RELATIONSHIP OF DIETS AND ENVIRONMENTAL CONTAMINANTS IN WINTERING BALD EAGLES

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Abstract: We investigated the relationship between diets and potential hazards in contaminants of wintering bald eagles (*Haliaeetus leucocephalus*) in the Klamath Basin of northern California and southern Oregon. We studied diets by identifying remains of 913 prey items found at perches, examining 341 castings collected from communal night roosts, and observing foraging eagles. We determined residues of organochlorine compounds, lead (Pb), and mercury (Hg) in bald eagles and their prey by analyzing eagle blood samples and carcasses and 8 major prey species. Bald eagles fed largely on waterfowl by scavenging cholera-killed ducks and geese and on microtine rodents during mid- to late winter. Residues of organochlorine pesticides and Hg in prey were low, and polychlorinated biphenyls (PCB's) were detected in low concentrations in 9% of prey samples. Mean Pb concentrations in prey ranged from 0.15 to 4.79 ppm. Mercury was detected in all eagle blood samples, and Pb was detected in 41% of the bald eagle blood samples. Mean Pb concentration in livers of dead eagles was 2.09 ppm and ranged as high as 27 ppm in an eagle that died of Pb poisoning. Prey of the eagles were relatively free of contaminants with the possible exception of embedded Pb shot in waterfowl, which may present a potential for Pb poisoning of eagles.

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Major declines in many populations of bald eagles from 1950 to 1975 (Stalmaster 1987:134) led to the species being classified as endangered in 43 of the 48 contiguous states and threatened in Oregon, Washington, Minnesota, Wisconsin, and Michigan (U.S. Fish Wildl. Serv. [USFWS] 1979). Many of these declines were attributed to lower rates of reproduction (Stalmaster 1987: 135), which were associated with eggshell thinning from 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (DDE) contamination (Wiemeyer et al. 1984). Contaminant residues in autopsied eagles have been reported periodically (Reichel et al. 1984), but few studies have investigated diets and pollutants in the prey of bald eagles (Wiemeyer et al. 1978) simultaneously.

The Klamath Basin of south-central Oregon and northern California supports 1 of the highest concentrations of wintering bald eagles in the 48 contiguous states with peak counts of 500 eagles during January and February (Keister et al. 1987). The Klamath–Tule Lake Basin also has a history of pesticide use and contaminant problems (Godsil and Johnson 1968), including

die-offs of fish-eating birds associated with organochlorine pesticides (Keith 1966, Boellstorff et al. 1985), which are extremely persistent in the environment (Fleming and Cromartie 1981, Stickel et al. 1984). An estimated 80% of the waterfowl in the Pacific Flyway stage or winter in the Klamath Basin (USFWS, Klamath Basin natl. wildl. refuges, Calif., Oreg.; Klamath Basin Nat. Wildl. Refuge, Tule Lake Calif., unpubl. rep., 16pp. 1980); heavy use of the basin by waterfowl hunters and bald eagles increases the potential for exposure of eagles to Pb shot (Pattee and Hennes 1983). The purpose of this study was to describe diets of bald eagles wintering in the Klamath Basin and determine levels of organochlorine compounds and heavy metals in bald eagles and their prey.

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STUDY AREA

The Klamath Basin was approximately 1,200 m in elevation, and the climate was characterized by wet, moderately cold winters and dry summers with a 3–4-month growing season. Annual precipitation ranged from approximately 40 to 130 cm, most of which fell as snow (or rain at lower elevations) between October and March. Air temperatures at Upper Klamath Lake ranged from −30 to 40 C, with an annual mean of about 9 C (U.S. For. Serv., unpubl. data). Water bodies froze and thawed throughout winter depending upon the severity of the weather.

The Klamath Basin contained approximately 15,000 ha of wetlands, and much of the large expanses of agricultural lands was reclaimed marsh or lake bottom. Over 1,000,000 waterfowl used the wetlands of the basin during autumn and spring migrations, which attracted many bald eagles (Keister et al. 1987). In non-cultivated areas the upland plant communities ranged from a semi-arid shrub steppe with western juniper (*Juniperus occidentalis*), big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus viscidiflorus* and *C. nauseosus*), and grasses, to temperate coniferous forests dominated by ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and white fir (*Abies concolor*). Keister and Anthony (1983) provided a detailed description of the study area.

METHODS

We estimated ages of bald eagles by examining plumage characteristics (Servheen 1975). Eagles were classified as subadults (hatching yr to maturity) or adults (maturity).

We described diets of bald eagles by observing eagles foraging, examining castings from communal roosts, and identifying remains at foraging perches. We collected regurgitated castings of bald eagles from the bases of perch trees in 4 of the major communal night roosts. Fur and feathers in castings were usually identified to family and were used to estimate the relative importance of avian and mammalian prey. Remains of prey items at perches used for hunting and feeding on Lower Klamath and Tule Lake national wildlife refuges were routinely examined during winter, 1979–82. Prey items were identified at the feeding sites or collected for comparison to reference collections. We identified remains of prey items to species when possible. Fresh prey items were saved for residue analyses; all prey remains were cleared from the perch area to ensure that items would not be reexamined on subsequent visits. The proportion of the eagle diet composed of waterfowl was estimated from the minimum number of individuals of each taxon identified (Mollhagen et al. 1972).

We determined residues of environmental

contaminants in bald eagles by analyses of whole blood from captured eagles and carcasses of bald eagles found dead in the study area. Fresh bald eagle carcasses were shipped on dry ice to the National Wildlife Health Laboratory, Madison, Wisconsin, for autopsies; livers, brains, and whole carcasses were forwarded to PWRC. We collected blood samples from live-trapped eagles using heparinized glass syringes, and stored them in glass vials that had been washed with nitric acid, rinsed with residue grade acetone, and covered with teflon-lined lids (Frenzel 1985). Blood samples were preserved by freezing.

Blood samples and eagle carcasses were analyzed by the Chemistry Section, PWRC. Sample preparation, extraction, and cleanup for organochlorine analysis were conducted as described by Cromartie et al. (1975). Silica gel or silicic acid was used for the separation of pesticides from PCB's as described by Kaiser et al. (1980). After the separation of pesticides from PCB's, all fractions were quantified by electron-capture gas-liquid chromatography (GLC) using a 1.83-m × 4-mm-inside diameter (id) glass column packed with 1.5% SP-2250/1.95% SP-2401 on 100–120 mesh Supelcoport (Supelco, Bellefonte, Pa.). Residues in approximately 10% of the samples were confirmed by GLC mass spectrometry (MS). The lower detectable limits of residues were 0.01 ppm for pesticides and 0.05 ppm for PCB's in blood samples, and 0.05 and 0.25 ppm for pesticides and PCB's, respectively, in other tissues. Atomic absorption was used for analysis of heavy metals. All Hg analyses were as described by Hatch and Ott (1968). Lead and cadmium (Cd) were run as described by Hinderberger et al. (1981) with slight modifications. The lower detectable limits of metals were 0.05, 0.02, and 0.005 ppm for Pb, Hg, and Cd, respectively, in blood samples, and 0.1, 0.02, and 0.1 ppm for Pb, Hg, and Cd, respectively, in other tissues.

Residues of environmental contaminants in prey of eagles were determined by analysis of whole carcass homogenates. We collected prey species from established foraging areas of bald eagles or retrieved them from bald eagles. Collected animals were wrapped in clean aluminum foil and frozen prior to laboratory preparation. A sample for residue analyses consisted of an approximately 115-g portion of a homogenate of pooled individuals of the same species. Voles (*Microtus* spp.) were pooled into groups of 5 individuals/sample prior to grinding; birds and rabbits were pooled into groups of 3 individuals/sample. Specimens were skinned and had gastrointestinal tracts, feet of mammalian species, beak, tips of wings, and the tarsi and feet of bird species removed prior to grinding. Pooled samples were homogenized with a stainless steel blender/grinder.

Hazleton Raltech, Incorporated (Madison, Wis.) analyzed prey samples for organochlorine compounds. Silicic acid separation was used after extraction and florisil cleanup of samples. All fractions were quantified by GLC using a 1.83-m × 4-mm-id glass column. Packing material used for analysis of chlordane isomers was 3% OV-1 (Supelco) on 80–100 mesh Supelcoport. Packing material used for analysis of all other chlorinated insecticides and PCB's was 1.5% Sp 2250/1.95% SP 2401 on 100–120 mesh Supelcoport. Lower detectable limits of residues were 0.1 ppm for toxaphene and PCB's, and 0.01 ppm for other chlorinated insecticides. Residues in 7 samples that had relatively high concentrations of a large number of contaminants were confirmed by GLC/MS; residues of *gamma*-chlordane, dieldrin, oxychlordane, and hexachlorobenzene (HCB) could not be confirmed and are not reported. Percent lipid of wet weight in samples was determined by solvent extraction and is reported to allow conversion of contaminant concentrations to lipid weight basis.

Analytical Bio Chemistry Laboratories, Incorporated (Columbia, Mo.) analyzed prey samples for Pb and Hg. Samples were prepared for metals analysis by refluxing 2–4 g of sample in 10-mL nitric acid for 4 hours. After refluxing, 10 drops of hydrochloric acid were added to the digestate to prevent loss of Hg on the container walls. Samples were analyzed by atomic absorption using a Perkin-Elmer 305B spectrophotometer with an HGA-2100 graphite furnace (Perkin-Elmer, Norwalk, Conn.). Mercury analysis used the cold vapor technique with a lower detectable limit of 0.01 ppm. Samples were analyzed for Pb by flame or graphite furnace, depending on concentration, with a lower detectable limit of 0.1 ppm.

We present all concentrations in ppm on a wet weight basis unless otherwise noted. We transformed residue concentrations to common logarithms prior to calculating means and 95% confidence intervals to correct for skewed distributions. Samples containing no detectable residue were arbitrarily given values of one-half the lower limit of detection to eliminate values

of zero prior to transformation. Means presented for residue data are geometric.

RESULTS

Diets

All of the 211 observations of successful foraging by bald eagles were on avian or mammalian prey, and no foraging attempts on fish were observed during the study. Montane voles (*M. montanus*) were a major component of the diet of wintering eagles and were captured by eagles in agricultural fields that were flooded for rodent control prior to spring planting. This flooding forced voles out of their burrows; we observed gulls (*Larus* spp.), red-tailed and rough-legged hawks (*Buteo jamaicensis* and *B. lagopus*), northern harriers (*Circus cyaneus*), common ravens (*Corvus corax*), great blue herons (*Ardea herodias*), sandhill cranes (*Grus canadensis*), and coyotes (*Canis latrans*) foraging on voles. Bald eagles were the most numerous predator attracted to flooded fields; ≥200 eagles were observed in a 250-ha field at 1 time. Bald eagles usually hunted for voles by perching on the ground near the leading edge of the flooding water and by capturing voles as they emerged from their burrows. Pirating of voles from gulls, ravens, and other eagles was common.

Bald eagles fed almost entirely on waterbirds when voles were not available in flooded fields. Most of the observed foraging on waterfowl by bald eagles was scavenging. Only 9% of the 55 observations of successful foraging on waterfowl was of birds taken alive. Waterfowl deaths caused by avian cholera (Keister et al. 1987) and Pb poisoning (J. L. Hainline, USFWS, pers. commun.) resulted in large numbers of carcasses available to eagles. During late February and early March 1981, large numbers of snow geese (*Chen caerulescens*) congregated in the Klamath Basin, and we recorded 128 observations of bald eagles feeding on cholera-killed snow geese.

We found waterfowl feathers in 68% of the 341 castings collected from bald eagle communal roosts. Fur of montane voles was found in 31% of the castings, and 70% of those castings consisted solely of montane vole fur. The incidence of fur of other mammals was low; black-tailed jack rabbits (*Lepus californicus*) and Nuttall's cottontails (*Sylvilagus nuttallii*) were found in 9.4% of the castings, deer (*Odocoileus hemionus*) in 1.5%, and Belding's ground squirrels (*Spermophilus beldingi*) in 0.9%.

Table 1. Prey items found at bald eagle hunting perches on Lower Klamath and Tule Lake national wildlife refuges, Oregon and California, 1979–82.

Species	No. individuals	% prey items
Birds		
Eared grebe (*Podiceps nigricollis*)	1	0.1
Tundra swan (*Cygnus columbianus*)	8	0.9
Canada goose (*Branta canadensis*)	15	1.6
Greater white-fronted goose (*Anser albifrons*)	35	3.8
Snow goose	69	7.6
Ross' goose (*C. rossii*)	28	3.1
Mallard	231	25.3
Northern pintail	135	14.8
Gadwall (*A. strepera*)	4	0.4
American wigeon	213	23.3
Northern shoveler (*A. clypeata*)	12	1.3
Cinnamon teal (*A. cyanoptera*)	1	0.1
Green-winged teal (*A. crecca*)	7	0.8
Unidentified Anatini	3	0.3
Redhead (*Aythya americana*)	1	0.1
Canvasback (*A. valisineria*)	2	0.2
Lesser scaup (*A. affinis*)	4	0.4
Common goldeneye	3	0.3
Bufflehead (*B. albeola*)	1	0.1
Common merganser (*Mergus merganser*)	5	0.5
Ruddy duck	86	9.4
Ringed-neck pheasant (*Phasianus colchicus*)	2	0.2
American coot (*Fulica americana*)	37	4.1
Killdeer (*Charadrius vociferus*)	1	0.1
California gull	3	0.3
Mammals		
Montane vole	2	0.2
Muskrat (*Ondatra zibethica*)	3	0.3
Reptiles		
Gartersnake (*Thamnophis sirtalis*)	1	0.1
Total	913	100.1

Over 99% of the 913 prey items found at perches were avian (Table 1), and 94% of the prey remains were waterfowl (Anseriformes). Dabbling ducks (Anatini) comprised 66% of the avian prey remains, with mallards (*Anas platyrhynchos*), American wigeon (*A. americana*), and northern pintails (*A. acuta*) being most important. Other duck species were less important, but ruddy ducks (*Oxyura jamaicensis*) comprised >9% of the prey remains. Geese and swans comprised 17% of the identified prey, but

Table 2. Levels ($\bar{x}$, 95% CI) of organochlorines, mercury (Hg), and lead (Pb) (ppm wet wt) in prey species from foraging areas of wintering bald eagles in the Klamath Basin, Oregon and California, 1979–82.

Species	n[b]	$\bar{x}$ % lipid (wet wt)	DDE		PCB's[a]		Hg		Pb	
			$\bar{x}$[c]	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
Snow goose	7	6.3	0.0015[e]	0.006–0.020	nd 0		0.0062	[nd–0.01][d]	1.2207	0.786–1.893
Ross' goose	7	8.8	0.0106	0.007–0.014	nd 0		0.0061	[nd–0.01][d]	1.1727	0.409–3.354
Mallard	7	9.1	0.0276	0.011–0.068	nd 0		0.0094	0.005–0.016	4.7887	1.890–12.13
Northern pintail[f]	7	10.9	0.0597	0.027–0.129	0.0571	[nd–0.121][d]	0.0126	0.008–0.020	0.6437	0.198–2.085
American wigeon	5	8.7	0.0082	[nd–0.02][d]	nd 0		0.0061	[nd–0.01][d]	0.1973	0.031–1.270
Ruddy duck[g]	7	5.8	0.2526	0.036–1.759	0.1244	0.052–0.300	0.0717	0.134–0.148	1.8787	0.439–8.042
Black-tailed jackrabbit	8	2.1	nd 0		nd 0		nd 0		0.1464	0.038–0.559
Montane vole	10	3.6	nd 0		nd 0		0.0074	[nd–0.02][d]	0.7249	0.235–2.225

[a] PCB's resembled Aroclor 1254.
[b] Three animals/sample, except for montane voles (5 animals/sample).
[c] Means are geometric, ½ of lower limit of detectable concentrations used for zeros; nd = no residue detected.
[d] Range presented instead of CI because frequency of occurrence in samples <50%, which produced unreliable variance estimates.
[e] No. samples with detectable concentrations.
[f] One sample also contained 0.02 ppm heptachlor epoxide.
[g] One sample also contained 0.29 ppm DDT. Two samples also contained 0.02 and 0.01 ppm heptachlor epoxide.

Table 3. Mean concentrations of organochlorines, mercury (Hg), and lead (Pb) (ppm wet wt) detected in prey items from bald eagles wintering in the Klamath Basin, Oregon and California, 1979–82.

Species	*n*	$\bar{x}$ wt (g)	% lipid (wet wt)	$\bar{x}$ DDE	$\bar{x}$ Hg	$\bar{x}$ Pb
Snow goose	4	1,074	7.1	nd[a]	0.01	0.48
Greater white-fronted goose[b]	1	1,414	22.4	nd	nd	0.72
Mallard	1	711	7.5	0.02	nd	2.80
Northern pintail	1	463	18.1	nd	0.02	0.26
American wigeon	3	405	13.0	nd	nd	0.26
Common goldeneye[c]	1	382	5.6	0.06	0.05	17.60
Ruddy duck	1	347	6.1	0.04	0.01	0.22

[a] nd = no residue detected.
[b] Sample also contained 0.02 ppm of endrin.
[c] Sample also contained 0.16 ppm PCB's.

were probably underrepresented because of the eagles' inability to carry the carcasses back to perches.

Environmental Contaminants in Prey

Organochlorines were not detected in black-tailed jackrabbits or montane voles (Table 2). Low concentrations of Hg were detected in 40% of the vole samples (Table 2), while Hg was not detected in jackrabbits. Lead was detected in 50% of the jackrabbit samples, and all of the vole samples contained detectable Pb residues.

We found DDE in 80% of the waterfowl samples, but at generally low concentrations (Table 2). Samples from ruddy ducks contained the highest concentrations of DDE, and the only occurrence of 1,1,1-trichloro-2,2-bis(*p*-chlorodiphenyl)ethane (DDT) was in a ruddy duck sample (0.29 ppm). The only other organochlorines detected in waterfowl samples were PCB's and heptachlor epoxide.

Residues in actual prey items taken from bald eagles were also low (Table 3) and comparable to potential prey items. However, detectable levels of Pb were found in all of the prey items, with 1 common goldeneye (*Bucephala clangula*) containing 17.6 ppm.

Mercury was detected at generally low concentrations in 52% of the waterfowl samples (Table 2); however, all of the ruddy duck samples contained detectable residues of Hg and had higher concentrations than other waterfowl. Lead was detected in 95% of the waterfowl samples. The highest concentrations of Pb were found in mallards and ruddy ducks, which were important eagle food items (Table 1). Some high Pb levels (10.6–16.5 ppm) in 12.5% of the waterfowl samples were probably the result of embedded Pb shot fragments in the whole carcass homogenates.

Environmental Contaminants in Bald Eagles

Blood samples of the 21 bald eagles that were captured on the wintering area contained low concentrations of organochlorines (Table 4). No residues of DDT, 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane (DDD), dieldrin, heptachlor

Table 4. Frequency of occurrence and mean concentrations of 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (DDE), polychlorinated biphenyls (PCB's), mercury (Hg), and lead (Pb) (ppm wet wt) in blood of bald eagles wintering in the Klamath Basin, Oregon and California, 1979–82.

	Ad				Subad			
Contaminant	*n*	No. with detectable concentration	$\bar{x}$[a]	95% CI	*n*	No. with detectable concentration	$\bar{x}$[a]	95% CI
DDE	16	15	0.042	0.028–0.064	5	5	0.030	0.007–0.126
PCB's	16	8	0.018	0.009–0.036	5	2	0.014	nd–0.08[b]
Hg	15	15	2.285	1.762–2.964	5	5	2.166	1.586–2.960
Pb	13	4	0.038	nd–0.25[b]	4	3	0.129	0.012–1.360

[a] Means are geometric, ½ of lower limit of detectable concentrations used for zeros.
[b] Range presented instead of CI because frequency of occurrence <50%, which produced unreliable variance estimates; nd = no residue detected.

Table 5. Concentrations (ppm wet wt) of organochlorines and heavy metals detected[a] in tissues of bald eagles found dead in the vicinity of the Klamath Basin wintering area, Oregon and California, 1979–82.

			Contaminant							
Age	Sex	Cause of death	DDE (C[b])	DDD (C)	Dieldrin (C)	Heptachlor epoxide (C)	Oxychlordane (C)	*trans*-nonachlor (C)	*cis*-nonachlor (C)	Toxaphene (C)
Ad	?	Undetermined	0.45	0.06	nd	nd	nd	0.05	nd	0.15
Ad	M	Emaciation	3.8	nd	nd	nd	0.06	0.13	0.05	nd
Ad	M	Undetermined	5.5	0.07	0.12	nd	0.06	nd	nd	nd
Ad	M	Emaciation	8.3	0.15	0.12	0.05	0.14	0.10	nd	nd
Ad	F	Lead poisoning	1.7	nd	nd	nd	nd	nd	nd	nd
Ad	F	Pneumonia	9.0	0.10	0.06	0.08	0.07	0.09	0.06	nd
Ad	F	Drowning	4.8	nd	0.07	0.22	nd	nd	nd	nd
Ad	F	Emaciation	3.8	nd	nd	nd	nd	0.15	nd	nd
Subad	F[c]	Electrocution	3.5	0.15	0.09	nd	0.05	0.23	nd	0.13
Subad	F	Head trauma	0.19	nd	0.11	nd	nd	nd	nd	nd

[a] No residues of DDT or endrin detected; nd = no residue detected; na = not analyzed.
[b] Tissue analyzed: C = carcass, L = liver.
[c] Sample also contained 0.09 ppm *cis*-chlordane.

epoxide, oxychlordane, *cis*-chlordane, *cis*-nonachlor, endrin, toxaphene, HCB, or mirex were detected in any samples. We found DDE in all but 1 of the eagle blood samples, but in fairly low concentrations. Less than half of the blood samples contained detectable residues of PCB's, and the only other organochlorine detected in eagle blood was *trans*-nonachlor (0.01 ppm) in 1 subadult.

Mercury was detected in all of the blood samples from the bald eagles analyzed for heavy metals (Table 4). The 5 subadults contained Hg concentrations very similar to the levels detected in the 15 adults. Residues of Pb in the blood samples were more variable. Lead was detected in 4 of the 13 adults and 3 of the 4 subadults. Concentrations of Pb in the blood of adults ranged as high as 0.25 ppm; subadult blood samples contained Pb residues as high as 0.62 ppm.

The carcasses of 10 bald eagles found in the vicinity of the wintering area contained a wider array of organochlorines than were detected in the blood samples (Tables 4 and 5); however, most of the contaminants were in relatively low concentrations. Concentrations of organochlorines and metals in brains of necropsied eagles were far below those associated with death. The highest concentrations of DDE (24.0 and 17.0 ppm) and PCB's (23.0 and 35.0 ppm) were in brains of the 2 eagles that died of starvation. Mean DDE concentration in whole carcass tissues of the 10 eagles was 2.61 ppm (95% CI = 1.06–6.42), and mean concentration of PCB's was 2.23 ppm (95% CI = 0.80–6.21). All other organochlorines were detected at <0.3 with means <0.05 ppm.

Concentrations of heavy metals in the livers of the necropsied eagles were generally moderate to low (Table 5); however, the liver of an eagle diagnosed as having died of Pb poisoning contained 27.0 ppm of Pb. Mean Pb concentration in 9 livers was 2.09 ppm (95% CI = 0.80–5.47). Cadmium was detected in 2 of the 7 samples analyzed for that metal (0.85 and 0.13 ppm). Mean concentration of Hg in the livers was 1.89 ppm (95% CI = 0.92–3.90).

DISCUSSION

Different types of data may produce biased results when used to determine diets of bald eagles (Hancock 1964, Ofelt 1975, Todd et al. 1982). Diets of bald eagles in this study were determined by using 3 different methods to reduce the biases associated with any single method. Identification of prey remains at perch sites favors bird and mammal parts that decompose slower than fish parts; and only prey items that are carried back to perch sites and not entirely eaten are sampled. Extremely large prey may be eaten at the capture site, and smaller or readily digestible prey remains may not be detected. Sampling casting material to identify prey remains favors prey that require the eagles to ingest substantial amounts of castable material such as fur, feathers, and hard bones. Direct observation of predation is biased towards prey items that are easily identified at a distance or are captured in areas where the eagles are easily observed; i.e., over open water. Sample sizes of direct observation of foraging eagles are also often low.

Table 5. Extended.

Contaminant				
HCB (C)	Mirex (C)	PCB's (C)	Pb (L)	Hg (L)
nd	nd	0.3	2.3	1.4
na	na	8.8	5.4	na
nd	nd	3.8	0.89	2.2
nd	0.05	10.0	2.8	8.0
nd	nd	3.5	27.0	na
0.09	0.07	6.0	0.32	2.9
na	na	1.3	1.5	1.6
nd	nd	3.0	na	na
0.06	0.05	3.0	2.0	1.0
0.05	nd	nd	0.94	0.76

Wintering concentrations of bald eagles are often associated with an abundant food source such as spawning salmonids (Knight and Knight 1983), road-killed jack rabbits (Platt 1976), or waterfowl concentrations (Southern 1964, Griffin et al. 1982, Keister et al. 1987). Concentrations of bald eagles in this study were associated with waterfowl that were subjected to high incidences of avian cholera (Keister et al. 1987); however, the Klamath Basin was unique in that bald eagles also preyed on large numbers of montane voles. The avian prey of eagles wintering in the Klamath Basin was largely dabbling ducks and geese, which were also important prey of resident bald eagles that nested in the Klamath Basin (Frenzel 1985). Scavenging and pirating habits of bald eagles in this study were similar to those reported in other studies (Dunstan and Harper 1975, Ogden 1975, Todd et al. 1982). By scavenging on dead and dying birds, wintering eagles undoubtedly increased the number of hunter-crippled, cholera-sickened, and Pb-poisoned waterfowl in their diet. Mortalities caused by avian cholera have been reported for bald eagles, and Locke et al. (1972) and Rosen (1972) suggested that extensive outbreaks of avian cholera in waterfowl concentrations could pose a threat to bald eagles. However, the number of eagle mortalities due to avian cholera appears low (Stalmaster 1987:145) relative to the incidence of eagles feeding directly on the carcasses of cholera-killed waterfowl.

The low concentrations of organochlorines and Hg in voles and jack rabbits in this study indicate that these prey are not contributing significantly to contamination of wintering bald eagles in the Klamath Basin. Species in terrestrial habitats have a lower potential for bioaccumulation (Saha 1972, Bevenue 1976), and herbivorous small mammals generally accumulate only very low residues of these contaminants (U.S. Dep. Agric. 1969). However, Pb residues in montane voles were comparable to some of the concentrations in waterfowl. These concentrations appear relatively high for tissue-bound as opposed to embedded Pb.

The concentrations of organochlorines and Hg in carcasses of dabbling ducks and geese sampled in our study were generally lower than levels reported in wings of ducks throughout the United States (Heath and Hill 1974, White 1979, Prouty and Bunck 1986). However, concentrations of residues in wings of waterfowl may not be directly comparable to those in whole carcass homogenates. The concentrations of organochlorines and Hg in the dabbling ducks and geese sampled in our study were similar to levels in samples of the same species collected from foraging territories of resident bald eagles in south-central Oregon (Frenzel 1985). Dabbling ducks typically have lower contaminant levels than diving ducks (Dindal and Peterle 1968, Baskett 1975). However, even the highest residue levels in the ruddy ducks in our study were lower than those in western grebes (*Aechmophorus occidentalis*) and California gulls (*Larus californicus*), which were implicated as the dietary source of elevated contaminant levels in resident nesting eagles in the Klamath Basin (Frenzel 1985).

The concentrations of DDE residues detected in the carcasses of eagles found on the wintering area were consistent with the low levels found in the blood samples. The mean DDE concentration in the carcasses of bald eagles in our study was similar to median DDE residues (2.4–3.0 ppm) reported by Reichel et al. (1984) for 293 bald eagles from 32 states from 1978 to 1981. The mean PCB concentration in the carcasses of bald eagles in our study was slightly lower than median PCB concentrations (3.0–5.3 ppm) reported by Reichel et al. (1984).

Mean Pb concentrations in waterfowl tissues in our study were fairly low and should not represent a major threat to the health of bald eagles. However, the extreme levels of Pb detected in some of the waterfowl sampled indicate the presence of embedded Pb shot. Lead shot poses the greatest threat to bald eagles wintering in the Klamath Basin, as repeated expo-

sure to embedded shot in waterfowl is a major source of Pb poisoning in bald eagles (Pattee and Hennes 1983). The presence of embedded shot and Pb poisoning in waterfowl is extensive (Stout and Cornwell 1976, Griffin et al. 1982), and Pb shot has been found in >50% of bald eagle castings from some wintering areas (Dunstan 1974, Platt 1976). Pattee et al. (1981) reported that 5 of 6 bald eagles experimentally force fed 10–156 Pb shot died in 10–133 days, while the sixth went blind. Besides embedded Pb, waterfowl may carry numerous Pb shot in their gastrointestinal tract (Pattee and Hennes 1983), and eagles that consume the gizzard of avian prey may ingest numerous Pb shot in 1 feeding. Fortunately, eagles usually reduce the amount of time that Pb shot stays in their digestive systems by casting most Pb shot along with other indigestible matter; otherwise the effect on bald eagle populations would be more severe. The use of steel shot instead of Pb shot for waterfowl hunting should also decrease the incidence of ingestion of Pb shot by bald eagles.

The bald eagles wintering in the Klamath Basin are undoubtedly being exposed to Pb shot through the waterfowl in their diet. One of the 10 eagles found dead during our study died of Pb poisoning, and ≥3 other bald eagle deaths from Pb poisoning in the vicinity of the Klamath Basin from 1975 to 1982 have been identified (USFWS 1986). Past exposure of captured bald eagles to Pb was evident from elevated levels of Pb in blood samples, especially those of subadults. The occurrence of Pb residues in the blood samples of adult eagles was 31%; however the biologically incorporated Pb in the eagles' prey would not be expected to markedly elevate levels in the eagle blood (Pattee and Hennes 1983). Eagles with high Pb contamination may be difficult to sample because they probably die in a fairly short period of time.

Mercury residues in blood samples of bald eagles in our study were high compared to levels in experimental mallards. Heinz (1980) reported that dietary Hg of approximately 0.5 ppm in dry food resulted in blood residues of about 0.5–0.6 ppm (wet wt). Mercury residues in blood of wintering bald eagles in our study were comparable to residues in resident adult eagles in south-central Oregon (Frenzel 1985). However, the prey species analyzed contained relatively low Hg concentrations. Bald eagles may have different physiological responses to Hg than other species that have been studied (Spann et al. 1972, Vermeer et al. 1973). Blood samples from 5 bald eagles that had been held in captivity from 1 to 13 years at PWRC contained from 0.17 to 0.31 ppm Hg, which were higher background levels than in control ducks at the Research Center (S. N. Wiemeyer, PWRC, pers. commun.). However, these blood residues were considerably lower than the blood Hg in eagles from our study.

The wintering eagles in the Klamath Basin do not appear to nest in Oregon. Resident eagles in south-central Oregon usually remain in the vicinity of their nesting territories despite their proximity to the wintering concentration (Frenzel 1985). Eagles nesting in other regions in Oregon are often engaged in nesting activities during early February (Isaacs et al. 1983) when large numbers of eagles are still wintering in the Klamath Basin (Keister et al. 1987). The data from banding recoveries and radio telemetry are scant, but preliminary evidence indicates that the source of some of the wintering eagles is far north, including portions of British Columbia and the Northwest Territories (Young 1983).

The bald eagles sampled from the Klamath Basin wintering area did not have elevated levels of organochlorines that would be associated with reproductive problems. This is probably a function of the wintering eagles' diet of waterfowl and montane voles and the low levels of organochlorines in these prey. In contrast, the levels of organochlorines in blood and eggs of resident bald eagles in the Klamath Basin (Frenzel 1985) were high and had a direct impact on reproductive success of some nesting pairs. The bald eagles that only winter in the Klamath Basin apparently nest in areas that have a relatively clean prey base or any contaminated prey species in the areas are of low dietary importance.

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