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Comparison of arsenic, cadmium, chromium, lead, manganese, mercury and selenium in feathers in bald eagle (*Haliaeetus leucocephalus*), and comparison with common eider (*Somateria mollissima*), glaucous-winged gull (Larus glaucescens), pigeon guillemot (*Cepphus columba*), and tufted puffin (*Fratercula cirrhata*) from the Aleutian Chain of Alaska

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Abstract

There is an abundance of field data for levels of metals from a range of places, but relatively few from the North Pacific Ocean and Bering Sea. In this paper we examine the levels of arsenic, cadmium, chromium, lead, manganese, mercury and selenium in feathers from common eiders (*Somateria mollissima*), glaucous-winged gulls (*Larus glaucescens*), pigeon guillemots (*Cepphus columba*), tufted puffins (Fratercula cirrhata) and bald eagles (Haliaeetus leucocephalus) from the Aleutian Chain of Alaska. Our primary objective was to test the hypothesis that there are no trophic levels relationships for arsenic, cadmium, chromium, lead, manganese, mercury and selenium among these five species of birds breeding in the marine environment of the Aleutians. There were significant interspecific differences in all metal levels. As predicted bald eagles had the highest levels of arsenic, chromium, lead, and manganese, but puffins had the highest levels of selenium, and pigeon guillemot had higher levels of mercury than eagles (although the differences were not significant). Common eiders, at the lowest trophic level had the lowest levels of some metals (chromium, mercury and selenium). However, eiders had higher levels than all other species (except eagles) for arsenic, cadmium, lead, and manganese. Levels of lead were higher in breast than in wing feathers of bald eagles. Except for lead, there were no significant differences in metal levels in feathers of bald eagles nesting on Adak and Amchitka Island; lead was higher on Adak than Amchitka. Eagle chicks tended to have lower levels of manganese than older eagles.

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Keywords

Metals; Birds; Feathers; Aleutians; Mercury; Lead; Cadmium; Trophic level

Introduction

Environmental contamination is a problem world-wide because of the potential effects of chemicals on humans and the environment. Levels of chemicals are particularly elevated in coastal ecosystems because of river influxes, runoff, point-source pollution, and atmospheric transport and deposition (Furness and Rainbow 1990; Burger and Gochfeld 2002). Many chemicals, such as mercury, are transported all over the world, including to relatively isolated lakes and oceanic environments (Fitzgerald 1989; Houghton et al. 1992; Fitzgerald et al. 2005; Hammerschmidt et al. 2006). Atmospheric deposition is of particular interest for mercury because the USA and other industrialized nations are poorly regulating emissions (Evers et al. 2005). Species that forage in aquatic environments are more vulnerable than terrestrial species because of the potential for rapid movement of contaminants in water, and because chemicals can be stored in bottom sediments (including the intertidal), providing a pool for years to come. Many oceanic islands are also without the contamination found in temperate regions, such as urban, industrial and agricultural emissions, effluents, and runoff (Mailman 1980).

Increasingly governmental agencies, Tribal Nations, public policy makers, managers, and the public are interested in levels of contaminants in wildlife that could prove a problem to either the wildlife themselves or to organisms that consume them. Marine birds are useful as bioindicatiors of environmental pollution (Walsh 1990; Peakall 1992; Monteiro and Furness 1995; Furness and Camphuysen 1997) because they are exposed to a wide range of chemicals and occupy high trophic levels, making them susceptible to bioaccumulation of pollutants (Lewis and Furness 1991; Burger and Gochfeld 2002; Nygard et al. 2001). Since most marine birds nest in colonies, local birds can be followed for many years (Burger and Gochfeld 2004; Scheifler et al. 2005). Further, Gilbertson et al. (1987) suggested that contaminant levels in seabirds have lower coefficients of variation than fish or marine mammals. Feathers can be used as indicators of metal contamination because: (1) Birds sequester metals in their feathers, (2) the proportion of body burden that is in feathers is relatively constant for each metal, (3) a relatively high proportion of the body burden of certain metals is stored in the feathers (Burger 1993), and (4) there is a high correlation between levels of contaminants in the diet of seabirds and levels in their feathers (Burger 1993; Monteiro and Furness 1995). Breast feathers are the best indicator of whole-body burdens (Furness et al. 1986). Moreover, breast feathers are easy to collect non-invasively and to store for decades or longer, making them especially useful for establishing temporal and spatial patterns without impacting populations, and for assessing metal contamination in endangered or threatened species.

In this paper we examine the levels of arsenic, cadmium, chromium, lead, manganese, mercury and selenium in the feathers of common eiders (*Somateria mollissima*), glaucous-winged gulls (*Larus glaucescens*), pigeon guillemots (*Cepphus columba*), tufted puffins

(*Fratercula cirrhata*) and bald eagles (*Haliaeetus leucocephalus)* from the Aleutian Chain of Alaska. Our main objective was to examine this suite of heavy metals in species occupying different tropic levels. We test the null hypotheses that there are no interspecific differences in metal levels that might be due to trophic levels. Other papers explore metal dynamics within each species as a function of island (see Burger and Gochfeld 2008 for puffins and eiders, Burger et al. 2007b for pigeon gullemots, Burger et al. 2008 for gulls), but regional means are presented for the first time in this paper, along with eagle data not previously reported. We also examined the levels of heavy metals in breast and wing feathers of bald eagles.

The Aleutians are extremely important because of their large and diverse seabird populations, comprising the most important and abundant populations in the USA (Merritt and Fuller 1977). Understanding metal dynamics in seabirds at different trophic levels within this system is important, and the data can serve as a baseline for further work. The data in this paper are for the middle Aleutian Islands, not usually examined because the largest and most diverse seabird colonies are in the Western Aleutians. Further, understanding the metals levels in adult seabirds is important because they are part of the subsistence diet of the Aleut peoples living on these islands, particularly when marine mammals or salmon are not available and during the egg-laying period when birds are close to islands. Eiders can be easily caught on their nests, other species can be shot, and birds can be dried or frozen for later use. The birds examined in this study (except eagles) are a traditional part of their diet, and many Aleuts continue to prize them today (Patrick 2002; Hamrick and Smith 2003; Fish and Wildlife Service 2004). From our visits to the Aleut villages it is also clear that teenagers often practice their shooting abilities with birds, and bring them home for supper.

Study sites and methods

Study sites

The Aleutian Islands were established as a National Wildlife Refuge in 1913 by executive order of President Taft (ATSDR 2004). Birds were collected from Adak, Amchitka and Kiska Islands. Adak Island is approximately 1,900 km west of Anchorage (Fig. 1). A Naval Air Facility occupied the northern portion of the island from 1942 until 1997, when operations closed (ATSDR 2004). At its peak, over 100,000 military personnel were stationed on the island, creating the potential for historic contamination of the marine environment, particularly near the seaport and airport areas of Adak. In 1994 the Naval Air Station at Adak was placed on the National Priority List after an EPA RCRA inspection (ATSDR 2004). Most of the population (currently less than 200 people) resides in the town of Adak, which has an airport and seaport. Adak is the only island of those reported herein that is currently occupied by people.

Amchitka Island (Fig. 1, 51° N lat; 179° E long) is part of the Alaska Maritime National Wildlife Refuge system. It contains important ecological resources (Merritt and Fuller 1977; Burger et al. 2005, 2006a, b). Amchitka is the only island where the USA detonated underground tests (Long Shot in 1965, Milrow in 1969, Cannikin in 1971). It is unusual among DOE-contaminated sites because of its remoteness, depth below ground surface of the contamination, and the importance of its ecological resources and seafood productivity that could be at risk if there were significant seepage of radionuclides from Amchitka tests to the marine environment (Burger et al. 2006b). Kiska (51° N lat; 177° E long) had military occupation during the Second World War, but has not been occupied since. It contains many of the same terrestrial and benthic environments as Amchitka (Burger et al. 2006b).

Protocol

Under appropriate state and federal permits, breast feathers were collected from adult common eiders (*Somateria mollissima*), glaucous-winged gulls (*Larus glaucescens*), pigeon guillemots (*Cepphus columba*), tufted puffins (*Fratercula cirrhata*) and bald eagles (*Haliaeetus leucocephalus*) from the Aleutian Chain of Alaska. Breast feathers were also collected from young bald eagles (*N*=3), and wing feathers were collected from bald eagles (*N*=3 young, 9 adults). All birds were collected in July during the breeding season; when most species were incubating eggs or had young chicks. Noting the exact timing of collecting is critical because Wayland et al. (2005) found that levels of cadmium, mercury and selenium can vary by time of the year. Birds were initially collected for a Department of Energy project to ascertain levels of radionuclides in biota (Powers et al. 2005; Burger et al. 2005, 2007a, b, c; Burger and Gochfeld 2007). All species were collected from Amchitka and Kiska, but only feathers from gulls and eagles were collected from Adak.

Breast feathers were placed in individual envelopes and labeled for later identification, and eggs were frozen in individual plastic bags, and both were then shipped to Rutgers University for analysis. Breast feathers were selected because they are considered to be more representative of exposure to metals than other feathers (Furness et al. 1986; Burger 1993). Metals enter feathers during the two-three weeks it takes for them to grow, then the blood supply atrophies, and there is no further uptake of metals (Burger 1993; Thompson et al. 1998). Thus, feathers are an archive of metal exposure during feather formation. Adults are exposed to heavy metals and selenium through their food and water. Once ingested, contaminants can be excreted directly or absorbed. Subsequently metals are delivered to target organs or sequestered in feathers (Braune 1987; Lewis and Furness 1991) or other tissues. Kim et al. (1996) recently suggested that some pelagic seabirds (albatrosses and petrels) are capable of demethylating methylmercury in the liver, and storing it as an immobilizable inorganic form, however the mercury in feathers is almost 100 % methylmercury (Thompson et al. 1991). Heavy metals in the feathers represent circulating concentrations in the blood during the few weeks of feather formation, which in turn represents both local exposure and mobilization from internal tissues (Monteiro 1996). Once the feather matures, the vascular connection atrophies, leaving the feather as a record of blood levels at the time of its formation, and the concentration of metals in a feather remains constant (Braune and Gaskin 1987). Most of the seabirds in the Aleutians are resident, remaining in Aleutians throughout the year, although they may wander from island to island (Kenyon 1961).

All feathers were analyzed in the Elemental Analysis Laboratory of the Environmental and Occupational Health Sciences Institute in Piscataway. Feathers were washed three times with acetone, and then digested individually in warm nitric acid mixed with the addition of

30% hydrogen peroxide, and subsequently diluted with deionized water. Mercury was analyzed by cold vapor technique, and the other elements were analyzed by graphite furnace atomic absorption (Burger and Gochfeld 1991). All concentrations are expressed in ng/g (ppb) on a dry weight basis using weights obtained from air-dried specimens.

Detection limits were: 0.02 ppb for cadmium, 0.08 ppb for chromium, 0.15 ppb for lead, 0.09 ppb for manganese, 0.2 ppb for mercury, and 0.7 ppb for selenium. All specimens were analyzed in batches with known standards, calibration standards, and spiked specimens. Recoveries ranged from 88% to 102%. Batches with recoveries of less than 85% were reanalyzed. The coefficient of variation on replicate, spiked samples ranged up to 10%.

Non-parametric Kruskal-Wallis chi square tests were used to examine differences among islands, and Duncan Multiple range tests were performed to distinguish significant differences between species, using log transformed data (SAS 1995). Both arithmetic and geometric means are given to facilitate comparisons with other studies. We accept a probability level of 0.05 as significance, but present all values below 0.10 to allow the reader to assess the significance themselves.

Results

There were interspecific differences for all metals examined (Table 1). Bald eagles had the highest levels of all metals except selenium and mercury (examining the geometric means). Puffins had the highest levels of selenium, and guillemots had the highest levels of mercury (although the difference was not significant for mercury). Common eiders, at the lowest trophic level, had the lowest levels of some metals, but not arsenic, cadmium, and manganese. The data generally support a trophic level relationship.

Levels of metals in bald eagles are reported here in greater detail since they have not been previously examined. There were no significant differences as a function of age, although sample sizes were small for chicks. However, by inspection, levels tended to be lower in chicks for most metals (Table 2); levels of cadmium and manganese almost reached significance. Only mercury and selenium levels were very similar among age classes (Table 2).

Levels of lead were higher in breast feathers than in wing feathers of bald eagles (Table 3). We had only 3 birds where we had both wing and breast feathers, so these data are preliminary. However, for most metals the levels were similar (except for manganese and lead).

Except for lead, there were no significant differences in metal levels in feathers of bald eagles nesting on Adak and Amchitka Island (Table 4). Lead levels were higher on Adak (the currently populated island that once had a Navy base) than on Amchitka.

Discussion

Interspecific comparisons

The primary objective of this paper was to compare metals levels in five species breeding on Adak, Amchitka, and Kiska Islands in the Aleutian Chain of Alaska, and to examine trophic relationships. There are at least two approaches to examining the effects of trophic level: measuring metal levels in each link of the food chain leading to a top level predator (e.g. plankton, invertebrates, fish, fish-eating seabird; Hahn et al. 1993; Bargagli et al. 1998), and measuring levels in several members of the same group known to be in different trophic levels (e.g. seabirds at different trophic levels). The former method is more difficult because site-specific information is required on the diets of all species forming the links in the food chain. The latter approach is more common, perhaps because it is easier to collect feathers or other tissues from a group of seabirds nesting in one general location.

A number of studies with several species of seabirds have examined trophic level relationships, and found increasing mercury levels with increasing trophic level (Hahn et al. 1993; Stewart et al. 1997; Burger and Gochfeld 1997, 2000a; Borga et al. 2006). However, no trophic level relationships have been found in a number of studies for manganese (Borga et al. 2006), and selenium (Sydeman and Jarman 1998; Borga et al. 2006). Further, negative relationships between trophic position and metal levels have been found for lead (Sydeman and Jarman 1998). Nonetheless, there are relatively few studies that examine trophic level relationships within seabirds from the same region, and still fewer studies that examine metals other than mercury or for birds in the North Pacific (but see Honda et al. 1990).

In this study, we compare levels of seven metals in five species from the same islands in the Aleutians. For interspecific comparisons, we used breast feathers, except for eagle, where wing feathers were used because we had larger sample sizes. There were no significant differences in levels of metals in breast and wing feathers for bald eagle, except for lead.

The species studied are at different trophic levels. Much of the information on diet in the literature either comes from the western Aleutians, or from the Alaskan peninsula, largely because the large colonies in the western Aleutians (Buldir, Verbeek 1993) or accessible (Alaska Peninsula, Piatt and Kitaysky 2002) seabird colonies are located there.

Common eiders eat mainly lower-trophic level benthic invertebrates in the intertidal and subtidal regions, but sometimes eat crustaceans and echinoderms (Goudie et al. 2000). In the Pacific/Bering Sea regions, the diet of common eiders was 46 % mollusks, 31 % crustaceans, and 14 % echinoderms (Cottam 1939). Pigeon guillemots eat primarily small benthic fish and invertebrates. In Alaska, chicks are fed mainly small gadids, sandlance, herring, and sculpins (Ewins 1993).

Glaucous-winged gulls eat a wide range of vertebrates and invertebrates (Verbeek 1993). The gulls we collected had mainly fish, molluscs, and a few sea urchins in their stomachs. In the eastern Aleutians glaucous-winged gulls feed mainly on invertebrates (Irons et al. 1986). However, in the western Aleutians there is great variation in foods taken. For example, the percent of sea urchins in the diet ranged from 1 to 80 on different islands, the percent of fish ranged from 0.2 to 77, and the percent of birds eaten ranged from 0.2 to 87 (Trapp 1979). At Buldir Island (west of Kiska in the Aleutians), nearly 80% of the diet of glaucous-winged gulls was birds and 20% was fish, but in other places they do not eat birds (Verbeek 1993).

Tufted puffins feed mainly on small schooling fishes during the breeding season, although they also eat invertebrates such as squid (Piatt and Kitaysky 2002). In the Aleutians, however, diets vary by location, with squid accounting for 80% of the items in puffin diets in the western Aleutians, but only 17% of diets in the eastern Aleutians (Piatt and Kitaysky 2002); fish made up 22% of diets in the eastern Aleutians. Walleye pollock, sandlance, and greenling were all important fish in the diet of puffins. Thus, to truly understand the diet of puffins, site-specific information is necessary, derived from either stomach content analysis or stable isotopic studies (Braune et al. 2002). The only items we found in stomachs of tufted puffins were small fish. Eagles are clearly at the top of the food chain, eating primarily fish that are larger in size than other species eat. In our study we observed eagles eating from large dead fish along the coast and bringing back fish to chicks, and found numerous fish heads and fish bones in their nests.

This data on prey types would suggest that the relative trophic level (from lowest to highest) would be eiders, pigeon guillemots, glaucous-winged gulls, tufted puffins, and eagles. This would in turn suggest a similar order for metal levels, given bioaccumulation. Except for selenium (and to a lesser extend mercury), the levels of metals in the feathers of eagles were higher than those of the other species. However, eiders had the lowest levels of only chromium, mercury and selenium in their feathers. Thus, although the data generally indicate a trophic level relationship, it is not complete.

The two greatest anomalies were that (1) pigeon guillemot had higher levels of mercury than eagles, and (2) eiders had higher levels of arsenic, cadmium, lead, and manganese than all species except eagles. Although pigeon guillemots had higher arithmetic and geometric means for mercury than eagles, the differences were not significant. This was not expected since eagles eat large fish, including much larger fish that they eat as carrion, and larger fish should have higher mercury levels. We cannot account for the relatively high levels of mercury in pigeon guillemot feathers, but suggest it bears further examination.

The relatively high levels of arsenic, cadmium, lead and manganese in common eiders was also surprising. Since the eiders eat primarily invertebrates, the data suggest that levels of these metals in their prey should be examined closely, both in the Aleutians, and elsewhere.

Age differences in bald eagles

We had expected that there might be age differences in metal levels in eagles because adults had longer to accumulate metals than chicks or juveniles. However, there were no significant differences, although cadmium and manganese approached significance ($P < 0.09$ and 0.07 respectively). The lack of differences may partly be due to small sample sizes for chicks, and the fact that eagles generally remain in the Aleutians, and do not migrate south. That is, exposure might be similar for adults and young. Future studies should obtain higher sample sizes for feathers of young eagles, which could be done without sacrificing the young. Eagles were initially collected for analyses of radionuclides (Burger et al. 2007a), where whole bodies were necessary.

Significance of levels

Contaminant levels of seabirds from the Aleutian Islands are of interest because of the possible effects on the guillemots themselves, of possible effects on secondary consumers, including humans (e.g. Aleuts, Patrick 2002; Fish and Wildlife Service 2004), and because they can serve as bioindicators of contamination in marine food webs. Of the species examined, eiders, and sometimes puffins, are eaten by the Aleuts.

Laboratory studies are necessary to identify the levels of metals that result in death and adverse impacts on the behavior, physiology, or reproductive success of birds. In general, mercury, cadmium and lead are of primary concern in marine environments (Mailman, 1980; Thompson and Furness, 1998), they are non-essential, and are toxic (Elliott et al. 1992). Each will be discussed below.

Mercury levels in feathers that are associated with adverse reproductive effects in birds are 5,000 ppb (Eisler 1987; Burger and Gochfeld 2000b). Concentrations of 15,000 ppb mercury are required for adverse effects in some predatory birds (Spry and Wiener 1991; Wiener and Spry 1996). The mean levels in the feathers of birds in this study were all below the latter criterion, but not the former (at least for guillemots). Mercury levels bear further examination in guillemots to determine if they are suffering adverse effects.

For lead, adverse effects in birds occur at levels of 4,000 ppb in feathers (Custer and Hoffman 1994; Burger and Gochfeld 2000c), although seabirds can often tolerate higher levels (Burger and Gochfeld 2000b). The levels in feathers of the seabirds examined in the Aleutians were all below these levels (with the possible exception of bald eagles).

Cadmium causes sublethal behavioral effects at lower concentrations than lead and mercury (Eisler 1985), but feather levels known to cause adverse effects in the birds themselves have not been determined from laboratory studies. However, conversion factors developed from Burger (1993) suggest that feather levels that are associated with adverse effects would range from 100 ppb (shearwaters) to 2,000 ppb (terns). The cadmium levels found birds from the Aleutians were well below these levels, except for eagles. Since the adverse effects levels vary so greatly, further study is necessary to determine if eagles are adversely affected.

There are few controlled laboratory studies for other metals, and those that do relate adverse effects to liver or kidney levels, making it difficult to interpret the significance of the levels found in the Aleutian birds. The manganese levels of eagles were over an order of magnitude higher for eagles than for the other species, suggesting that these levels should be examined to determine if there are effects. For selenium, feather levels of 3,800 to 26,000 ppb (depending upon species) result in mortality (converted after Burger 1993), and 1,800 ppb result in sublethal adverse effects (after Heinz 1996). The levels of selenium in feathers of most species from the Aleutians averaged below even the sublethal effects level, except for guillemots and eagles.

Overall, the results of this study indicate that for most metals, average levels in the feathers of birds from the Aleutians indicate they are below any effects levels. However, the case is less clear for mercury in guillemots (and perhaps eagles), lead and cadmium in eagles, and selenium in guillemots and eagles. Partly the issue is species-specific tolerances, which have not been examined for either guillemots or eagles, making it difficult to predict possible effects. Since eagle populations are thriving in the Aleutians, it suggests they are not adversely affected by contaminants, but the populations of guillemots are not as well documented.

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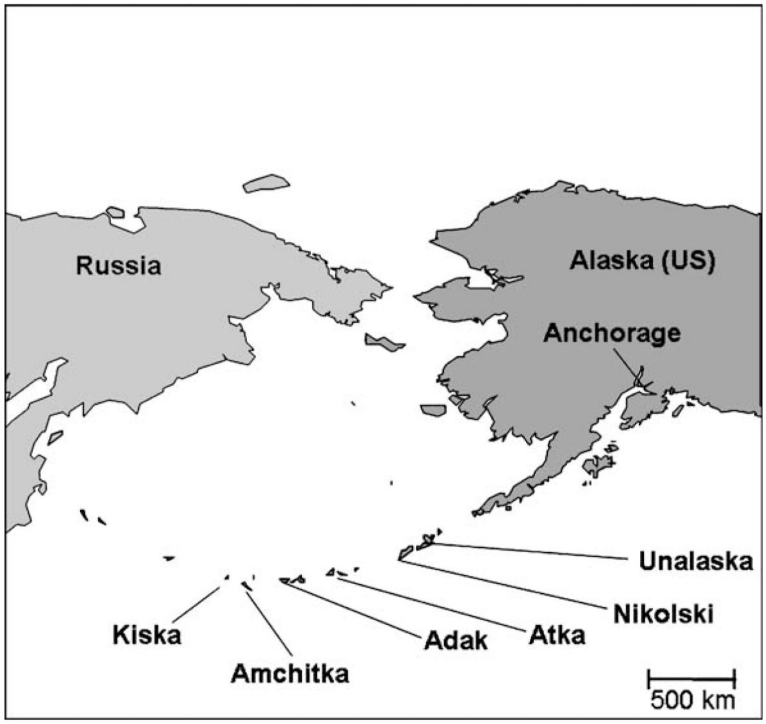

Fig. 1.
Collection locations for feathers from the Aleutian Islands of Alaska collected in 2004

Table 1

Metal levels (ppb, ng/g dry weight) of feathers of adult birds collected from Adak, Amchitka, and Kiska in the Aleutian Islands, Alaska

Common name	**Common eider**	**Tufted puffin**	**Pigeon guillemot**	**Glaucous-winged gull**	**Bald eagle**[a]	$X^2(p)$
n	26	39	38	63	23	
Feather type	Breast	Breast	Breast	Breast	Wing	
Arsenic	138± 18.0	136±25.6	157±25.8	144±26.7	547±75.8	38.7 (<0.0001)
	107	15.0	44.5	15.7	425	
	(B)	(C)	(B,C)	(C)	(A)	
Cadmium	79.8±3.96	80.3±12.9	31.0±6.02	77.3±12.1	253±39.6	58.0 (<0.0001)
	77.0	49.1	5.14	50.5	127	
	(A)	(A)	(B)	(A)	(A)	
Chromium	172±49.9	1,820±230	1,670±402	829 ±190	2,170±193	91.5 (<0.0001)
	34.6	1,450	912	383	2,000	
	(D)	(A,B)	(B)	(C)	(A)	
Lead	993 ±132	1,260±339	1,280±274	855±133	4570±799	42.3 (<0.0001)
	828	104	785	444	3,350	
	(B)	(C)	(B)	(B)	(A)	
Manganese	1,870±267	622±58.1	1,060±90	1,430±255	34,300±5,550	80.7 (<0.0001)
	1,460	531	919	766	27,200	
	(B)	(D)	(B,C)	(C,D)	(A)	
Mercury	840±81.5	2,540±195	7110±657	3,680±374	4,910±772	69.5 (<0.0001)
	715	2,120	5,860	2,370	3,940	
	(C)	(B)	(A)	(B)	(A)	
Selenium	878±88.3	6,600±344	3,350±259	996±53.5	2,550±268	139 (<0.0001)
	731	6,110	2,990	848	2,320	
	(C)	(A)	(B)	(C)	(B)	

Given are arithmetic means±SE (geometric means below) with Duncan values in parenthesis

[a]Only Eagle were wing feathers

Table 2

Metal levels (ppb, dry weight)(ng/g) in wing feathers of bald eagles collected from the Aleutian Islands, Alaska

Wing feathers	**Age**			***X*** ^{2}**(*p*)**
	Chick	**Juvenile**	**Adult**	
	***n*=2**	***n*=6**	***n*= 17**	
Arsenic	388±112	604±124	527±94.4	0.96 (NS)
	371	546	389	
	(A)	(A)	(A)	
Cadmium	36.6±3.38	187±78.7	277±45.8	4.70 (0.09)
	36.5	108	135	
	(A)	(A)	(A)	
Chromium	1,620±552	2,500±437	2,060±211	1.01 (NS)
	1,520	2,300	1,910	
	(A)	(A)	(A)	
Lead	795±202	3,600±1,214	4,920±998	4.33 (NS)
	769	2,780	3,570	
	(B)	(A)	(A)	
Manganese	5,470±903	32,300±6,880	35,000±7,202	5.4 (0.07)
	5,400	28,500	26,700	
	(B)	(A)	(A)	
Mercury	5,070±748	4,320±1,410	5,110±938	0.59 (NS)
	5,020	3,230	4,220	
	(A)	(A)	(A)	
Selenium	2,020±117	2,420±315	2,590±350	0.13 (NS)
	2,010	2,330	2,320	
	(A)	(A)	(A)	

Given are arithmetic means±SE (geometric means below) with Kruskal–Wallis chi square values and *p* values. Duncan values are given in parenthesis; different letters denote significant differences

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Table 3

Comparison of metal levels between breast and wing feathers

	Breast	**Wing**	$X^2(p)$
Arsenic	370±57.6	380±64.6	0.1 (NS)
	345	334	
Cadmium	55.5±9.04	42.2±6.24	0.3 (NS)
	52.6	35.6	
Chromium	3,200±1,050	1,520± 195	1.0 (NS)
	2,430	1,440	
Lead	1,520±391	788±76.4	3.8 (0.05)
	1,310	745	
Manganese	19,900±7,080	7,190±1,250	1.5 (NS)
	13,800	6,280	
Mercury	7,050±2,140	6,180 ±870	0.5 (NS)
	5,620	5,820	
Selenium	1,970±235	2,280±212	2.0 (NS)
	1,910	2,220	

Breast and wing feathers were taken from two chicks and one adult. Feather were analyzed in triplicate. Given are arithmetic means±SE (geometric means below) with Kruskal–Wallis chisquare values and *p* values

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Table 4

Metal levels (ppb, dry weight) (ng/g) in feathers of adult and juvenile bald eagles collected from the Aleutian Islands, Alaska

Wing feathers	Adak	Amchitka	$X^2(p)$
	***n*=18**	***n*=5**	
Arsenic	569±86.2	467±173	0.40 (NS)
	460	320	
Cadmium	239±36.6	307±135	0.01 (NS)
	183	34.6	
Chromium	2,300±234	1,710±169	1.52 (NS)
	2,110	1,670	
Lead	5,230±955	2,200±632	3.91 (0.05)
	3,974	1,810	
Manganese	32,900±4,710	39,200±20,800	0.50 (NS)
	28,200	23,700	
Mercury	4,080±553	7,900±2,740	2.22 (NS)
	3,470	6,200	
Selenium	2,470±329	2,840±371	2.72 (0.09)
	2,210	2,750	

Given are arithmetic means±SE (geometric means below) with Kruskal–Wallis chi square values and *p* values. Duncan values are given in parenthesis