Bull. Environm. Contam. Toxicol. 30, 178–185 (1983)

Heavy Metal Residues in Prefledgling Black-crowned Night-Herons from Three Atlantic Coast Colonies

Thomas W. Custer and Bernard L. Mulhern

*U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center
Laurel, MD 20708*

In 1979 we had the opportunity to salvage prefledgling black-crowned night-herons (*Nycticorax nycticorax*) that were found dead in three Atlantic coast heron colonies. The first colony is on an island in Narragansett Bay, Rhode Island. Narragansett Bay is in a major U.S. center for electroplating and receives industrial wastes, effluent, and sludge from a large metropolitan area. Metal concentrations in sediments in the Providence River which joins upper Narragansett Bay are among the highest known (EISLER et al. 1977). The other two colonies, located on islands in Newport River, North Carolina (WHALING et al. 1977), and in Duxbury Bay, Massachusetts, are in areas that receive chronic low concentrations of metals from effluent and sludge from nearby small communities.

Aquatic birds may serve as indicators of regional metal contamination. For example, liver tissues from seaducks collected at two sites in British Columbia had higher metal concentrations in areas of greater metal contamination (VERMEER & PEAKALL 1979). Also, a positive correlation has been suggested between metal residues in petrels and exposure to industrialized areas (ANDERLINI et al. 1972:49-61).

Because the food of prefledgling herons comes only from areas near the colony, their tissues should reflect local metal contamination. Our hypothesis was that prefledgling herons from the Rhode Island colony should have higher concentrations of metals than do those from either the North Carolina or Massachusetts colonies.

METHODS

Prefledgling black-crowned night herons, 1-4 weeks of age, were found dead in three Atlantic coast colonies in 1979: Clarks Island, Massachusetts (Colony No. 324001; see reference OSBORN & CUSTER 1978); Hope Island, Rhode Island (Colony No. 352004); and the Annex subcolony of Newport River, North Carolina (Colony No. 523008). The dead young were wrapped in aluminum foil, sealed in a plastic bag, and frozen as soon as possible. Because of rapid decomposition on the islands the young were probably not dead more than 2 days before they were collected. Livers were

0007-4861/83/0030-0178 $01.60

extracted from the birds several months later, placed in chemically clean jars, and then frozen.

Tissue samples were homogenized in a blender and a 5-g portion was weighed into a crucible for heavy metal analysis, dried in a drying oven, and then charred in a muffle furnace. The temperature was raised to 550°C at a rate of 100°C/hr and left to ash overnight. The ash was cooled, dissolved over a hot plate in about 2 ml of concentrated nitric acid and 1 ml of concentrated hydrochloric acid, transferred to a 12-ml polypropylene centrifuge tube, and diluted to 10 ml with distilled, deionized water.

Analysis was by flame atomic absorption spectrophotometry with a Perkin-Elmer model 703 A.A.S. equipped with a deuterium arc background corrector, an AS-50 autosampler, and a PRS-10 printer. The lower limit of reportable residues was 0.1 ppm, except for chromium which was 0.05 ppm. Recoveries of all metals from fortified chicken livers ranged from 81 to 105 percent. Residues were not corrected for percent recovery.

Means for metals were calculated on a dry weight (dw) basis when at least one-half of the samples had detectable levels. In determining and comparing mean metal concentrations, one-half the lower detection limit was given to samples where no residues could be detected.

RESULTS

All seven metals were detectable in one or more of the 22 black-crowned night-heron liver samples (Table 1). Copper, zinc, and cobalt were found in all samples, lead in more than 75 percent of samples, and chromium, nickel, and cadmium in less than 50 percent of the samples. The frequency of detection for chromium, nickel, and cadmium did not differ significantly (χ^2, $P > 0.05$) between the Hope Island and Annex colonies.

Mean concentrations (ppm dw) of lead, zinc, and cobalt in heron livers did not differ significantly among the three colonies (Table 2, ANOVA $P > 0.05$). Concentrations of copper were significantly greater in herons collected on Clarks Island than in those from Annex or Hope Island. The Bonferoni Multiple Comparison Procedure (overall $\alpha = 0.05$) was used for the copper comparison, since only copper had unequal variance among colonies (Bartlett's test, $\alpha = 0.05$) and an ANOVA would have been inappropriate. Because of low frequency of occurrence, means of chromium, nickel, and cadmium were not tested among colonies.

No significant intercorrelations ($P > 0.05$) existed among liver samples for lead, copper, zinc, or cobalt for the 12 herons collected on Hope Island. However, when all 22 samples were combined, cobalt and zinc were significantly intercorrelated ($P = 0.025$, $r = 0.48$).

Table 1. Frequency of metal residues in livers of prefledgling black-crowned night-herons, 1979.

Metal	Number (Percent) with Residues		
	Annex, NC (N = 7)	Clarks Is., MA (N = 3)	Hope Is., RI (N = 12)
Lead	5 (71)	2 (67)	10 (83)
Copper	7 (100)	3 (100)	12 (100)
Zinc	7 (100)	3 (100)	12 (100)
Cobalt	7 (100)	3 (100)	12 (100)
Chromium	3 (43)	0 (0)	6 (50)
Nickel	0 (0)	0 (0)	4 (33)
Cadmium	1 (14)	1 (33)	1 (8)

Weight and sex of the heron did not influence concentrations of lead, copper, or zinc when either the Hope Island data or all data were analyzed (Analysis of Covariance $\alpha = 0.05$). Weight and sex also did not influence cobalt residues when all data were taken into account (Analysis of Covariance; $P > 0.05$). However, when the Hope Island data were analyzed, females had significantly more cobalt than males and weight was not a significant factor (Analysis of Covariance; males = 0.61 ppm, n = 8, females = 0.97 ppm, n = 3; weight P = 0.76, sex P = 0.04).

DISCUSSION

The data do not support our initial hypothesis that young herons from Hope Island have greater metal residues than those from the Clarks Island or Annex colonies. Zinc, cobalt, and lead were not significantly different among colonies. High concentrations of copper found in herons on Clarks Island were unexpected. Chromium, nickel, and cadmium were as frequently detected in the Annex samples as in the Hope Island samples. On the other hand, the highest concentrations of chromium and nickel were found in the Hope Island herons, the only samples with nickel present were from Hope Island (4 of 12), and one individual from Hope Island may have died of nickel poisoning (see later discussion).

Metal residues in livers of Hope Island herons may have been similar to those from other areas because of several factors. First, the adult herons at Hope Island may have been feeding outside Narragansett Bay. Black-crowned night-herons flew an average of 4.5 km at high tide and 1.9 km at low tide (maximum = 7.2 km) on feeding trips from a North Carolina colony (CUSTER & OSBORN 1978). If these distances held true for the Rhode Island

Table 2. Concentrations of metals (ppm, dry weight) in livers of prefledgling black-crowned night-herons, 1979

	Metal Concentrations (mean, range)						
Colony	Lead[1]	Copper[2]	Zinc[1]	Cobalt[1]	Chromium	Nickel	Cadmium
Annex, NC	1.07 (nd[3]-2.89)	86.71 A (23.6-129.8)	648.83 (475-857)	0.96 (.7-1.32)	-- (nd-0.287)	-- (nd)	-- (nd-0.64)
Clarks Is., MA	0.83 (nd-1.29)	257.26 B (100-381)	602.11 (482-784)	0.65 (.57-.78)	-- (nd)	-- (nd)	-- (nd-0.33)
Hope Is., RI	1.24 (nd-5.26)	119.99 A (33-266)	503.02 (246-885)	0.71 (0.3-1.1)	0.20 (nd-0.51)	-- (nd-9.18)	-- (nd-0.38)

1 No significant differences (ANOVA α = 0.05)
2 Significant differences are shown by means not sharing a common letter (Bonferoni Multiple Comparison Procedure, overall α = 0.05).
3 nd = not detected

colony, feeding sites could have been outside the Bay. Second, the herons at Hope Island may have been feeding on organisms not highly contaminated with metals. We can not assess the metal levels in heron prey organisms at the various sites. Except for qualitative information, we do not know the composition of the diet of prefledgling herons nor do we have comparative metal levels for potential prey species in these areas. Finally, differential accumulation of metals may not occur for prefledgling herons at the concentrations found in their diet.

Cadmium and lead concentrations in our study were equivalent to or lower than those of the following species: Immature and adult cattle egrets (*Bubulcus ibis*), and immature and adult laughing gulls (*Larus atricilla*) (HULSE et al.1972); ospreys (*Pandion haliaetus*) (WIEMEYER et al. 1980); Atlantic puffins (*Fratercula arctica*) (PARSLOW et al. 1972); brown pelicans (*Pelecanus occidentalis*) (BLUS et al. 1977 and CONNORS et al. 1972); American white pelicans (*Pelecanus erythrorhynchos*) (CONNORS et al. 1972); common terns (*Sterna hirundo*) (CONNORS et al. 1975); mute swans (*Cygnus olor*) (FRANK & BORG 1979); canvasbacks (*Aythya valisineria*) (WHITE et al. 1979); and ruddy ducks (*Oxyura jamaicensis*) (WHITE & KAISER 1976). Also, see a review of lead levels for several avian species (BAGLEY & LOCKE 1967). In contrast, cadmium and lead were not detected in livers of immature and adult great blue herons (*Ardea herodias*), black-crowned night-herons or great egrets (*Casmerodius albus*) (HOFFMAN & CURNOW 1973).

Concentrations of cobalt and chromium found in our study were equivalent to or lower than those found in common terns (CONNORS et al. 1975), and in brown pelicans and white pelicans (CONNORS et al. 1972). Concentrations of chromium were equivalent to or lower than those in canvasbacks (WHITE et al. 1979), three species of petrels (ANDERLINI 1972), ospreys (WIEMEYER et al. 1980), brown pelicans (BLUS et al. 1977), common eiders (*Somateria mollissima*), and lesser black-backed gulls (*Larus fuscus*) (LANDE 1977).

Copper concentrations were relatively high (24-381 ppm dw, Table 2) when compared with other species (see reference BECK 1956) and this may reflect age. Copper residues in livers of immature ospreys collected in July in Maryland averaged 141 ppm wet weight (ww), whereas adults from the same area averaged 3.0 ppm ww. Immature ospreys collected from other areas in September averaged 4.0 ppm ww (WIEMEYER et al. 1980). Liver concentrations of copper were 18-98 ppm dw in brown pelicans (CONNORS et al. 1972), 4.3-9.0 ppm ww in 6-week-old to adult brown pelicans (BLUS et al. 1977), 13-28 ppm dw in common terns (CONNORS et al. 1975), averaged 17 ppm dw in lesser black-backed gulls (LANDE 1977), averaged 17-21 ppm dw in petrels of three species (ANDERLINI et al. 1972), were 35-66 ppm dw in greater scaup (*Aythya marila*) and surf scoters (*Melanitta perspicillata*) (VERMEER & PEAKALL 1979), averaged 59 ppm ww in canvasbacks (WHITE et al. 1979), and were 19-53 ppm dw in common puffins (PARSLOW et al. 1972). In contrast, 30 percent of mute swans had over 1000 ppm ww copper in the liver (FRANK &

BORG et al. 1979). And the mean concentrations of copper in common eider livers was 367 ppm dw (LANDE 1977).

Zinc residues were also high (246-885 ppm dw, Table 2) when compared with other species and again may reflect age. Zinc in osprey livers (WIEMEYER et al. 1980) was higher in immatures (mean 67 ppm ww) than in adults (mean 38 ppm ww). Liver concentrations of zinc were 26-55 ppm ww in 6-week-old to adult brown pelicans (BLUS et al. 1977), 80-172 ppm dw in brown pelicans (CONNORS et al. 1972), 69-214 ppm dw in common terns (CONNORS et al. 1975), averaged 204 ppm dw in common eiders, and 89 ppm dw in lesser black-backed gulls (LANDE 1977), were 24-568 ppm ww in mute swans (FRANK & BORG 1979), were 154-602 ppm dw (PARSLOW et al. 1972) and 98-151 ppm dw (OSBORN et al. 1979) in common puffins, 117-170 ppm dw in Manx shearwaters (*Pufinus puffinus*) (OSBORN et al 1979), 225-688 ppm dw in northern fulmars (*Fulmarus glacialis*) (OSBORN et al. 1979), averaged 41 ppm ww in canvasbacks (WHITE et al. 1979), were 104-148 ppm dw in greater scaup and surf scotters (VERMEER & PEAKALL 1979), and averaged 131-176 ppm dw in petrels of three species (ANDERLINI et al. 1972).

One immature heron from Rhode Island had 9.2 ppm dw (2.5 ppm ww) nickel in the liver and may have died of nickel poisoning. Mallard (*Anas platyrhynchos*) ducklings fed 1,200 ppm dietary nickel averaged 3.7 ppm ww nickel in the liver after 30 days, whereas ducklings fed 800 ppm nickel, 200 ppm nickel, and control diet did not accumulate over 1.3 ppm ww in the liver (CAIN & PAFFORD 1981). Only 1 of the 12 ducklings on 1,200 ppm nickel was still alive after 90 days, but all 12 ducklings in each of the other three groups were still alive. The high value reported here is also greater than the values reported for common eiders (LANDE 1977), lesser black-backed gulls (LANDE 1977), snow petrels (*Pagodroma nivea*) (ANDERLINI et al. 1972), and brown pelicans (BLUS et al. 1977 and CONNORS et al. 1972). In contrast, mean nickel levels were 8.4 ppm dw and 7.2 ppm dw in Wilson's petrel (*Oceanites oceanicus*), and 17.3 ppm dw in ashy petrels (*Oceanodroma homochroa*) (ANDERLINI et al. 1972).

The value of using salvaged young herons as biological indicators of metal contamination is in question. The young were not of the same age and metal concentrations may increase (see references FRANK & BORG 1979; HULSE et al. 1980; WIEMEYER et al. 1980) or decrease (see references CAIN & PAFFORD 1981 and WIEMEYER et al. 1980) with age. Another concern is that metals may differentially move from tissues at various times after death (IYENGAR 1980). Since we took advantage of birds found dead, we could not control this variable. Quantitive comparisons among species are also difficult because seasonal differences in metal residues can occur for a given species (OSBORN 1979). Finally, the concentration of one metal may influence the concentration of others. For example, copper, zinc, or both may increase in the liver with increased cadmium in the diet (ASHBY et al. 1980, BEHARI & TANDON 1980).

ACKNOWLEDGMENTS

We thank John Fussell III, James Myers, Brian Harrington, and Lorrae Fuentes for assistance in collecting the herons; Gary Hensler for statistical assistance; and Louis Sileo for help in preparing the tissues. Stanley Wiemeyer identified critical references. Eugene Dustman, Gary Hensler, Harry Ohlendorf, and Stanley Wiemeyer reviewed the manuscript.

REFERENCES

ANDERLINI, V. C., P. G. CONNORS, R. W. RISEBROUGH, and J. H. MARTIN: Concentrations of heavy metals in some Antarctic and North American sea birds. pp. 49-61. In: B. C. Parker (ed.). Proceedings of the Colloquium on Conservation Problems in Antarctica. Allen Press, Lawrence, Kansas. 1972.

ASHBY, S. L., L. J. KING, and D. V. W. PARKE: Environ. Res. 21, 177 (1980).

BAGLEY, G. E. and L. N. LOCKE: Bull. Environ. Contam. Toxicol. 2, 297 (1967).

BECK, A. B: Australian J. Zool. 4, 1 (1956).

BEHARI, J. R. and S. K. TANDON: Toxicol. Lett. 5, 151 (1980).

BLUS, L. J., B. S. NEELY, JR., T. G. LAMONT, and B. MULHERN: Pestic. Monit. J. 11, 40 (1977).

CAIN, B. W. and E. A. PAFFORD: Environ. Contam. Toxicol. 10, 737 (1981).

CONNORS, P. G., V. C. ANDERLINI, R. W. RISEBROUGH, J. H. MARTIN, R. W. SCHREIBER, and D. W. ANDERSON: Cal-Neva Wildlife, 56 (1972).

CONNORS, P. G., V. C. ANDERLINI, R. W. RISEBROUGH, M. GILBERTSON, and H. HAYS: Can. Field-Nat. 89, 157 (1975).

CUSTER, T. W. and R. G. OSBORN: Auk 95, 733 (1978).

EISLER, R., R. L. LAPAN, JR., G. TELEK, E. W. DAVEY, A. E. SOPER, and M. BARRY: Mar. Pollut. Bull. 8, 260 (1977).

FRANK, A. and K. BORG: Acta. Vet. Scand. 20, 447 (1979).

HOFFMAN, R. D. and R. D. CURNOW: Toxic heavy metals in Lake Erie herons. pp. 50-53. In: Proc. 16th Conf. Great Lakes Res. Internat. Assoc. Great Lakes Res. 1973.

HULSE, M., J. S. MAHONEY, G. D. SCHRODER, C. S. HACKER, and S. M. PIER: Arch. Environm. Contam. Toxicol. 9, 65 (1980).

IYENGAR, G. V: Sci. Tot. Environ. 15, 217 (1980).

LANDE, E: Environ. Pollut. 12, 187 (1977).

OSBORN, D: Environ. Pollut. 19, 145 (1979).

OSBORN, D., M. P. HARRIS, and J. K. NICHOLSON: Comp. Biochem. Physiol. 64, 61 (1979).

OSBORN, R. G. and T. W. CUSTER: Herons and their allies: Atlas of Atlantic coast colonies: 1975 and 1976. Biol. Serv. Prog., U. S. Fish and Wildl. Serv. FWS/OBS-77/08. 1978.

PARSLOW, J. L. F., D. J. JEFFERIES, and M. C. FRENCH: Bird Study 19, 18 (1972).

VERMEER, K. and D. B. PEAKALL: Mar. Pollut. Bull. 10, 189 (1979).

WHITE, D. H. and T. E. KAISER: Pest. Monit. J. 9, 155 (1976).
WHITE, D. H., R. C. STENDELL, and B. M. MULHERN: Wilson Bull. 91, 279 (1979).
WIEMEYER, S. N., T. G. LAMONT, and L. N. LOCKE: Estuaries 3, 155 (1980).
WHALING, P. J., R. T. BARBER, and J. C. PAUL: The distribution of toxic metals in marine ecosystems as a result of sewage disposal and natural processes. Report No. 123 Water Resources Research Institute, Univ. of North Carolina. 1977.

Accepted December 11, 1982