HEAVY METAL CONCENTRATIONS IN LIVER AND KIDNEY TISSUES OF PACIFIC WALRUS

continuation of a baseline study

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MARINE MAMMALS MANAGEMENT
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ABSTRACT

The U.S. Fish and Wildlife Service continued a 1981-1984 baseline study (Taylor et al. 1989) in 1986-1989, to evaluate contaminant levels in tissues of Pacific walrus harvested in the spring by Alaskan Natives. Samples from 56 walrus (32 males, 24 females) were collected in the villages of Diomede (n=21), Gambell (n=31), and Savoonga (n=4). Analyses for metals and metalloids were conducted on 50 kidneys and 53 livers. All samples were from adult walrus (ages 11-32 years, $\bar{x}=19$). Analyses were completed for 23 elements; special focus was on arsenic, cadmium, lead, mercury, selenium, and zinc. All tissues and samples had these six elements in detectable quantities. Mean cadmium concentrations were not significantly higher than those previously reported for walrus. However, mean cadmium concentrations continue to exceed levels (13 mg/kg wet weight) thought by the Environmental Protection Agency (EPA) to interfere with organ function in some animals. A positive correlation between cadmium and age was found in both liver and kidney tissues. Similar relationships were found between age and concentrations of zinc (kidney) and arsenic (liver and kidney). Mean mercury concentrations were not significantly higher than previously reported. A close correlation between mercury and selenium was found both in the liver and kidney. Male and female tissues significantly differed in mean concentrations of arsenic (liver and kidney) and selenium (liver). It is uncertain what these results mean to the health of walrus.

INTRODUCTION

During the last decade, oil and gas development, mining, fin and shellfish fisheries have increased within the range of the Pacific walrus (*Odobenus rosmarus divergens*) (Figure 1). Possible contamination of walrus from these activities and the effects on the health of marine mammal and human populations of the Bering and Chukchi seas are a concern. In 1981, the U.S. Fish and Wildlife Service (FWS) began a project to collect samples to assess and monitor contaminant levels in walrus tissues.

Primary objectives of the program were to:

(1) determine baseline levels of trace elements in tissues collected from spring walrus subsistence harvests which occurred during northward migration; and

(2) determine if correlations existed between key contaminants in tissues from walrus of differing age, sex, and location of collection.

Through the FWS Harvest Monitoring Program, walrus tissue samples were collected in the spring from subsistence hunters at major villages harvesting walrus in the Bering Sea. A few (n=4) additional samples were collected aboard the *Zakharovo* (a Soviet walrus research/hunting ship) in the winter of 1984. Taylor et al. (1989) reported results of analyses completed on tissues collected in 1981-1984. They found the mean concentration of cadmium (47 mg/kg wet weight or 181.4 mg/kg dry weight) in kidney tissue significantly exceeded levels thought by the Environmental Protection Agency (EPA) to interfere with mammalian organ function (13 mg/kg or ppm wet weight). Mercury occurred in all of these liver samples at a mean concentration of 1.5 mg/kg wet weight (4.5 mg/kg dry weight). Although methyl mercury was not measured, they felt that the high levels of total mercury warranted further study. The Taylor et al. (1989) study was based largely on walrus harvested from a restricted geographical region. They recognized that additional studies were needed throughout the species' range. Samples collected between 1986-1989 from the same region were recently analyzed for metals and metalloids. These analyses are the basis of this paper.

METHODS

Walrus were harvested by subsistence hunters in the spring between April and June, 1986-1989. FWS employees monitored the harvest at three primary hunting villages: Diomede (Inalik) on Little Diomede Island, and Savoonga and Gambell on St. Lawrence Island (Figure 2). During the harvest, walrus tissues were opportunistically collected. Hunters were instructed on the acceptable methods for removing walrus tissues (liver and kidney), and lower canine teeth (for age determination). Tissues were stored in either plastic bags or aluminum foil and then frozen until processed.

Liver and kidney tissues were later analyzed for inorganic elements. Teeth were labeled and stored in paper sampling bags until processed.

Core samples were extracted from the tissues with a stainless steel knife under clean laboratory conditions and placed in precleaned sample jars. Knives and work surfaces were cleaned prior to each extraction with high grade ethanol and distilled water. An average core sample weighed approximately 150 grams and were shipped frozen to a FWS contract laboratory for inorganic analysis.

Each sample was analyzed for trace metal residues. Analytical priority was given to total mercury, arsenic, selenium, cadmium, lead, and zinc. Methyl mercury concentrations were not measured. Quality assurance data, provided with the sample data, were checked by the FWS Quality Assurance/Quality Control Officer and the data were acceptable based on FWS Quality Assurance guidelines. Dr. Francis Fay (University of Alaska, Fairbanks) aged the walrus teeth by sectioning them longitudinally and counting cementum layers.

Data from 1981-1984 (Taylor et al. 1989) were converted from mg/kg (ppm) wet weight to mg/kg (ppm) dry weight for comparison purposes based on percent moisture. The following formula was used for the conversion:

$$\text{mg/kg dry weight} = \text{mg/kg wet weight} / (1 - (\%\ \text{moisture} / 100))$$

Percent moisture was supplied for each sample during the original laboratory analysis for metal residues. All data presented are in mg/kg (ppm) dry weight units unless otherwise noted.

Non-parametric statistics were selected after determining data were unevenly distributed. Analysis of covariance was used to determine correlations between age and element concentrations and between elements. Positive correlations were further analyzed and regression lines analyzed for significance of fit. All results were evaluated at 0.05 level of significance. The Wilcoxon rank-sum test was used to test for differences of mean element concentrations between the 1981-1984 data and 1986-1989 data, age distribution differences, and the means between sexes and an element. The Kruskal-Wallis test was used to test differences between sample locations for an element.

RESULTS

Samples from 56 walrus (32 males, 24 females) were collected from the villages of Diomede (n=21), Gambell (n=31), and Savoonga (n=4) (Table 1). Analyses for trace metals were conducted on 50 kidneys and 53 livers. All samples were from adult walrus ($\bar{x}=19$ years; range 11-32) with the mean male age of 20 years and mean female age of 19 years. There were no significant differences ($P>0.05$) between the mean age of female or male walrus in our samples and those sampled by Taylor et al. (1989).

Analyses were completed on 23 elements with analytical priority on arsenic, cadmium, lead, mercury, selenium, and zinc. These elements were detected in all tissues (Figure 3, Table 2 and Table 3).

Mean concentrations of arsenic, cadmium, lead, mercury, selenium, and zinc in walrus liver and kidney tissues collected between 1981-1989 are shown in Table 4. Mean concentrations of selenium (liver, $P<0.0116$), arsenic (liver, $P<0.0001$), and lead (liver and kidney, $P<0.0001$) were significantly higher than previously reported walrus data (Taylor et al. 1989). Both mean cadmium concentrations and mean mercury concentrations were not significantly higher ($P>0.05$) than levels from 1981-1984 data. Zinc levels were not analyzed prior to 1984. The 1984 data were excluded from these comparisons due to the absence of percent moisture data needed to convert wet weight to dry weight.

We found a significant, but relatively weak, relationship between cadmium and age in the 1986-1989 data from kidney ($r^2=0.30$, $P<0.0002$) and liver ($r^2=0.23$, $P<0.0003$) tissues (Figure 4). In contrast, Taylor et al. (1989) reported no significant relationship between cadmium and age in either the kidney or liver tissues. Our values for arsenic (liver and kidney, $P<0.008$) and zinc (kidney, $P<0.04$) concentrations also were significantly correlated with age. Sample sizes from 1981-1984 were too small to test for correlations between arsenic or zinc and age (Taylor et al. 1989). We found no correlations between age and concentrations of lead, mercury, or selenium in the 1986-1989 data.

Male and female walrus had significantly different mean concentrations of selenium in the liver ($P<0.0079$) and arsenic in both the liver ($P<0.004$) and kidney ($P<0.0278$) tissues. Females had higher concentrations of selenium ($\bar{x}=7.0$ mg/kg) than males ($\bar{x}=4.7$ mg/kg). Males had higher concentrations of arsenic in liver ($\bar{x}=0.49$ mg/kg) and kidney ($\bar{x}=1.31$ mg/kg) tissues than females (liver $\bar{x}=0.31$ mg/kg; kidney $\bar{x}=0.70$ mg/kg).

We found no significant differences ($P>0.05$) between sample location, sex, and mean concentrations of cadmium (liver and kidney), zinc (liver and kidney), mercury (kidney), and lead (liver). Although selenium concentrations were found to be correlated to sex, they were not significantly correlated ($P>0.05$) with sample location. Significant differences were found between sample location and mean concentrations of mercury (liver, $P<0.03$), and lead (liver, $P<0.004$). Mean concentrations of mercury and lead in liver were both higher in walruses from Gambell (lead $\bar{x}=0.70$ mg/kg; mercury $\bar{x}=4.7$ mg/kg) than in either Savoonga (lead $\bar{x}=0.60$ mg/kg; mercury $\bar{x}=3.2$ mg/kg), or Diomede (lead $\bar{x}=0.51$ mg/kg; mercury $\bar{x}=2.9$ mg/kg). Arsenic was the only element which exhibited both a significant difference between sample location and sex in both tissues. Savoonga male samples had higher concentrations of arsenic (liver $\bar{x}$=0.68 mg/kg; kidney $\bar{x}$=3.70 mg/kg) than male samples from either Gambell (liver $\bar{x}$=0.57 mg/kg; kidney $\bar{x}$=1.31 mg/kg) or Diomede (liver $\bar{x}$=0.31 mg/kg; kidney $\bar{x}$=0.54 mg/kg). For female samples, Diomede had higher concentrations of arsenic (liver $\bar{x}$=0.31 mg/kg; kidney $\bar{x}$=1.28 mg/kg) than Gambell (liver $\bar{x}$=0.24 mg/kg; kidney $\bar{x}$=0.59 mg/kg). There were no female samples collected in Savoonga.

Interdependency between mercury and selenium was tested. No significant relationship was found between mercury and selenium with age or sex, and location ($P>0.05$). However, we found a significant correlation between the two elements in both the liver ($r=0.5$, $P<0.0001$) and kidney ($r=-0.3$, $P<0.02$) tissues when the data from all locations were pooled.

DISCUSSION

Marine mammals have long been known to have elevated levels of potentially toxic metals and metalloids in their tissues. The effects of these elements on the health of many marine mammals are still largely unknown. This project is designed to establish a long-term basis for monitoring trace element levels in subsistence harvested walrus. An objective of future research will be to understand what the potential effects of these elements might be to the health of the walrus population. Interpretation of these results is difficult because: (1) for walrus, as with many marine mammals, only limited baseline data are available for making such comparisons; (2) factors influencing toxicity in marine biota are largely unknown; and (3) toxicity criteria, set by regulating agencies, are established for domestic vertebrates. We thus have compared our 1986-1989 data both with previously reported walrus data from 1981-1984 (Taylor et al. 1989) and with other marine mammal studies to better understand the significance of various trace element levels.

The overall increases in arsenic, lead, and selenium concentrations found in our samples compared to the 1981-1984 samples might be explained by a larger sample size, change in the source of contamination (i.e., new or contaminated food items, new feeding grounds, diet changes, increased industrial activities, geophysical activities), or sample contamination (i.e., through storage containers, handling, or collecting methodology). Increases in the element concentrations are not attributed to sampling a different age group of walrus (e.g., older animals) because there was not a significant difference in mean ages of walrus sampled by Taylor et al. (1989) and this study.

Mercury

Based on data previously reported (Born et al. 1981; Wagemann and Muir 1984; Eisler 1987; Wagemann 1989; and Taylor et al. 1989), we anticipated finding high levels of mercury and cadmium. Pinnipeds have been found to contain the highest levels of mercury in their tissues of all mammals (Eisler 1987). The mean liver mercury concentration in our walrus samples ($\bar{x}$=4.2 mg/kg dry weight or 1.1 mg/kg wet weight) was similar to mean concentrations found previously in Pacific walrus ($\bar{x}$=1.5 mg/kg wet weight or 4.5 mg/kg dry weight, Taylor et al. 1989) and Atlantic walrus, *Odobenus rosmarus rosmarus*, ($\bar{x}$=1.78 mg/kg wet weight, Born et al. 1981). Taylor et al. (1989) reported that mean concentrations of mercury was above the FDA (Food and Drug Administration) action concentration established for mercury in human and animal food. Their comparison to the FDA level was inappropriate as the action concentration of 1 mg/kg (ppm) wet weight was established for methyl mercury and their analyses reported values of total mercury. The mean concentrations we found in walrus liver samples are substantially lower than concentrations found in liver tissues from northern fur seals, *Callorhinus ursinus,* ($\bar{x}$=10.74 mg/kg wet weight) from the Pribilof Islands (Goldblatt and Anthony 1983), ringed seals, *Phoca hispida*, ($\bar{x}$=16.14 mg/kg wet weight), and bearded seals, *Erignathus barbatus*, ($\bar{x}$=79.2 mg/kg wet weight) from Barrow Strait (Smith and Armstrong 1978).

We anticipated finding a relationship between mercury and age based on data from humans (Galster 1976), methyl mercury age data from marine mammals (Born et al. 1981; Hamanaka et al. 1982; Honda and Tatsukawa 1983; Eisler 1987; Himeno et al. 1989), and total mercury data from cetaceans (Hansen et al. 1990). However, both our data and data from 1981-1984 (Taylor et al. 1989) showed no correlation between mercury and age. The lack of correlation in the walrus data appears to be unusual and may be due to a more complex relationship between mercury and age. For example, we only sampled adult walrus and therefore may have excluded potential relationships occurring over the full age spectrum of the population. Furthermore, the toxic effect of mercury in marine mammals is best determined by analyzing both total mercury and methyl mercury levels. Analyses of methyl mercury levels indicate the amount of mercury converted within the tissue and therefore the level of potential toxicity (P. Becker, pers. comm.; Himeno et al. 1989). Unfortunately, methyl mercury analyses were not conducted for these samples; however, analyses are in progress on other samples that will examine the relationship between methyl mercury levels, total mercury, and walrus age.

Cadmium

Mean cadmium levels were not significantly higher than the 1981-1984 walrus data (Taylor et al. 1989). Concentrations were comparable to those found in northern fur seals (kidney $\bar{x}=184.81$; liver $\bar{x}=53.34$) on two rookeries on St. Paul Island, Alaska (Richard and Skoch 1986). Cadmium concentrations in walrus tissues continue to exceed the 10 mg/kg (ppm) wet weight level set by the EPA for vertebrate kidney and liver tissues. Cadmium concentrations above 13 mg/kg (ppm) wet weight are at a point thought to interfere with organ function in some animals and may represent a hazard to animals in the higher trophic levels (Eisler 1985). Cadmium has been implicated as the cause of various deleterious effects in fish and wildlife. Sublethal effects of cadmium toxicity include growth retardation, anemia, testicular damage, hypertrophy of the heart, and renal disfunction (Eisler 1985). At present, it is unknown whether any of these sublethal effects have occurred in walrus. Additional sampling and analysis are planned to examine the potential for these effects.

Cadmium levels have been reported to correlate positively with age. The relationship is especially pronounced in carnivores and marine invertebrates (Eisler 1985). Such a relationship between cadmium and age also has been found in harbor seals (*Phoca vitulina richardsi*, Miles et al. 1992) and northern fur seals (Goldblatt and Anthony 1983). We also found a correlation between cadmium and age in both the liver and kidney tissues. However, this correlation was not strongly represented by a regression model. Lack of a linear regression may be a function of not having the full age spectrum in the data rather than there being no relationship. No correlation between cadmium and age was observed for walrus data collected between 1981-1984 (Taylor et al. 1989). We are uncertain why these data did not show a correlation.

Selenium

Levels of selenium, a non-metallic element, are worth examining since selenium can be toxic to animals at high concentrations. Selenosis, or excess selenium, is particularly well documented in agricultural drainage areas, causing severe reproductive problems (i.e., congenital malformations and growth retardation), respiratory failure, and pathological changes to the organs of farm animals and birds (Eisler 1985). Alternatively, selenium is a required nutrient and can be deficient in humans and animals. Selenium tolerance levels have been established both to prevent selenium deficiency and protect against selenosis. Because tolerance levels can vary greatly from species to species (Eisler 1985), it is difficult to evaluate the significance of the values we obtained. Based on critical levels set for other mammals (e.g., rats at 1,000 mg/kg and horses at 4,000 mg/kg; Eisler 1985), the concentrations found in our study do not appear to be a cause for concern.

The levels of selenium we found were higher than those previously reported by Taylor et al. (1989). In addition, selenium levels were higher in female livers than in male livers. Although Taylor et al. (1989) did not report any difference in selenium concentrations by sex, their data indicate that females had higher concentrations than males in the liver tissue (females $\bar{x}=3.14$ mg/kg wet weight; males $\bar{x}=1.95$ mg/kg wet weight). We found no differences between sex and selenium levels in the kidney tissue. Other than arsenic, selenium was the only element for which we observed a correlation between sex and tissue type.

Another important aspect of selenium is its potentially antagonistic relationship with mercury and other metals such as cadmium (P. Becker pers. comm.; Lee et al. 1977; Himeno et al. 1989; Taylor et al. 1989; Hansen et al. 1990). Metal accumulation in the liver and kidney organs is related to metal-binding proteins which form metallothioneins. Metallothionein binds and stores the metals in a non-toxic form within the liver and kidney (Becker et al. 1988). Lee et al. (1977) suggest that metallothionein also may separate inorganic mercury and cadmium and cause them to bind with selenium. While we found a correlation between mercury and selenium in both the liver and kidney, no relationship was found between selenium and cadmium in either tissue. Taylor et al. (1989) observed a similar correlation between mercury and selenium, but did not test for a relationship between cadmium and selenium. Since the 1981-1984 data, mercury and cadmium levels did not significantly increase whereas selenium levels did increase. Although there is evidence for a relationship between selenium and mercury, this suggests the relationship may not be a 1:1 ratio. Instead, selenium levels may be increasing as a response to another metals' increase within the tissues.

Arsenic, Zinc, and Lead

Arsenic is of interest not only for its possible toxicity, but for its antagonistic relationship with selenium. Eisler (1988) reports that in several animal species (e.g., rats, dogs, cattle, poultry, and swine), arsenic protects against selenium poisoning. The arsenic concentrations observed in the 1986-1989 data are comparable to data reported by Wagemann (1989) from two groups of ringed seals (liver $\bar{x}=0.71$ and

1.69 mg/kg dry weight; kidney $\bar{x}=0.36$ and 1.31 mg/kg dry weight) in the Canadian arctic. Marine organisms (i.e., marine invertebrates) have been documented to contain arsenic concentrations at more than 100 mg/kg (ppm) dry weight and still be considered within "normal" limits (Eisler 1988). If this applies, current levels of arsenic in walrus tissues may not present a hazard. However, arsenic levels should continue to be monitored for any changes.

We found that tissues from male walrus had higher levels of arsenic than females. Eisler (1988) points out that most arsenic is absorbed after ingestion and then rapidly excreted in the urine; and therefore, arsenic levels found are probably a result of continuous daily exposure, rather than of accumulation. The differences in arsenic levels between males and females might be explained if females were transferring their daily arsenic into both milk and urine and consequently reducing their total arsenic load at a higher rate than males. This hypothesis needs to be explored further, particularly with regard to the female-calf relationship or possible temporal and spatial dietary differences between walruses of different ages and sexes. Further analysis of differences between female and male arsenic levels also may explain the relationship we found between arsenic levels and age; a relationship not previously observed in the 1981-1984 walrus samples collected by Taylor et al. (1989).

The relationship found between zinc and age is also noteworthy, but its significance remains unclear. One case of age accumulation of zinc was documented in a female narwhal (*Monodon monoceros*) (Hansen et al. 1990). Richard and Skoch (1986) and Skoch (1990) theorized that when cadmium, zinc, and selenium are combined, their potential individual effect on a tissue or system becomes masked. Based on this theory, it is possible that with an age related accumulation of cadmium, there would be an age related accumulation of zinc and selenium; however, the effects (e.g., toxicity) of increased levels of these elements may not be apparent. Zinc data were not collected prior to 1984; therefore, we can not compare our data with Taylor et al. (1989).

Mean lead levels were higher than the levels previously reported by Taylor et al. (1989). Our lead concentrations were similar to concentrations found in ringed seals (liver range 0.020-0.2 mg/kg dry weight; kidney range 0.002-1.58 mg/kg dry weight) in the Canadian arctic (Wagemann 1989) and fur seals (liver $\bar{x}$=1.13 mg/kg dry weight; kidney $\bar{x}$=0.27 mg/kg dry weight) in the Pribilof Islands, Alaska (Goldblatt and Anthony 1983). There is sufficient documentation that lead pollution world-wide is high and poses a sufficient hazard to warrant continued lead monitoring. Lead is toxic in most of its chemical forms and has been reported to be transferred into the body by inhalation, ingestion, absorption, and placental transfer to the fetus (Eisler 1988).

Conclusions

We confirmed several expected relationships and a few new unanticipated relationships: (1) levels of cadmium and mercury did not significantly increase since the 1981-1984 data; (2) levels of selenium, arsenic, and lead significantly increased since the 1981-1984 data; (3) cadmium concentrations remained higher than levels thought by the EPA to interfere with mammalian organ function (13 mg/kg); (4) mercury levels were not correlated with age; (5) mercury and selenium levels were strongly correlated; (6) arsenic levels were correlated with age, sex, and location; (7) selenium levels were correlated with sex; and (8) zinc levels were correlated with age. The significance of these relationships to the health of individuals and ultimately to the overall walrus population is unclear. However, it is important to continue monitoring these relationships, particularly the accumulation of cadmium with age and mercury/selenium correlations, as they may provide evidence of excessive heavy metal loading with potential consequences for animal health. Most of the elements analyzed do not have EPA recommended tolerance levels set for mammals, much less for specific marine mammals. Consequently, future contaminant data will only further increase our understanding of contaminant processes and potential effects on animal populations. In addition, we can inform public health agencies of these results so they may evaluate the potential for risk to subsistence users.

Future study plans include continued monitoring of trace element concentrations, particularly heavy metals, in walrus tissues collected from both the FWS harvest monitoring program and joint USA-USSR/Russia cooperative research cruises. These combined data will be valuable to further determine baseline contaminant levels in the walrus population. Additional attention will be focused on: (1) the detection of contaminants in the age groups and sexes that have been inadequately sampled; (2) histological examination of organ tissues which concentrate contaminants to assess the potential impact on animal health; and (3) the identification of transfer routes of contaminants through the ecosystem. By continuing to monitor element levels, relationships between those levels and the condition of the population may become apparent.

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LITERATURE CITED

Becker, P. R., S. A. Wise, B. J. Koster, and R. Zeisler. 1988. Alaskan marine mammal tissue archival project: a project description including collection protocols. U.S. Dept. Commerce, Natl. Bureau Standards NBSIR 88-3750.

Born, E.W., I. Kraul, and T. Christensen. 1981. Mercury, DDT and PCB in the Atlantic walrus (*Odobenus rosmarus rosmarus*) from the Thule District, North Greenland. Arctic 34(3):255-250.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.10). 46 pp.

Eisler, R. 1985. Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.5). 52 pp.

Eisler, R. 1987. Mercury hazard to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 87(1.10). 54 pp.

Eisler, R. 1988. Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.12). 92 pp.

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.14). 134 pp.

Galster, W.A. 1976. Mercury in Alaskan Eskimo mothers and infants. Environ. Health Perspective 15:135-140.

Goldblatt, C.J., and R.G. Anthony. 1983. Heavy metals in northern fur seals (*Callorhinus ursinus*) from the Pribilof Islands, Alaska. J. Environ. Qual. 12(4):478-482.

Hansen, C. T., C. O. Nielsen, R. Dietz, and M. M. Hansen. 1990. Zinc, cadmium, mercury, and selenium in minke whales, belugas, and narwhals of West Greenland. Polar Biol. 10:529-539.

Hamanaka, T., T. Itoo, and S. Mishima. 1982. Age related change and distribution of cadmium and zinc concentrations in the Steller sea lion (*Eumetopias jubata*) from the east coast of Hokkaido, Japan. Mar. Pollut. Bull. 13(2):57-61.

Himeno, S., C. Watanabe, T. Hongo, T. Suzuki, A. Naganuma, and N. Imura. 1989. Body size and organ accumulation of mercury and selenium in young harbor seals (*Phoca vitulina*). Bull. Environ. Contam. Toxicol. 42:503-509.

Honda, K., and R. Tatsukawa. 1983. Distribution of cadmium and zinc in tissues and organs, their age-related changes in striped dolphins, *Stenella coeruleoalba*. Arch. Environ. Contam. Toxicol. 12(5):543-552.

Lee, S. S., B. R. Mate, K.T. von der Trenck, R. A. Rimerman, and D. R. Buhler. 1977. Metallothionein and the subcellular localization of mercury and cadmium in the California sea lion. Comp. Biochem. Physiol. 57C:45-53.

Miles, A. K., D. G. Calkins, and N. C. Coon. 1992. Toxic elements and organochlorines in harbor seals (*Phoca vitulina richardsi*), Kodiak, Alaska, USA. Bull. Environ. Contam. Toxicol. 48:727-732.

Richard, C.A., and E.J. Skoch. 1986. Comparison of heavy metal concentrations between specific tissue sites in the northern fur seal. IAAAM Proceedings 17:94-103.

Skoch, E. J. 1990. Heavy metals in marine mammals: presence and analytical methods (pp 127-137) in CRC handbook of marine mammal medicine. L. A. Direrauf, editor. CRC Press Inc., Florida.

Smith, T. G., and F. A. J. Armstrong. 1978. Mercury and selenium in ringed and bearded seal tissues from arctic Canada. Arctic 31(2): 75-84.

Taylor, D.L., S. Schliebe, and H. Metsker. 1989. Contaminants in blubber, liver, and kidney tissue of Pacific walruses. Mar. Pollut. Bull. 20(9):465-468.

Wagemann, R. 1989. Comparison of heavy metals in two groups of ringed seals (*Phoca hispida*) from the Canadian arctic. Can. J. Fish. Aquat. Sci. 46:1558-1563.

Wagemann, R., and D.C.C. Muir. 1984. Concentration of heavy metals and organochlorines in marine mammals of northern waters: overview and evaluation. Can. Tech. Rep. Fish. Aquatic Sci. 1279. 97 pp.

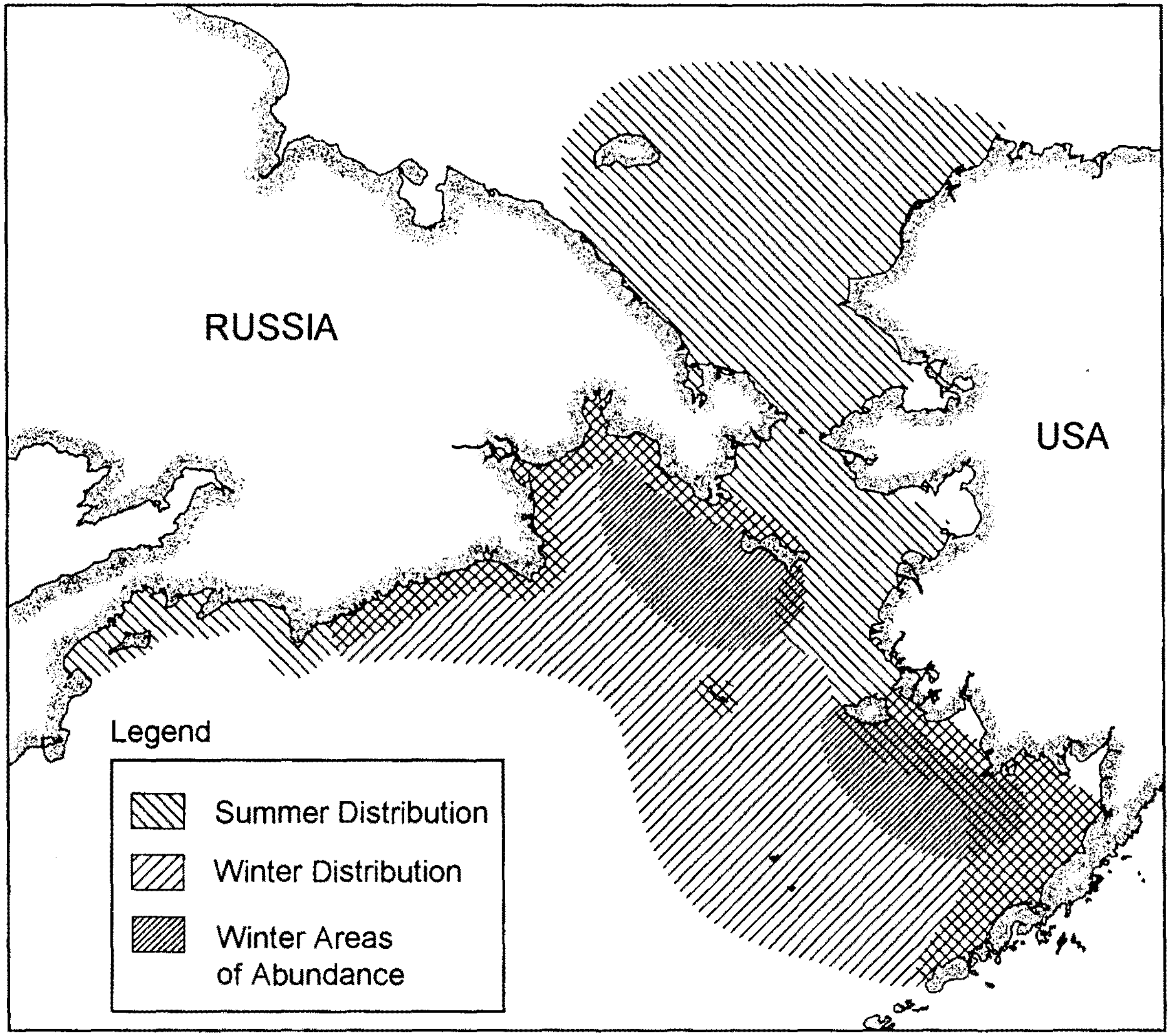


Figure 1. Generalized distribution of the Pacific walrus.

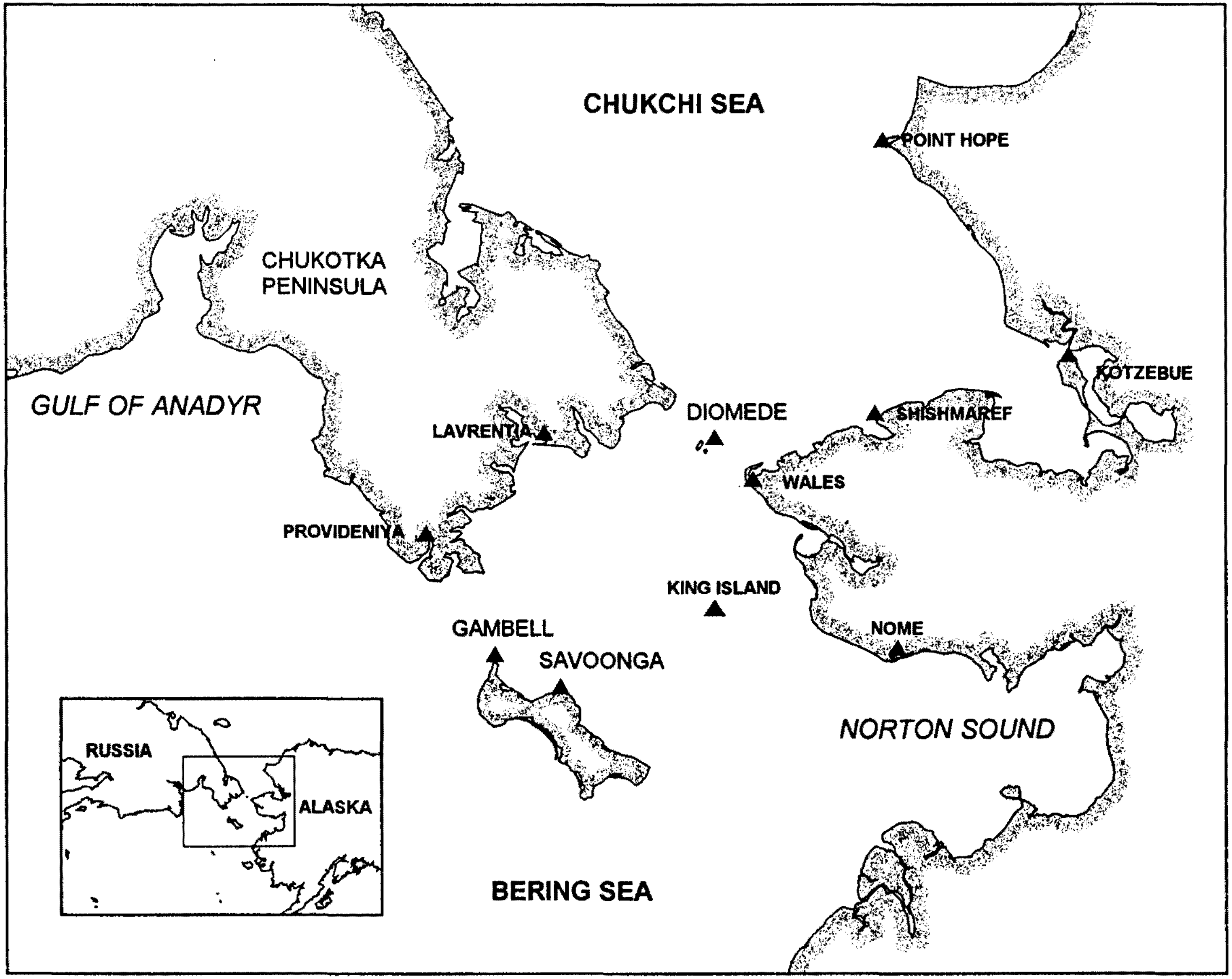


Figure 2. Location map of Diomede, Gambell, and Savoonga.

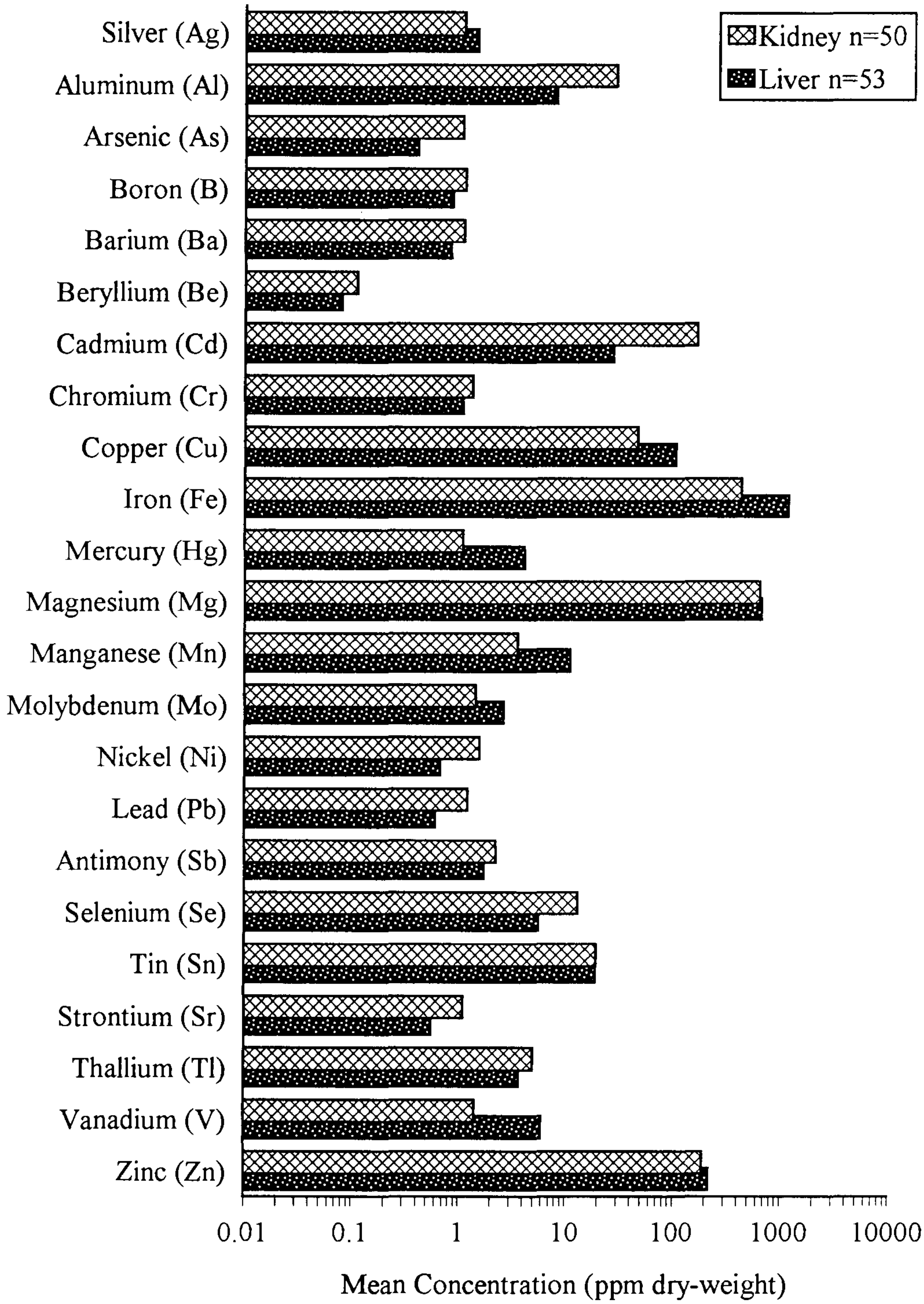
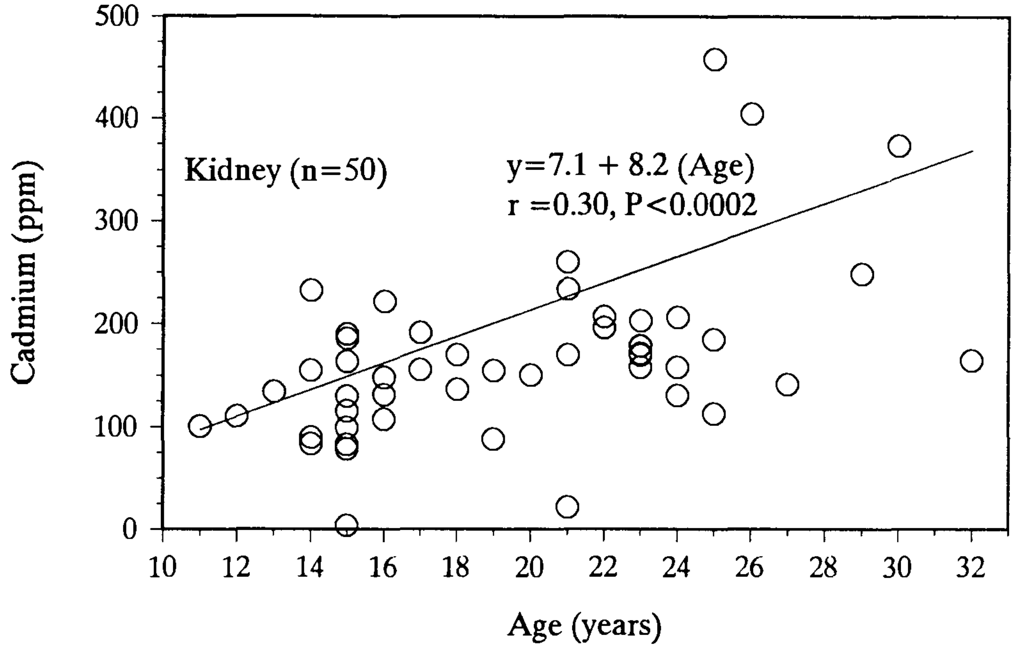


Figure 3. Mean element concentrations found in liver and kidney tissues during the walrus harvest monitoring program, 1986-1989.



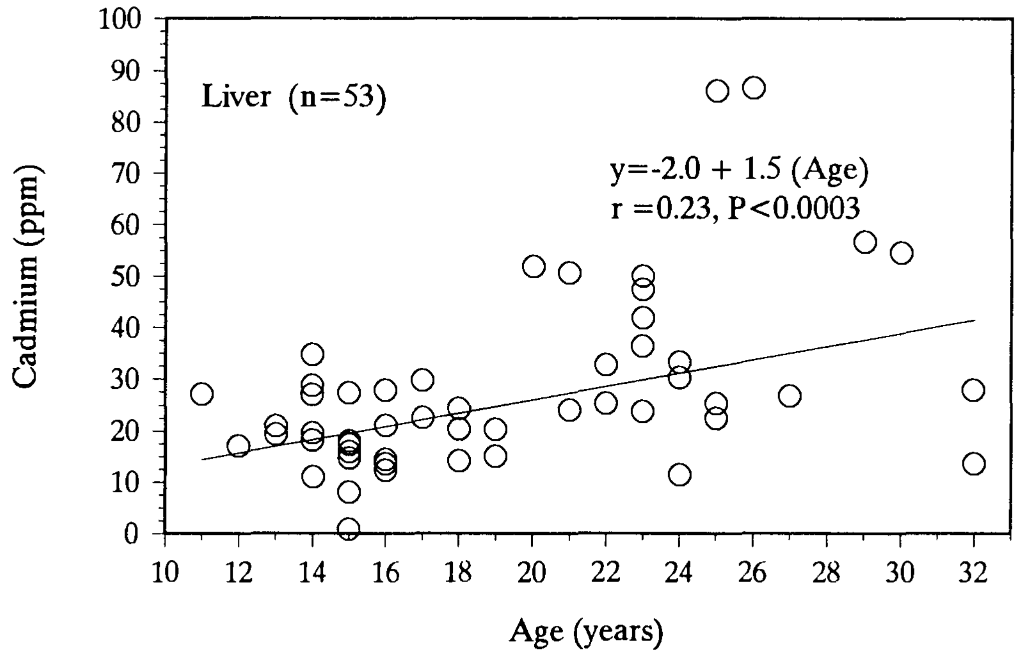


Figure 4. Relationship of cadmium levels and age in kidney and liver tissues collected during the walrus harvest monitoring program, 1986-1989. Cadmium levels are in dry weight units.

Table 1. Summary table of the total number of walrus analyzed for inorganic residues in liver and kidney tissues, 1986-1989.

Village:	Diomede	Gambell	Savoonga	
Year	male/female	male/female	male/female	Total
1986	5/7	0/0	0/0	12
1988	0/0	14/17	4/0	35
1989	9/0	0/0	0/0	9
Total:	14/7	14/17	4/0	56

Table 2. Statistical summary of 23 elements analyzed in walrus kidney tissues, 1986-1989.

KIDNEY (n=50)		Concentration (mg/kg dry weight)			
Element		Minimum	Maximum	Mean	Std. Deviation
Ag	Silver	0.89	1.36	1.12	0.09
Al	Aluminum	1.83	622.73	29.38	96.32
As	Arsenic	0.18	4.59	1.07	1.03
B	Boron	0.89	2.19	1.14	0.17
Ba	Barium	0.70	1.36	1.12	0.10
Be	Beryllium	0.09	0.14	0.11	0.01
Cd	Cadmium	3.58	457.63	166.50	82.00
Cr	Chromium	0.88	4.66	1.34	0.53
Cu	Copper	7.98	388.24	46.60	52.13
Fe	Iron	156.78	1326.24	434.05	180.92
Hg	Mercury	0.29	7.56	1.10	1.06
Mg	Magnesium	473.48	830.92	645.76	89.82
Mn	Manganese	2.20	12.48	3.58	1.51
Mo	Molybdenum	0.92	3.82	1.45	0.73
Ni	Nickel	0.63	31.18	1.57	4.29
Pb	Lead	0.53	11.76	1.21	1.63
Sb	Antimony	1.78	2.72	2.24	0.17
Se	Selenium	3.44	39.30	13.04	6.15
Sn	Tin	1.14	35.75	19.50	6.56
Sr	Strontium	0.18	2.51	1.10	0.46
Tl	Thallium	3.55	10.29	5.02	1.64
V	Vanadium	0.92	4.72	1.43	0.85
Zn	Zinc	100.44	382.22	190.23	50.92

Table 3. Statistical summary of 23 elements analyzed in walrus liver tissues, 1986-1989.

LIVER (n=53)		Concentration (mg/kg dry weight)			
Element		Minimum	Maximum	Mean	Std. Deviation
Ag	Silver	0.70	5.11	1.49	1.11
Al	Aluminum	1.53	57.38	8.15	12.56
As	Arsenic	0.16	1.16	0.41	0.28
B	Boron	0.70	1.98	0.87	0.17
Ba	Barium	0.76	0.97	0.84	0.05
Be	Beryllium	0.07	0.10	0.08	0.01
Cd	Cadmium	0.96	86.74	27.60	16.93
Cr	Chromium	0.73	1.59	1.09	0.19
Cu	Copper	17.63	353.70	105.62	59.41
Fe	Iron	279.32	2418.60	1195.88	467.02
Hg	Mercury	0.27	37.01	4.17	6.07
Mg	Magnesium	504.56	909.97	675.15	96.66
Mn	Manganese	7.20	23.10	11.08	2.64
Mo	Molybdenum	0.79	4.84	2.63	0.88
Ni	Nickel	0.56	0.78	0.67	0.04
Pb	Lead	0.42	1.76	0.61	0.29
Sb	Antimony	1.51	3.15	1.73	0.27
Se	Selenium	1.95	19.16	5.69	3.26
Sn	Tin	0.96	26.69	19.29	4.00
Sr	Strontium	0.16	1.54	0.56	0.32
Tl	Thallium	2.80	8.87	3.74	1.32
V	Vanadium	0.96	14.55	6.04	3.12
Zn	Zinc	118.81	1380.60	218.15	173.20

Table 4. Comparison of mean concentrations of arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), selenium (Se), and zinc (Zn) in walrus kidney (kid) and liver (liv) tissues. Data from 1981-1984 are from Taylor et al. (1989) and have been converted to mg/kg (ppm) dry weight units[1] for comparison with 1986-1989 data.

Year	As		Cd		Pb		Hg		Se		Zn	
	kid	liv	kid	liv	kid	liv	kid	liv	kid	liv	kid	liv
1981	<0.01	0.03	204.9	41.2	<0.01	0.03	-	3.3	-	13.3	-	-
1982	<0.01	<0.01	173.2	22.0	0.9	0.7	-	0.7	-	8.3	-	-
1983	<0.01	0.01	180.3	20.1	0.09	0.1	-	5.7	-	6.7	-	-
1984[2]												
1985[3]												
1986	0.9	0.4	146.6	20.1	0.8	0.6	1.0	3.7	16.2	4.2	145.8	263.1
1987[3]												
1988	1.2	0.5	166.3	29.4	1.3	0.7	1.1	4.6	11.3	6.0	195.8	201.9
1989	0.6	0.2	180.6	32.1	1.1	0.5	1.1	2.7	17.6	6.6	198.1	223.1

[1] In order to compare Taylor et al. (1989) data with the more recent data, Taylor's data in mg/kg (ppm) wet weight was converted to mg/kg (ppm) dry weight. The following formula was used for the conversion:

$$\text{mg/kg dry weight} = \text{mg/kg wet weight} / (1 - (\%\text{moisture} / 100))$$

[2] Moisture data for Taylor's 1984 data were unavailable; and therefore, these data could not be converted.

[3] Contaminant samples were not collected in 1985 or 1987.