Bull Environ Contam Toxicol (2009) 83:698–702
DOI 10.1007/s00128-009-9848-8

Mercury Contamination in Idaho Bald Eagles, *Haliaeetus leucocephalus*

Marc J. Bechard · Dusty N. Perkins · Gregory S. Kaltenecker · Steve Alsup

Received: 26 November 2008 / Accepted: 3 August 2009 / Published online: 19 August 2009

Abstract Because mercury contamination is potentially threatening to bald eagle (*Haliaeetus leucocephalus*) populations, we collected molted feathers at nests to determine the level of contamination in bald eagles in the state of Idaho, USA. Eagle feathers contained measurable amounts of cadmium (Cd), chromium (Cr), selenium (Se), lead (Pb), as well as mercury (Hg). Cadmium, Cr, Se, and Pb levels averaged 0.17, 4.68, 2.02, and 1.29 mg/kg dry weight, respectively, and were at or below concentrations indicated as causing reproductive failure in bald eagles. Mercury contamination was found to be the highest averaging 18.74 mg/kg dry weight. Although a concentration of only 7.5 mg/kg dry weight Hg in bird feathers can cause reduced productivity and even sterility, all of the eagles we sampled bred successfully and the population of bald eagles continues to grow annually throughout the state.

Keywords Bald eagle · *Haliaeetis leucocephalus* · Mercury contamination · Idaho

Heavy metal contamination, particularly that of mercury (Hg), is a concern for populations of bald eagles (*Haliaeetus leucocephalus*) across North America. High levels of Hg which can potentially cause reproductive impairment have been recorded in bald eagles in Florida, South Carolina, the Great Lakes Region, Montana, and Oregon (Bowerman et al. 1994; Harmata 1993; Wood et al. 1996; Anthony et al. 1999; Jagoe et al. 2002). Despite the widespread occurrence of Hg contamination, bald eagle populations have increased dramatically across the US since DDT was banned in the early 1970s. Most breeding populations of bald eagles have recovered and, having met recovery goals set for the species, it was delisted from the Endangered Species List in 2007. Over the past 20 years, the bald eagle population in the state of Idaho has increased to a high of 170 breeding pairs in river drainages throughout the state including the North and South Forks of the Snake River, the Boise River system, the Payette River drainage especially near Lake Cascade, the Salmon River system, and the Coeur d'Alene River drainage including the Kootenai Valley. Of these, 107 pairs produced a total of 179 young in 2005 or an average of 1.15 fledglings/breeding pair. Herein, we report the results of a study conducted to determine the heavy metal contamination in bald eagles throughout the state of Idaho and we compare them to contaminant levels in bald eagles in other areas of the US and Canada.

Materials and Methods

Feather collections at the bases of nest trees are relatively noninvasive and minimize the potential for adverse effects caused by disturbance of nesting eagles. Also, eagle feathers have been routinely analyzed for heavy metal residues throughout the US for more than 20 years (Bowerman et al. 1994; Wood et al. 1996) so they provide a reliable means of comparing heavy metal contamination in bald eagles across North America. We collected feather samples at 23 bald eagle nesting territories in the Snake, Boise, Payette, Salmon, and Coeur d'Alene River drainages in 2004 and 2006. Adult feathers were collected at four nesting territories in each river drainage except the Snake River where, due to its large size, we collected feathers at four nests in the upper

M. J. Bechard (✉) · D. N. Perkins · G. S. Kaltenecker · S. Alsup
Raptor Research Center, Department of Biology, Boise State University, 1910 University Dr., Boise, ID 83725, USA
e-mail: mbechard@boisestate.edu; morkbechard@q.com

segment of the river above Pallisades Reservoir and in the lower segment of the river in Hells Canyon. We collected molted adult feathers under each nest tree at all sampling sites except for the Salmon River drainage where we also collected feathers from a nestling eagle which had recently died. Feathers were collected opportunistically by conducting 1-m visual sweeps of the ground within 20–30 m of each nest tree during the nestling and post-fledging periods. Feathers were placed in new zip-lock plastic bags containing silica gel to retard bacterial growth. Because adult feathers collected at each bald eagle nesting territory could have originated from either the male or female of the pair, we pooled all adult feathers collected at each nesting territory for the heavy metal analysis. Feathers were homogenized at cryogenic temperatures (Spex 6800 mill) and then digested with nitric and hydrochloric acids and hydrogen peroxide in a block digester (CPI ModBlock, Brookens et al. 2008). Heavy metal analysis was performed using inductively coupled plasma-optical emission spectroscopy, inductively coupled plasma-mass spectroscopy, and cold vapor atomic absorption spectroscopy (Wylie et al. 2009). Detection limits were 0.02 mg/kg for Cd, 0.2 mg/kg for Cr, 0.035 mg/kg for Se, 0.01 mg/kg Pb, and 0.005 mg/kg Hg. Digestion batches included the following quality control samples: method blanks, reference materials, duplicate samples, fortified blanks, and fortified samples. For fortified samples, an aliquot of homogenized sample was carried through the digestion and analytical procedures after having been spiked with known amounts of analyte. Recovery of the spike, along with similar calculations for spiked blanks and unspiked reference materials were used to evaluate accuracy. Precision was evaluated from sample-duplicate pairs using the relative percent difference (range divided by the average). All heavy metal concentrations are expressed as mg/kg dry weight.

Results and Discussion

All of the feathers we collected contained measurable amounts of five heavy metals, Cd, Cr, Hg, Pb, and Se, which have been routinely monitored in adult bald eagles in the US and Canada (Table 1). Levels of Cd averaged 0.17 mg/kg and were lowest in central Idaho in the Salmon River drainage (mean = 0.08 ± 0.07, ± SD, range = 0.03–0.19 mg/kg) and highest in northern Idaho in the Coeur d'Alene River drainage (mean = 0.37 ± 0.336, range = 0.10–0.86 mg/kg). Chromium levels were lowest in northern Idaho (mean = 0.73 ± 0.57, range = 0.33–1.56 mg/kg) and highest in southeastern Idaho (mean = 10.52 ± 5.59, range 2.56–15.6 mg/kg). Selenium levels were lowest in the Coeur d'Alene River drainage (mean = 1.46 ± 0.26, range = 1.21–1.81 mg/kg) and highest in the upper portion of the Snake River drainage (mean = 3.47 ± 1.43, range = 2.08–5.32 mg/kg) and Pb levels were lowest in the Boise River drainage (mean = 0.66 ± 0.29, range = 0.50–1.10 mg/kg) and highest in the upper portion of the Snake River drainage (mean = 2.05 ± 0.53, range = 1.47–2.53 mg/kg). Mercury contamination was consistently the highest of all the heavy metals tested, ranging between 3.7 and 37.4 mg/kg (mean = 18.74 ± 9.61 mg/kg). Bald eagles in the Salmon River drainage had the lowest levels ranging between 3.7 and 20.1 mg/kg (mean = 9.78 ± 6.19 mg/kg) and eagles in the lower portion of the Snake River drainage had the highest levels ranging from 34.4 to 37.4 mg/kg (mean = 36.07 ± 1.53 mg/kg).

The levels of Cd, Cr, and Se we recorded were similar to levels recorded in bald eagles in Alaska (Stout and Trust 2002) and Montana (Harmata 1993), but below the levels which have been indicated as causing toxic effects on eagles (Eisler 1985a, b, 1986). Bald eagle feathers averaged 1.27 mg/kg Pb with levels exceeding 1 mg/kg in the Coeur d'Alene River and Snake River drainages. Harmata (1993) found lower levels of Pb contamination (range = 0.05–0.39 mg/kg) in bald eagles in Montana and California. Redig et al. (1983) suggested that contamination levels ranging from 0.20 to 1.00 mg/kg are evidence of toxic, chronic, sublethal exposure to Pb in eagles and the US Fish and Wildlife Service has established a level of ≥0.50 mg/kg in eagle blood as indicative of toxic but sublethal exposure to Pb. Despite the relatively high level of Pb contamination in Idaho, the bald eagle population continues to reproduce normally and the population is expanding annually throughout the state. Nevertheless, it is concerning that Pb continues to contaminate eagles. The effect of this level of exposure on the status of the state's bald eagle population remains unclear but warrants continued monitoring.

The toxicity of Hg in wildlife has long been known and levels as low as 5.0 mg/kg can cause neuropathologies that result in changes in behavior and reproductive impairment (Eisler 1987). The level of Hg contamination we recorded in eagle feathers was nearly four times that at which there should be concern about the health of the population. Eagles in southwestern Idaho had the highest levels of Hg contamination averaging 23.60 mg/kg with eagles in the lower portion of the Snake River in Hells Canyon showing the highest level of contamination at 36.07 mg/kg. Thomas and Burch (2005) conducted a similar analysis of heavy metals in adult bald eagle feathers in the Boise River drainage at Lake Lowell and also detected elevated levels of Hg contamination with an average of 21 mg/kg (range = 11–33 mg/kg). Their study also found elevated levels of Hg and Se in Great Blue Herons (*Ardea herodius*) and Western/Clark's Grebes (*Aechmophorus occidentalis* and *A. clarkii*) as well as in fish such as bass (*Micropterus*

Table 1 Concentrations (mg/kg dry weight) of heavy metal contaminants in bald eagle feathers collected in 2004 and 2006 at nest sites in river drainages throughout the state of Idaho

Sampling locations	Element				
	Cadmium	Chromium	Selenium	Lead	Mercury
Coeur d'Alene river					
Anderson lake	0.86	0.39	1.81	1.80	16.5
Killarney lake	0.10	0.33	1.47	3.49	14.7
Windy bay	0.35	1.56	1.21	1.84	13.4
Turner bay	0.17	0.64	1.33	0.99	14.7
Mean	0.37 ± 0.34	0.73 ± 0.57	1.46 ± 0.26	2.03 ± 1.05	14.83 ± 1.27
Salmon river					
Carmen (adult)	0.19	10.80	2.18	1.96	20.1
Carmen (nestling)	0.03	0.45	2.27	0.50	7.5
Allison creek	0.07	1.19	1.96	0.73	9.9
Morgan creek	0.08	0.95	0.98	1.06	3.7
Struggle gulch	0.03	1.33	2.05	0.50	7.7
Mean	0.08 ± 0.07	2.94 ± 4.40	1.89 ± 0.52	0.95 ± 0.61	9.78 ± 6.19
Boise river					
Barber pools	0.24	0.93	1.54	1.10	19.1
Fairview creek	0.05	12.70	1.63	0.50	18.2
South fork arrowrock	0.20	0.81	1.49	0.55	26.8
Arrowrock	0.03	2.28	1.25	0.50	12.9
Mean	0.13 ± 0.11	4.18 ± 5.72	1.48 ± 0.16	0.66 ± 0.29	19.25 ± 5.73
Payette river					
Paddy flat	0.04	9.48	1.18	3.58	5.67
Cabarton	0.02	2.62	1.27	0.20	31.3
Sugarloaf	0.02	2.55	1.84	0.25	15.2
Goldfork	0.03	4.22	1.63	0.25	22.8
Mean	0.03 ± 0.01	4.72 ± 3.27	1.48 ± 0.31	1.07 ± 1.67	18.74 ± 10.92
Upper snake river					
Trout creek	0.18	11.5	2.67	1.47	27.4
Van point south	0.44	15.6	5.32	1.73	24.5
Van point north	0.35	2.56	3.81	2.53	14.2
Hoffman east	0.40	12.40	2.08	2.46	15.3
Mean	0.34 ± 0.11	10.52 ± 5.59	3.47 ± 1.43	2.05 ± 0.53	20.35 ± 6.59
Lower snake river					
Airport	0.05	5.15	2.25	0.41	37.4
Cottonwood	0.04	4.28	2.21	0.48	34.4
Hibble gulch	0.05	1.77	2.30	1.62	36.4
Mean	0.47 ± 0.01	3.73 ± 1.76	2.25 ± 0.05	0.84 ± 0.68	36.07 ± 1.53

spp.), invertebrates, and bullfrogs (*Rana catesbiana*) indicating that Hg pollution occurs extensively within the food chain at Lake Lowell. Overall, our findings indicate that Hg pollution occurs throughout the southwestern portion of Idaho.

The level of Hg contamination we detected was high but typical of bald eagles across North America (Wiemeyer et al. 1989). Of bald eagle tissues sampled in North America, eggs have been reported to contain the lowest levels of Hg contamination ranging from 0.05 to 0.11 mg/kg in Alaska and British Columbia (Table 2). Blood samples taken from nestlings in Oregon, Washington, Montana, Florida, and South Carolina were reported to contain higher levels ranging from 0.21 to 1.20 mg/kg Hg whereas Hg levels in subadult and adult blood samples were even higher ranging from 1.50 to 3.07 mg/kg. Feathers typically contain the highest levels of Hg with adult feathers having the highest levels of contamination. Concentrations in adult feathers

Table 2 Mean concentrations of mercury contamination (mg/kg) reported in bald eagles in the US and Canada

Location	Tissue	Mercury contamination	Source
Alaska	Eggs	0.05[a]	Anthony et al. (1999)
British Columbia	Eggs	0.11[a]	Elliot et al. (1996)
Florida	Nestling feathers	3.23[a]	Wood et al. (1996)
	Nestling blood	0.13[a]	
	Adult feathers	6.03[a]	
Great lakes region	Nestling feathers	9.55[b]	Bowerman et al. (1994)
	Adult feathers	19.4[b]	
Idaho	Adult feathers	21.0[b]	Thomas and Burch (2005)
Montana	Nestling blood	0.21[a]	Harmata (1993)
	Adult blood	2.16[a]	
Oregon	Nestling blood	1.20[a]	Wiemeyer et al. (1989)
	Subadult blood	3.00[a]	
	Adult blood	2.30[a]	
South Carolina	Nestling feathers	3.67[b]	Jagoe et al. (2002)
	Nestling down	2.43[b]	
	Nestling blood	0.08[b]	
	Adult feathers	45.9[b]	
	Adult down	36.1[b]	
Washington	Nestling blood	0.23[a]	Wiemeyer et al. (1989)

[a] Wet weight, [b] dry weight

have been detected 10 times higher than in nestling feathers. The levels we detected were similar to levels of Hg contamination in adult and nestling feathers detected in Florida and the Great Lakes region which ranged from 6 to 19 mg/kg but they were lower than in South Carolina where adult bald eagle feathers were found to contain levels ranging from 36.1 to 45.9 mg/kg. This level of contamination does not appear to be causing reproductive impairment in eagle populations across the country (Jagoe et al. 2002).

Interpretation of Hg concentrations in shed feathers must be made with caution. Feathers are a route of excretion and not target organs so the concentration of Hg may be affected by the time to last molt, feather type, and the age of the bird. Eisler (1987) has proposed a concentration of 7.5 mg/kg Hg in bird feathers as a level of concern with concentrations above this causing reduced productivity and even sterility. Except for two samples from the Salmon and Payette River drainages, all of the feathers we collected had levels of Hg contamination that exceeded this accepted level of concern. Nevertheless, all of the eagles we sampled appeared to be healthy and breeding successfully. As is the case of Pb contamination, the effect of Hg contamination on bald eagles remains unclear. Despite its widespread occurrence as a contaminant, bald eagle populations continue to reproduce normally and appear to be increasing throughout North America. At present, it is unclear what effect moderate exposure to Hg has on eagle health but its widespread occurrence indicates that bald eagles should continue to be monitored for this contaminant (Wiemeyer et al. 1989).

The high level of Hg contamination we found in bald eagles in Idaho is cause for concern because it indicates there is widespread Hg pollution throughout the state and that Hg is pervasive in the state's river ecosystems. The Hg that is found in eagle feathers originates as methyl mercury in their tissues and in their fish prey, indicating that Hg contaminates fish populations in river drainages throughout the state. This finding was supported by the results of the one nestling whose feathers we sampled. With a level of 7.5 mg/kg Hg, this indicated it was ingesting mercury at its nest site. Such high levels of Hg contamination may simply be the result of a natural phenomenon associated with the fact that Idaho is situated in a mercuriferous belt in the western US and British Columbia where underlying rock contains elevated Hg levels. Nevertheless, these elevated levels could also be from anthropogenic sources. High levels of Hg are often associated with Hg leaching from hard rock mine tailings where Hg has been used as an amalgam in gold mining. Active and inactive gold mines are located throughout Idaho as well as the northern Rocky Mountains and western Canada. Mercury can also become elevated in aquatic ecosystems through atmospheric transport of Hg from industrial sources such as pulp mills, fossil-fuel burning power plants, smelters, and waste incinerators (Fitzgerald et al. 1998). There is the possibility that the high mercury levels recorded in the southwestern portion of the state of Idaho are the result of downwind contamination from gold mines in Nevada and a cement factory in southeastern Oregon. The use of mercurials in seed dressings, fungicides, and paints as well as the industrial production of chlorine can also result in elevated Hg levels, as can the construction of dams that can also mobilize Hg in reservoirs leading to elevated Hg concentrations in fish and wildlife in these systems. High levels of Hg associated with reservoirs could explain the high levels of Hg found in southwestern Idaho. Eagles nesting on reservoirs in southwestern portion of the state consistently had the highest levels of contamination we found.

Acknowledgments This project was funded by the Idaho Department of Fish and Game and Idaho Power Company. We would like to thank the following for their assistance throughout this project: B. Alford, Jon Beals, Blackrock Development Project Manager Kyle Capps, Leslie Carpenter, Kathy and Tom Flint, Toni Holthuijzen, Carrie Hugo, Sonya Knetter, Jeff Knetter, Von Pope, Beth Waterbury, and Mike Whitfield.

References

Anthony RG, Miles AK, Estes JA, Isaacs FB (1999) Productivity, diets, and environmental contaminants in nesting bald eagles from the Aleutian Archipelago. Environ Toxicol Chem 18:2054–2062. doi:10.1897/1551-5028(1999)018<2054:PDAECI>2.3.CO;2

Bowerman WW, Evans ED, Giesy JP, Postupalsky S (1994) Using feathers to assess risk of mercury and selenium to bald eagle reproduction in the Great Lakes Region. Arch Environ Contam Toxicol 27:294–298. doi:10.1007/BF00213162

Brookens TJ, O'Hara TM, Taylor RJ, Bratton GR, Harvey JT (2008) Total mercury body burden in Pacific harbor seal, *Phoca vitulina richardii*, pups from central California. Mar Poll Bull 56:27–41. doi:10.1016/j.marpolbul.2007.08.010

Eisler R (1985a) Cadmium hazards to fish, widlife, and invertebrates: a synoptic review. Biological report 85(1.2), USFWS. Patuxent Wildlife Research Center, Laurel, MD

Eisler R (1985b) Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. Biological report 85(1.10), USFWS. Patuxent Wildlife Research Center, Laurel, MD

Eisler R (1986) Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. Biological report 85(1.6), USFWS. Patuxent Wildlife Research Center, Laurel, MD

Eisler R (1987) Mercury hazards to fish, wildlife and invertebrates: a synoptic review. Biological report 85(1.10), USFWS. Patuxent Wildlife Research Center, Laurel, MD

Elliot JE, Norstrom RJ, Smith GEJ (1996) Patterns, trends, and ecological significance of chlorinated hydrocarbon and mercury contaminants in bald eagles from the Pacific Coast of Canada, 1990–1994. Arch Environ Contam Toxicol 31:354–367. doi:10.1007/BF00212674

Fitzgerald WF, Engstrom DR, Mason RP, Nater EA (1998) The case for atmospheric mercury contamination in remote areas. Environ Sci Technol 32:1–7. doi:10.1021/es970284w

Harmata AR (1993) Heavy metal and pesticide contamination of bald and golden eagles in the western United States. Unpubl. Rep., US Dept. Interior, EPA. Washington, DC

Jagoe CH, Bryan AL Jr, Brant HA, Murphy TM, Brisbin IL Jr (2002) Mercury in bald eagle nestlings from South Carolina. USA Wildl Dis 38:706–712

Redig PT, Stove CM, Barnes DM, Aront TD (1983) Lead toxicosis in raptors. Am Vet Med Assoc 177:941–943

Stout JH, Trust KA (2002) Elemental and organochlorine residues in bald eagles from Adak Island. Alaska Wildl Dis 38:511–517

Thomas CM, Burch S (2005) Evaluation of inorganic and organic organochlorine contaminants in sediment and biota from Lake Lowell, deer flat national wildlife refuge. Unpubl. Rep. USFWS, Boise, ID

Wiemeyer SN, Frenzel RW, Anthony RG, McClelland BR, Knight RL (1989) Environmental contaminants in blood of western bald eagles. Raptor Res 23:140–146

Wood PB, White JH, Steffer A, Wood JM, Facemire CF, Percival HF (1996) Mercury concentrations in tissues of Florida bald eagles. J Wildl Manage 60:178–185. doi:10.2307/3802053

Wylie GD, Hothem RL, Bergen DR, Martin LL, Taylor RJ, Brussee BE (2009) Metals and trace elements in giant garter snakes (*Thamnophis gigas*) from the Sacramento Valley, California. USA Arch Environ Contam Toxicol 56:577–587. doi:10.1007/s00244-008-9265-8