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HEAVY METAL AND SELENIUM LEVELS IN FEATHERS OF FRANKLIN'S GULLS IN INTERIOR NORTH AMERICA

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ABSTRACT.—Although there are abundant data on heavy metals from coastal and oceanic seabirds, there is little for interior-nesting species. Heavy-metal and selenium levels in breast feathers of adult and fledgling Franklin's Gulls (*Larus pipixcan*) were examined in northwestern Minnesota, eastern South Dakota, eastern North Dakota, and central Montana in 1994. Metal levels in the feathers of Franklin's Gulls were within the range reported for other species. However, cadmium levels were at the high end and selenium levels at the low end. There were locational differences in metal levels for all metals for both adults and young. Using the levels in feathers of young as indicative of local exposure: (1) Lake Alice and Sand Lake had the lowest levels of lead and chromium, and the highest levels of mercury; (2) Agassiz and Benton had the lowest levels of manganese; and (3) Benton had the highest levels of selenium, lead, and chromium. There were age-related differences in metal levels for 19 of 24 possible comparisons. Adults had significantly higher levels of metals, except for selenium. Young birds had significantly higher levels of selenium than did adults. *Received 3 February 1995, accepted 25 April 1995.*

THE RECOGNITION of the occurrence, importance, and effects of contaminants on food chains and ecosystems has led to the development of monitoring schemes aimed at directly measuring the levels of contaminants in various organisms, and biomonitoring schemes that use indicator species to estimate the levels in other parts of the ecosystem (Messer et al. 1991, O'Connor and Ehler 1991). In the Great Lakes, terns and gulls have been used for many years to monitor toxic chemicals, and these species have suffered extensive reproductive losses (Fox et al. 1991). Considerable attention has been devoted to determining the levels and effects of chemicals on organisms, populations, and communities. Often it is not feasible or desirable to collect whole animals; thus, nondestructive methods of assessing chemical levels are required. The use of feathers as indicators of heavy metal exposure in birds was developed to fill this need (Furness et al. 1986, Walsh 1990, Burger 1994).

Heavy metals and selenium are derived primarily from the underlying soil and bedrock as well as from agricultural runoff, industrial effluent, storm-water runoff, volcanism, natural erosion, and biogeochemical cycles (Mailman 1980). Because many of the sources of heavy metal contamination are from industrialization and urbanization (Fowler 1990), one might expect that levels in biota would be lower in rural areas that are away from such sources. In this paper, I examine heavy-metal and selenium levels in the feathers of adult and juvenile Franklin's Gulls (*Larus pipixcan*) from breeding colonies in northwestern Minnesota, eastern South Dakota, eastern North Dakota, and central Montana. These colonies were selected because they are the largest known breeding colonies, and span the major breeding range in the United States (Burger and Gochfeld 1994). All four are in agricultural areas far from large cities. There are no published data on heavy metals in Franklin's Gulls or from birds that nest in interior prairie marshes.

Franklin's Gulls breed in small to large colonies in the interior of North America, and always build their nests over water (Bent 1921, AOU 1983). During the breeding season, adults normally stay within 30 km of the colony when searching for food, and a large portion of their diet comes from the marshes where they breed (Burger 1974). For up to 10 weeks after dispersal from the colony, both adults and young remain within 150 km of the colony in agricultural areas (Burger 1974). They then migrate through Texas and Mexico to the western coast of South America, south of the equator (AOU 1983).

Because Franklin's Gulls breed in inland freshwater lakes far from densely-populated urban and industrial centers, and spend the winter off the coast of Peru and Chile, I expected the levels of heavy metals in both fledglings and adults to be lower than levels in coastal-nesting seabirds or in other species living in urban areas. Since adults of the whole North American population migrate to the same general areas of South America, I expected levels in adults to be similar among breeding study sites. I also predicted that young would have lower levels than adults because adults have had longer to bioaccumulate heavy metals within internal tissues, and can then sequester them in feathers during molt (Burger 1994). Although adults can excrete metals in feathers, some remain in the internal body tissues from year to year.

Feathers are useful for measuring heavy metal levels in birds because: (1) birds deposit heavy metals in feathers during their formation (Furness et al. 1986, Braune and Gaskin 1987, Lewis and Furness 1991, Burger 1994); (2) metals are deposited during the short period of feather growth when the blood supply to the feather is intact (thus, levels in feathers are a record of circulating blood levels at the time of feather formation); (3) feathers are easy to collect from either live or dead specimens; (4) feathers can be collected from live birds without undue damage (they usually regrow in two to four weeks; Burger et al. 1992); (5) collection is noninvasive and can be easily performed by field assistants; and (6) feathers can be stored in metal-free containers, do not require refrigeration, and metal profiles in feathers are not easily disrupted by storage at room temperatures given that the feathers are maintained in such a way that they are not exposed to external contamination (Walsh 1990, Burger 1994). Moreover, the ratio of metal levels in feathers to other tissues is fairly consistent for most metals (Burger 1994).

METHODS

In 1994 under appropriate federal (PRT 67409) and state permits (Minnesota no. 6886, Montana no. 1383, South Dakota no. 48, North Dakota), I collected breast feathers from adult and fledgling Franklin's Gulls nesting at: Agassiz National Wildlife Refuge, Middle River, Minnesota (40,000 breeding pairs); Sand Lake National Wildlife Refuge, Columbia, South Dakota (55,000); Lake Alice at Devil's Lake National Wildlife Refuge, North Dakota (65,000); and Benton National Wildlife Refuge, Great Falls, Montana (16,000). These are among the largest breeding colonies of Franklin's Gulls. Adults were trapped at the nest using wire traps, and young were captured just before they were able to fly. All birds were banded and released immediately following handling. Feathers were collected from 15 to 19 young at each site, as well as the following number of adults: 6 at Benton Lake; 15 at Sand Lake and Lake Alive; and 64 at Agassiz. All feathers were stored separately at room temperature for later analysis.

Preparation, extraction, and analytical methods were modified from U.S. Environmental Protection Agency (1981) procedures. Feathers were washed vigorously in deionized water alternated with acetone to remove loosely adherent external contamination. Feathers were digested in warm nitric acid with the addition of hydrogen peroxide and subsequently were diluted in deionized water.

Mercury was analyzed by cold-vapor technique, while the other metals were analyzed by graphite-furnace atomic absorption. All concentrations are expressed in parts per billion ($ng \cdot g^{-1}$) on a dry mass basis using masses obtained from air-dried specimens. Detection limits ranged from 0.3 to about 10 parts per billion (ppb). All specimens were run in batches that included a standard calibration curve and spiked specimens. The recoveries ranged from 90 to 103%, and batches with recoveries less than 85% were rerun. The CV on replicate, spiked samples ranged from 3 to 5%. Further quality control included periodic blind analysis of an aliquot from a large sample of known concentrations, and blind runs of duplicate samples.

I used SAS nonparametric procedures on log transformed data to analyze levels among locations and age groups, Wilcoxon tests and Kendall tau correlation coefficients to compare metals within age groups (SAS Institute 1985), and Duncan multiple range tests to determine differences among sites. Both arithmetic and geometric means are given to facilitate comparisons with the literature. The results and discussion focus on the geometric means as most representative of levels.

RESULTS

Metal levels of adults and fledglings varied among study sites for all metals (Table 1). However, the patterns in geometric means were not consistent, suggesting spatial differences in bioavailability. Lead levels in adults were significantly lower at Sand Lake than in the other sites. Mercury in adults was lowest at Agassiz, chromium in adults was highest at Agassiz, cadmium levels in adults were lowest at Lake Alice and Sand Lake, selenium levels in adults were highest at Benton, and manganese levels were highest at Benton and Sand Lake. For feathers of young: Lake Alice and Sand Lake had the lowest levels of lead and chromium and the highest levels of mercury; Agassiz and Benton had the lowest levels of manganese; and Benton

TABLE 1. Metal levels (ng·g^{-1} dry mass) in feathers of Franklin's Gulls. Shown are geometric mean with $\bar{x}$ ± SE in parentheses. Means followed by same letter have metal values that do not differ significantly within a given age (ns, $P > 0.1$; Duncan multiple range test).

	Agassiz	Lake Alice	Sand Lake	Benton	Wilcoxon X^2 (P)
			Cadmium		
Adult	360^{A} (537 ± 79)	230^{B} (356 ± 203)	135^{B} (142 ± 24)	270^{A} (851 ± 558)	12.3 (<0.007)
Young	130^{A} (525 ± 356)	210^{B} (293 ± 92)	90^{A} (311 ± 164)	150^{A} (493 ± 307)	7.7 (<0.05)
X^2 (P)	16.5 (<0.001)	ns	ns	3.4 (<0.06)	
			Chromium		
Adult	1,150^{A} (1,554 ± 109)	590^{B} (615 ± 74)	343^{B} (490 ± 243)	625^{B} (708 ± 85)	17.0 (<0.007)
Young	450^{B} (594 ± 99)	280^{C} (861 ± 207)	20^{C} (146 ± 44)	660^{A} (735 ± 79)	20.6 (<0.001)
X^2 (P)	12.2 (<0.001)	15.5 (<0.001)	4.1 (<0.04)	ns	
			Lead		
Adult	1,430^{A} (2,865 ± 672)	1,980^{A} (3,067 ± 1,501)	750^{B} (891 ± 338)	2,100^{A} (3,273 ± 1,126)	7.0 (<0.07)
Young	440^{B} (630 ± 135)	253^{C} (735 ± 331)	170^{C} (676 ± 488)	805^{A} (836 ± 52)	14.6 (<0.002)
X^2 (P)	14.7 (<0.001)	10.5 (<0.005)	4.6 (<0.03)	16.2 (<0.001)	
			Manganese		
Adult	3,620^{A} (3,860 ± 166)	8,300^{B} (8,442 ± 732)	21,400^{A} (24,055 ± 5,995)	18,600^{A} (20,438 ± 2,219)	56.5 (<0.001)
Young	3,070^{C} (3,380 ± 388)	5,970^{B} (7,027 ± 1,318)	12,400^{A} (13,904 ± 1,724)	3,800^{C} (4,029 ± 56)	35.4 (<0.001)
X^2 (P)	3.2 (<0.07)	5.0 (<0.08)	3.2 (<0.07)	25.5 (<0.001)	
			Mercury		
Adult	530^{B} (660 ± 56)	1,070^{A} (1,442 ± 506)	1,090^{A} (1, 363 ± 510)	910^{A} (962 ± 84)	13.4 (<0.003)
Young	80^{C} (223 ± 83)	1,540^{A} (1,569 ± 79)	1,720^{A} (1,933 ± 220)	390^{B} (473 ± 74)	44.3 (<0.001)
X^2 (P)	17.6 (<0.001)	ns	ns	14.9 (0.001)	
			Selenium		
Adult	520^{B} (847 ± 77)	630^{B} (929 ± 335)	1,130^{B} (1,151 ± 138)	1,300^{A} (1,384 ± 123)	13.3 (<0.004)
Young	870^{C} (884 ± 44)	1,310^{B} (1,443 ± 163)	1,610^{B} (1,643 ± 81)	3,800^{A} (3,963 ± 322)	48.7 (<0.001)
X^2 (P)	ns	8.7 (<0.01)	5.3 (<0.02)	25.5 (<0.001)	

Lake had the highest levels of selenium, lead and chromium.

There were significant age differences for many of the comparisons (Table 1). In all cases where there were significant differences, except selenium, adults had significantly higher levels than young. For selenium, young had significantly higher levels than adults, except at Agassiz where there was no difference. There were no age-related differences in cadmium and mercury at Lake Alice and Sand Lake, the two freshwater nesting lakes that were dry for several years during the drought of the late 1980s and early 1990s.

I examined correlations among metals for the adults at Agassiz ($n = 64$). There were significant positive correlations between: lead and cadmium ($r = 0.39$, $P < 0.001$); and mercury and chromium ($r = 0.26$, $P < 0.002$). That for lead and selenium ($r = 0.18$, $P < 0.06$) almost reached significance. There were significant negative correlations between: mercury and selenium ($r = -0.30$, $P < 0.001$); and selenium and chromium ($r = -0.36$, $P < 0.001$).

DISCUSSION

Methodological considerations.—Franklin's Gulls obtain heavy metals primarily from their food. They feed on earthworms and insects in agricultural fields during the breeding season, and small fish and invertebrates in the coastal waters off Peru and Chile during the winter (Burger and Gochfeld 1994). The levels of metals in feathers are derived from circulating-blood levels during the period when feathers are formed. At the time feathers are forming, toxics can be delivered to the growing feather, and those with an affinity for the sulfhydryl groups of the keratin protein are likely to be sequestered in the feather (Burger 1993, 1994). The circulating-blood levels reflect inputs such as ingestion, inhalation, and mobilization from tissue stores, and outputs such as excretion and deposition in feathers and eggs (Evans and Moon 1981, Walsh 1990, Burger 1994). Thus, understanding metal levels in feathers requires knowledge of the molt cycle and where the bird was when it molted. Such information is more readily discernable for young than for adults.

The feathers of Franklin's Gull adults collected on the breeding ground were grown on the wintering ground; those of the fledglings were grown entirely on the breeding ground. Whereas the levels in the feathers of adults could represent both current exposure at the time of feather formation and mobilization from internal tissues (derived from past exposure), the levels in feathers of fledglings represent local exposure, since the chicks are fed exclusively on foods derived within 40 km of the breeding colonies (Burger 1972, 1974). Thus, metal levels in the feathers of young are a good indicator of local exposure. Although the chicks acquire some heavy metals from the egg, this is small given the growth rate of the chicks before feather formation. Nonetheless, the limits to interpreting metal levels in feathers must be borne in mind in the following discussion.

Metal levels.—Overall, the metal levels in the feathers of Franklin's Gulls were within the range reported for feathers from other birds, including gulls and terns (Table 2). Cadmium levels, although within the range reported from feathers of other birds, averaged over four times higher than the median levels for other birds (Table 2; Burger 1994). Feathers from Herring Gulls (*Larus argentatus*) from the Great Lakes averaged less than 100 ppb (Struger et al. 1983). Cadmium levels in adult Franklin's Gulls were higher at Agassiz compared to the other sites, although the mean levels at all four sites were higher than the median, for all birds, as well as for gulls and terns (Table 2). Cadmium comes from erosion of surface deposits of cadmium-containing minerals and from anthropogenic sources, including purification of ores from smelters and mines, as well as commercial products such as batteries, paints, coatings on metal devices, and plastic stabilizers (Parmeggiani 1983). Franklin's Gulls are eating primarily earthworms and insects gathered from the surrounding farmland (Burger 1974), suggesting that either the earthworms are living in cadmium-rich soils or are exposed to air-borne cadmium contamination from smelters.

There are few reports in the literature of chromium and manganese levels in the feathers of birds. Like other metals, chromium can come from natural sources, but most chromium in biota comes from anthropogenic activities involved with mining, refining, and subsequent use of chromium (electroplating equipment and alloying; Parmeggiani 1983). Thus, chromium levels might be expected to be higher in industrial areas, but this has not been adequately tested. The levels of chromium in feathers of Franklin's Gulls were similar to those reported

TABLE 2. Comparison of metal levels (ppb, dry mass) in feathers as reported in literature for all species, as well as for gulls and terns (after Burger 1994). Overall arithmetic means for Franklin's Gulls from this study included for comparison.

	Cadmium	Chromium	Lead	Manganese	Mercury	Selenium
			All birds species			
No. studies[a]	63	17	69	19	180	42
Low	0	0	0	0	0	300
High	24,000	17,900	32,700	119,900	172,000	54,000
Median	100	8,100	1,600	3,400	2,100	2,200
			Gulls and terns			
No. studies	26	1	31	1[b]	19	11
Low	30	—	100	—	450	1,200
High	425	—	4,300	—	14,900	18,700
Median	80	550	1,300	1,500	1,900	3,900
			Franklin's Gull ($\bar{x}$ ± SE)			
All adults	568 ± 118	1,287 ± 90	2,868 ± 524	8,108 ± 903	795 ± 62	965 ± 66
All young	413 ± 131	591 ± 67	961 ± 226	6,827 ± 723	1,022 ± 109	2,040 ± 180
Ratio (adult/young)	1.4	2.2	2.9	1.2	0.8	0.5

[a] Studies or locations.

[b] From Great Lakes.

for feathers of Herring Gulls on the Great Lakes (Struger et al. 1983) and for Herring Gulls from Long Island (Burger 1995).

Lead levels in feathers of Franklin's Gulls averaged 961 ppb (young) and 2,868 ppb (adults) compared to 870 to 4,610 ppb for Herring Gulls from the Great Lakes (Struger et al. 1983), and 1,818 to 2,101 ppb for Herring Gull fledglings from Long Island (Burger and Gochfeld 1993). This is somewhat surprising since one primary source of lead is residue from leaded gasoline, and all four breeding colonies of Franklin's Gulls occur in relatively pristine areas of inland North America, where human population density is relatively low, and there are fewer cars than on the East Coast or around the Great Lakes. Both the East Coast and Great Lakes are highly industrialized, and local pollution should add to the body burden of young.

Levels of manganese, another essential element, in feathers of Herring Gulls in the Great Lakes ($\bar{x} \approx$ 1,500 ppb; Struger et al. 1983) were lower than those reported for Herring Gulls on Long Island ($\bar{x} \approx$ 2,300 to 5,300 ppb; Burger 1995). Both were slightly lower than those I report for Franklin's Gulls (means of 6,827–8,108 ppb). Thus, limited data from the literature suggest that Franklin's Gulls are at the high end of the normal values. Since manganese is an essential element, it might be partially regulated within the body. The differences among locations for Franklin's Gulls may indicate differences in bedrock levels, since it is mined in South Dakota, where it was highest in the gull feathers.

Mercury comes from erosion from soils and underlying bedrock, and from anthropogenic sources such as: soils contaminated by agricultural mercurials (fungicides on seeds); industrial emissions from plants that use or manufacture mercurial compounds; hazardous-waste sites; incinerators; and cold-fired power plants (Parmeggiani 1983). Thus, it is not surprising that mercury levels of Franklin's Gulls are at the low end of the range reported for other birds and for gulls and terns (Table 2).

Selenium is an essential dietary component and occurs naturally in soils. It also can come from: rectifiers that convert alternating current into direct current; colorizing or decolorizing glass; alloying with stainless steel and copper; and insecticides (Parmeggiani 1983). None of these anthropogenic sources are known to provide a problem to wildlife. Selenium has been of interest because of the high levels found in plants and animals in the San Joaquin Valley of California, with subsequent adverse effects on birds (Hoffman et al. 1988, Ohlendorf et al. 1989). In the San Joaguin Valley the key problem was the reuse of agricultural drain water. Selenium levels in Franklin's Gulls were within the range reported for other birds (Table 2). However, they were lower than the median reported for other gulls and terns. This indicates that Franklin's Gull adults, on average, are exposed to lower selenium levels than many other birds, perhaps because of their relative inland isolation during the breeding season, and presence on South American wintering grounds where they may be away from industrial sources (Burger and Gochfeld 1994). Selenium levels, however, were highest in both adults and young at Benton Lake, reflecting the elevated concentrations of selenium in water, sediment, and biota from there (Lambing et al. 1994).

Differences among sites.—There were some differences in metal levels in the feathers of Franklin's Gulls among the four sites, in both adults and young. This was remarkable since the wintering population of Franklin's Gulls is presumed to be in one general area (Burger and Gochfeld 1994), predicting that levels in the feathers of adults should be similar since feathers collected in May were grown on the wintering grounds. Adults winter in Peru and Chile, where the mountains are volcanic, and the soils are desertic and rich in selenium. Adults often concentrate near bays and river mouths (Burger and Gochfeld 1994), resulting in differences due to watershed and anthropogenic activities. However, metal levels for cadmium, lead, and mercury also reflect long-term exposure because these metals have long biological half-life.

There was no clear pattern among sites for adults. Lead was significantly lower at Sand Lake, cadmium was lowest at Sand Lake and Lake Alice, mercury was lowest at Agassiz, selenium was highest at Benton, chromium was highest at Agassiz, and manganese was much higher at Sand Lake and Benton Lake compared to the other sites.

These differences in metal levels in the feathers of Franklin's Gulls suggest that adults from the different breeding colonies are not feeding on the same foods during the winter when these feathers are formed, they are not feeding in the same areas off Peru and Chile, they are mobilizing different levels from internal tissues (derived from exposure on the breeding grounds), or a combination of these. Since the patterns are similar for some metals, the differences may reflect differences in mobilization of the metals from internal tissues.

To use Franklin's Gulls as indicators of exposure on the breeding grounds, the metal levels in fledglings should be examined. Levels in feathers of young reflect local exposure, since all of their food is collected by parents from within 50 km of the breeding colony (Burger and Gochfeld 1994). Differences in the levels in the food reflect underlying bedrock levels, including their origin and history.

As with adults, metal levels in young were different at different sites. There were a few patterns: (1) Lake Alice and Sand Lake had the lowest levels of lead and chromium, and the highest levels of mercury; (2) Agassiz and Lake Alice had the lowest levels of manganese; and (3) selenium, lead, and chromium levels were highest at Benton compared to the other sites. For both adults and young, selenium levels were significantly higher at Benton Lake compared to all other sites.

Although all four sites were shallow-water marshes surrounded by agricultural lands, there were differences. Sand Lake and Lake Alice are more vulnerable to drought conditions, and both were dry during the late 1980s and early 1990s. Second, the farmlands around both Sand Lake and Lake Alice are more fertile than the other two sites, and normally have higher production of higher cash-value crops; this might result in more use of pesticides that eventually reach lakes through run-off.

Flooding of previously dry land results in more mobilization of mercury from the soil than occurs normally at the bottom of lakes (Zillioux et al. 1993, Hudson et al. 1994), and this may account for some of the differences in mercury levels. Both Sand Lake and Lake Alice, with the highest mercury levels in the feathers of young, were very dry in the late 1980s and reflooded recently, allowing for resuspension and mobilization of mercury from lake bottom sediments. In contrast, Agassiz and Benton did not dry down. Moreover, mercury bioconcentrates at higher rates as pH decreases (Hudson et al. 1994). No data on pH are available, however.

Another potential difference may relate to the method of foraging. At Agassiz, parents feed their chicks primarily on earthworms gathered from the surrounding farmfields (Burger 1974). Insects and earthworms are often high in cadmium, lead, mercury and selenium (Nehring 1976, Beyer and Cromartie 1985). However, there were fewer fields immediately surrounding either Lake Alice or Sand Lake that were being plowed during the period when gulls had chicks. At these two locations, the parents may rely primarily on food resources (e.g. insects) obtained directly from the marshes, rather than from the surrounding fields.

Differences in atmospheric deposition or runoff also could account for the differences, since local and regional sources can alter deposition rates (Mierle 1990, Aastrup et al. 1991, Swain et al. 1991, Zillioux et al. 1993). However, since Agassiz, Lake Alice, and Sand Lake are all close together, deposition among these sites should be similar. Benton Lake, however, could experience different deposition rates. Levels in the feathers of fledglings from Benton Lake differed from the other sites in that they had the highest levels of selenium, lead, and chromium. Adult feathers from Benton Lake also had the highest levels of selenium, compared to the other sites. Since Benton Lake is just east of the rockies, increased rain levels may deposit high levels of air-borne contaminants, although underlying bedrocks and local anthropogenic sources are more significant.

Age differences.—In a review of metal levels in feathers, I (Burger 1994) reported that there were significant differences in feather levels between adults and young for mercury (20 of 21 studies), lead (4 of 7 studies), cadmium (3 of 5 studies), manganese (5 of 5 studies), and selenium (3 of 3 studies). Only one of four studies with chromium showed an age-related differences. Thus, it is the usual case to find that levels of metals are higher in the feathers of adults than fledglings.

Levels in adult feathers might be expected to be higher than those of fledglings because the adults have had several years to bioaccumulate metals in their internal tissues, and these can be mobilized into the blood and deposited in feathers during their formation (Burger 1994). Differences in metal levels in adults and fledglings might also occur if adults and young eat different foods during the breeding season, or different-sized food items (Burger 1993). However, Franklin's Gull adults and young both eat primarily worms and insects during the breeding season, and both eat whole organisms. Thus, exposure during the breeding season should be similar at a given site.

Age differences in metal levels in the feathers of Franklin's Gull, therefore, should reflect difference in the location of exposure. Fledgling feathers represent levels acquired almost entirely on the breeding grounds, while adult feathers collected on the breeding ground were grown on the wintering grounds and reflect levels obtained there, as well as long-term accumulation.

For most comparisons where there was age differences, adults had significantly higher levels of heavy metals than young. For selenium, young had significantly higher levels than adults at three of the four sites. Overall, for Franklin's Gulls, lead (adults had 2.9× that of young) and chromium (2.2×) showed the greatest differences between adults and young (Table 2). These age-related differences suggest that adults are either bioaccumulating heavy metals that are sequestered in feathers, they are exposed to higher levels of heavy metals on the wintering grounds than the young are exposed to on the breeding grounds, or both. These age-related differences in metal levels are consistent with the literature (Burger 1994).

However, the finding that young gulls had higher levels of selenium than adults at all sites (although the difference was not significant at Agassiz) is unusual, since the five other studies that have examined selenium levels in feathers have reported that adults had significantly higher levels than young (Burger 1994). This clearly indicates that young are exposed to higher levels of selenium on the breeding grounds than are the adults on the wintering grounds. The levels of selenium in the feathers of fledglings are not high compared to other birds (Table 2); they are simply high compared to adult Franklin's Gulls.

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