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Toxic Elements and Organochlorines in Harbor Seals (*Phoca vitulina richardsi*), Kodiak, Alaska, USA

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Marine and estuarine habitats near urban or industrialized regions are vulnerable to contaminated runoff. Harbor seals (*Phoca vitulina richardsi*), which occur throughout much of the northern hemisphere, are useful mammalian biomonitors because they feed, reproduce, and rest near or on shore and are high-level trophic consumers. They have often been monitored for contaminants in Europe (Wagemann and Muir 1984). To date, no studies have been reported on contaminants in harbor seals from industrialized areas of Alaska. In the vicinity of Anchorage, Alaska's largest urban and industrial city, harbor seals are sedentary and limited to coastal waters; some movements have been documented but there is no evidence of extensive migrations. Although some harbor seals in the Kodiak Archipelago move up to 100 km along the shore, strong fidelity to specific haulout sites is more common (Pitcher and Calkins 1979). These seals eat mainly non-migratory fishes and octopi.

Harbor seal numbers have declined substantially from unknown causes in the southern part of the Kodiak Archipelago. The Alaska Department of Fish and Game (ADF&G) suggested that the decline is a trend for the entire Kodiak region and other Alaskan waters. Contaminants have been suggested as a possible reason for the precipitous decline of Steller sea lions (*Eumetopias jubatus*) in the region (Braham et al. 1980), and were suspected in the decline of harbor seals.

In this study, harbor seals were sampled from throughout the Kodiak Archipelago to determine concentrations of certain metals, metalloids, polychlorinated biphenyls (PCBs), and organochlorine pesticides, and to determine if these concentrations varied by sex or accumulated with age. All seals were collected within 75 km of Cook Inlet, an estuary next to Anchorage. The targeted elements or compounds were known to be toxic to a wide spectrum of organisms (e.g., MARC 1980; Eisler 1986).

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MATERIALS AND METHODS

Twenty-three harbor seals were randomly selected from a larger collection taken for the Outer Continental Shelf Environmental Assessment Program by ADF&G in the Gulf of Alaska. The seals were collected within 4.8 km of shore between April - November, 1976, 1977 and 1978. Most were shot in the water, but some were taken at haulouts.

Kidney, liver, and blubber samples were removed on site from one male and one female harbor seal 1, 4, 7, 10, 14, 16, 19, and 22 years of age. Additional samples were collected from seven 4 year-old males, which was the most common group represented in the animals taken. Ages were estimated by counting cementum annuli in stained, decalcified microsections of canine tooth roots. Tissues were immediately wrapped in aluminum foil and frozen. A subsample from the center of each sample was used for chemical analyses in order to circumvent possible contamination during field handling.

Tissues that most likely concentrated specific elements or compounds were analyzed (Reijnders 1980). Livers or kidneys were analyzed for arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), and selenium (Se). Blubber was analyzed for PCBs and for the organochlorine pesticides DDT, DDD, DDE, dieldrin, heptachlor epoxide, oxychlordane, *cis*-chlordane, *cis*-nonachlor, endrin, toxaphene, hexachlorobenzene, and mirex.

Residue analyses were conducted at the Patuxent Wildlife Research Center of the U. S. Fish and Wildlife Service. Samples were prepared and analyzed by methods described by Haseltine et al. (1981) and Krynitsky (1987). Elements were analyzed by atomic absorption spectrophotometry and chlorinated compounds by gas-liquid chromatography. Residues in 10% of the samples were confirmed by gas-liquid chromatography/ mass spectrometry. Minimum detection limits were 0.02 $\mu g \cdot g^{-1}$ (wet weight) for Hg, 0.05 $\mu g \cdot g^{-1}$ for As, and 0.10 $\mu g \cdot g^{-1}$ for Cd, Pb, Se, and the organochlorines.

We used analysis of covariance to compare residue concentrations between sexes, and to determine correlations between age and residue concentrations. Significant correlations were further analyzed by sex and the regression lines analyzed by t-test for significance of fit (H_0: slope = 0). All results were evaluated at the 0.05 level of significance. Samples with concentrations below detection limits were given a value of one-half that limit and included in the statistical analyses if more than 50% of the samples were above detection limits. The data were normalized by log transformations and geometric means are provided. Ranges provided are untransformed residue concentrations in individual samples.

RESULTS AND DISCUSSION

All targeted elements were detected in kidneys or livers of the harbor seals (Table 1). Average Cd concentrations were highest; 52% of the samples contained > 10 $\mu g \cdot g^{-1}$. Among males, Cd measured highest of the residues, and the mean concentration (11.2 $\mu g \cdot g^{-1}$) was significantly higher in males than in females (2.5 $\mu g \cdot g^{-1}$).

Among females, Hg concentrations were highest of the residues and were similar in concentration to that in males (Table 1). However, the liver from a 19 year-old male contained 72 $\mu g \cdot g^{-1}$ Hg, which was the highest individual residue concentration in any sample. Mercury concentrations > 10 $\mu g \cdot g^{-1}$ were in 39% of the livers.

Lead, selenium, and arsenic concentrations were similar in males and females. Lead concentrations were similar in both liver and kidney tissues. Selenium was in all livers, but 96% of the seals had concentrations lower than 8.0 $\mu g \cdot g^{-1}$. The 19 year-old male mentioned above had the highest Se, Cd, and Hg concentrations among all seals. Arsenic was detected in 13 livers and was the only toxic element not found in all 23 seals. Arsenic concentrations also averaged lowest of the residues.

Of the 13 organochlorine compounds for which we analyzed, only total PCBs and the pesticides DDT, DDE, and oxychlordane were detected (Table 1). PCBs were detected in 21 of 22 blubber samples, and concentrations were similar between males and females. DDT was significantly higher in males than females and was detected in 68% of the samples. DDE, a derivative of DDT, was found in all samples. Oxychlordane, a highly toxic animal metabolite of the insecticide chlordane, was detected in 55% of the samples. DDE and oxychlordane tended to be higher in males than females.

Three of the 9 detected residues correlated significantly with age: Hg (liver; $r = 0.71$), Pb (liver; $r = 0.55$), and Cd (kidney; $r = 0.74$). However, analysis of the slopes of the regression lines for males and females indicated that the correlations of age with residue concentrations were significant only for male harbor seals (Table 1).

Residue concentrations were less in Kodiak harbor seals than in pinnipeds of more industrialized regions in the northern hemisphere (Wagemann and Muir 1984), indicating that the Kodiak Archipelago was relatively uncontaminated. This study is the first to report As, Se, and oxychlordane in Alaskan pinnipeds; the other residues detected have been reported elsewhere (Anas and Wilson 1970; Galster and Burns 1972; Anas 1974a,b; Goldblatt and Anthony 1983). Mercury concentrations reported here and in harbor seals from the Pribilof Islands were similar (Anas 1974a). Cadmium, mercury, lead, and DDT concentrations in northern fur seals (*Callorhinus*

Table 1. Geometric means and ranges ($\mu g \cdot g^{-1}$ wet wt.) of Cd, Pb, Hg, Se, As, and organochlorine concentrations in 23 harbor seals from Kodiak, Alaska.

	Total (23)	Male (15)	Female (8)	Range	Frequency (%)	sex (significant diff. $P \leq 0.05$)	age
Kidney							
Cd	6.6	11.2	2.5	0.3 - 44.0	100	F=7.68(3,19)[a]	t=4.44(19)[b]
Pb	0.8	0.7	0.9	0.3 - 2.2	100		
Liver							
As	0.08	0.09	0.08	n.d.[c] - 0.9	56		
Pb	0.7	0.7	0.7	0.2 - 2.1	100		t=2.87(19)[b]
Hg	5.0	4.8	5.5	0.4 - 72.0	100		t=4.32(19)[b]
Se	1.6	1.4	1.9	0.2 - 18.0	100		
Blubber[d]							
DDE	0.9	1.2	0.6	0.2 - 2.4	100		
DDT	0.1	0.2	0.07	n.d. - 0.4	68	F=3.79(3,18)	
Oxychlordane	0.09	0.1	0.06	n.d. - 0.3	55		
PCBs	2.2	2.1	2.3	n.d. - 6.6	95		

[a] ( ) = degrees of freedom.

[b] significant in male seals only- no correlation of age and residues in females.

[c] n.d. = not detected.

[d] residues from 22 seals.

ursinus) from the Pribilof Islands and PCBs, DDT, and DDE in fur seals from St. Paul Island were higher than in Kodiak harbor seals (Anas and Wilson 1970; Anas 1974a; Goldblatt and Anthony 1983). Why these contaminants were greater in pinnipeds from non-industrialized areas than in harbor seals from the Kodiak region is puzzling; the source of exposure and species-specific propensity to uptake of contaminants need to be determined.

Little is known of the direct effects of the residues found in this study on marine mammals. Reproductive failure in marine mammals in the wild has been associated with considerably higher organochlorine concentrations than those in this study (Delong et al. 1973; Reijnders 1980). Harp seals (*Pagophilus groenlandicus*) dosed with 25.0 mg/kg bw/day methyl mercuric chloride died within 26 days (Ronald et al. 1977). Smaller (0.25 mg/kg bw/day) doses of methyl mercuric chloride caused histological damage to the inner ear of harp seals (Ramprashad and Ronald 1977).

Our results support reported correlations between age and Cd, Hg, and Pb accumulation in pinniped tissues (Goldblatt and Anthony 1983; Wagemann 1989). Selenium, PCBs, and DDT have also been suggested to bioaccumulate with age (van de Ven and Koeman 1979; Reijnders 1980). The correlation of certain residues with age appeared sex dependent; Cd and some organochlorine concentrations were higher in males than females. Organochlorines concentrate in adipose tissue, but female harbor seals tend to be fatter than males, even during the pupping, lactation, and mating period (May - July; Pitcher 1986). It is possible that organochlorines were mobilized with fat in the production of milk during lactation, accounting for the lower level of these compounds in females.

Our findings suggest that other population limiting factors, e.g., disease, may be more important than contaminants in the decline of harbor seal numbers in the Kodiak Archipelago. Still, high Cd, Hg, and Se concentrations were measured in individual seals, and differences in concentrations of some contaminants between sexes were demonstrated. Monitoring of Kodiak harbor seals should be continued as a bioindication of the environmental health of this region.

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