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Heavy Metal Concentrations in Great Blue Heron Fecal Castings in Washington State: A Technique for Monitoring Regional and Global Trends in Environmental Contaminants

R. E. Fitzner,[1] R. H. Gray,[1] W. T. Hinds[2]

[1]Battelle, Pacific Northwest Laboratory, P.O. Box 999, Richland, Washington 99352, USA
[2]U.S. Department of Energy, Washington, DC 20585, USA

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Growing concern over the health of the world's environment necessitates development of methods to monitor environmental changes over time. Various proposals involving "literally" thousands of useful ecological indicators (Cairns and McCormick 1992) have been published over the past two or three decades. Hinds (1984) and Cairns and McCormick (1992) discuss several aspects of such proposals, including the theoretical foundations for the use of indicators in ecosystem-based monitoring.

Sampling of animals often requires a choice between killing individuals in the field to allow measurement, or using an indirect or correlation-based non-destructive sampling technique. The latter is preferred usually for long-term monitoring programs. Sampling of feathers to determine metal concentrations in tropical Pacific Rim birds, including herons, was reported by Burger (1993), Burger and Gochfeld (1991, 1993), and Burger et al. (1992, 1993). While collection of feathers did not harm the birds, the feathers still had to be plucked from the birds. We report a method that does not involve disturbing the birds.

Great blue herons (*Ardea herodius*) feed at the top of a diverse but reasonably well understood food web. The birds are colonial during their reproductive season, and gather into identifiable, replicable, and annually repeated groups, using the same nests (usually in trees) for years at a time. Herons maintain nests free of regurgitated prey parts and nestling fecal materials by discarding detritus and fecal sacs over the nest edge. This behavior produces a "rain" of fecal matter including identifiable discarded or undigested items (e.g., bones) that reflect the food on which herons prey. Collecting this material provides a quantifiable estimate of contaminants in the food web (Fitzner et al. 1982) and makes the heron a prime sampling target (Fitzner et al. 1982; Carlile and Fitzner 1983; Hinds 1983).

We discuss here the results of a two-year study designed to determine the relationship between heavy metal residues in heron fecal castings and those in heron tissues from the same colonies. We also evaluated whether analysis of heron excrement was a reliable indication of heavy metals in the environment.

Correspondence to: R. H. Gray

MATERIALS and METHODS

Five heron colonies in eastern Washington were studied in 1982 and 1983. Two colonies were located at the Potholes Reservoir near Moses Lake. These colonies were within 5 km of each other. Another colony was located at Sylvan Lake in Douglas County. These colonies occurred in a sparsely populated region near agricultural and range lands and were isolated from any industrial development. Another colony was located on the U.S. Department of Energy (DOE) Hanford Site and another was on Foundation Island near Burbank. Both colonies were along the shoreline of the Columbia River. The Hanford colony was situated downwind from the Hanford Site. Foundation Island was near a paper pulp mill operated by the Boise Cascade Company. In 1983, seven additional heron colonies were studied in western Washington. Two colonies, Dumas Bay and Auburn were located near Tacoma close to industrial developments and a major interstate highway, I-5. A colony at Samish Island was located near a major oil refinery. Colonies at Oyster Bay and Fort Lewis were located near Olympia and urban environments and major interstate highways, although they were not near industrial complexes. Colonies at Indian Island and Deception Pass were located in northern Puget Sound and were not directly associated with industries, urbanization or major highways.

Fecal castings from heron nests were collected during the nestling period (May-July). Excrement falling from nests was caught in five-liter polyethylene buckets. Twenty buckets were placed under active nests (treatments) and twenty buckets were placed several hundred meters away to quantify contamination contributed from precipitation and other airborne deposition and foliar drip (controls). Each bucket was first chemically sterilized in sequence with dilute nitric and sulfuric acid and distilled water to remove any heavy metal residues. Five pieces of Whatman 42 ashless filter paper (7.0 cm) were placed in the bottom of each bucket to absorb excrement. The filter papers were later collected, air dried and ground into fine powder that was analyzed (Am Test Inc., Seattle, Washington) for lead (Pb), cadmium (Cd), mercury, chromium (Cr), and cobalt (Co). Dried samples were digested by wet ashing with nitric and perchloric acids. The resulting solution was diluted to 100 ml and analyzed by graphite furnace atomic absorption spectroscopy. Lower limits of detection were 0.01 μg/gm for all metals. Recovery ranged from 88-104% for spiked material; residues were not corrected based on these values. Blank samples of filter paper were analyzed for metal content; no measurable levels were detected.

RESULTS and DISCUSSION

Pacific Northwest heron populations were studied in landscapes that ranged from marine to mountainous to semi-arid. The objective was to estimate the birds' utility for monitoring contaminants and to determine if this wide-ranging species could quantitatively reflect regional variations in environmental contamination.

Pb, Cd, Cr, and Co were detected in all samples from eastern Washington in both years (Table 1). Highest Pb levels were found at Hanford (6.01 μg/g wet wt.) and Foundation Island (5.28 μg/g wet wt.) in 1983 (Table 1). The highest Cd level in eastern Washington was found at Hanford (0.53 μg/g wet wt.) in 1982 (Table 1). Foundation Island samples showed Cr and Co levels nearly two times that of other areas in 1983 (Table 1). Controls had residue levels generally below treatment values except for Cr

Table 1. Metal concentrations (μg/g wet wt.) in great blue heron fecal castings from eastern Washington.

Location	Year	Element[(a)] Cd	Cr	Co	Pb
Hanford					
T	1982	0.53±0.13	0.79±0.10	0.49±0.03	3.13±0.49
C		0.45±0.26(9)	0.46±0.26(7)	0.43±0.10(8)	1.16±0.29(9)
T	1983	0.25±0.04	1.53±0.35	0.45±0.12	6.01±0.85
C		0.06±0.01	0.76±0.07	0.13±0.01(7)	1.26±0.13
Potholes East					
T	1982	0.15±0.03	0.71±0.08	0.34±0.09	2.19±0.69
C		0.12±0.03	0.96±0.14	0.91±0.35	0.51±0.19(7)
T	1983	0.13±0.06	0.86±0.06	0.45±0.08	1.12±0.13
C		0.05(1)	0.61±0.03	0.16±0.01	0.72±0.03
Potholes West					
T	1982	0.12±0.02	0.77±0.15	0.38±0.06	2.19±0.69(9)
C		0.39±0.07	0.74±0.08	0.38±0.06	0.98±0.11
T	1983	0.08±0.01	0.85±0.12	0.25±0.02	0.37±0.04
C		0.08±0.01(4)	0.54±0.04	0.18±0.01	0.58±0.06
Sylvan Lake					
T	1982	0.10±0.01	1.03±0.22	0.83±0.15	1.08±0.52
C		0.19±0.06	0.47±0.03	0.52±0.09	1.15±0.15
T	1983	0.06(1)	1.04±0.03	0.27±0.03	0.70±0.11
C		0.05(1)	0.72±0.06	0.20±0.02	0.41±0.08(9)
Foundation Island					
T	1982	0.17±0.02(9)	1.62±0.38(8)	0.47±0.09(9)	2.60±0.85(9)
C		0.45±0.26	0.46±0.26	0.43±0.10	1.16±0.29
T	1983	0.34±0.07	3.34±0.41	1.67±0.29	5.28±1.83
C		0.13±0.03(4)	1.38±0.18	0.42±0.04(9)	1.76±0.45

(a) Number of positive samples = 10 unless otherwise noted in parentheses; data as geometric mean plus or minus standard error.

Legend: T = treatment, C = control.

and Co at the Potholes East colony, Cd and Co at Potholes West, Cd and Pb at Sylvan Lake, and Cd at Foundation Island (Table 1). These exceptions all occurred in 1992. The control values were over twice the treatment values indicating airborne deposition rather than foodchain transport.

Western Washington colonies (Table 2) had heavy metal concentrations above or similar to those at Hanford and Foundation Island (Table 1). Auburn and Dumas Bay samples had the highest Pb concentrations (10.45 and 8.53 μg/g wet wt., respectively). These two colonies, and Oyster Bay, also contained the highest Co values in western Washington. Cd and Cr levels were generally low and did not occur in any particular pattern in western Washington.

In eastern Washington, the Hanford Site and Foundation Island Colonies showed the highest Pb and Cd levels during both years (Table 1). Foundation Island had higher Cr levels than the other colonies. Foundation Island also had higher levels of all four metals in 1983 than in 1982. Foundation Island is within 4 km of a large pulp mill at Wallula.

Table 2. Metal concentrations (μg/g wet wt.) in Great Blue Heron fecal castings from western Washington

	Element[(a)]			
Location	Cd	Cr	Co	Pb
Auburn				
T	0.34±0.11	2.91±0.60	1.42±0.54	10.45±2.40
C	0.12±0.01(9)	1.26±0.09	0.19±0.01(6)	7.36±1.41
Fort Lewis				
T	0.22±0.04(6)	1.92±0.26	0.56±0.14(7)	5.98±0.60
C	0.18(1)	0.98±0.11	0.20±0.05	2.31±0.21
Dumas Bay				
T	0.24±0.03	4.25±1.14(9)	1.54±0.24	8.53±2.57(9)
C	0.16±0.06(6)	0.93±0.18	0.20±0.01	2.83±0.15
Oyster Bay				
T	0.36±0.11(6)	3.19±0.89	1.87±0.84	2.38±0.39
C	0.10±0.01	0.59±0.07	0.20±0.06	0.20±0.02
Indian Island				
T	0.18±0.03(9)	3.11±0.36	0.75±0.50(9)	5.15±1.41
C	0.07±0.01(3)	1.92±0.63	0.26±0.12(2)	2.40±0.43
Samish Island				
T	0.57±0.16(9)	2.61±0.36	0.68±0.09	4.12±0.71
C	0.12±0.01(6)	1.63±0.73	0.49±0.21(6)	2.45±0.53
Deception Pass				
T	0.20±0.06(9)	4.21±0.86	1.08±0.19(9)	2.82±0.46
C	0.09±0.03(2)	1.92±0.29	0.29±0.15(2)	2.06±0.58

(a) Number of positive samples = 10 unles otherwise noted in parentheses; data as geometric mean plus or minus standard error.

Legend: T = treatment, C = control.

Co, Cr, Cd, and Pb are associated with liquid effluents from this mill that are discharged to the Columbia River. Hanford and Foundation Island are situated along the banks of the Columbia River which receives discharges from several irrigation canals that return agricultural water to the river. Chemicals used in agriculture thus enter Columbia River water, fish and herons.

Co, Cr, and Cd levels were similar for 1982 and 1983 in Potholes West and Potholes East colonies (Table 1). The two colonies were near each other and birds from these colonies likely shared a common feeding area, Potholes Reservoir. Apparently there was little change in contaminant availability to herons during these years.

Heavy metal levels in fecal castings from twelve heron colonies from eastern and western Washington in 1983 show a distinct pattern (Tables 1 and 2). The Potholes East and West, and Sylvan Lake colonies generally had the lowest metal residues. This probably reflects the distances of these colonies from major industrial areas, and their sparse human populations. Western Washington has a far greater human population than eastern Washington. As human populations increase so do industries, auto emissions, sewage and other waste products. The pattern of increased heavy metal concentrations in heron fecal material in western Washington and at Hanford and Foundation Island colonies likely reflect the elevated human populations near these colonies and associated increased contaminant load to the environment. Fitzner et al. (1982) found the same distribution pattern for Pb and Cd in heron excrement from Hanford, Potholes and Auburn (Tacoma) colonies. There has been little change in the levels of Pb or Cd over the 5-year span since that study.

Blus et al. (1985) reported levels of Pb and Cd in hatchlings, advanced embryos and subadult great blue herons from two of the colonies (Hanford and Fort Lewis) we studied. One hatchling at Fort Lewis contained 0.22 μg/g (fresh wet wt.) Pb and 0.22 μg/g Cd in whole body tissues. Excrement we analyzed in 1983 contained 0.18 μg/g (wet wt.) Cd and 2.31 μg/g Pb (Table 2). The higher Pb we found in excrement may indicate that Pb is not actively assimilated in heron tissues and passes out in waste products. Neither Pb nor Cd were detected in subadult herons from Fort Lewis or Hanford (Blus et al. 1985), again indicating that these metals may not be incorporated or bioaccumulated in heron tissues. Some heavy metals may be excreted through chemical binding with metallothionein and thus not retained in the avian body (Viarengo 1985). The lack of metals in heron embryos and subadults may also be related to the age of birds. Adult birds accumulate Cd with age (Maedgen et al. 1982).

These data suggest that great blue heron colonies can serve as regional ecological monitoring tools. For example, sites in a common area, such as Potholes East and Potholes West, showed a close relationship in concentrations of heavy metals (see Table 1). Similarly, regional exposure to widespread urban and industrial development was associated with generally higher levels of the commonest of heavy metals, as seen by comparing lead levels in Tables 1 and 2.

Because foods eaten by adult herons and fed to nestlings come from areas near the colony, contaminants in heron excrement reflect local conditions and herons serve as indicators of environmental contamination. Collection and analysis of heron fecal castings is relatively inexpensive, does not kill the birds, and appears to be a sensitive indicator of heavy metals in the environment. Herons, used in this manner, allow comparison of pollution trends in widely separated areas. We suggest that a network of heron colonies could be used to monitor long-term trends in inorganic and perhaps organic contaminants and, thus, environmental quality on a national or global level.

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