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Reproduction, Mortality, and Heavy Metal Concentrations in Great Blue Herons from Three Colonies in Washington and Idaho

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Abstract.—We collected eggs in nests, hatchlings and eggs with advanced embryos on the ground, and prefledgling young of Great Blue Herons (*Ardea herodias*) at three nesting colonies in Washington and Idaho. Intact fish were also collected on the ground at the Idaho colony. The Ft. Lewis colony near Puget Sound in Washington and the Lake Chatcolet colony in northern Idaho were located near areas extensively polluted with heavy metals from mining or smelting activities. The Hanford Reservation colony near Richland, Washington was located some distance from point sources of heavy metal pollution. Heavy metals in heron samples were generally low and were all below concentrations known to induce mortality or adversely affect reproductive success. The elevated copper in one of three prefledglings from Ft. Lewis paralleled that found in an occasional nestling of several species of birds in other studies; the significance of this relationship is unclear. Breeding herons apparently fed near their colonies in areas removed from the sites of heaviest contamination, but birds in the Lake Chatcolet colony were preying on fish containing as much as 6 μg/g lead.

Key words: Great Blue Heron, *Ardea herodias*, heavy metal concentrations, lead, cadmium, copper, mercury, fish, Washington, Idaho.

The Great Blue Heron (*Ardea herodias*) is a wide-ranging species that is associated with a variety of habitats; therefore, it has been the subject of numerous studies related to the effects of pollutants including chlorinated hydrocarbons and heavy metals (Vermeer & Reynolds 1970, Dustman et al. 1972, Faber et al. 1972, Faber & Hickey 1973, Hoffman & Curnow 1973 and 1979, Fimreite 1974, King et al. 1978, Blus et al. 1980, Mitchell et al. 1981, Ohlendorf et al. 1981, Fitzner et al. 1982, La Porte 1982). The objectives of this paper are to report concentrations of heavy metals detected in tissues and eggs of Great Blue Herons from 3 colonies in Washington and Idaho and to interpret their impact on this species.

STUDY AREAS AND METHODS

Samples were collected from two areas in Washington and one area in Idaho in 1981 and 1982 (Fig. 1). The Ft. Lewis colony near Puget Sound in Washington and the Lake Chatcolet colony in northern Idaho were both located in the vicinity of areas with severe heavy metals pollution.

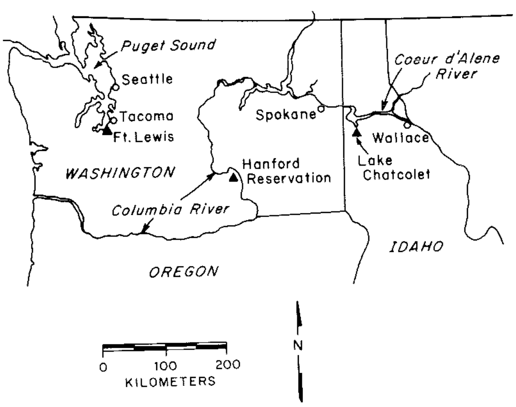

Fig. 1. Location of Great Blue Heron colonies in Idaho and Washington.

A large copper (Cu) smelter near Tacoma, Washington 25 km north of Ft. Lewis has been in operation since 1890; tremendous quantities of pollutants occur in smokestack emissions (metric tons per year) including Cu (460), lead (Pb, 2800), and zinc (Zn, 830). Lesser quantities of arsenic (As) and antimony (Sb) also occur in the emissions (Crecelius et al. 1975, Schell & Nevissi 1977). Just northeast of the Lake Chatcolet heronry, the North Idaho Mining District of the Silver Valley occupies a narrow intermountain area on the South Fork of the Coeur d'Alene River. This area has been the center of extensive heavy metals mining since 1885. As a result of pollution from mining and associated activities, the Coeur d'Alene River system was essentially devoid of aquatic life from Wallace, Idaho to its mouth more than 50 years ago (Ellis 1940). More recent studies indicate the persistence of serious problems from heavy metals contamination (Savage & Rabe 1973, Rabe & Bauer 1977). Until the last few years when mining and smelting activities were sharply curtailed, this area was one of the major producers of silver (Ag), Pb, and Zn in the world and significant amounts of gold (Au), Cu, cadmium (Cd), and Sb were also mined (Savage & Rabe 1973, Maxfield et al. 1974, Burrows et al. 1981). In the 1970s, the Silver Valley contained 14 active mines, an Sb plant, an electrolytic Zn plant, a sulfuric acid plant, a fertilizer plant, and a large Pb/Zn smelter (Burrows et al. 1981). In contrast, the Hanford Reservation near Richland, Washington has no known pollution problems from heavy metals and was selected as the "control" area for comparing concentrations of metals found in herons with those that might be associated with adverse effects in the two contaminated areas.

Samples included prefledglings that were shot with a rifle (Pb bullet); eggs taken from nests; and a nestling, hatchlings, eggs with large embryos, and fish found on the ground under nests. A sample egg was collected from each of 16 marked nest in the Ft. Lewis (3) and Hanford (13) colonies. The eggs were refrigerated until weighed, volumed, and measured; each egg was opened at the equator and its contents placed in a chemically cleaned jar.

Egg, tissue, and whole body samples were stored frozen until shipped to the Patuxent Wildlife Research Center, Laurel, Maryland, where they were analyzed for selected heavy metals. Samples for total Hg were prepared as described by Monk (1961) and determinations were made using the method of Hatch & Ott (1968). Determinations were made by the method of additions using a Perkin Elmer 403 atomic absorption spectrophotometer equipped with a Perkin Elmer MHS-20 hydride generator. Samples for other metals were prepared by the method described for As, Pb, Cu, Zn, Cd, and chromium (Cr) in Haseltine et al. (1981). Concentrations were determined by comparison with aqueous standards on a Perkin-Elmer model 5000 atomic absorption spectrophotometer. Recoveries ranged from 80 to 102% for spiked material; residues were not corrected on the basis of these values. The lower limits of reportable residues on a wet weight basis were 0.10 μg/g for Pb, Cu, Zn, nickel (Ni), Cd, magnesium (Mg), and cobalt (Co); 0.05 μg/g for Hg, As, Cr, and manganese (Mn); 1.0 μg/g for aluminum (Al); and 0.5 μg/g for molybdenum (Mo).

The fish were air dried at 50°C and shipped to Am Test, Inc., Seattle, Washington where the whole bodies were analyzed for concentrations of six heavy metals. The dried fish samples were digested by wet ashing using sulfuric acid followed by a mixture of nitric acid and hydrogen peroxide. Samples to be anayzed for total Hg were digested using aqua regia followed by oxidation with potassium permangenate. Mercury was analyzed by cold vapor atomic absorption utilizing a Perkin Elmer Model 603 atomic absorption spectrometer with HGA Model 2100 graphite furnace. Concentrations were converted to wet weight basis using an average moisture content of 80%. Lower limits of detection (wet weight) were ≤ 0.01 for all metals. Geometric means for individual heavy metals were calculated for certain groups when ≥ 50% of the samples were positive for the contaminant; one-half the detection limit was used for samples in these groups where the heavy metal was not detected. recoveries from spiked material ranged from 88 to 104%; residues were not corrected for these values.

One young heron found dead in the Ft. Lewis colony was shipped to the National Wildlife Health Laboratory, Madison, Wisconsin for necropsy.

Metal concentrations in a sample egg collected from each marked nest were related to fledging success in 13 nests at Hanford and hatching success in 3 nests at Ft. Lewis. Marked nests were checked several times each season to determine fate of eggs and young. When possible, data were also obtained for nests that were not marked. A nest was considered successful if one or more young hatched (Ft. Lewis) or fledged (Hanford). Inaccessibility of nests at the two colonies in contaminated areas precluded intensive sample egg collections. Comparative residues of organochlorine pollutants in tissues and eggs and eggshell thickness relationships will be presented in a subsequent paper (Fitzner et al., in prep.).

RESULTS

Reproductive Success

Except for the Hanford colony in 1981, data on reproductive success are generally limited because we made only two to four visits each season. The only indication of a serious reproductive problem occcurred on 11 June 1981 in the Ft. Lewis colony that contained about 50 nests. About 30 to 40 young (most about 4 weeks of age) were found dead on the ground. The carcasses were either deteriorated or scavenged and only one specimen was salvaged for necropsy. This bird, a female, was emaciated and weighed 1100 g. There were fibrin deposits on the epicardium indicating possible pericarditis and focal levels of hemorrhage were also seen in the right lung. Postmortem deterioration precluded bacterial or viral studies and the tissues were lost before metals analyses were performed. The reason for the die-off was not determined.

Only one dead young heron was found in the Ft. Lewis colony in 1982; there was no evidence of significant reproductive problems. About 35 nests were counted on 28 April; 4 of 5 nests observed contained from 1 to 4 eggs and the other had 3 recently hatched young. Each of three marked nests from which a sample egg was collected on 28 April contained two or three young (about 1 to 4 weeks of age) when last visited on 2 June. Of 25 other nests observed in the Ft. Lewis colony while climbing to the 3 marked nests on 2 June, 18 contained from 1 to 4 young, 6 were empty, and 1 had 3 eggs.

We have the least amount of data on reproductive success at the Lake Chatcolet colony that contained about 100 nests situated from 20 to 40 m above the ground. Few dead young were located in this colony—1 in 1981 and 12 (11 were hatchlings) in 1982. We observed a large number of young near fledging each year, but it was not possible to obtain an accurate count from the ground. Reproductive success in the Lake Chatcolet colony was intensively studied in 1977 (109 nests) and 1978 (148 nests); reproductive success was excellent both years with about two young fledged per active nest (Collazo 1981).

The colony at the Hanford Reservation also experienced excellent reproductive success in 1981 and 1982. All 13 marked nests with a sample egg fledged from 1 to 4 young. There were 84 nesting pairs in 1981 when 1.76 young were fledged per active nest. Little mortality was observed in this colony, and the population increased to about 100 breeding pairs in 1984.

Concentrations in Eggs

Eggs were analyzed for four heavy metals (Table 1). Arsenic was not detected in the 12 eggs collected from Hanford and Ft. Lewis in 1982. All 16 eggs were analyzed for Cu, Zn, and Hg; relatively low levels of Cu (≤2.71 μg/g) and Zn (≤6.37

TABLE 1. Concentrations of heavy metals in eggs of Great Blue Herons, 1981 and 1982.

			μg/g (fresh wet weight)			
Colony	Year	n	Cu	Zn	Hg	As
Hanford	1981	4	1.18 (4)[1] 0.65-2.71	5.78 (4) 5.30-6.37	0.17 (4) 0.11-0.37	NA
	1982	9	0.56 (9) 0.45-0.76	4.06 (9) 3.59-5.68	0.02 (6) ND-0.10	ND
Ft. Lewis	1982	3	0.46 (3) 0.29-0.59	3.87 (3) 3.08-4.66	0.06 (3) 0.04-0.12	ND

[1]Geometric mean (number of positive samples) and range. ND = no concentrations detected, NA = metal not analyzed for.

μg/g) were found in all eggs and low levels of Hg (≤0.37 μg/g) were detected in 13 eggs. Concentrations of these heavy metals were found in eggs of other species of birds including the Brown Pelican *Pelecanus occidentalis* (Blus et al. 1977).

Concentrations in Hatchlings and Advanced Embryos

Whole bodies of nine hatchlings (most had an egg tooth) and advanced embryos found dead under nests at Lake Chatcolet and Ft. Lewis were analyzed for concentrations of Pb, Cu, Zn, Cd, and Hg. Low levels of Cu, Zn, and Hg were detected in all samples; whereas, Pb and Cd were detected at low levels in only a few samples (Table 2). Two samples were also analyzed for eight additional metals; Cr, Al, Mg, and Mn were detected in both samples and Ni, As, Mo, and Co were not detected.

Concentrations in Tissues of Young

Liver of all 14 young collected near fledging were analyzed for concentrations of Pb, Cu, Zn, and Hg; their kidneys were analyzed for Cd (Table 3). Lead was detected irregularly at low levels and Cd was not detected. Zinc, Cu, and Hg were detected in all samples analyzed. A heron from Lake Chatcolet was the only one that was found dead; its liver also contained Cr, Mg, and Mn, but Ni, As, Al, Mo, and Co were not detected. The only concentration that seemed elevated was the 90 μg/g of Cu in the liver of a heron from Ft. Lewis.

Concentrations in Fish

Whole bodies of seven fish of three species that were found on the ground in the Lake Chatcolet colony were analyzed individually for six heavy metals (Table 4). Cobalt was not detected in any of the sam-

TABLE 2. Concentrations of heavy metals in whole bodies of hatchlings and advanced embryos, June 1982

		μg/g (fresh wet weight)				
Colony	n	Pb	Cu	Zn	Cd	Hg
Lake Chatcolet	8[1]	0.14 (3)[2] ND-0.44	0.98 (8) 0.62-1.1	7.91 (8) 6.3-11.0	(2) ND-0.20	0.05 (8) 0.03-0.08
Ft. Lewis	1[3]	0.22	1.1	8.0	0.22	0.06

[1]Concentrations (μg/g) detected in one sample included Cr—0.77, Al—12, Mg—150, and Mn—4.2—Ni As, Mo, and Co were not detected.
[2]Geometric mean (number of positive samples) and range; ND = no concentrations detected.
[3]Additional concentrations (μg/g) included: Cr—1.5, Al—1.4, Mg—110, and Mn—1.2; Ni, As, Mo, and Co were not detected.

TABLE 3. Concentrations of heavy metals in tissues of Great Blue Heron young near fledging, 1981-1982

			Concentrations (μg/g, fresh wet weight)[1]			
Year	Colony	n	Pb	Cu	Zn	Hg
1981	Ft. Lewis	3	ND	26.1 (3)[2] 9.9-90	65.0 (3) 57-83	1.14 (3) 0.82-1.5
	Lake Chatcolet	4	0.14 (3) ND-0.30	2.76 (4) 1.9-4.8	38.7 (4) 28-62	0.71 (4) 0.52-0.90
	Hanford	6	(1) ND-0.28	6.83 (6) 2.8-16	34.8 (6) 20-46	0.56 (6) 0.40-0.74
1982	Lake Chatcolet	1[3]	ND	6.8	87	NA

[1]Kidneys analyzed only for Cd (no concentrations detected); livers analyzed for other metals listed.
[2]Geometric mean (number of positive samples) and range; ND = no concentrations detected; NA = metal not analyzed for.
[3]Additional concentrations (μg/g) included: Cr—0.51, Mg—150, and Mn—2.1; Ni, As, Al, Mo, and Co were not detected. This bird was found dead; all others appeared healthy when collected.

TABLE 4. Concentrations (μg/g, fresh wet weight) of heavy metals in whole bodies of fish, Lake Chatcolet heronry, 1982.

Fish species	n	Length (cm)	Geometric mean, range, and (no. positive samples)[1]				
			Ag	Cd	Cr	Cu	Pb
Tench	2	25-30				1.25	0.43
(*Tinca tinca*)			ND-0.01	ND0.02	ND-0.14	1.2-1.3	0.11-1.7
			(1)	(1)	(1)	(2)	(2)
Pumpkinseed	3	8-10		0.07		0.92	1.35
(*Lepomis gibbosus*)			ND-0.01	0.03-0.14	ND	0.80-1.1	1.0-1.9
			(1)	(3)		(3)	(3)
Brown Bullhead	2	15-20		0.04		1.40	3.57
(*Ictalurus nebulosus*)			ND-0.02	0.03-0.05	ND-0.10	0.98-2.0	2.2-5.8

[1]Cobalt not detected in these samples.

ples; concentrations of Ag, Cd, Cr, and Cu were low. In contrast, concentrations of Pb in most of these fish were elevated with a maximum of 5.8 μg/g in a brown bullhead (see Table 4 for scientific names).

DISCUSSION

Residues in eggs and tissues of Great Blue Herons in this study probably do not reflect the level of contamination present in the immediate vicinity of the mines or smelters because each colony was about 20 to 30 km from the areas of heaviest contamination. Breeding herons from the Ft. Lewis colony probably fed most commonly in the extreme southern portion of Puget Sound, and the herons in Idaho probably fed most frequently in Lake Chatcolet and nearby areas that are about 18 km south of the entrance of the Coeur d'Alene River into Lake Coeur d'Alene and even farther from the actual mining and smelting activities on the South Fork of the Coeur d'Alene River. Residues in bottom sediments at the southern end of Puget Sound contained lower quantities of polychlorinated biphenyls (PCBs), aromatic hydrocarbons, and several metals including As, Cu, Hg, and Zn than were detected in most other sampling sites in the Sound (Crecelius et al. 1975, Riley et al. 1983). The aquatic biota around Lake Chatcolet appeared unaffected by pollutants even during the 1930s (Ellis 1940). Concentrations of Cu, Cd, Pb, and Zn in sediments were lowest in Lake Chatcolet and other southern sampling stations in the Lake Coeur d'Alene system; the highest concentrations occured north of the heronry at the mouth of the Coeur d'Alene River (Maxfield et al. 1974). Also, sediments and fish upstream near the mining and smelting activities contained very high concentrations of some heavy metals (Rabe & Bauer 1977). Die-offs of Tundra Swans (*Cygnus columbianus*) and other waterfowl have been attributed to Pb in vegetation and sediments in this area (Chupp & Dalke 1964, Benson et al. 1976).

Although the relations of Great Blue Herons to heavy metals at the Ft. Lewis and Lake Chatcolet colonies are confounded by migration and our incomplete knowledge of feeding areas of breeding birds, it appears that the herons from the colonies included in this study do not feed in the most heavily contaminated sites. In 1981 and 1982, we observed breeding Great Blue Herons at Lake Chatcolet that were feeding extensively on vole (*Microtus* spp.). Contaminant levels in voles were not determined; the Pb concentrations in whole bodies of the few prey fish analyzed were generally higher than those found in a number of species of fish collected in a recent national monitoring program (May & McKinney 1981).

The chlorinated hydrocarbon pollutants (Fitzner et al. in prep.) and heavy metals detected in Great Blue Herons from our study areas were considerably below levels associated with mortality or reproductive problems in ardeids and other birds as summarized by Custer & Mulhern (1983). Similarly, Pb and Cd were below detectable levels in livers of young and adult Great Blue Herons that were collected in Ohio (Hoffman & Curnow 1973). Livers of apparently healthy adult Great Blue Herons collected in Lake St. Clair, Michigan in 1970 contained from 15 to 175 μg/g Hg (Dustman et al. 1972). Most of the research involving Great Blue Herons and heavy metals has been directed toward Hg—particularly in polluted areas where biomagnification was documented (Dustman et al. 1972, Fimreite 1974). The biomagnification potential of Pb in aquatic and terrestrial systems is generally rather low (Birdsall et al., in press; Sharma & Shupe 1977). The small series of data from Lake Chatcolet provides no evidence for biomagnification of Pb from prey fish to Great Blue Heron tissues.

Few records of adverse effects of heavy metals on other ardeids exist. Gray Herons (*Ardea cinerea*) experienced a marked mortality in the Netherlands during a short cold spell in January and February 1976 (Van der Molen et al. 1982). Mercury residues in livers of Gray Herons found dead ranged from 1.6 to 773 μg/g dry weight (about 0.45 to 216 μg/g wet weight) compared to 116 to 211 μg/g (wet weight) of Hg in livers of experimental Gray Herons that died from methyl Hg poisoning. Van der Molen et al. (1982) concluded that some of the Hg levels in wild Gray Herons were lethal and the 19% decline in the breeding population the next year was related to Hg contamination in combination with extreme weather conditions. There was a possible Ni-induced mortality of a prefledgling Black-crowned Night-Heron (*Nycticorax nycticorax*) in Rhode Island (Custer & Mulhern 1983).

The 90 μg/g Cu in the liver of one nestling Great Blue Heron from Ft. Lewis was greatly elevated over that found in livers of all other young in our study. Livers of adults recently collected in contaminated areas of Puget sound contained a maximum of about 16 μg/g Cu, wet weight (Riley et al. 1983). Copper concentrations in livers of an occasional nestling of both Ospreys (*Pandion haliaetus*) and Black-crowned Night-Herons were much higher than in adults and fledged young from the same nesting locations in the eastern United States (Wiemeyer et al. 1980, Custer & Mulhern 1983). The significance of this relationship is not known. Only one of the three nestlings at Ft. Lewis had highly elevated Cu levels, and the relationship has not been found in other species including the Brown Pelican (Blus et al., 1977).

Population trend data are generally unavailable for Great Blue Herons in the northwestern United States, but in all colonies recently studied, reproductive success seemed "normal" and no long-term downward trends were evident (Werschkul et al. 1977, Bayer 1978, English 1978, Blus et al. 1980, Collazo 1981). Results from these recent studies support the conclusion of Henny (1972) that Great Blue Heron populations were relatively stable throughout their range even during the period of extensive use of DDT and other extremely toxic organochlorine insecticides.

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