0.016	3.941 ± 0.052	NA	1.222 ± 0.024	≤0.18	≤0.30
			3.90 ± 0.36	26.08 ± 0.34	0.200 ± 0.018	3.888 ± 0.051	NA	1.181 ± 0.032	≤0.30	≤0.30
692-RGSL-008	MM2L042		6.40 ± 0.31	36.98 ± 0.48	0.584 ± 0.015	2.818 ± 0.037	NA	3.515 ± 0.062	≤0.27	0.519 ± 0.067
			6.54 ± 0.32	36.73 ± 0.48	0.634 ± 0.021	2.798 ± 0.037	NA	3.523 ± 0.050	≤0.23	0.524 ± 0.073
		0.0315 ± 0.0015[c]	6.30 ± 0.03[c]	37.0 ± 2.0[c]						
	MM2K043		7.66 ± 0.46	26.61 ± 0.35	0.444 ± 0.020	3.205 ± 0.042	NA	1.718 ± 0.032	≤0.20	≤0.33
			3.34 ± 0.26	26.06 ± 0.34	0.428 ± 0.024	3.092 ± 0.041	NA	1.720 ± 0.028	≤0.27	≤0.32
692-RGSL-011	MM3L054		8.00 ± 0.55	32.35 ± 0.28	2.46 ± 0.03	3.707 ± 0.036	NA	1.613 ± 0.058	≤1.3	0.403 ± 0.080
			7.72 ± 0.44	33.01 ± 0.28	2.37 ± 0.03	3.767 ± 0.036	NA	1.663 ± 0.066	≤1.4	≤0.31
		0.0177 ± 0.0002[c]	7.69 ± 0.17[c]	33.37 ± 0.55[c]						
692-RGSL-012	MM3L057		8.94 ± 0.66	52.00 ± 0.44	1.517 ± 0.011	5.441 ± 0.055	17.3 ± 0.7	2.527 ± 0.061	≤1.690	≤0.49
			8.04 ± 0.52	52.64 ± 0.45	1.713 ± 0.035	5.536 ± 0.056	14.4 ± 0.7	2.627 ± 0.066	≤1.619	≤0.75
692-RGSL-013	MM3L060		7.95 ± 0.45	27.61 ± 0.24	2.15 ± 0.03	2.730 ± 0.028	NA	2.254 ± 0.056	≤1.3	0.416 ± 0.086
			8.82 ± 0.47	27.77 ± 0.24	2.06 ± 0.03	2.736 ± 0.027	NA	2.235 ± 0.056	≤1.2	0.299 ± 0.078
		0.0385 ± 0.0025[c]	7.98 ± 0.17[c]	26.39 ± 0.89[c]						
692-RGSL-014	MM3L063		23.70 ± 0.79	56.11 ± 0.47	1.276 ± 0.013	3.031 ± 0.035	16.3 ± 0.7	2.740 ± 0.054	≤1.679	≤0.61
			23.72 ± 0.69	54.71 ± 0.46	1.386 ± 0.020	2.957 ± 0.033	13.9 ± 0.6	2.747 ± 0.065	≤1.613	≤0.63
692-RGSL-015	MM3L066		17.23 ± 0.71	37.79 ± 0.32	1.650 ± 0.014	2.885 ± 0.032	18.6 ± 0.7	3.098 ± 0.072	≤1.590	≤0.55
			16.24 ± 0.60	37.68 ± 0.32	1.845 ± 0.023	2.895 ± 0.033	17.8 ± 0.7	2.996 ± 0.073	≤1.577	0.51 ± 0.13

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

[c] Samples analyzed by voltammetry

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 6)

Animal Identification Number	NIST Identification Number[b]	Ni	Cu	Zn	As	Se	Br	Rb	Sr	Mo
692-RGSL-016	MM5L155		24.04 ± 0.71	88.74 ± 0.74	0.358 ± 0.012	1.350 ± 0.024	34.7 ± 1.1	2.880 ± 0.115	≤2.676	≤0.38
			23.83 ± 0.72	87.72 ± 0.74	0.270 ± 0.019	1.381 ± 0.025	33.3 ± 1.1	2.911 ± 0.129	≤2.738	≤0.47
692-RGSL-017	MM5L158		7.02 ± 0.52	43.21 ± 0.37	1.088 ± 0.011	3.416 ± 0.038	13.6 ± 0.6	3.078 ± 0.078	≤1.833	≤0.49
			6.90 ± 0.40	44.97 ± 0.38	1.206 ± 0.022	3.563 ± 0.039	13.1 ± 0.6	2.997 ± 0.087	≤1.941	≤0.76
692-RGSL-018	MM5L161		7.19 ± 0.48	35.65 ± 0.30	0.798 ± 0.012	1.544 ± 0.022	15.0 ± 0.7	2.624 ± 0.048	≤1.333	≤0.46
			6.63 ± 0.59	35.40 ± 0.30	0.830 ± 0.021	1.509 ± 0.021	16.1 ± 0.7	2.600 ± 0.059	≤1.417	0.59 ± 0.15
692-RGSL-029	MM7L226		9.22 ± 0.72	44.30 ± 0.20	0.702 ± 0.010	1.924 ± 0.027	9.7 ± 0.3	≤1.78	≤0.6	0.48 ± 0.05
			9.79 ± 0.72	45.00 ± 0.20	0.701 ± 0.009	1.973 ± 0.027	13.6 ± 0.4	≤1.53	≤0.6	0.51 ± 0.05
692-RGSL-030	MM7L229		43.85 ± 1.00	114.20 ± 0.30	0.171 ± 0.008	1.310 ± 0.023	13.8 ± 0.4	≤5.40	≤0.6	0.40 ± 0.05
			46.49 ± 1.11	114.00 ± 0.30	0.159 ± 0.008	1.336 ± 0.024	14.3 ± 0.4	≤2.90	≤0.6	0.35 ± 0.05
692-RGSL-031	MM7L232		14.86 ± 0.74	52.80 ± 0.20	0.270 ± 0.009	4.290 ± 0.052	8.7 ± 0.4	≤2.56	≤0.6	0.38 ± 0.05
			18.01 ± 0.78	50.20 ± 0.20	0.263 ± 0.008	4.081 ± 0.050	9.7 ± 0.3	≤1.97	≤0.6	0.42 ± 0.05
692-RGSL-032	MM7L247		8.30 ± 0.64	49.90 ± 0.20	0.918 ± 0.013	1.209 ± 0.022	15.9 ± 0.4	≤1.77	≤0.6	4.38 ± 0.13
			7.51 ± 0.62	48.80 ± 0.20	0.947 ± 0.014	1.174 ± 0.023	15.4 ± 0.5	≤3.38	≤0.6	4.31 ± 0.13

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (µg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 7)

Animal Identificaiton Number	NIST Identification Number[b]	Ag	Cd	Sn	Sb	I	Cs	Ba	La
692-RGSL-004	MM2L030	0.1644 ± 0.0031	2.77 ± 0.12	≤0.53	0.00662 ± 0.00034	0.95 ± 0.07	0.0308 ± 0.0007	≤1.2	≤0.0083
		0.1656 ± 0.0047	2.55 ± 0.14	≤1.1	0.00664 ± 0.00052	0.69 ± 0.06	0.0306 ± 0.0010	≤0.78	≤0.0071
			2.42 ± 0.02[c]						
	MM2K031	0.0022 ± 0.0006	6.76 ± 0.16	≤0.32	0.00304 ± 0.00018	≤0.18	0.0289 ± 0.0005	≤0.60	≤0.011
		≤0.0025	6.61 ± 0.16	≤0.58	0.00329 ± 0.00032	≤0.17	0.0281 ± 0.0006	≤0.84	≤0.0093
692-RGSL-008	MM2L042	0.0474 ± 0.0016	2.14 ± 0.12	≤0.45	0.00556 ± 0.00027	0.67 ± 0.06	0.0235 ± 0.0005	≤1.1	≤0.0079
		0.0472 ± 0.0015	2.13 ± 0.12	≤0.47	0.00513 ± 0.00021	0.75 ± 0.07	0.0238 ± 0.0005	≤0.25	≤0.0070
			2.18 ± 0.06[c]						
	MM2K043	0.0022 ± 0.0007	3.37 ± 0.15	0.82 ± 0.15	0.00191 ± 0.00016	≤0.22	0.0241 ± 0.0004	≤0.70	≤0.012
		≤0.0023	3.80 ± 0.16	≤0.60	0.00253 ± 0.00023	≤0.16	0.0240 ± 0.0006	≤0.32	≤0.0097
692-RGSL-011	MM3L054	0.0734 ± 0.0030	1.72 ± 0.15	NA	0.01290 ± 0.00110	7.64 ± 0.72	0.0464 ± 0.0013	NA	≤0.0074
		0.0753 ± 0.0033	1.94 ± 0.20	NA	0.01100 ± 0.00120	9.38 ± 0.85	0.0491 ± 0.0012	NA	≤0.011
			1.84 ± 0.02[c]						
692-RGSL-012	MM3L057	0.0670 ± 0.0060	7.82 ± 0.33	≤2.52	0.01730 ± 0.00140	2.98 ± 0.34	0.0154 ± 0.0005	≤16	≤0.011
		0.0640 ± 0.0050	9.76 ± 0.23	≤2.34	0.01550 ± 0.00150	2.74 ± 0.33	0.0154 ± 0.0005	≤3	≤0.019
692-RGSL-013	MM3L060	0.0935 ± 0.0039	1.95 ± 0.18	NA	0.00610 ± 0.00110	6.03 ± 0.81	0.0470 ± 0.0013	NA	≤0.0072
		0.0898 ± 0.0031	1.74 ± 0.17	NA	0.00575 ± 0.00078	6.72 ± 0.73	0.0442 ± 0.0011	NA	≤0.0070
			1.99 ± 0.04[c]						
692-RGSL-014	MM3L063	0.2320 ± 0.0060	≤1.44	≤2.53	0.00930 ± 0.00120	1.49 ± 0.23	0.0111 ± 0.0005	≤21	≤0.009
		0.2230 ± 0.0050	1.45 ± 0.15	≤2.32	0.00750 ± 0.00100	1.48 ± 0.21	0.0113 ± 0.0005	≤4	≤0.003

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

[c] Samples analyzed by voltammetry

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 8)

Animal Identificaiton Number	NIST Identification Number[b]	Ag	Cd	Sn	Sb	I	Cs	Ba	La
692-RGSL-015	MM3L066	0.1240 ± 0.0050	≤1.34	≤2.32	0.00840 ± 0.00110	1.20 ± 0.24	0.0078 ± 0.0005	≤19	≤0.009
		0.1200 ± 0.0050	1.14 ± 0.15	≤2.25	0.00920 ± 0.00130	1.00 ± 0.20	0.0077 ± 0.0005	≤9	≤0.003
692-RGSL-016	MM6L155	0.154 ± 0.009	≤0.67	≤3.56	≤0.0037	≤0.56	0.0081 ± 0.0008	≤17	≤0.007
		0.162 ± 0.009	≤0.79	≤3.56	≤0.0037	≤0.30	0.0086 ± 0.0008	≤5	≤0.003
692-RGSL-017	MM6L158	0.016 ± 0.005	5.02 ± 0.30	≤2.65	0.0216 ± 0.0015	2.87 ± 0.34	0.0102 ± 0.0006	≤14	0.0190 ± 0.0030
		0.013 ± 0.005	6.07 ± 0.19	≤2.76	0.0224 ± 0.0016	2.59 ± 0.32	0.0097 ± 0.0006	≤4	0.0230 ± 0.0020
692-RGSL-018	MM6L161	0.043 ± 0.003	1.19 ± 0.24	≤2.07	0.0095 ± 0.0011	≤0.76	0.0098 ± 0.0004	≤16	≤0.008
		0.042 ± 0.004	1.14 ± 0.14	≤2.14	0.0107 ± 0.0010	1.04 ± 0.22	0.0091 ± 0.0004	≤4	≤0.003
692-RGSL-029	MM7L226	0.058 ± 0.005	1.60 ± 0.07	≤2.3	0.0190 ± 0.0030	1.84 ± 0.30	0.0346 ± 0.0016	≤2	0.0032 ± 0.0008
		0.046 ± 0.004	1.69 ± 0.08	≤2.1	0.0140 ± 0.0020	1.38 ± 0.20	0.0340 ± 0.0016	≤3	0.0032 ± 0.0006
692-RGSL-030	MM7L229	0.192 ± 0.008	≤0.137	≤3.2	≤0.006	≤0.81	0.0051 ± 0.0016	≤2	0.0026 ± 0.0008
		0.194 ± 0.008	≤0.090	≤1.5	≤0.004	≤0.62	0.0039 ± 0.0013	≤2	0.0023 ± 0.0007
692-RGSL-031	MM7L232	0.144 ± 0.007	3.40 ± 0.09	≤2.5	≤0.007	2.79 ± 0.30	0.0234 ± 0.0016	≤2	0.0059 ± 0.0008
		0.134 ± 0.007	3.30 ± 0.09	≤2.6	≤0.006	2.83 ± 0.30	0.0209 ± 0.0018	≤2	0.0042 ± 0.0008
692-RGSL-032	MM7L247	0.043 ± 0.007	≤0.106	≤3.5	≤0.006	≤0.72	0.0130 ± 0.0019	≤2	≤0.002
		0.027 ± 0.006	≤0.155	≤3.4	≤0.005	≤0.57	0.0150 ± 0.0019	≤2	≤0.002

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 9)

Animal Identification Number	NIST Identification Number[b]	Ce	Sm	Eu	Tb	Hf	Ta	Au	Hg	Methyl-Hg	Pb
692-RGSL-004	MM2L030	≤0.0057	≤0.0012	≤0.00038	≤0.00031	≤0.00052	≤0.00047	≤0.0003	NA		
		≤0.0096	≤0.0019	≤0.00077	≤0.00064	≤0.00084	≤0.00093	≤0.0003	NA		
									6.35 ± 0.11[c]	0.28[c]	0.0287 ± 0.0014[d]
	MM2K031	≤0.0034	≤0.0012	≤0.00020	≤0.00019	≤0.00029	≤0.00020	≤0.0004	NA		
		≤0.0059	≤0.0014	≤0.00035	≤0.00034	≤0.00049	≤0.00035	≤0.0004	NA		
692-RGSL-008	MM2L042	0.0050 ± 0.0018	≤0.0013	≤0.00034	≤0.00026	≤0.00046	≤0.00042	≤0.0003	NA		
		≤0.0037	≤0.0018	≤0.00033	≤0.00027	≤0.00034	≤0.00040	≤0.0003	NA		
									1.95 ± 0.29[c]	0.17[c]	0.0312 ± 0.0012[d]
	MM2K043	≤0.0038	≤0.0013	≤0.00022	≤0.00021	≤0.00032	≤0.00024	≤0.0004	NA		
		≤0.0050	≤0.0015	≤0.00032	≤0.00035	≤0.00041	≤0.00036	≤0.0004	NA		
692-RGSL-011	MM3L054	≤0.016	≤0.00091	≤0.00097	≤0.0014	≤0.0011	≤0.00083	≤0.00030	NA		
		≤0.017	≤0.00099	≤0.0010	≤0.0015	≤0.0011	≤0.00088	≤0.00041	NA		
									1.63 ± 0.83[c]	0.70[c]	0.0287 ± 0.0033[d]
692-RGSL-012	MM3L057	≤0.0094	≤0.002	0.0007 ± 0.0001	≤0.0014	≤0.0015	≤0.0013	≤0.003	4.59 ± 0.28		
		≤0.0095	≤0.003	0.0006 ± 0.0001	≤0.0013	≤0.0016	≤0.0012	≤0.002	5.78 ± 0.36		
692-RGSL-013	MM3L060	≤0.017	≤0.0010	≤0.00086	≤0.0012	≤0.0011	≤0.00064	≤0.00028	NA		
		≤0.016	≤0.00095	≤0.00081	≤0.0011	≤0.0010	≤0.00067	≤0.00028	NA		
									1.42 ± 0.03[c]	0.49[c]	0.0237 ± 0.0001[d]
692-RGSL-014	MM3L063	≤0.0095	≤0.002	≤0.0002	≤0.0014	≤0.0015	≤0.0012	≤0.004	4.38 ± 0.27		
		≤0.0091	≤0.002	≤0.0002	≤0.0013	≤0.0015	≤0.0011	≤0.002	4.11 ± 0.25		

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

[c] Samples analyzed by cold vapor atomic absorption spectrometry.

[d] Samples analyzed by voltammetry.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 10)

Animal Identification Number	NIST Identification Number[b]	Ce	Sm	Eu	Tb	Hf	Ta	Au	Hg	Methyl-Hg	Pb
692-RGSL-015	MM3L066	≤0.0082	≤0.002	≤0.0002	≤0.0012	≤0.0015	≤0.0014	≤0.004	0.66 ± 0.05		
		≤0.0082	≤0.002	≤0.0002	≤0.0012	≤0.0015	≤0.0014	≤0.002	0.67 ± 0.05		
692-RGSL-016	MM5L155	≤0.0104	≤0.002	≤0.0004	≤0.0018	≤0.0025	≤0.0028	≤0.004	0.45 ± 0.04		
		≤0.0108	≤0.003	≤0.0004	≤0.0018	≤0.0025	≤0.0028	≤0.002	NA		
692-RGSL-017	MM5L158	≤0.0092	0.0022 ± 0.0008	≤0.0003	≤0.0014	≤0.0017	≤0.0017	≤0.003	0.61 ± 0.05		
		≤0.0162	0.0019 ± 0.0009	0.0007 ± 0.0001	≤0.0014	≤0.0018	≤0.0019	≤0.002	0.51 ± 0.04		
692-RGSL-018	MM5L161	≤0.0082	≤0.002	≤0.0002	≤0.0012	≤0.0012	≤0.0009	≤0.004	0.36 ± 0.03		
		≤0.0086	≤0.002	≤0.0002	≤0.0012	≤0.0013	≤0.0009	≤0.002	0.56 ± 0.04		
692-RGSL-029	MM7L226	≤0.023	≤0.0006	≤0.0006	≤0.0015	≤0.004	≤0.0017	≤0.00065	NA		
		≤0.024	≤0.0006	≤0.0002	≤0.0014	≤0.004	≤0.0021	≤0.00063	NA		
692-RGSL-030	MM7L229	≤0.048	≤0.0008	≤0.0005	≤0.0023	≤0.009	≤0.0020	≤0.00069	NA		
		≤0.028	≤0.0009	≤0.0005	≤0.0019	≤0.009	≤0.0019	≤0.00071	NA		
692-RGSL-031	MM7L232	≤0.032	≤0.0007	≤0.0002	≤0.0017	≤0.005	≤0.0021	≤0.0065	NA		
		≤0.31	≤0.0007	≤0.0003	≤0.0016	≤0.005	≤0.0020	≤0.0076	NA		
692-RGSL-032	MM7L247	≤0.033	≤0.0007	≤0.0003	≤0.0022	≤0.007	≤0.0027	≤0.0074	NA		
		≤0.032	≤0.0008	≤0.0002	≤0.0021	≤0.007	≤0.0027	≤0.0021	NA		

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 11)

Animal Identification Number	NIST Identification Number[b]	Th	U
692-RGSL-004	MM2L030	≤0.00078	≤0.054
		≤0.0012	≤0.060
	MM2K031	≤0.00047	≤0.063
		≤0.00078	≤0.060
692-RGSL-008	MM2L042	≤0.00069	≤0.052
		≤0.00045	≤0.057
	MM2K043	≤0.00052	≤0.069
		≤0.00060	≤0.065
692-RGSL-011	MM2L054	NA	≤0.085
		NA	≤0.099
692-RGSL-012	MM3L057	≤0.0024	≤0.08
		≤0.0025	≤0.10
692-RGSL-013	MM2L060	NA	≤0.092
		NA	≤0.086
692-RGSL-014	MM3L063	≤0.0025	≤0.10
		≤0.0024	≤0.07
692-RGSL-015	MM3L066	≤0.0022	≤0.09
		≤0.0022	≤0.07
692-RGSL-016	MM5L155	≤0.0032	≤0.09
		≤0.0034	≤0.09

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-4. Concentrations (μg/g wet weight) of Inorganic Constituents in Ringed Seal (*Phoca hispida*) Liver and Kidney[a] (Page 12)

Animal Identification Number	NIST Identification Number[b]	Th	U
692-RGSL-017	MM5L158	≤0.0025	≤0.08
		≤0.0028	≤0.08
692-RGSL-018	MM5L161	≤0.0021	≤0.08
		≤0.0023	≤0.08
692-RGSL-029	MM7L226	≤0.012	≤0.06
		≤0.011	≤0.06
692-RGSL-030	MM7L229	≤0.030	≤0.07
		≤0.030	≤0.07
692-RGSL-031	MM7L232	≤0.014	≤0.07
		≤0.013	≤0.07
692-RGSL-032	MM7L247	≤0.018	≤0.08
		≤0.017	≤0.07

[a] All elements are determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standards and samples.

[b] In the NIST Identification Number, the letters L, and K indicates the sample type, i.e., L = Liver and K = Kidney.

Table C-5. Concentrations (μg/g wet weight) of Inorganic Constituents in Bowhead Whale (*Balaena mysticetus*) Liver[a] (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number	Na	Mg	Al	Cl	K	Ca	Sc	V
692-BWHD-001	Barrow	MM6L197	1562 ± 11	66 ± 12	0.45 ± 0.09	1932 ± 17	1902 ± 112	47 ± 4	0.00153 ± 0.00003	0.086 ± 0.007
			1600 ± 11	60 ± 16	0.48 ± 0.08	1980 ± 18	1927 ± 107	42 ± 5	0.00150 ± 0.00004	0.081 ± 0.007
692-BWHD-006	Barrow	MM6L208	1040 ± 9	130 ± 4	0.28 ± 0.06	1592 ± 19	2808 ± 43	20 ± 4	0.00038 ± 0.00004	0.790 ± 0.013
			1018 ± 8	124 ± 4	0.14 ± 0.06	1536 ± 19	2784 ± 45	21 ± 5	0.00051 ± 0.00003	0.758 ± 0.013
692-BWHD-007	Barrow	MM6L210	1654 ± 13	89 ± 5	≤0.17	1903 ± 23	1776 ± 36		0.00042 ± 0.00003	1.268 ± 0.019
			1656 ± 13	111 ± 8	≤0.16	1895 ± 23	1902 ± 40		0.00070 ± 0.00007	1.195 ± 0.019

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, propagated for standard and samples.

Table C-5. Concentrations (μg/g wet weight) of Inorganic Constituents in Bowhead Whale (*Balaena mysticetus*) Liver[a] (Page 2)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-BWHD-001	MM6L197	1.04 ± 0.04	176 ± 2	0.0117 ± 0.0009		2.30 ± 0.60	19.5 ± 0.2
		0.99 ± 0.02	168 ± 2	0.0119 ± 0.0013		2.30 ± 0.60	18.5 ± 0.1
				0.0171 ± 0.0005[b]	0.0304 ± 0.0031[b]	2.33 ± 0.02[b]	19.4 ± 0.4[b]
				0.0124 ± 0.00002[b]	0.0471 ± 0.0005[b]	2.24 ± 0.07[b]	22.6 ± 0.6[b]
692-BWHD-006	MM6L208	1.19 ± 0.13	395 ± 3	0.0339 ± 0.0006		4.06 ± 0.45	33.1 ± 0.3
		1.10 ± 0.10	387 ± 3	0.0325 ± 0.0006		4.07 ± 0.51	32.6 ± 0.3
				0.0352 ± 0.0014[b]	0.0421 ± 0.0019[b]	3.82 ± 0.08[b]	31.1 ± 0.6[b]
				0.0369 ± 0.0036[b]	0.0456 ± 0.0033[b]	3.77 ± 0.03[b]	29.0 ± 0.6[b]
692-BWHD-007	MM6L210	0.91 ± 0.05	700 ± 6	0.0404 ± 0.0007		≤1.35	31.1 ± 0.3
		0.84 ± 0.05	687 ± 6	0.0393 ± 0.0008		≤1.32	30.6 ± 0.3
				0.0261 ± 0.0012[b]	0.0434 ± 0.0014[b]	2.72 ± 0.12[b]	27.0 ± 1.9[b]
				0.0241 ± 0.0007[b]	0.0497 ± 0.0017[b]	2.68 ± 0.19[b]	32.6 ± 0.7[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry

Table C-5. Concentrations (μg/g wet weight) of Inorganic Constituents in Bowhead Whale (*Balaena mysticetus*) Liver[a] (Page 3)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-BWHD-001	MM6L197	≤0.041	0.47 ± 0.01	23.1 ± 0.4	2.361 ± 0.037	≤0.46	≤0.33	0.011 ± 0.001	≤0.35
		≤0.047	0.44 ± 0.01	23.2 ± 0.4	2.213 ± 0.078	≤0.71	≤0.32	0.010 ± 0.002	≤0.33
									≤0.012[b]
									≤0.012[b]
692-BWHD-006	MM6L208	0.361 ± 0.011	1.108 ± 0.017	22.7 ± 0.9	2.576 ± 0.056	≤1.286	≤0.42	0.051 ± 0.004	17.91 ± 0.41
		0.318 ± 0.024	1.072 ± 0.017	19.5 ± 0.8	2.523 ± 0.062	≤1.281	0.40 ± 0.13	0.048 ± 0.004	19.39 ± 0.31
									16.58 ± 0.85[b]
									16.28 ± 0.98[b]
692-BWHD-007	MM6L210	0.303 ± 0.026	1.197 ± 0.017	24.2 ± 1.0	1.170 ± 0.066	≤1.249	0.46 ± 0.10	0.025 ± 0.003	19.33 ± 0.30
		0.344 ± 0.030	1.187 ± 0.016	19.4 ± 0.9	1.789 ± 0.058	≤1.229	0.42 ± 0.14	0.020 ± 0.003	20.00 ± 0.34
									17.66 ± 0.60[b]
									18.74 ± 0.63[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry

Table C-5. Concentrations (μg/g wet weight) of Inorganic Constituents in Bowhead Whale (*Balaena mysticetus*) Liver[a] (Page 4)

Animal Identification Number	NIST Identification Number	Sn	Sb	I	Cs	Ba	La	Ce	Sm	Eu	Tb
692-BWHD-001	MM6L197	≤3.8	≤0.007	≤0.75	0.0110 ± 0.0010	≤3.5	≤0.004	≤0.012	≤0.0017	≤0.00070	≤0.695
		≤3.4	≤0.008	≤0.71	0.0100 ± 0.0010	≤3.5	≤0.003	≤0.016	≤0.0018	≤0.00096	≤1.253
692-BWHD-006	MM6L208	≤1.90	0.0082 ± 0.0009	≤0.53	0.0035 ± 0.0003	≤12	≤0.006	≤0.0073	≤0.002	≤0.0002	≤0.0011
		≤1.86	0.0084 ± 0.0010	≤0.48	0.0039 ± 0.0004	≤3	≤0.005	≤0.0073	≤0.002	≤0.0002	≤0.0010
692-BWHD-007	MM6L210	≤1.70	0.0108 ± 0.0010	≤0.40	0.0025 ± 0.0004	≤4	≤0.004	≤0.0062	≤0.002	≤0.0002	≤0.0009
		≤1.66	0.0093 ± 0.0012	≤0.52	0.0025 ± 0.0003	≤3	≤0.005	≤0.0064	≤0.003	≤0.0002	≤0.0009

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, propagated for standard and samples.

Table C-5. Concentrations (μg/g wet weight) of Inorganic Constituents in Bowhead Whale (*Balaena mysticetus*) Liver[a] (Page 5)

Animal Identification Number	NIST Identification Number	Hf	Ta	Au	Hg	Pb	Th	U
692-BWHD-001	MM6L197	≤0.0007	≤0.0004	≤0.00023	0.32 ± 0.07		≤0.0012	≤0.04
		≤0.0012	≤0.0004	≤0.00020	0.27 ± 0.06		≤0.0027	≤0.03
						0.0471 ± 0.0012[b]		
						0.0457 ± 0.0010[b]		
692-BWHD-006	MM6L208	≤0.0012	≤0.0010	≤0.002	0.12 ± 0.02		≤0.0020	≤0.07
		≤0.0012	≤0.0010	≤0.002	0.12 ± 0.02		≤0.0020	≤0.08
						0.0497 ± 0.0014[b]		
						0.0473 ± 0.0008[b]		
692-BWHD-007	MM6L210	≤0.0012	≤0.0010	≤0.002	0.095 ± 0.017		≤0.0017	≤0.07
		≤0.0012	≤0.0010	≤0.002	0.10 ± 0.02		≤0.0018	≤0.09
						0.0494 ± 0.0017[b]		
						0.0470 ± 0.0019[b]		

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 1)

Animal Identification Number	Sampling Site	NIST Identification Number	Na	Mg	Al	Cl	K	Ca	Sc	V
692-BLKA-001	Point Hope	MM3L069	1333 ± 15	220 ± 5	0.48 ± 0.08	1535 ± 14	2268 ± 110	21 ± 4	0.00030 ± 0.00008	0.050 ± 0.005
			1346 ± 14	218 ± 23	0.52 ± 0.09	1577 ± 15	2362 ± 50	29 ± 5	0.00034 ± 0.00005	0.048 ± 0.006
692-BLKA-002	Point Hope	MM3L072	1215 ± 10	151 ± 5	0.42 ± 0.06	1390 ± 10	2531 ± 80	24 ± 2	≤0.00013	0.089 ± 0.004
			1199 ± 9	162 ± 5	0.53 ± 0.06	1394 ± 10	2576 ± 100	29 ± 4	≤0.00014	0.096 ± 0.005
692-BLKA-003	Point Hope	MM3L075	NA	NA	NA	NA	NA	NA	≤0.00018	NA
			1049 ± 8	78 ± 3	0.44 ± 0.06	1496 ± 11	2704 ± 110	27 ± 4	≤0.00018	0.095 ± 0.006
692-BLKA-004	Point Hope	MM3L077	951 ± 9	113 ± 5	0.60 ± 0.09	1383 ± 13	2338 ± 90	31 ± 4	≤0.00034	0.039 ± 0.006
			970 ± 10	111 ± 18	0.56 ± 0.08	1386 ± 13	2207 ± 50	30 ± 4	0.00050 ± 0.00007	0.029 ± 0.006
692-BLKA-005	Point Lay	MM4L125	1385 ± 10	128 ± 8	1.05 ± 0.07	1805 ± 16	2469 ± 110	41 ± 6	≤0.00016	0.185 ± 0.007
			1387 ± 10	123 ± 7	0.21 ± 0.06	1797 ± 16	2327 ± 120	43 ± 5	≤0.00014	0.188 ± 0.008
692-BLKA-006	Point Lay	MM4L128	1141 ± 9	60 ± 9	≤0.20	1649 ± 15	2745 ± 130	38 ± 4	≤0.00016	0.195 ± 0.009
			1131 ± 9	57 ± 12	0.25 ± 0.05	1627 ± 15	2633 ± 120	43 ± 5	≤0.00016	0.191 ± 0.008
692-BLKA-007	Point Lay	MM4L131	1138 ± 13	166 ± 27	≤1.16	1464 ± 14	2513 ± 110	30 ± 6	≤0.0009	0.294 ± 0.022
			1144 ± 12	154 ± 18	0.44 ± 0.07	1508 ± 14	2372 ± 50	27 ± 4	0.00210 ± 0.00180	0.263 ± 0.010
692-BLKA-008	Point Lay	MM4L134	1405 ± 10	129 ± 8	0.49 ± 0.11	1927 ± 17	2500 ± 110	26 ± 5	≤0.00014	0.189 ± 0.009
			1389 ± 10	128 ± 7	0.38 ± 0.09	1889 ± 17	2334 ± 110	24 ± 5	≤0.00015	0.175 ± 0.008
692-BLKA-009	Point Lay	MM4L137	1279 ± 10	135 ± 20	≤0.21	1817 ± 17	2844 ± 140	22 ± 5	≤0.00014	0.033 ± 0.005
			1284 ± 10	137 ± 17	≤0.21	1846 ± 17	2556 ± 120	19 ± 6	≤0.00013	0.040 ± 0.006
692-BLKA-010	Point Lay	MM4L140	1473 ± 11	167 ± 8	≤0.169	1774 ± 16	2154 ± 120	48 ± 5	≤0.00021	0.119 ± 0.007
			1487 ± 11	161 ± 8	≤0.199	1802 ± 16	2341 ± 140	40 ± 6	≤0.00021	0.136 ± 0.007

[a] All element determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with INAA are due to counting statistics, propagated for standard and samples.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 2)

Animal Identification Number	Sampling Site	NIST Identification Number	Na	Mg	Al	Cl	K	Ca	Sc	V
692-BLKA-011	Point Lay	MM4L143	1571 ± 11	115 ± 16	≤0.20	1877 ± 17	2096 ± 120	24 ± 5	≤0.00029	0.203 ± 0.008
			1582 ± 11	92 ± 12	≤0.13	1882 ± 17	2339 ± 120	37 ± 6	≤0.00029	0.208 ± 0.009
692-BLKA-012	Point Lay	MM4L146	1530 ± 18	168 ± 22	0.33 ± 0.10	1796 ± 16	2407 ± 120	33 ± 3	≤0.0004	0.092 ± 0.008
			1459 ± 16	176 ± 7	0.56 ± 0.08	1755 ± 16	2016 ± 50	49 ± 6	0.00053 ± 0.00008	0.877 ± 0.007
692-BLKA-013	Point Lay	MM4L149	1528 ± 11	105 ± 16	≤0.19	1856 ± 17	2198 ± 110	17 ± 5	≤0.00015	0.213 ± 0.008
			1518 ± 11	99 ± 19	0.33 ± 0.09	1841 ± 17	2238 ± 120	21 ± 6	≤0.00025	0.227 ± 0.009
692-BLKA-014	Point Lay	MM4L152	1323 ± 10	130 ± 17	≤0.20	1792 ± 16	2654 ± 120	30 ± 6	≤0.00011	0.089 ± 0.008
			1329 ± 10	151 ± 22	≤0.21	1789 ± 16	2300 ± 120	27 ± 4	≤0.00019	0.091 ± 0.007
692-BLKA-015	Cook Inlet	MM6L216	1583 ± 12	150 ± 8	≤0.17	1918 ± 23	2611 ± 50	40 ± 5	≤0.00010	0.040 ± 0.006
			1551 ± 12	138 ± 6	≤0.16	1862 ± 23	2535 ± 40	49 ± 5	≤0.00009	0.029 ± 0.004

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standard and samples.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 3)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-BLKA-001	MM3L069	3.03 ± 0.21	387 ± 10	0.0078 ± 0.0013		10.27 ± 0.63	32.3 ± 0.4
		3.34 ± 0.05	387 ± 10	0.0114 ± 0.0011		13.73 ± 0.70	32.2 ± 0.4
				NA	0.0243 ± 0.0005[b]	12.12 ± 0.29[b]	32.2 ± 0.2[b]
692-BLKA-002	MM3L072	3.33 ± 0.04	363 ± 3	0.0118 ± 0.0007		14.52 ± 0.45	38.5 ± 0.3
		3.39 ± 0.04	362 ± 3	0.0111 ± 0.0007		14.27 ± 0.50	38.5 ± 0.3
				0.0104 ± 0.0006[b]	0.0521 ± 0.0025[b]	13.84 ± 0.08[b]	39.2 ± 1.0[b]
692-BLKA-003	MM3L075	NA	627 ± 6	0.0178 ± 0.0011		NA	30.3 ± 0.3
		3.09 ± 0.04	618 ± 6	0.0178 ± 0.0010		13.15 ± 0.53	30.2 ± 0.3
				0.0317 ± 0.0014[b]	0.0418 ± 0.0003[b]	12.17 ± 0.17[b]	32.8 ± 1.7[b]
692-BLKA-004	MM3L077	2.86 ± 0.04	591 ± 15	0.0101 ± 0.0013		13.05 ± 0.76	22.7 ± 0.2
		2.15 ± 0.04	584 ± 15	0.0114 ± 0.0011		11.68 ± 0.66	22.5 ± 0.2
				NA	0.0197 ± 0.0026[b]	12.48 ± 0.47[b]	21.7 ± 0.7[b]
692-BLKA-005	MM4L125	1.78 ± 0.04	540 ± 4	0.0150 ± 0.0009		7.20 ± 0.50	21.3 ± 0.2
		1.60 ± 0.04	532 ± 4	0.0138 ± 0.0009		6.50 ± 0.50	20.9 ± 0.2
				≤0.0048[b]	0.0078 ± 0.0001[b]	7.10 ± 0.26[b]	20.9 ± 0.5[b]
				≤0.0048[b]	0.0071 ± 0.0001[b]	7.50 ± 0.76[b]	17.3 ± 0.5[b]
692-BLKA-006	MM4L128	2.51 ± 0.04	643 ± 5	0.0121 ± 0.0010		8.2 ± 0.7	23.4 ± 0.2
		2.29 ± 0.04	653 ± 5	0.0140 ± 0.0010		7.7 ± 0.7	23.8 ± 0.2
				≤0.0053[b]	≤0.013[b]	6.5 ± 0.6[b]	23.5 ± 0.3
				≤0.0053[b]	0.0166 ± 0.0006[b]	7.0 ± 0.2[b]	23.4 ± 1.3[b]
692-BLKA-007	MM4L131	1.92 ± 0.18	769 ± 20	0.0153 ± 0.0033		41.2 ± 5.3	23.8 ± 0.3
		1.85 ± 0.04	792 ± 20	0.0143 ± 0.0032		40.1 ± 1.1	24.3 ± 0.3
				NA	0.0142 ± 0.0011[b]	33.4 ± 1.0[b]	23.2 ± 0.1[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 4)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-BLKA-008	MM4L134	1.75 ± 0.04	476 ± 4	0.0157 ± 0.0010		26.1 ± 0.8	21.7 ± 0.2
		1.82 ± 0.04	473 ± 4	0.0141 ± 0.0011		26.7 ± 0.9	21.7 ± 0.2
				≤0.0048[b]	0.0228 ± 0.0008[b]	21.3 ± 1.1[b]	20.4 ± 1.5[b]
				0.0088 ± 0.00002[b]	0.0231 ± 0.0005[b]	21.9 ± 1.3[b]	20.0 ± 0.4[b]
692-BLKA-009	MM4L137	1.59 ± 0.04	718 ± 5	0.0078 ± 0.0008		10.2 ± 0.6	21.7 ± 0.2
		1.65 ± 0.05	734 ± 5	0.0090 ± 0.0008		11.1 ± 0.8	22.1 ± 0.2
				≤0.0051[b]	0.0178 ± 0.0003[b]	9.8 ± 0.6[b]	21.2 ± 0.8[b]
				≤0.0051[b]	0.0165 ± 0.0014[b]	10.3 ± 0.5[b]	21.5 ± 1.2[b]
692-BLKA-010	MM4L140	2.32 ± 0.05	628 ± 5	0.0138 ± 0.0013		12.2 ± 0.7	26.1 ± 0.2
		2.33 ± 0.04	648 ± 5	0.0154 ± 0.0014		12.1 ± 0.8	26.7 ± 0.2
				≤0.0049[b]	0.0108 ± 0.00002[b]	11.3 ± 0.1[b]	21.5 ± 0.2[b]
				≤0.0049[b]	0.0111 ± 0.0003[b]	12.1 ± 0.8[b]	24.2 ± 0.7[b]
692-BLKA-011	MM4L143	2.06 ± 0.05	666 ± 5	0.0145 ± 0.0012		12.6 ± 0.8	28.7 ± 0.2
		1.95 ± 0.05	659 ± 6	0.0129 ± 0.0015		11.3 ± 0.6	28.6 ± 0.2
				≤0.0046[b]	≤0.012[b]	NA	NA
				≤0.0046[b]	≤0.012[b]	11.350 ± 0.046[b]	25.8 ± 1.9[b]
692-BLKA-012	MM4L146	1.80 ± 0.05	556 ± 14	0.0070 ± 0.0015		14.88 ± 0.77	20.7 ± 0.2
		1.51 ± 0.04	568 ± 14	0.0093 ± 0.0014		16.67 ± 0.88	21.1 ± 0.2
				NA	0.01433 ± 0.00065[b]	14.59 ± 0.57[b]	19.8 ± 0.2[b]
692-BLKA-013	MM4L149	1.69 ± 0.04	509 ± 4	0.0116 ± 0.0012		12.8 ± 0.9	23.5 ± 0.2
		1.81 ± 0.03	507 ± 5	0.0109 ± 0.0013		12.5 ± 0.8	23.8 ± 0.2
				0.0081 ± 0.0004[b]	≤0.012[b]	10.03 ± 0.30[b]	20.4 ± 0.8[b]
				≤0.0047[b]	0.01298 ± 0.00068[b]	11.39 ± 0.21[b]	25.0 ± 0.7[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 5)

Animal Identification Number	NIST Identification Number	Mn	Fe	Co	Ni	Cu	Zn
692-BLKA-014	MM4L152	2.24 ± 0.04	329 ± 2	0.0209 ± 0.0008		6.9 ± 0.5	25.7 ± 0.2
		2.19 ± 0.03	335 ± 3	0.0214 ± 0.0009		7.3 ± 0.5	26.5 ± 0.2
				0.0061 ± 0.00005[b]	0.02257 ± 0.00023[b]	8.42 ± 0.13[b]	24.9 ± 0.9[b]
				NA	NA	7.82 ± 0.23[b]	25.4 ± 1.9[b]
692-BLKA-015	MM6L216	1.52 ± 0.17	491 ± 4	0.0109 ± 0.0008		53.78 ± 0.96	27.4 ± 0.2
		1.87 ± 0.21	498 ± 4	0.0122 ± 0.0008		54.40 ± 0.93	28.0 ± 0.2
				≤0.005[b]	0.00643 ± 0.00023[b]	40.32 ± 0.25[b]	26.0 ± 1.5[b]
				≤0.005[b]	≤0.013[b]	39.8 ± 1.5[b]	24.4 ± 0.9[b]

[a] All elements determined ny instrumental neutron activation analysis (INAA) except as noted; the uncertainties associated with the INAA results are due to counting statistics, propagated for standard and samples.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 6)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-BLKA-001	MM3L069	0.215 ± 0.014	7.24 ± 0.08	24.17 ± 0.68	NA	≤3.4	≤0.27	17.68 ± 0.12	1.42 ± 0.14
		0.244 ± 0.012	7.16 ± 0.08	24.54 ± 0.72	NA	≤3.4	≤0.35	17.58 ± 0.12	1.83 ± 0.18
									1.62 ± 0.073[b]
692-BLKA-002	MM3L072	0.132 ± 0.015	3.99 ± 0.04	NA	1.15 ± 0.07	≤2.5	0.606 ± 0.087	14.36 ± 0.09	0.33 ± 0.11
		0.194 ± 0.020	3.99 ± 0.04	NA	1.20 ± 0.07	≤2.5	0.416 ± 0.090	14.36 ± 0.10	0.58 ± 0.15
									1.11 ± 0.01[b]
692-BLKA-003	MM3L075	0.294 ± 0.024	14.27 ± 0.13	NA	1.46 ± 0.10	≤3.7	≤0.28	30.53 ± 0.18	1.97 ± 0.18
		0.209 ± 0.021	14.23 ± 0.13	NA	1.58 ± 0.10	3.98 ± 0.84	0.275 ± 0.084	30.49 ± 0.18	1.71 ± 0.18
									2.45 ± 0.02[b]
692-BLKA-004	MM3L077	0.183 ± 0.013	6.26 ± 0.07	24.92 ± 0.73	NA	≤2.2	≤0.23	14.25 ± 0.09	≤0.91
		0.170 ± 0.010	6.23 ± 0.07	26.32 ± 0.75	NA	≤2.2	≤0.27	14.92 ± 0.09	≤0.59
									0.90 ± 0.04[b]
692-BLKA-005	MM4L125	≤0.129	15.44 ± 0.12	17.77 ± 0.44	1.29 ± 0.08	≤1.53	≤0.13	14.49 ± 0.11	≤2.59
		≤0.078	15.22 ± 0.12	18.96 ± 0.48	1.19 ± 0.07	≤1.30	≤0.08	14.28 ± 0.11	≤2.23
									1.02 ± 0.05[b]
									1.06 ± 0.05[b]
692-BLKA-006	MM4L128	0.591 ± 0.015	18.91 ± 0.15	19.65 ± 0.49	1.194 ± 0.092	≤1.49	0.59 ± 0.02	16.04 ± 0.12	1.51 ± 0.39
		0.641 ± 0.016	19.20 ± 0.15	21.57 ± 0.46	1.144 ± 0.079	≤1.51	0.64 ± 0.02	16.36 ± 0.12	1.87 ± 0.38
		NA	NA	NA	NA	NA	NA	NA	1.22 ± 0.09[b]
		NA	NA	NA	NA	NA	NA	NA	1.40 ± 0.04[b]
692-BLKA-007	MM4L131	0.205 ± 0.019	74.38 ± 0.82	22.99 ± 0.69	NA	≤8.7	≤0.64	105.55 ± 0.68	3.51 ± 0.25
		0.198 ± 0.015	76.64 ± 0.84	23.25 ± 0.74	NA	≤8.9	≤0.42	109.21 ± 0.71	3.69 ± 0.24
		NA	NA	NA	NA	NA	NA	NA	3.49 ± 0.20[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 7)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-BLKA-008	MM4L134	≤0.111	6.99 ± 0.06	18.98 ± 0.48	1.36 ± 0.08	≤1.42	≤0.11	19.88 ± 0.15	≤2.12
		≤0.073	7.03 ± 0.06	19.39 ± 0.48	1.59 ± 0.10	≤1.30	≤0.07	19.98 ± 0.15	≤1.16
									1.09 ± 0.02[b]
									1.03 ± 0.08[b]
692-BLKA-009	MM4L137	0.042 ± 0.013	9.08 ± 0.06	20.59 ± 0.47	1.48 ± 0.07	≤1.30	≤0.37	15.69 ± 0.08	1.13 ± 0.19
		0.053 ± 0.013	9.24 ± 0.06	23.41 ± 0.53	1.51 ± 0.06	≤1.49	≤0.26	16.17 ± 0.09	1.15 ± 0.20
									0.79 ± 0.02[b]
									0.76 ± 0.04[b]
692-BLKA-010	MM4L140	≤0.108	28.48 ± 0.22	18.42 ± 0.50	0.92 ± 0.10	≤2.19	≤0.11	40.22 ± 0.30	≤1.99
		≤0.081	29.24 ± 0.22	19.65 ± 0.52	1.05 ± 0.11	≤2.17	≤0.08	41.16 ± 0.31	≤2.16
									1.76 ± 0.16[b]
									1.75 ± 0.04[b]
692-BLKA-011	MM4L143	0.061 ± 0.015	29.67 ± 0.20	22.40 ± 0.41	1.27 ± 0.09	≤2.56	≤0.36	36.73 ± 0.19	2.36 ± 0.23
		0.077 ± 0.019	29.06 ± 0.20	23.71 ± 0.44	≤1.18	≤3.99	≤0.48	36.72 ± 0.19	2.27 ± 0.22
									0.88[b]
									0.98 ± 0.02[b]
692-BLKA-012	MM4L146	0.180 ± 0.015	18.06 ± 0.20	40.33 ± 1.00	NA	≤5.2	≤0.22	22.21 ± 0.15	3.60 ± 0.19
		0.176 ± 0.015	18.50 ± 0.21	30.82 ± 0.84	NA	≤3.8	≤0.34	22.67 ± 0.15	3.70 ± 0.22
									3.36 ± 0.19[b]
692-BLKA-013	MM4L149	0.079 ± 0.016	21.00 ± 0.14	21.02 ± 0.43	0.95 ± 0.07	≤1.57	≤0.46	26.49 ± 0.15	1.86 ± 0.20
		0.051 ± 0.014	21.11 ± 0.15	20.79 ± 0.33	≤1.00	≤3.37	≤0.44	26.30 ± 0.18	1.97 ± 0.17
									1.94 ± 0.07[b]
									2.02 ± 0.05[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 8)

Animal Identification Number	NIST Identification Number	As	Se	Br	Rb	Sr	Mo	Ag	Cd
692-BLKA-014	MM4L152	0.161 ± 0.014	18.05 ± 0.12	17.3 ± 0.4	1.442 ± 0.062	≤1.04	≤0.43	9.99 ± 0.06	2.59 ± 0.15
		0.164 ± 0.015	18.34 ± 0.13	17.2 ± 0.4	1.992 ± 0.032	≤2.18	0.45 ± 0.15	10.11 ± 0.06	2.92 ± 0.19
									2.62 ± 0.03[b]
									2.45 ± 0.16[b]
692-BLKA-015	MM6L216	≤0.040	3.563 ± 0.037	21.0 ± 0.8	1.711 ± 0.058	≤1.745	≤0.53	5.83 ± 0.04	≤0.71
		0.065 ± 0.021	3.474 ± 0.037	19.8 ± 0.8	1.657 ± 0.051	≤1.709	≤0.27	6.02 ± 0.04	0.38 ± 0.12
									≤0.013[b]
									≤0.013[b]

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 9)

Animal Identification Number	NIST Identification Number	Sn	Sb	I	Cs	Ba	La	Ce	Sm	Eu	Tb
692-BLKA-001	MM3L069	NA	0.0123 ± 0.0013	5.97 ± 0.87	0.045 ± 0.002	NA	≤0.0038	≤0.031	≤0.0012	≤0.0006	≤0.0088
		NA	0.0107 ± 0.0018	4.69 ± 1.07	0.046 ± 0.002	NA	≤0.0050	≤0.031	≤0.0014	≤0.0006	≤0.0089
692-BLKA-002	MM3L072	NA	0.0092 ± 0.0024	4.46 ± 0.75	0.032 ± 0.002	NA	≤0.0072	0.0114 ± 0.0055	≤0.0010	≤0.0013	≤0.0016
		NA	≤0.0065	5.16 ± 0.62	0.031 ± 0.002	NA	≤0.0070	≤0.0175	≤0.0011	≤0.0013	≤0.0017
692-BLKA-003	MM3L075	NA	≤0.0095	NA	0.039 ± 0.002	NA	≤0.0076	≤0.022	≤0.0011	≤0.0019	≤0.0023
		NA	≤0.0098	5.30 ± 0.76	0.036 ± 0.002	NA	≤0.0087	≤0.022	≤0.0011	≤0.0019	≤0.0023
692-BLKA-004	MM3L077	NA	0.0030 ± 0.0008	6.37 ± 0.98	0.022 ± 0.002	NA	≤0.0030	≤0.028	≤0.0010	≤0.0005	≤0.0089
		NA	0.0019 ± 0.0007	4.79 ± 0.85	0.019 ± 0.002	NA	≤0.0037	≤0.028	≤0.0011	≤0.0005	≤0.0088
692-BLKA-005	MM4L125	≤2.6	≤0.004	2.16 ± 0.31	0.031 ± 0.002	≤ 8.6	≤0.021	≤0.023	≤0.0096	≤0.00044	≤0.224
		≤2.2	≤0.004	2.18 ± 0.31	0.029 ± 0.002	≤12.5	≤0.006	≤0.018	≤0.0052	≤0.00040	≤0.088
692-BLKA-006	MM4L128	≤2.4	≤0.004	0.71 ± 0.32	0.035 ± 0.002	≤10.5	≤0.005	≤0.021	≤0.0088	≤0.00046	≤0.070
		≤2.2	≤0.005	0.81 ± 0.32	0.032 ± 0.002	≤ 9.1	≤0.005	≤0.020	≤0.0042	≤0.00046	≤0.058
692-BLKA-007	MM4L131	NA	0.0654 ± 0.0053	4.87 ± 1.14	0.027 ± 0.004	NA	0.0466 ± 0.0034	0.089 ± 0.022	≤0.0029	≤0.0017	≤0.020
		NA	0.0371 ± 0.0065	5.33 ± 1.49	0.038 ± 0.004	NA	0.0431 ± 0.0032	≤0.067	≤0.0017	≤0.0018	≤0.020
692-BLKA-008	MM4L134	≤2.4	≤0.004	≤0.62	0.030 ± 0.002	≤ 6.8	≤0.018	≤0.015	≤0.0078	≤0.00044	≤0.172
		≤2.4	≤0.005	≤0.56	0.028 ± 0.002	≤10.8	≤0.006	≤0.015	≤0.0046	≤0.00045	≤0.073
692-BLKA-009	MM4L137	≤2.7	≤0.003	≤0.89	0.025 ± 0.001	≤ 5.1	≤0.004	≤0.021	≤0.0018	≤0.00036	≤0.016
		≤2.4	≤0.003	≤0.80	0.023 ± 0.001	≤ 5.1	≤0.004	≤0.019	≤0.0018	≤0.00034	≤0.015
692-BLKA-010	MM4L140	≤3.6	≤0.007	1.09 ± 0.35	0.026 ± 0.002	≤ 6.3	≤0.002	≤0.017	≤0.0076	≤0.00074	≤0.156
		≤3.6	≤0.007	1.28 ± 0.34	0.027 ± 0.002	≤11.3	≤0.001	≤0.024	≤0.0052	≤0.00074	≤0.075
692-BLKA-011	MM4L0143	≤4.7	≤0.004	0.84 ± 0.27	0.029 ± 0.002	≤ 5.9	≤0.004	≤0.039	≤0.0022	≤0.00068	≤0.017
		≤5.6	≤0.009	0.67 ± 0.26	0.022 ± 0.002	≤ 5.3	≤0.003	≤0.077	≤0.0023	≤0.00065	≤0.014

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

Table C-6. Concentrations (µg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 10)

Animal Identification Number	NIST Identification Number	Sn	Sb	I	Cs	Ba	La	Ce	Sm	Eu	Tb
692-BLKA-012	MM4L146	NA	0.0043 ± 0.0027	≤4.6	0.0337 ± 0.0019	NA	0.018 ± 0.002	≤0.035	≤0.0013	≤0.00064	≤0.0097
		NA	≤0.0047	6.43 ± 1.07	0.0369 ± 0.0024	NA	0.018 ± 0.003	≤0.036	≤0.0014	≤0.00067	≤0.0098
692-BLKA-013	MM4L149	≤2.9	≤0.003	0.92 ± 0.22	0.0270 ± 0.0020	≤ 5.4	≤0.009	≤0.024	≤0.0021	≤0.00043	≤0.015
		≤4.7	≤0.006	0.72 ± 0.25	0.0280 ± 0.0020	≤ 4.8	≤0.004	≤0.066	≤0.0021	≤0.00053	≤0.029
692-BLKA-014	MM4L152	≤2.0	≤0.002	1.28 ± 0.32	0.0310 ± 0.0010	≤ 4.6	0.010 ± 0.003	≤0.022	≤0.0020	≤0.00026	≤0.011
		≤3.1	≤0.005	1.12 ± 0.30	0.0290 ± 0.0010	≤ 4.0	0.013 ± 0.002	≤0.058	≤0.0020	≤0.00032	≤0.021
692-BLKA-015	MM6L216	≤2.42	0.0035 ± 0.0009	≤0.55	0.0090 ± 0.0005	≤17	≤0.009	≤0.0074	≤0.002	≤0.0003	≤0.0012
		≤2.30	≤0.0027	≤0.51	0.0090 ± 0.0004	≤ 4	≤0.003	≤0.0071	≤0.002	≤0.0003	≤0.0011

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 11)

Animal Identification Number	NIST Identification Number	Hf	Ta	Au	Hg	Methyl-Hg	Pb	Th	U
692-BLKA-001	MM3L069	≤0.0069	≤0.0049	≤0.00023	NA			NA	≤0.11
		≤0.0054	≤0.0049	0.00170 ± 0.00013	NA			NA	≤0.13
					3.803 ± 0.073[b]	0.361 ± 0.049[b]	0.439 ± 0.0032[b]		
692-BLKA-002	MM2L072	≤0.0022	≤0.0030	0.00235 ± 0.00013	NA			NA	≤0.090
		≤0.0023	≤0.0030	0.00340 ± 0.00015	NA			NA	≤0.095
					1.397 ± 0.012[b]	0.41[b]	0.1185 ± 0.0002[b]		
692-BLKA-003	MM3L075	≤0.0034	≤0.0045	0.00288 ± 0.00018	NA			NA	≤0.10
		≤0.0035	≤0.0048	0.00275 ± 0.00019	NA			NA	≤0.10
					10.18 ± 0.36[b]	0.75[b]	0.0460 ± 0.0090[b]		
692-BLKA-004	MM3L077	≤0.0052	≤0.0046	≤0.00021	NA			NA	≤0.09
		≤0.0051	≤0.0047	≤0.00023	NA			NA	≤0.10
					3.52 ± 0.37[b]	0.37[b]	0.0733 ± 0.0003[b]		
692-BLKA-005	MM4L125	≤0.0027	≤0.0031	≤0.00161	NA			≤0.0027	≤0.21
		≤0.0023	≤0.0027	0.00163 ± 0.00028	NA			≤0.0023	≤0.13
					NA	NA	0.0119 ± 0.0009[b]		
					NA	NA	0.0096 ± 0.00005[b]		
692-BLKA-006	MM4L128	≤0.0026	≤0.0031	≤0.00067	NA			≤0.0026	≤0.11
		≤0.0027	≤0.0031	≤0.00061	NA			≤0.0027	≤0.10
					NA	NA	0.0188 ± 0.0011[b]		
					NA	NA	0.0205 ± 0.0014[b]		
692-BLKA-007	MM4L131	≤0.0015	≤0.0014	≤0.00040	NA			NA	≤0.26
		≤0.0015	≤0.0015	≤0.00032	NA			NA	≤0.16
					72.9 ± 4.6[b]	2.15 ± 0.43[b]	0.0651 ± 0.0015[b]		

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 12)

Animal Identification Number	NIST Identification Number	Hf	Ta	Au	Hg	Methyl-Hg	Pb	Th	U
692-BLKA-008	MM4L134	≤0.0025	≤0.0031	≤0.00133	NA			≤0.0024	≤0.18
		≤0.0026	≤0.0031	0.00129 ± 0.00035	NA			≤0.0025	≤0.12
					NA	NA	0.0156 ± 0.0012[b]		
					NA	NA	0.0239 ± 0.0007[b]		
692-BLKA-009	MM4L137	≤0.0023	≤0.0026	0.00053 ± 0.00011	17.65 ± 0.37			≤0.0027	≤0.07
		≤0.0021	≤0.0024	0.00044 ± 0.00010	17.82 ± 0.45			≤0.0025	≤0.07
					NA	NA	0.0279 ± 0.0015[b]		
					NA	NA	0.0269 ± 0.0010[b]		
692-BLKA-010	MM4L140	≤0.0039	≤0.0049	≤0.00123	NA			≤0.0036	≤0.41
		≤0.0039	≤0.0048	≤0.00075	NA			≤0.0036	≤0.12
					NA	NA	0.0135 ± 0.0018[b]		
					NA	NA	0.0143 ± 0.0015[b]		
692-BLKA-011	MM4L143	≤0.0042	≤0.0048	0.00135 ± 0.00015	65.73 ± 0.70			≤0.0047	≤0.08
		≤0.0022	≤0.0023	0.00143 ± 0.00015	61.59 ± 0.63			≤0.0027	≤0.08
					NA	NA	0.0210 ± 0.0016[b]		
					NA	NA	0.0221 ± 0.0009[b]		
692-BLKA-012	MM4L146	≤0.0061	≤0.0057	≤0.00023	NA			NA	≤0.12
		≤0.0061	≤0.0052	≤0.00028	NA			NA	≤0.13
					24.64 ± 0.24[b]	0.688 ± 0.017[b]	0.0043 ± 0.0002[b]		
692-BLKA-013	MM4L149	≤0.0026	≤0.0029	0.00028 ± 0.00012	49.74 ± 1.12	NA		≤0.0029	≤0.07
		≤0.0077	≤0.0051	0.00028 ± 0.00009	50.54 ± 0.61	NA		≤0.0131	≤0.07
						NA	0.0172[b]		
						NA	0.0255 ± 0.0014[b]		

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.

[b] Samples analyzed by voltammetry.

Table C-6. Concentrations (μg/g wet weight) of Inorganic Constituents in Belukha Whale (*Delphinapterus leucus*) Liver[a] (Page 13)

Animal Identification Number	NIST Identification Number	Hf	Ta	Au	Hg	Methyl-Hg	Pb	Th	U
692-BLKA-014	MM4L152	≤0.0017	≤0.0017	0.00122 ± 0.00011	57.18 ± 0.49			≤0.0021	≤0.07
		≤0.0048	≤0.0031	0.00138 ± 0.00010	NA			≤0.0009	≤0.06
					NA	NA	0.0186 ± 0.0015[b]		
					NA	NA	0.0171 ± 0.0002[b]		
692-BLKA-015	MM6L216	≤0.0018	≤0.0019	0.00348 ± 0.00017	2.97 ± 0.18			≤0.0022	≤0.09
		≤0.0017	≤0.0019	0.00317 ± 0.00066	2.68 ± 0.17			≤0.0022	≤0.07
					NA	NA	0.0466 ± 0.0020[b]		
					NA	NA	0.0426 ± 0.0033[b]		

[a] All elements determined by instrumental neutron activation analysis (INAA) except as noted; the uncertainities associated with the INAA results are due to counting statistics, including propagated uncertainities of the standard.
[b] Samples analyzed by voltammetry.

Table C-7. Conversion factors, ratio of dry weight to wet weight, for liver tissue analyzed by INAA.

Animal Identification Number	NIST Identification Number	Conversion Factor (Ratio of dry to wet weight)
692-BDSL-001	MM3L051	0.2810
692-BDSL-004	MM7L223	0.2684
692-BDSL-005	MM7L250	0.2757
692-SPSL-001	MM5L164	0.2803
692-RGSL-004	MM2L030	0.2873
692-RGSL-008	MM2L042	0.2915
692-RGSL-011	MM3L054	0.2758
692-RGSL-012	MM3L057	0.3115
692-RGSL-013	MM3L060	0.2790
692-RGSL-014	MM3L063	0.2834
692-RGSL-015	MM3L066	0.2711
692-RGSL-016	MM5L155	0.2955
692-RGSL-017	MM5L158	0.2811
692-RGSL-018	MM5L161	0.2743
692-RGSL-029	MM7L226	0.2996
692-RGSL-030	MM7L229	0.2795
692-RGSL-031	MM7L232	0.2949
692-RGSL-032	MM7L247	0.2996
692-BWHD-001	MM6L197	0.2412
692-BWHD-006	MM6L208	0.2733
692-BWHD-007	MM6L210	0.2406
692-BLKA-001	MM3L069	0.2438
692-BLKA-002	MM3L072	0.2494
692-BLKA-003	MM3L075	0.2804
692-BLKA-004	MM3L077	0.2628
692-BLKA-005	MM4L125	0.2403
692-BLKA-006	MM4L128	0.2648
692-BLKA-007	MM4L131	0.2532
692-BLKA-008	MM4L134	0.2397
692-BLKA-009	MM4L137	0.2578
692-BLKA-010	MM4L140	0.2474
692-BLKA-011	MM4L143	0.2361
692-BLKA-012	MM4L146	0.2416
692-BLKA-013	MM4L149	0.2513
692-BLKA-014	MM4L152	0.2506
692-BLKA-015	MM6L216	0.2562

APPENDIX D

QUALITY CONTROL FOR INORGANIC ANALYSIS: RESULTS OF INAA OF CONTROL MATERIALS

Table D-1. Quality assurance: results of instrumental neutron activation analysis (INAA) of control materials included with the analysis of marine mammal liver tissues concentrations in μg/g. The uncertainties represent the standard deviation of the average value.

	NIST SRM 1577a, Bovine Liver		QA Pilot Whale Liver Homogenate	
ELEMENT	AVERAGE	CERTIFIED	AVERAGE	WISE ET AL., 1993
Na	2290 ± 63.5	2430 ± 130	1279 ± 5	1260
Mg	637 ± 33	600 ± 15	125 ± 3	138
Al	1.14 ± 0.26	(2)[a]	NA[b]	inhomogeneous
Cl	2639 ± 86	2800 ± 100	1745 ± 16	1730
K	9827 ± 371	9960 ± 70	2712 ± 30	2640
Ca	128 ± 21	120 ± 7	40 ± 5	46
Sc	≤0.001	NC[c]	≤0.001	≤0.0008
V	0.085 ± 0.014	NC	≤0.02	≤0.02
Mn	9.48 ± 0.41	9.9 ± 0.8	2.70 ± 0.04	2.81
Fe	186 ± 5	194 ± 20	448 ± 5	438
Co	0.228 ± 0.010	0.21 ± 0.05	0.0144 ± 0.0006	0.014
Cu	151 ± 5	158 ± 7	3.10 ± 0.08	2.96
Zn	121 ± 2	123 ± 8	32.5 ± 1.0	32.2
As	≤0.06	0.047 ± 0.006	0.512 ± 0.024	0.529
Se	0.67 ± 0.04	0.71 ± 0.07	11.4 ± 2	11.0
Br	NA	(9)	13.7 ± 0.6	NA
Rb	12.3 ± 0.5	12.5 ± 0.1	1.99 ± 0.08	2.0
Sr	≤3	0.138 ± 0.003	≤2	≤0.8
Mo	3.02 ± 0.30	3.5 ± 0.5	≤0.4	≤0.4
Ag	0.046 ± 0.005	0.04 ± 0.01	0.181 ± 0.007	0.181
Cd	≤1	0.44 ± 0.06	8.17 ± 0.06	8.51
Sb	≤0.01	(0.003)	≤0.01	≤0.08
I	≤2	NC	≤1	≤1
Cs	0.0123 ± 0.0039	NC	0.0069 ± 0.0006	0.006

	NIST SRM 2710 Montana Soil		SRM 1571 Orchard Leaves	
ELEMENT	AVERAGE	CERTIFIED	AVERAGE	CERTIFIED
Hg	32.6 ± 0.9	32.6 ± 1.8	0.154 ± 0.021	0.155 ± 0.015

[a]Values in parentheses are for information only and are not certified values.
[b]NA = not analyzed
[c]NC = not certified