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Food habits and levels of organochlorine compounds, lead, and mercury in resident and wintering bald eagles were studied in southcentral Oregon and California, 1979-83. Food habits were assessed by examination of castings from winter communal roosts, identification of 2938 prey items found at nest sites and foraging areas, and observations of 16 eagles with radios. Contaminant residues in prey were determined by analyses of 290 pooled samples of potential prey. Contaminant residues in eagles were determined by analyses of 13 addled eggs, blood samples from 24 adults, 8 sub-adults, and 82 nestlings, and carcasses of 11 eagles. Non-resident eagles concentrated in the southern Klamath Basin during winter months and fed largely on microtine rodents and cholera-killed dabbling ducks and geese. Contaminant residues in samples of prey from the wintering area were low with the possible exception of lead shot in waterfowl, which presented a potential for lead poisoning in eagles. Wintering bald eagles did not have elevated body burdens of organochlorines which have been associated with reproductive problems. Diets of resident eagles in southcentral Oregon were highly diverse, changed seasonally, and differed markedly by geographic region.

Eagles fed largely on fish during summer months with the importance of ducks and fish-eating birds increasing during the fall and late winter. Most prey of resident eagles were taken live or pirated from osprey; scavenging comprised less than 20% of the observed predation. Contamination of the majority of the prey of resident bald eagles was fairly low. However, DDE, PCBs, and mercury were consistently detected at moderate levels and indicated biomagnification in the food-chain. Fish-eating birds in the eagles' diets were apparently the source of elevated environmental contaminants in the eagles on Upper Klamath Lake. Concentrations of DDE in eagle blood and eggs indicated that reproductive success of specific nest sites in the Klamath Basin was reduced. Although contamination was not at levels associated with critical population declines, its effects should not be discounted considering the number and severity of other factors impinging on eagle populations.

ENVIRONMENTAL CONTAMINANTS AND ECOLOGY OF BALD EAGLES IN SOUTHCENTRAL OREGON

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ENVIRONMENTAL CONTAMINANTS AND ECOLOGY OF BALD EAGLES IN SOUTHCENTRAL OREGON

FOOD HABITS, ENVIRONMENTAL CONTAMINANTS, AND PRODUCTIVITY OF BALD EAGLES NESTING IN SOUTHCENTRAL OREGON

ABSTRACT

Food habits, levels of organochlorine compounds and heavy metals, and productivity of bald eagles were studied from 1979 to 1983 in three nesting areas in southcentral Oregon. Food habits were assessed by examination of 2025 prey items found at nest sites and observations of 16 eagles (10 adults, 2 sub-adults, and 4 nestlings) equipped with radio transmitters. Levels of environmental contaminants in the prey bases were determined by residue analyses of 232 pooled samples of potential prey items. Concentrations of environmental contaminants in bald eagles were determined by residue analyses of the contents of 13 addled eggs and blood samples from 8 adults, 3 sub-adults, and 82 nestlings. Diets of eagles changed seasonally and differed markedly by geographic region. On Upper Klamath Lake fish comprised 62% of the observed prey items during the nesting season (March-June) and 69% during the post-breeding season (July-September); avian prey (62%) became the major component of the diet from October through February. In the Cascade Lakes, fish were of greater dietary importance; all of the 88 observed prey items taken during the nesting and post-breeding season were fish. The majority of prey items were taken live; scavenging comprised less than 20% of the observed predation, although 28% of the successful foraging observed in the Cascade Lakes was pirating fish from osprey. The composite diet of bald eagles nesting

in southcentral Oregon was highly diverse; remains of 16 species of fish, 46 species of birds, 20 species of mammals, and 2 invertebrate species were identified at nest sites. The important fish in the diet on Upper Klamath Lake were chubs and suckers. Fish prey remains in the outer Klamath Basin were largely bullheads, suckers, centrarchids, and chubs. Mountain whitefish alone comprised 38% of the fish prey items in the High Cascade Lakes, and five species of trout comprised 38%. Eared, horned, and western grebes were the important avian prey species on Upper Klamath Lake, as were ruddy ducks and dabbling ducks, and to a lesser degree coots and divers. The pattern was similar in the Cascades; however, the relative importance of coots appeared higher, and the importance of ruddy ducks much lower. In the Klamath Basin, coots alone comprised over 33% and dabblers 34% of the avian prey items.

Samples of most prey species from Upper Klamath Lake contained higher residues of organochlorines than samples from the Cascade Lakes. The contamination of the majority of the prey base of the bald eagles in southcentral Oregon was fairly low for most of the organochlorine compounds and heavy metals analyzed. However, PCBs were obviously present in the system, and DDE and mercury were consistently detected at moderate levels, showing definite biomagnification in the food chain. Concentrations of DDE in the western grebes and California gulls from Upper Klamath Lake, and eared grebes, western grebes, and ring-billed gulls from the Cascade Lakes, were comparable to levels in prey items of osprey populations that have had reproductive failures and dietary concentrations which have caused significant shell-thinning in eggs of kestels. Fish-eating birds in the eagles' diets were apparently the source of elevated concentrations of environmental contaminants in the eagles on Upper Klamath Lake. Lead as embedded shot also posed a potential hazard in the Klamath Basin because of large numbers of wintering waterfowl, heavy hunting pressure by humans, and the high incidence of these species in the diets of the bald eagles.

The occurrence of DDE, PCBs, and mercury in blood samples from the bald eagles confirms low level contamination of the prey base. Levels of environmental contaminants in nestlings from the outer Klamath Basin and Upper Klamath Lake were higher than in nestlings from the Cascade Lakes. Higher residues of organochlorines in the blood of adults from Upper Klamath Lake compared with Cascade Lake adults reflected the higher contamination of their prey base and greater accumulation due to the greater incidence of birds in their diet. The degree of eggshell thinning (8%) was not indicative of complete reproductive failure, but indicated contamination of individual females. Nest sites with the greatest shell thinning were located on Upper Klamath Lake, consistent with the data on diets and residues in the prey base and blood samples. Six intact eggs from Upper Klamath Lake and outer Klamath Basin contained the widest array and highest concentrations of organochlorine compounds detected. DDE concentrations ranged from 6.3 to as high as 20.0 ppm, and DDD was detected in all but one of the eggs. Concentrations of the other organochlorines were fairly low, but exposure was evident.

Annual productivity of bald eagles fluctuated markedly from 1978 to 1983 in the three breeding areas; nesting success for the southcentral Oregon population ranged from a low of 49% in 1982 to as high as 76% in 1978. Yearly changes in breeding success were fairly consistent from area to area, indicating that a common factor, such as widespread inclement weather may have an overall influence on breeding success. Productivity of the bald eagles in this study compared favorably with values reported from other populations that were fairing well. Concentrations of DDE in intact eggs and blood provide strong evidence that the reproductive success of specific nest sites in the outer Klamath Basin and on Upper Klamath Lake was reduced. The total effect of the contamination is depression of productivity of the areas and recurrent reproductive failure of some nesting pairs. Although environmental contaminants in the area are not at levels associated with critical population declines in other bald eagle populations, their effects should not be discounted, especially considering the number and severity of other factors impinging on reproductive success in southcentral Oregon.

INTRODUCTION

Major declines in many populations of bald eagles (Haliaeetus leucocephalus) from 1950 to 1975 (Broley 1958, Sprunt and Ligas 1966, Abbott 1967) 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 and Wildlife Service 1979). Many of the declines have been associated with environmental contaminants, either from circumstantial evidence or from examining eggs (Stickel et al. 1966, Krantz et al. 1970, Postupalsky 1971, Wiemeyer et al. 1972, Sprunt et al. 1973, Wiemeyer et al. 1984a), however, the exact relationship has been difficult to isolate (Grier 1974). Residue levels in autopsied eagles have also been reported periodically (Reichel et al. 1969a, 1969b, Mulhern et al. 1970, Belisle et al. 1972, Cromartie et al. 1975, Prouty et al. 1977, Kaiser et al. 1980), but few studies have evaluated pollutants specifically in the prey of bald eagles (Wiemeyer et al. 1978).

Declines in raptor populations caused by environmental contaminants have largely been attributed to lowered rates of reproduction rather than direct mortalities (Henny 1972) and have been associated with eggshell thinning induced by the DDT-metabolite, DDE (Newton 1979, p. 239). DDE has been shown to cause thinning of eggshells experimentally in raptors and other birds (Porter and Wiemeyer 1969, Bitman et al. 1969, Wiemeyer and Porter 1970, Longcore and Sampson 1973), and has been linked to significant shell thinning in wild populations of bald eagles (Hickey and Anderson 1968, Krantz et al. 1970, Anderson and Hickey 1972, Wiemeyer et al. 1972, Grier 1974). Wiemeyer et al. (1984a) found significant correlations between DDE residues in bald eagle eggs, shell thinning, and decreased reproductive success at individual nest sites. DDT use in North America peaked around 1959 and dropped to nearly zero in 1973 following its ban in the United States in 1972 (Newton 1979, p. 251). Most bald eagle populations stopped declining by 1975 (Hammerstrom et al. 1975), and reproduction has since improved (Postupalsky 1978, Grier 1982).

The state of Oregon supports a substantial population of bald eagles, with over 147 nesting territories (over 300 nests). Approximately 70% of the breeding sites are in two regions in southcentral Oregon: 70 nest territories in the Klamath Basin, and 32 territories in the Cascade Lakes (Isaacs et al. 1983). Productivity of a portion of the Klamath Basin population, which was monitored from 1971 to 1977, fluctuated markedly, showing a possible downward trend (R.J. Anderson, unpublished data). Isaacs et al. (1983) reported that productivity values for the entire state of Oregon during 1978-82 appeared to be within the range reported for stable populations, but there was a downward trend in annual success rates and number of young produced per occupied site. In contrast to other bald eagle populations and other raptor populations (Nagy 1977, Henny 1977, Spitzer et al. 1978), the productivity of bald eagles in Oregon has not increased with the general improvement of the environment (Haseltine et al. 1981, Ohlendorf 1981).

Considering the history of pesticide use in the Klamath-Tule Lake Basin of southern Oregon and northern California and its past contaminant problems (Pillmore 1961, Godsil and Johnson 1968), environmental contaminants may be affecting productivity of bald eagles in the area. Geothermal development, sewage outflows and lumber mills along the Klamath River increase the potential for heavy metal and other environmental contamination. High concentrations of endrin have been found in the aquatic biota and particularly in fish and fish-eating birds (Federal Water Quality Administration 1970). Die-offs of white pelicans (Pelicanus erythrorhynchos) have been associated with endrin pollution in the Klamath Basin (D.J. Lenhart, pers. comm.) and between 1960 and 1962 an unusual mortality of over 1,100 birds of ten fish-eating species occurred as a result of toxaphene poisoning; the bird populations also contained residues of DDT and other organochlorines in concentrations capable of affecting reproduction (Keith 1966). DDE is extremely persistent both in the environment and in the bodies of birds (Longcore and Stendell 1977, Beyer and Gish 1980, Fleming and Cromartie 1981, Stickel et al. 1984). Biomagnification of DDT from food to bald eagles is as high as 4-fold in 120 days, but DDT residues decrease slowly even after a total clean-up of the diet (Stickel et al. 1966, Chura and Stewart 1967).

In view of the threatened and endangered status of the bald eagle, evaluation of factors affecting reproduction and population stability of the species is critical. The objectives of this study were to document the nesting success and productivity of bald eagles throughout southcentral Oregon and determine the levels of organochlorines and heavy metals in the eagles and their prey base.

The study was funded by the Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service and conducted through the Oregon Cooperative Wildlife Research Unit with the U.S. Fish and Wildlife Service, Oregon State University, Oregon Department of Fish and Wildlife, and the Wildlife Management Institute cooperating.

STUDY AREA

The bald eagle nesting territories in southcentral Oregon can be divided into two adjoining physiographic regions: The Klamath Basin and the High Cascade Lakes (Figure 1). In this paper the nesting territories in the Klamath Basin are further divided into two areas: the territories on Upper Klamath Lake and the territories in the outer Basin (The Klamath Basin excluding Upper Klamath Lake).

Upper Klamath Lake, a eutrophic lake with a surface area of over 335 square kilometers, is located in the Klamath Basin at an elevation of about 1200 m. The 45 known bald eagle nesting territories surrounding Upper Klamath Lake and the 25 territories near smaller water bodies, marshes, and rivers scattered throughout the outer Basin are usually located at elevations ranging from 1200 to 1500 m. The climate of the Klamath Basin is characterized by wet, moderately cold winters and dry summers with a fairly short growing season of three to four months; annual precipitation throughout the area ranges from approximately 40 to 130 cm, mostly falling as snow between October and March, or rain at the lower elevations. Air temperatures at Upper Klamath Lake range from -30 to 40° C, with an annual mean of about 9° C (unpublished data, U.S. Forest Service). Water bodies variously freeze and thaw throughout winters depending upon the severity of the weather. The city of Klamath Falls and its adjoining urban areas are located at the south end of Upper Klamath Lake and have a population of about 45,000 people (1980 census); the remainder of the Klamath

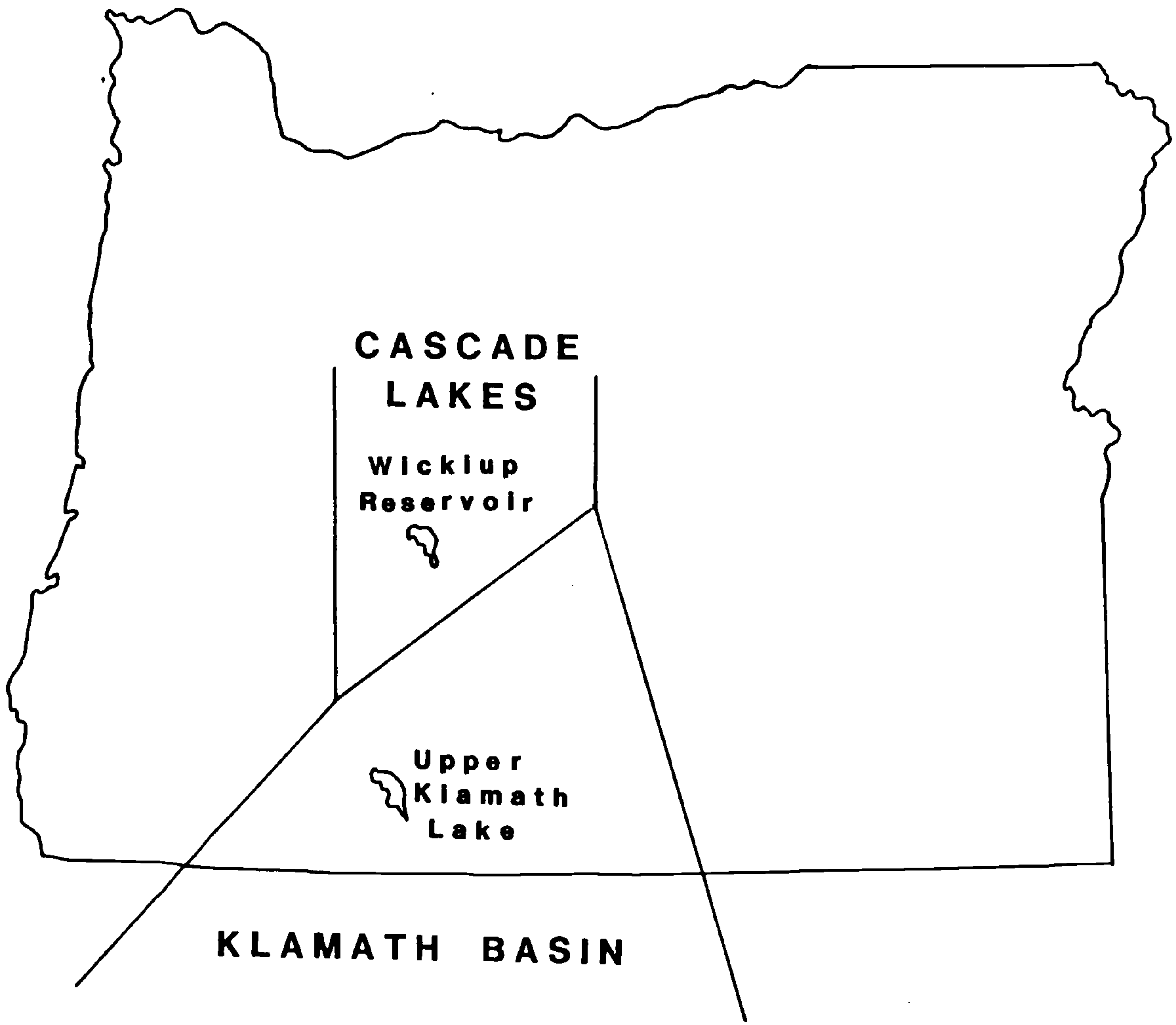

Figure 1. The Cascade Lakes and Klamath Basin study areas in southcentral Oregon.

Basin is generally forested, agricultural, or rangeland, with a population density below 4 persons/km^2.

The 32 known bald eagle nesting territories in the High Cascades region are located in the vicinity of natural mountain lakes, rivers, and three major reservoirs, including seven territories on Wickiup Reservoir which is fed by the Deschutes River. These nest territories are usually at elevations of 1500 to 1700 m, although one active site lies at over 1900 m. The general climate is similar to the forested areas of the Klamath Basin; however, due to the higher elevations, the growing season is generally shorter. Most of the area is covered with snow and the lakes largely frozen over during the winter months. The resident human population of the Cascade Lakes area is low; however, the area is used heavily by recreationists for camping and fishing during the late spring and summer.

The plant communities of southcentral Oregon range 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). Bald eagle nesting territories are associated with mature or over mature stands of timber with nest platforms usually located in dominant, old-aged trees (Anthony et al. 1982).

A wintering population of bald eagles also utilizes portions of the Klamath Basin including Upper Klamath Lake from November to March with peak numbers of over 600 eagles during January and February

(Keister and Anthony 1983). These eagles utilize communal night roosts and feed on large concentrations of waterfowl and waterbirds which winter or stage in the Klamath-Tule Basin.

METHODS

AGE ESTIMATION

Ages of bald eagles were estimated by examination of plumage (Southern 1964, 1967, Servheen 1975). For the purposes of this paper eagles were classified as nestlings (prior to fledging), sub-adults (hatching year to maturity) or adults (maturity). Sub-adults with essentially an adult plumage, but still having some dark feathers in the head and/or tail, were noted as near-adults.

NESTING SUCCESS

Nesting activity and productivity of bald eagles were assessed by aerial and ground surveys from 1978 to 1983 as described by Isaacs et al. (1983). Terminology used in this paper to describe nesting success follows Postupalsky (1974). When possible, nesting territories were surveyed from both fixed-wing aircraft and the ground at least twice each year: once during the early incubation period (mid to late March) to determine activity of nest sites, and later in the same year (late May to early June) to determine nesting success and number of young. From 1979 to 1982 active nests were climbed during the month of June. Nest trees classified as unsuccessful were climbed to assess possible causes of nesting failure; nest trees which contained nestlings were climbed when the young were 8 to 11 weeks old to obtain blood samples and mark them with U.S. Fish and Wildlife Service bands. Nests and the general area surrounding nest trees were searched for prey remains, eggshell fragments, and addled eggs. A sample of fine nesting material was usually collected from nest cups for identification of fish scales.

FOOD HABITS

Diets of the nesting eagles were assessed by examination of prey remains at nests. Prey items were either identified at the nests or collected for comparisons to reference collections. Remains of prey items were identified to species when possible; fish scales were identified at least to taxonomic family (Casteel 1972, 1973). Fresh prey items found in nest cups were recorded and left in the nest cup or collected for residue analyses; all old remains of prey were cleared from the vicinity of the nests to ensure that items would not be re-examined on subsequent visits. Composite diets for the nest sites in each geographic area were estimated by frequency of occurrences of the minimum number of individuals of each taxon identified (Mollhagan et al. 1972). Percentages of a species or group of species in the diets were calculated within taxonomic class.

Food habits were also estimated by direct observation of eagles foraging on Upper Klamath Lake and Wickiup Reservoir. Observations of the eagles were facilitated by placement and monitoring of radio transmitters on a total of 16 bald eagles from May 1979 to April 1982. On Upper Klamath Lake seven adults (two males, five females) and one nestling were equipped with transmitters; on Wickiup Reservoir three adults (two males, one female), two sub-adults, and three nestlings were radioed. Adult and sub-adult eagles were captured using snares on a floating bait over open water (Frenzel and Anthony 1982);

nestlings were radio-tagged during climbing of nest trees. Transmitters weighing approximately 60 g were fitted on the eagles using a backpack type harness. Eagles with transmitters were monitored and observed from a boat or from shore for continuous periods of time during daylight hours, and, when possible, from sunrise to sunset.

CONTAMINANT ANALYSES

Levels of environmental contaminants of bald eagles were determined by residue analyses of samples of whole blood from nestlings and captured adult and sub-adult eagles, contents of addled eggs, 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 Lab in Madison, Wisconsin, for autopsies; liver, brain, and whole carcass tissues were forwarded to Patuxent Wildlife Research Center (P.W.R.C.). Blood samples were collected using heparinized glass syringes which were washed and rinsed three times with residue grade acetone. The 6 to 12 cc samples were stored in glass vials which had been washed with nitric acid and rinsed with residue grade acetone and covered with teflon lined lids. Blood samples were frozen and stored 8 to 24 months prior to residue analyses. Intact eggs were wrapped in clean foil and refrigerated.

Blood samples, eggs, and eagle carcasses were analyzed by the P.W.R.C. Chemistry Section. Sample preparation, extraction, and Florisil cleanup for organochlorine analysis were as described by Cromartie et al. (1975). For the blood samples, special precautions were taken in rinsing glassware and procedural blanks were run with every 20th sample since the lower limit of sensitivity for blood was 0.01 ppm for pesticides. Silica gel or silicic acid was used for the separation of pesticides from polychlorinated biphenyl compounds (PCBs) and is described in detail in Kaiser et al. (1980). After the separation of pesticides from PCBs, all fractions were quantified by electron-capture gas-liquid chromatography (GLC) using a 1.83 m x 4 mm id glass column packed with 1.5% SP-2250/1.95% SP-2401 on 100/120 mesh Supelcoport. Residues in approximately 10% of the samples were confirmed by gas-liquid chromatography/mass spectrometry (GLC/MS). The lower limits of reportable residues were 0.01 ppm for pesticides and 0.05 ppm for PCBs for blood samples and 0.05 ppm for pesticides and 0.25 ppm for PCBs for all other samples. Residues were corrected for procedural blank background for blood samples only.

Atomic absorption was used for analysis of heavy metals. All mercury analyses were as described by Monk (1961) and Hatch and Ott (1968). Lead and cadmium were run as described by Haseltine et al. (1981) or Hinderberger et al. (1981) with slight modifications. Egg volume and thickness measurements followed Stickel et al. (1973) and Krantz et al. (1970); residue concentrations in eggs were calculated as μg/ml on the basis of total egg volume and converted to ppm assuming a specific gravity of 1.0 (Stickel et al. 1966). Thinning of egg shells was calculated as percent deviation from mean shell thickness of bald eagle eggs from the region prior to 1946.

Levels of environmental contaminants in the prey base of the eagles were determined by residue analysis of whole carcass homogenates of prey species. Prey species were collected during 1979 to 1982 from established foraging areas of bald eagles in the Cascade Lakes and on Upper Klamath Lake. Actual prey items of bald eagles were also retrieved when possible. Fish species were collected using gill nets or trap nets; birds and mammals were collected using a shotgun with steel shot or occasionally a .22 rifle using copperclad solid point bullets which would pass through the animals intact. Collected animals were wrapped in clean foil and frozen prior to lab preparation. A sample for residue analyses consisted of an approximately 115 g portion of a homogenate of pooled individuals of the same species. Fish species were pooled into groups of five intact individuals per sample prior to grinding. Bird and mammal species were skinned and had gastrointestinal tracts removed prior to being pooled into groups of three individuals, usually of the same age and sex. All accessible fat was removed from skins and included in pooled samples. The feet of mammalian species, and beak, tips of wings, and the tarsi and feet of bird species were removed prior to grinding. Pooled samples were homogenized using a large blender/grinder with blades and container made of stainless steel with teflon washers. Actual eagle kills were not pooled but were prepared separately. Samples were stored in chemically cleaned vials with teflon lids and frozen prior to residue analyses.

Prey samples were analyzed for residues of organochlorine compounds by Hazelton Raltech, Inc., Madison, Wisconsin, by gas chromatography. Residues in seven samples which had relatively high concentrations of a large number of contaminants were confirmed by

GLC-MS; residues of gamma-chlordane, dieldrin, oxychlordane, and HCB could not be confirmed and therefore are not reported. Percent lipid of samples was calculated by solvent extraction. Prey samples were analyzed for lead and mercury residues by Analytical Bio Chemistry Laboratories, Inc., Columbia, Missouri, by atomic absorption spectrophotometry.

STATISTICAL PROCEDURES

All concentrations in this paper are presented in ppm on a wet-weight basis unless otherwise noted. Residue concentrations were transformed to common logarithms prior to statistical procedures to correct for skewed distributions; values below detection limits were arbitrarily given values of 1/2 the lower limit of detection prior to transformation. Means presented for residue data are geometric. Two way analysis of variance (ANOVA) (Kim and Kohout 1975) was used to determine significant differences between age and area for residues in blood of adult and nestling eagles on Upper Klamath Lake and the Cascade Lakes. Other differences in residue concentrations were compared using one way ANOVA; Sheffe's test was used to separate means if ANOVA showed significant differences (Kim and Kóhout 1975). Differences in frequencies of occurrences were tested using a chi-square test for proportions (Dixon and Massey 1969, p. 249). A Bonferroni technique (Snedecor and Cochran 1980, p. 116) was used to adjust significance levels for multiple comparisons between areas. All statistical hypotheses were tested at the 0.05 level of significance; P values are presented where appropriate.

RESULTS

FOOD HABITS

Direct observations of the bald eagles foraging on Upper Klamath Lake provided the most reliable estimate of the general composition of the diet throughout the year (Figure 2), as identification of prey remains at nests favors bird and mammal parts which decompose slower than fish (Hancock 1964, Ofelt 1975, Dunstan and Harper 1975, Todd et al. 1982). Bald eagles were year-round residents, but remains of prey at nests give no indication of the diet outside of the breeding season.

Fish were most frequently preyed upon on Upper Klamath Lake during the spring and summer months, comprising 62% of the diet during the breeding season (March through June) and increasing slightly to 69% during the post-breeding season (July through September). Compared to the summer months, avian prey were of greater dietary importance in the early spring when nesting waterbirds were arriving in the area and wintering waterfowl were still present. The incidence of mammals as prey items was low, though it increased in the summer with an increase in Belding's ground squirrel (Spermophilus beldingi) activity. Ground squirrels were important in the diet of eagles at a few sites in the vicinity of colonies, especially during the eagles' fledging period. Birds became the major component of the diet of the eagles on Upper Klamath Lake during the fall and winter, comprising over 82% of the observed prey taken from October through February.

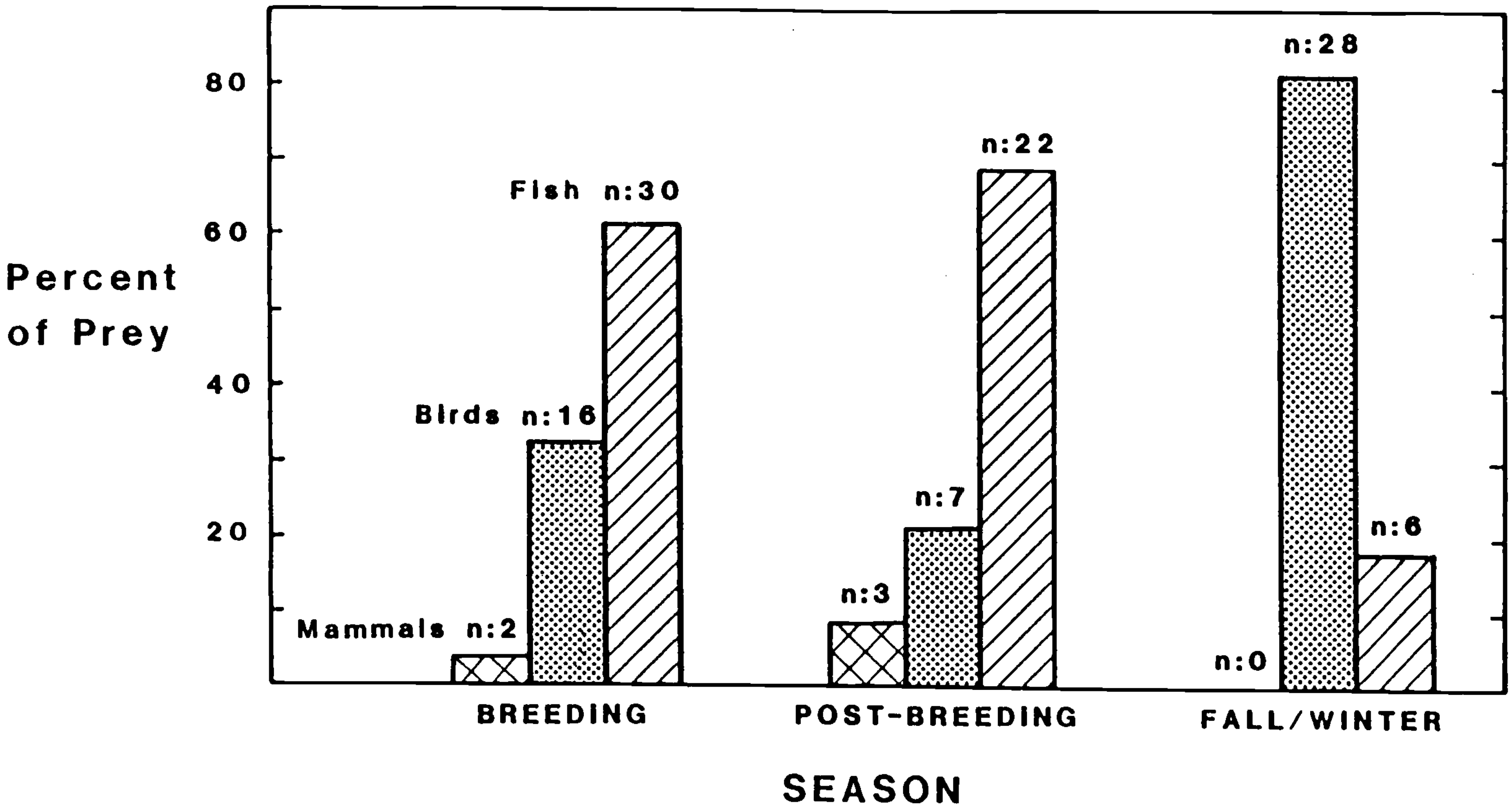

Figure 2. Prey observed taken by adult eagles on Upper Klamath Lake, southern Oregon, 1979-81 (n = number of observations).

Observations of foraging eagles on Wickiup Reservoir indicate a higher importance of fish in their diet during spring and summer than eagles on Upper Klamath Lake. Virtually 100% of the 88 observed prey items taken on Wickiup Reservoir were fish. However, the observations may be biased towards fish as 26% of the remains at the three nests of eagles equipped with transmitters were birds and 45% of the prey remains from the other four active nest sites on the reservoir were birds. The majority of observations of foraging were of the eagles with transmitters, which may have had a higher incidence of fish in their diet.

The majority of prey items of adults were taken live on the wing on both Upper Klamath Lake and Wickiup Reservoir (Figure 3). Seventy-seven percent of the observed prey on Upper Klamath Lake were taken live. However, scavenging as a foraging method by adults on Upper Klamath Lake occurred in all seasons; 20% of the observed avian prey were scavenged, generally old kills on the ice during the winter or apparently diseased birds floating in the water during spring and summer, while less than 12% of the predation on fish was by scavenging. The incidence of pirating (kleptoparasitism) by bald eagles on Upper Klamath Lake was low, generally involving theft of scavenged birds from river otters (*Lutra canadensis*) during the winter or stealing scavenged fish from gulls during spring and summer.

The incidence of scavenging fish by adults on Wickiup Reservoir was similar to that on Upper Klamath Lake; however, pirating comprised nearly 28% of the successful predation observed (Figure 3). A large

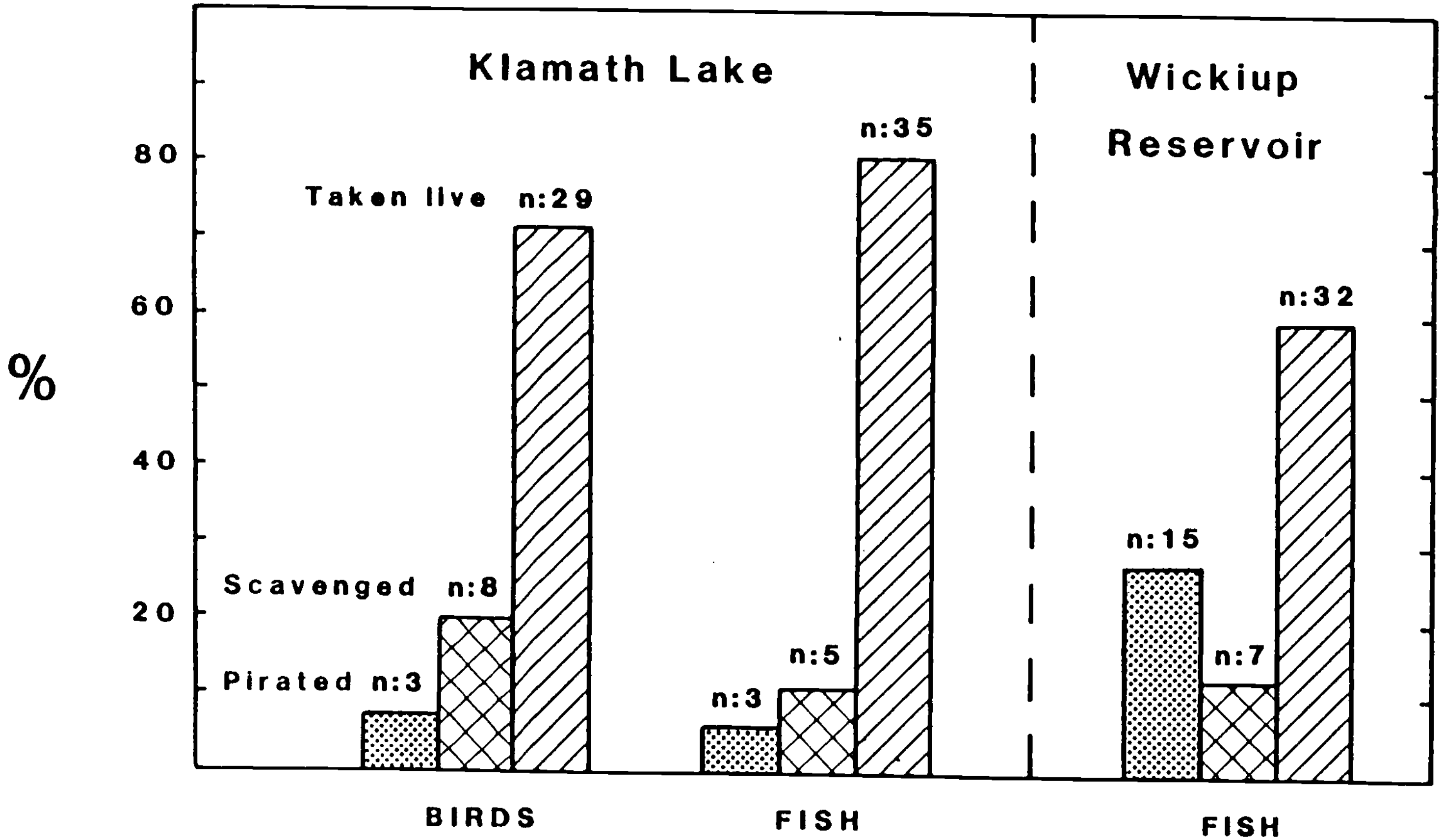

Figure 3. Observed method of predation by adult bald eagles on Upper Klamath Lake and Wickiup Reservoir, southcentral Oregon, 1979-81 (n = number of observations).

number of osprey (Pandion haliaetus) forage on Wickiup Reservoir and all of the pirating by eagles was theft of fish caught by osprey. Taking fish live and pirating from osprey appear to be fairly high skill methods of predation. Sub-adult eagles were less successful than adults; of the 14 successful foraging attempts by sub-adults observed on Wickiup Reservoir 11 were scavenged, 2 were pirated and 1 was taken live.

Upper Klamath Lake, the outer Klamath Basin, and the Cascade Lakes all have diffèrent prey abundance and foraging opportunities as reflected by the identification of 2025 prey remains from eagle nest sites, from 1979 to 1983 (Table 1, Appendix 1). The tendency of this method to underestimate the importance of fish in the diet, compared to direct observations (Todd et al. 1982), is illustrated by comparison of the results of the two methodologies for Upper Klamath Lake (Figure 2, Table 1). Over 62% of the observed prey taken during the breeding season were fish, yet fish comprised only 25% of the food items found at the nests on Upper Klamath Lake. However, the remains of prey items at nest sites are a fairly good indicator of the species composition of the eagles' diet within taxonomic classes (i.e. mammals, birds, fish) during the breeding season, and can give a general indication of the relative importance of prey in each geographic area.

Fish comprised 36% and birds 55% of the food items collected from nest sites in the Cascade Lakes region, indicating the relatively greater importance of fish in the diet compared to the other areas (Table 1). The results of determining the diet by direct observation

Table 1. Classification of prey items found at bald eagle nests from three breeding areas in southcentral Oregon, 1979-83.

Classification	Upper Klamath Lake[a] Number of individuals	Upper Klamath Lake[a] Percent of class	Outer Klamath Basin[b] Number of individuals	Outer Klamath Basin[b] Percent of class	Cascade Lakes[c] Number of individuals	Cascade Lakes[c] Percent of class
FISH						
Mountain whitefish: (Prosopium williamsoni)	--	--	2	1.1	43	38.4
Trout: Salmo (5 spp.)	16	6.2	10	5.3	42	37.5
Tui and Blue Chub (Gila bicolor and G. coerulea)	126	49.0	8	4.3	24	21.4
Suckers: Catostomus and Chasmistes (3 spp.)	78	30.4	22	11.7	3	2.7
Bullheads: (Ictalurus melas and I. nebulosus)	34	13.2	132	70.2	--	--
Sunfish and Perch: Centrarchidae and Percidae (3 spp.)	3	1.2	14	7.4	--	--
Σ Fish:	257	100	188	100	112	100
% of total prey	24.7%		28.0%		35.7%	
BIRDS						
Grebes: Podicipedidae (3 spp.)	159	23.1	40	9.8	33	19.2
Double-crested cormorant: Phalacrocorax auritus	7	1.0	2	0.5	1	0.6
Herons and Bitterns: Ardeidae (3 spp.)	31	4.5	6	1.5	11	6.4
Geese: Anserini (3 spp.)	26	3.8	14	3.4	9	5.2
Dabblers: Anatini (8 species)	125	18.2	139	34.2	32	18.6
Divers: Aythyini (4 spp.)	74	10.8	23	5.7	14	8.1
Bufflehead and Common goldeneye (Bucephala albeola and B. clangula)	29	4.2	6	1.5	3	1.7
Ruddy duck: (Oxyura jamaicensis)	87	12.7	11	2.7	5	2.9
Other waterfowl: Aix and Mergus (2 spp.) and unidentified	22	3.2	8	2.0	9	5.2
American coot: (Fulica americana)	89	13.0	135	31.2	31	18.0
Gulls and Terns: Larus and Sterna (4 spp.)	18	2.6	5	1.2	14	8.2
Small birds: Passeriformes, Colaptes, Phalaropus, and Ceryl (12 spp.)	17	2.5	18	4.4	6	3.5
Owls: Strigiformes (2 spp.)	2	0.2	--	--	--	--
Σ Birds:	687	100	407	100	172	100
% of total prey	66.1%		60.6%	54.8%		
MAMMALS						
Rabbits: Lepus and Sylvilagus (3 spp.)	23	25.0	8	10.7	5	20.8
Yellow bellied marmot: (Marmota flaviventris)	15	16.3	2	2.7	1	4.2
Ground squirrels: Spermophilus (3 spp.)	15	16.3	16	21.3	5	20.8
Tree and flying squirrels: Tamiasciurus and Glaucomys (2 spp)	2	2.2	--	--	1	4.2
Montane vole: (Microtus montanus)	11	12.0	6	8.0	1	4.2
Muskrat: (Ondatra zibethica)	16	17.4	24	32.0	1	4.2
Mule Deer: (Odocoileus hemionus)	5	5.4	7	9.3	7	29.2
Domestic livestock: Bos, Ovis, and Sus (3 spp.)	1	1.1	6	8.0	2	8.3
Other: Erithizon, Mustela, Felis, Canis, Geomyidae (5 spp.), and unidentified	4	4.3	6	8.0	1	4.2
Σ Mammals	92	100	75	100	24	100
% of total prey	8.9%		11.2%	7.6%		
INVERTEBRATES						
Crayfish and clams: Astacus and Corbicula (2 spp.)	4	100	2	100	6	100
Σ All species	1039		672		314	

[a] 27 nest sites sampled, a total of 99 times. [b] 16 nest sites sampled, a total of 44 times. [c] 22 nest sites sampled, a total of 58 times.

are also supported by the relatively greater importance of avian prey on Upper Klamath Lake, where over 66% of the nest items were birds; and avian prey appeared to also have a high dietary importance in the outer Klamath Basin, where birds comprised over 60% of the prey items.

The relative importance in the diet of certain taxa within classes also changes with breeding area. On Upper Klamath Lake tui (Gila bicolor) and blue chub (G. coerulea) comprised 49%, and suckers (Catostomus or Chasmistes) 30% of the total fish remains identified, despite the presence of a naturally breeding rainbow trout (Salmo gairdneri) population. Other studies have reported that fine-boned species such as salmonids are often under-represented in prey remains (Dunstan and Harper 1975, Todd et al. 1982); however, this bias should be partially compensated for by the presence or absence of scales in the samples of nest material. Only 18% of the nests on Upper Klamath Lake contained trout scales, while 95% contained chub scales and 82% contained sucker scales.

In the outer Klamath Basin the frequency of occurrence of different fish species was more equitably distributed, with bullheads (Ictalurus spp.), suckers, centrarchids, and chubs totaling nearly 94% of the fish items from the nest sites. Salmonids were the most important food items in the Cascade Lakes, with mountain whitefish (Prosopium williamsoni) alone comprising 38% and five species of trout comprising over 37% of the fish remains. Tui chub are widely distributed throughout the Cascade Lakes and were a major prey item on Upper Klamath Lake. However, chubs comprised only 21% of the total fish items from the Cascade Lakes, although they were found at 36% of the nests.

Grebes, ducks, and coots (Fulica americana), comprised 85% of the avian prey items at nest sites on Upper Klamath Lake, 89% in the Klamath Basin, and 74% of the birds in the Cascade Lakes. Eared (Podiceps nigricollis), horned (P. auritus) and western grebes (Aechmorphorus occidentalis) were the important avian prey species on Upper Klamath Lake, as were ruddy ducks (Oxyura jamaicensis) and dabbling ducks (Antini), and to a lesser degree coots and diving ducks (Aythyini). The pattern was similar in the Cascades; however, the relative importance of coots appears higher, and the importance of ruddy ducks much lower. In the Klamath Basin, coots alone comprised over 33% and dabblers 34% of the avian prey items; the importance of grebes and divers is considerably less in the outer Klamath Basin compared to the other two nesting areas. Gulls, herons and bitterns (totaling 6% of the avian prey) were consistently present in fair numbers in all areas, but do not appear to be a major dietary component to the eagle populations. Passerines and other small birds were also found among the prey items at nests in all three areas, but totaled only 3% of the avian prey items.

The relatively low importance of mammals in the diet, as determined from actual observations, is supported by a low incidence of mammalian prey at nests. Mammals comprised less than 12% of the total prey items in all areas. Rabbits, ground squirrels, and muskrats (Ondatra zibethica) were the most common mammalian prey. Jack rabbits (Lepus californicus) were present in 14% of the Upper

Klamath Lake nests and 16% of the nests in the outer Klamath Basin. Belding's ground squirrels comprised over 17% of the total mammalian prey in the three areas and were found in 34% of the nests in the Klamath Basin. Muskrats were found in 15% of the Upper Klamath Lake nests, and 27% of the outer Klamath Basin nests, comprising 21% of the total mammalian prey; although, none were found in nests from the Cascade Lakes. There is evidence of some scavenging of deer and livestock in the Cascade Lakes and the outer Klamath Basin. Snowshoe hares (*L. americanus*) and scavenged deer may be of greater dietary importance to eagles in the Cascade Lakes during the winter and early spring, when there is snow cover and much of the water is iced over.

The composite diet of bald eagles nesting in southcentral Oregon was highly diverse, demonstrating the broad prey base of the eagles; 16 species of fish, 46 species of birds, 20 species of mammals and 2 invertebrate species were identified (Appendix 1). At individual nest sites, as many as 22 species of prey were represented. The mean number of prey species represented in successful nests in the outer Klamath Basin and on Upper Klamath Lake was 11.2, and in the Cascade Lakes a mean of 5.9 species was found at successful nests. Some specialization on certain prey items by individuals or pairs of eagles was evidenced by the number of individuals of a prey species found at single nests; examples include: 4 marmots (*Marmota flaviventris*), 7 muskrats, 5 black-crowned night-herons (*Nycticorax nycticorax*), 14 coots, 7 eared grebes, 7 ruddy ducks, 11 rainbow trout, and 54 bullheads. Specialization on certain prey species is probably a result of search image formation and functional response of the eagles to normal changes in seasonal abundance; but, local die-offs of prey can also be a factor.

The bald eagles utilized a broad range of sizes of vertebrate prey. Prey items ranged from 20 g voles to 2.6 kg jack rabbits to Canada geese (*Branta canadensis*) weighing as much as 4.1 kg. The mean weight of five mountain whitefish and a kokanee (*Oncorhynchos nerka*), retrieved after being captured by eagles on Wickiup Reservoir, was 501 g. However, the carcass of a brown trout (*Salmo trutta*), taken live and dragged to shore by an adult male eagle equipped with a transmitter, weighed 2051 g after being fed on by the eagle and his mate for a total of 45 minutes.

RESIDUES IN PREY SPECIES

The mammalian prey species analyzed for environmental contaminants contained very low to non-detectable levels of residues, with the exception of lead in Belding's ground squirrels (Table 2). Lead was detected in all the ground squirrels collected from both Upper Klamath Lake and the Cascade Lakes areas. The presence of high values (i.e. 38.5 and 89.1 ppm) indicates that at least some of the lead was in the form of embedded shot. Only 50% of the jack rabbits contained detectable residues of lead. Mercury was not detected in any of the mammalian samples. DDE was the only organochlorine detected, and then only in low levels in five Belding's ground squirrel samples from the vicinity of Upper Klamath Lake.

Fish species collected from both Upper Klamath Lake and the Cascade Lakes contained a wider array of low level contaminants than

Table 2. Frequency of occurrence and concentrations of DDE and lead in mammals collected from bald eagle foraging areas in southcentral Oregon.

			p,p'-DDE			Lead		
Area and Species	Sample Size[b]	Mean % Lipid of wet weight	Mean[a] ppm wet weight	Range	% of samples with residue	Mean[a] ppm wet weight	95% C.I.	% of samples with residue
Upper Klamath Lake								
Black-tailed jack rabbit	8	2.1	N.D.	-	0	0.146	(0.038-0.559)	50.0
Nuttall's cottontail	1	2.4	N.D.	-	0	N.D.	-	0
Belding's ground squirrel	18	24.1	0.006	(N.D.-0.02)	27.8	2.262[c]	(1.141-4.487)	100
Cascade Lakes								
Belding's ground squirrel	11	28.3	N.D.	-	0	3.216	(1.289-8.027)	100

a Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration of DDE = 0.01 ppm. Detectable concentration of lead = 0.1 ppm. N.D. indicates no residue detected.

b Three animals per sample.

c Two high outliers excluded in computation of mean and 95% C.I.

the mammalian prey (Table 3); most notably, mercury was present in over 90% of the fish samples, while none was detected in the terrestrial mammals. Mercury was detected in all but one fish from the relatively remote Cascade Lakes; however, concentrations of mercury in samples of fish species from Upper Klamath Lake were slightly higher (Table 4). Tui chub was the only species sampled from both areas; the mean concentration of mercury in tui chub from Upper Klamath Lake was significantly greater ($P = 0.012$) than in tui chub from the Cascade Lakes. Lead residues were detected in approximately half of the fish samples; the frequency of occurrence of lead in fish was slightly higher in the Cascades, most notably in mountain whitefish, which had detected lead residues in all eight samples, with a mean of 0.30 ppm.

DDE was the most frequently detected organochlorine in the fish samples (Table 3). DDE was present in 97% of the fish from Upper Klamath Lake, but was detected at a significantly lower frequency of occurrence (24%) in fish samples from the Cascade Lakes ($P < 0.001$). The frequency of occurrence of DDE in tui chub samples from the Cascade Lakes was only 30%, significantly lower ($P < 0.001$) than in the tui chub samples from Upper Klamath Lake, which had DDE detected in all but one sample. The concentrations of DDE were fairly low in tui chubs from both areas, ranging only as high as 0.09 ppm; however, mean concentrations of DDE in tui chubs were twice as high on Upper Klamath Lake as in the Cascades ($P < 0.007$), largely reflecting the difference in frequencies of occurrence. The only other organochlorine detected in fish samples was BHC, detected in low

Table 3. Frequency of occurrence of organochlorines, mercury and lead detected in fish collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample size[b]	Percent of samples with detectable residues[a]				
		p,p'-DDE	Alpha BHC	Gamma BHC	Mercury	Lead
Upper Klamath Lake						
Blue chub	15	100	0	13.3	100	13.3
Tui chub	15	93.3	0	6.7	93.3	40.0
Klamath large-scale sucker	3	100	0	0	100	33.3
Cascade Lakes						
Mountain whitefish	8	25.0	0	0	100	100
Coho salmon	2	50.0	0	0	100	0
Kokanee	5	0	20.0	0	100	60.0
Brook trout	10	30.0	0	0	90.0	50.0
Rainbow trout	10	50.0	0	0	100	80.0
Tui chub	10	30.0	0	20.0	100	40.0

[a] Detectable concentrations of lead, toxaphene and PCBs = 0.1 ppm, dectectable concentrations of all other organochlorines and mercury = 0.01 ppm.

[b] Five fish per sample.

Table 4. Concentrations of organochlorines, mercury and lead detected in fish collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample Size[c]	Mean % lipid of wet weight	Mean[a] ppm wet weight (95% C.I.[b] in parenthesis)		
			p,p'-DDE	Mercury	Lead
<u>Upper Klamath Lake</u>					
Blue chub[d]	15	4.5	0.017 (0.013-0.022)	0.132 (0.110-0.158)	0.064 [N.D.-0.50]
Tui chub[e]	15	5.4	0.015 (0.010-0.023)	0.083 (0.053-0.130)	0.076 [N.D.-0.22]
Klamath large-scale sucker	3	3.5	0.013 [N.D.-0.02]	0.119 [0.05 -0.31]	0.075 [N.D.-0.17]
<u>Cascade Lakes</u>					
Mountain whitefish	8	5.3	0.006 [N.D.-0.01]	0.013 (0.010-0.018)	0.300 (0.197-0.457)
Coho salmon	2	1.6	0.007 [N.D.-0.01]	0.024 [0.02-0.03]	N.D.
Kokanee[f]	5	9.1	N.D.	0.028 (N.D.-0.095)	0.101 (N.D.-0.247)
Brook trout	10	3.6	0.012 [N.D.-0.25]	0.020 (0.013-0.032)	0.103 (N.D.-0.185)
Rainbow trout	10	1.8	0.008 (N.D.-0.011)	0.019 (0.014-0.025)	0.160 (0.085-0.300)
Tui chub[g]	10	4.2	0.007 [N.D.-0.03]	0.039 (0.029-0.053)	0.076 [N.D.-0.23]

[a] Means are geometric, ½ of lower limit of detectable concentrations used for zeros, detectable concentration (ppm) of DDE and mercury = 0.01, detectable concentration of lead = 0.1. N.D. indicates no residues detected in samples.

[b] Ranges are presented in brackets instead of confidence intervals if sample size < 4 or frequency of occurrence in samples < 50%, which produce unreliable variance estimates. N.D. = Below detectable limit.

[c] Five fish per sample.

[d] Two samples also contained 0.01 ppm <u>gamma</u>-BHC.

[e] One sample also contained 0.01 ppm <u>gamma</u>-BHC.

[f] One sample also contained 0.01 ppm <u>alpha</u>-BHC.

[g] Two samples also contained 0.01 and 0.02 ppm <u>gamma</u>-BHC.

levels in both a blue chub and a tui chub sample from Upper Klamath Lake, and in two tui chub samples and a kokanee sample from the Cascade Lakes.

Five mountain whitefish, a kokanee, and a brown trout, that were actual prey items of bald eagles from the Cascade Lakes, had contaminant levels comparable to fish collected from the foraging areas, with the exception of significantly higher ($P < 0.004$) concentrations of mercury in the mountain whitefish retrieved from eagles (mean = 0.026 ppm, 95% C.I. = 0.019 - 0.034) (Appendix 3). Despite its relatively large size, the organochlorines in the 2051 g carcass of the brown trout were not noticeably higher than in fish collected from foraging areas; however, it contained 0.15 ppm mercury, about 7.5 times the mean concentration in the samples of brown trout from the same area.

Mercury was detected in all samples of ducks and coots analyzed from both areas (Table 5); Canada geese, which are typically terrestrial grazers, were the only waterfowl analyzed which did not contain detectable residues of mercury and contained the lowest concentrations of lead (Table 6). The highest concentrations of mercury among the ducks were detected in the lesser scaup (*Aythya affinis*) samples, which were the only Aythyini collected (Table 6). Lead was detected in a majority of the samples of duck species, again with lesser scaup containing the highest concentrations. Coots were the only species of this group collected from both Upper Klamath Lake and the Cascade Lakes that were analyzed for mercury and lead; neither

Table 5. Frequency of occurrence of organochlorines, mercury and lead detected in ducks, coots and geese collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample size for organo-chlorines[b]	Percent of samples with detectable residue levels[a]				Sample size for metals[b]	Mercury	Lead
		p,p'-DDE	PCBs[c]	trans-Nonachlor	alpha-BHC			
Upper Klamath Lake								
Canada goose	3	33.3	0	0	0	2	0	50.0
Mallard	5	100	0	0	0	-	-	-
Gadwall	1	100	0	0	0	-	-	-
Lesser scaup	8	100	75.0	12.5	0	7	100	100
Ruddy duck	2	100	50.0	0	0	2	100	100
American coot	10	100	10.0	0	0	10	100	80.0
Cascade Lakes								
Mallard	11	100	9.1	0	9.1	4	100	100
Goldeneye	1	100	100	0	0	-	-	-
American coot	25	96.0	4.0	0	4.0	18	100	55.6

[a] Detectable concentrations of toxaphene, PCBs and lead = 0.1 ppm, detectable concentrations of all other organochlorines and mercury = 0.01 ppm.

[b] Three birds per sample.

[c] PCBs resembled Aroclor 1254 or Aroclor 1260.

Table 6. Concentrations of organochlorines, mercury and lead detected in ducks, coots and geese collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample size for organo-chlorines[c]	Mean % lipid wet weight	Mean[a] ppm wet weight (95% C.I.) or [range][b]		Sample size for metals[c]	Mean[a] ppm wet weight (95% C.I.) or [range][b]	
			p,p'-DDE	PCBs		Mercury	Lead
Upper Klamath Lake							
Canada goose	3	2.3	0.006 [N.D.-0.01]	N.D.	2	N.D.	0.071 [N.D.-0.1]
Mallard	5	2.8	0.027 (0.007-0.106)	N.D.	-	--	--
Gadwall	1	1.8	0.01	N.D.	-	--	--
Lesser scaup[d]	8	4.0	0.258 (0.108-0.615)	0.285 (0.107-0.756)	7	0.075 (0.055-0.102)	0.959 (0.289-3.183)
Ruddy duck	2	9.6	0.232 [0.15-0.36]	0.126 [N.D.-0.32]	2	0.024 [0.01-0.06]	0.343 [0.21-0.56]
American coot	10	4.0	0.037 (0.024-0.056)	0.054 [N.D.-0.11]	10	0.024 (0.014-0.039)	0.452 (0.119-1.722)
Cascade Lakes							
Mallard[e]	11	5.1	0.041 (0.015-0.113)	0.059 [N.D.-0.32]	4	0.030 (0.014-0.064)	0.451 (0.180-1.128)
Goldeneye	1	4.8	0.08	0.16	-	--	--
American coot[f]	25	9.5	0.029 (0.020-0.041)	0.055 [N.D.-0.56]	18	0.021 (0.017-0.027)	0.169 (0.080-0.355)

[a] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros, detectable concentration of DDE and mercury = 0.01 ppm, detectable concentration of PCBs and lead = 0.1 ppm, PCBs resemble Aroclor 1254 or Aroclor 1260. N.D. = no residue detected.

[b] Ranges are presented instead of confidence interval if sample size < 4 or frequency of occurrence < 50%, which produce unreliable variance estimates.

[c] Three birds per sample

[d] One sample also contained 0.01 ppm trans-nonachlor.

[e] One sample also contained 0.14 ppm alpha-BHC.

[f] One sample also contained 0.18 ppm alpha-BHC.

concentrations nor frequencies of occurrences of heavy metals were significantly different between areas.

DDE was detected in over 98% of the duck and coot samples collected from both areas (Table 5); the highest residues (mean = 0.258 ppm DDE) were present in the lesser scaup samples from Upper Klamath Lake (Table 6). Ruddy ducks, an important avian prey item of bald eagles on Upper Klamath Lake, had DDE residues nearly as high as the scaup, however, the low sample size (n = 2) makes comparison difficult. PCBs were prevalent only in the lesser scaup samples, 75% of which contained detectable residues; with a mean concentration of 0.285 ppm. BHC and nonachlor were the only other organochlorines confirmed in the ducks and coots: 0.01 ppm nonachlor in a lesser scaup sample from Upper Klamath Lake, and 0.14 ppm BHC in a mallard sample and 0.18 ppm BHC in a coot sample from the Cascade Lakes.

Grebes and gulls contained the widest variety and highest concentrations of environmental contaminants of the eagle prey species collected and analyzed (Tables 7, 8 and 9). Mercury was detected in all samples of gulls and grebes from both areas, with slightly higher concentrations in samples from Upper Klamath Lake. Sample size of mercury in western grebes from the Cascade Lakes was too low for valid comparison to the same species on Upper Klamath Lake. California gull (*Larus californicus*) samples from Upper Klamath Lake had concentrations of mercury significantly higher ($P < 0.001$) than ring-billed gull (*Larus delawarensis*) samples from the Cascade Lakes. Western grebes on Upper Klamath Lake had significantly greater residues of mercury than eared grebes from the same area ($P < 0.001$).

Table 7. Frequency of occurrence and concentrations of mercury and lead in grebes and gulls collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample size[a]	Mercury: % of samples with detectable residues	Mercury: Mean[b] ppm wet weight (95% C.I)[c]	Lead: % of samples with detectable residues	Lead: Mean[b] ppm wet weight (95% C.I.)
Upper Klamath Lake					
Eared Grebe	13	100	0.092 (0.059-0.144)	61.5	0.142 (0.079-0.255)
Western Grebe	13	100	0.287 (0.222-0.371)	84.6	1.312[d] (0.307-5.607)[d]
California gull	5	100	0.298 (0.135-0.659)	100	3.067 (1.497-6.284)
Cascade Lakes					
Western grebe	3	100	0.212 [0.18-0.23]	100	6.203 [2.20-31.0]
Ring-billed gull	5	100	0.046 (0.039-0.053)	100	1.591 (0.897-2.820)

[a] Three birds per sample.

[b] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros, detectable concentration of mercury = 0.01 ppm, detectable concentration of lead = 0.1 ppm.

[c] Range is presented in brackets instead of confidence interval if sample size < 4, because of unreliable variance estimates.

[d] One high outlier excluded from computation.

Table 8. Frequency of occurrence of organochlorines detected in grebes and gulls collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample size[b]	Percent of samples with detectable residue concentrations[a]									
		DDE	DDD	DDMU	Heptachlor epoxide	*cis*-Nonachlor	*trans*-Nonachlor	*alpha*-Chlordane	*alpha*-BHC	Endrin	PCBs[c]
Upper Klamath Lake											
Eared grebe	13	92.3	0	0	0	0	0	0	15.4	0	23.1
Western grebe	13	100	100	23.1	7.7	92.3	53.8	15.4	0	0	100
Ring-billed gull	1	100	0	0	100	0	100	0	100	100	100
California gull	5	100	0	0	100	0	100	100	0	0	100
Cascade Lakes											
Eared grebe	7	100	0	0	0	0	0	0	0	0	14.3
Western grebe	5	100	80.0	0	40.0	80.0	80.0	0	0	0	80.0
Ring-billed gull	7	100	0	0	100	0	71.4	0	0	0	100

[a] Three birds per sample.

[b] Detectable concentration of PCBs and toxaphene = 0.1 ppm, detectable concentration of other organochlorines = 0.01 ppm.

[c] PCBs resembled Aroclor 1254 or Aroclor 1260.

Table 9. Concentrations of organochlorines detected in grebes and gulls collected from bald eagle foraging areas in southcentral Oregon.

Area and Species	Sample[a] size	Mean % lipid wet weight	Mean[b] ppm wet weight (95% C.I. in parentheses) [range[c] in brackets]							
			p,p'-DDE	p,p'-DDD	DDMU	Heptachlor-epoxide	cis-Nonachlor	trans-Nonachlor	alpha-Chlordane	PCB's[d]
Upper Klamath Lake										
Eared grebe[e]	13	17.9	0.056 (0.027-0.113)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.067 [N.D.-0.34]
Western grebe	13	12.0	4.150 (2.794-6.164)	0.452 (0.238-0.858)	0.014 [N.D.-1.16]	0.006 [N.D.-0.03]	0.059 (0.031-0.113)	0.024 (0.009-0.069)	0.008 [N.D.-0.28]	3.760 (2.345-6.028)
Ring-billed gull[f]	1	6.7	2.14 --	N.D.	N.D.	0.21 --	N.D.	0.02 --	N.D.	1.37 --
California gull	5	5.5	2.587 (1.978-3.385)	N.D.	N.D.	0.015 (0.009-0.024)	N.D.	0.081 (0.062-0.104)	0.023 (0.011-0.047)	1.839 (1.278-2.647)
Cascade Lakes										
Eared grebe	7	17.7	1.637 (1.039-2.579)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.066 [N.D.-0.34]
Western grebe	5	11.6	2.001 (0.050-80.38)	0.164 (0.012-2.236)	N.D.	0.009 [N.D.-0.03]	0.049 (0.007-0.351)	0.074 (0.008-0.663)	N.D.	1.807 (0.104-31.26)
Ring-billed gull	7	8.4	4.337 (3.168-5.938)	N.D.	N.D.	0.048 (0.027-0.085)	N.D.	0.025 (0.008-0.076)	N.D.	0.628 (0.397-0.994)

[a] Three birds per sample.

[b] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration of toxaphene and PCBs = 0.1 ppm. Detectable concentration of other organochlorines = 0.01 ppm. N.D. = no residue detected.

[c] Range presented instead of confidence interval if sample size < 4 or frequency of occurrence in samples < 50%, which produce unreliable variance estimates.

[d] PCBs resembled Aroclor 1254 or Aroclor 1260.

[e] Two samples also contained 0.01 ppm alpha-BHC.

[f] Sample also contained 0.02 ppm endrin and 0.09 ppm alpha-BHC.

Mercury concentrations in eared grebes from Upper Klamath Lake were not much greater than those in fish samples from that area. However, western grebes from Upper Klamath Lake had a mean mercury concentration 2.6 times that of fish samples from that area, despite those fish being much larger in size than those typically fed on by western grebes. The California gull samples from Upper Klamath Lake also contained approximately 2.8 times the concentrations of mercury in the fish samples. In the Cascade Lakes the ring-billed gull samples had mercury concentrations approximately 2 times the residues in the fish samples from the area, and western grebes contained mercury residues nearly nine-fold the concentrations in the fish species. Lead residues were detected in most of the grebe and gull samples analyzed. Concentrations of lead in the gulls and western grebes were higher than in the fish and other avian prey analyzed. Some extreme levels in some western grebe samples (31 ppm in the Cascades, and 544 ppm on Upper Klamath Lake) indicate that at least some of the lead was in the form of embedded shot.

A wide range of organochlorine compounds, including heptachlor epoxide, nonachlor, chlordane, and BHC, were detected in some of the grebe and gull samples; DDE was the most prevalent, occurring in most samples analyzed (Table 8). PCB concentrations were highest in this group of prey species (Table 9), ranging as high as 15.2 ppm in a western grebe sample; the exceptions are PCB concentrations in eared grebe samples, which were low in both areas. Western grebes contained the broadest spectrum of contaminants. The residues of DDE in western grebe samples from Upper Klamath Lake ranged as high as 14.1 ppm, and their mean was over 240 times the concentrations in fish samples from that area. Similarly, DDE residues in western grebes from the Cascade Lakes were 200 times the concentrations in samples of the area's fish species. The DDT-metabolites, DDD and DDMU, were detected only in western grebe samples; DDD was detected in all the western grebe samples except one from the Cascade Lakes, and DDMU was detected in 23% of the samples from Upper Klamath Lake.

Although mean concentrations of DDE and PCBs in western grebes were higher in samples from Upper Klamath Lake than from the Cascade Lakes, the differences are not significant (DDE: $P = 0.397$; PCBs: $P = 0.312$) because of low sample size and high variability among samples. In contrast, concentrations of DDE in eared grebes were significantly greater ($P < 0.001$) in the Cascade Lakes than in samples from Upper Klamath Lake. Concentrations of DDE in samples of California gulls from Upper Klamath Lake were significantly lower ($P = 0.014$) than residues of DDE in ring-billed gull samples from the Cascade Lakes; mean % lipid of wet weight was 5.5 in the California gull samples, and 8.4 in the ring-billed gulls. However, the one ring-billed gull sample from Upper Klamath Lake had a DDE concentration less than half the mean concentration of ring-billed gulls from the Cascade Lakes, and 30% below the lower 95% confidence limit. Ring-billed gull samples from the Cascade Lakes had DDE concentrations 434 times the residues in the area's fish, and eared grebes from the Cascade Lakes had 164 times the DDE concentrations of fish samples from the area. Samples of California gulls from Upper Klamath Lake had factors of 162 times, and eared grebes only 3.5 times the DDE concentrations of local fish samples. These relatively higher concentrations of DDE in gulls and eared grebes from the Cascade Lakes do not follow the general pattern of higher contamination in samples from the Upper Klamath Lake area.

RESIDUES IN BALD EAGLES

Mercury was detected in all but one sample of blood from nestling bald eagles and at fairly high levels ($\overline{x}$ = 1.22 ppm) considering that the eaglets were only about 9 weeks old when sampled and had little time to accumulate these residues (Table 10). Mercury concentrations were high in the blood samples from all three breeding areas, including the Cascade Lakes. Cadmium was detected in only five of the blood samples of nestlings and was generally in low concentrations. Residues of lead were detected in only 5% of the nestling blood samples, were generally in low concentrations, and ranged as high as 0.22 ppm in one sample from the outer Klamath Basin.

DDE, DDD, and PCBs were the only organochlorine compounds detected in the blood of nestling eagles (Table 11). The concentrations of DDE in the nestling blood samples from Upper Klamath Lake and the outer Klamath Basin were significantly greater than in samples from nestlings from the Cascade Lakes ($P < 0.05$). The frequency of occurrence of DDE in the blood samples was also greater in the outer Klamath Basin and Upper Klamath Lake ($P < 0.001$). DDD was present in relatively low proportions of the nestling blood samples. DDD occurred in a larger percent of the samples from the

Table 10. Frequency of occurrence and concentrations of heavy metals detected in blood of nestling bald eagles from southcentral Oregon.

Area	Mercury			Lead			Cadmium		
	Sample Size	Percent Occurrence	Mean[a] (95% C.I.) (ppm wet weight)	Sample Size	Percent Occurrence	Range (ppm wet weight)	Sample Size	Percent Occurrence	Range (ppm wet weight)
Upper Klamath Lake	29	96.6	1.167 (0.734-1.856)	23	4.4	[N.D.-0.15]	18	11.1	[N.D.-0.11]
Outer Klamath Basin	18	100	1.431 (1.195-1.713)	12	8.3	[N.D.-0.22]	14	0	-
Cascade Lakes	35	100	1.165 (0.974-1.394)	23	4.4	[N.D.-0.052]	24	12.5	[N.D.-0.11]
Total	82	98.8	1.220 (1.047-1.422)	58	5.2	[N.D.-0.22]	56	9.9	[N.D.-0.11]

[a] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. N.D. = No residue detected. Detectable concentration of mercury = 0.02 ppm. Detectable concentration level of lead = 0.05 ppm. Detectable concentration of cadmium = 0.005 in 30 samples and 0.1 ppm in 26 samples. Means of lead and cadmium are below detectable concentrations for all areas.

Table 11. Frequency of occurrence and concentrations of organochlorines detected[a] in blood of nestling bald eagles from southcentral Oregon.

Area	Sample Size	p,p'-DDE		p,p'-DDD		Estimated PCB's[b]	
		Percent Occurrence	Mean[c] ppm wet weight (95% C.I.)	Percent Occurrence	Range[d] [ppm wet weight]	Percent Occurrence	Mean[c] ppm wet weight [range][d]
Upper Klamath Lake[e]	24	79.2	0.023 (0.015-0.036)	8.3	[N.D.-0.040]	12.5	B.D. [N.D.-0.14]
Outer Klamath Basin	17	76.5	0.022 (0.014-0.037)	17.6	[N.D.-0.026]	23.5	0.011 [N.D.-0.29]
Cascade Lakes	34	41.2	0.010 [N.D.-0.07][f]	2.9	[N.D.-0.020]	11.8	B.D. [N.D.-0.14]
Total	75	61.3	0.016 (0.012-0.020)	8.0	[N.D.-0.040]	14.7	B.D. [N.D.-0.29]

[a] No residues of p,p'-DDT, dieldrin, heptachlor epoxide, oxychlordane, cis-chlordane, cis-nonachlor, endrin, toxaphene, HCB, or mirex were detected in any samples.

[b] PCBs = polychlorinated biphenyls.

[c] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration = 0.01 ppm. Mean of DDD was below detectable concentration for all areas. B.D. = mean below detectable concentration.

[d] N.D. = no residue detected.

[e] One sample also contained 0.02 ppm trans-nonachlor.

[f] Range presented because frequency of occurrence <50%.

outer Klamath Basin and Upper Klamath Lake than the Cascade Lakes, although the difference was not statistically significant ($P = 0.07$). PCBs were detected in a fairly low proportion of the nestling blood samples, especially from the Cascade Lakes and Upper Klamath Lake. PCBs were detected in nearly 25% of the nestling blood samples from the Klamath Basin and ranged as high as 0.29 ppm.

Blood samples from eight adult bald eagles contained residues of DDE, PCBs and mercury at concentrations significantly greater than in nestlings ($P = 0.026$). Adult blood contained elevated concentrations of mercury as high as 4.8 ppm, but generally only negligible residues of lead or cadmium (Table 12). Mercury residues were relatively high in all the eagles from both areas. Mercury residues in the three sub-adult blood samples were also elevated, with concentrations much higher than nestlings and comparable to residues in adult blood.

DDE residues in the blood of adults on Upper Klamath Lake were all higher (5.5 times) than the samples from adults from Wickiup Reservoir (Table 12). DDT was not detected in any samples; and DDD was detected in only two blood samples of adults, both from Upper Klamath Lake. The mean concentration of DDE in blood of adults on Upper Klamath Lake was 41 times that of nestlings from that area, and the adults from Wickiup Reservoir had residues in their blood 17 times the mean concentration of DDE in nestling blood from the Cascade Lakes.

PCBs were detected in blood of all adults sampled, but are noticeably higher in samples from Upper Klamath Lake where concentrations ranged from 0.40 to 0.71 ppm, while the highest

Table 12. Concentrations of organochlorines and heavy metals detected[a] in blood of adult and sub-adult bald eagles in southcentral Oregon.

Age/Area	ID Number	Sex	Success History[c]	ppm wet weight[b] p,p'-DDE	p,p'-DDD	*cis*-Chlordane	*trans*-Nonachlor	PCBs	Mercury	Lead	Cadmium
ADULTS											
Upper Klamath Lake	1	Female	N.A.	1.10	0.010	0.018	0.01	0.63	4.80	--	0.10
	231	Male	50.0	1.40	0.029	N.D.	0.016	0.71	1.10	--	0.11
	232	Female	--	0.97	N.D.	N.D.	N.D.	0.55	--	--	--
	244	Female	100	0.68	N.D.	N.D.	N.D.	0.40	3.60	N.D.	N.D.
	514	Female	0	0.77	N.D.	N.D.	0.02	0.48	2.20	0.25	--
Geo. Mean				0.952				0.543	2.543		
95% C.I.				(0.667-1.359)				(0.411-0.718)	(0.911-7.095)		
Wickiup Reservoir	502	Male	66.6	0.08	N.D.	N.D.	N.D.	0.05	3.30	N.D.	N.D.
	503	Male	33.3	0.20	N.D.	N.D.	N.D.	0.06	1.50	N.D.	N.D.
	516	Female	100	0.32	N.D.	N.D.	0.10	0.10	1.80	N.D.	--
Geo. Mean				0.172				0.067	2.073		
SUB-ADULTS											
	243	--	--	0.15	N.D.	N.D.	N.D.	N.D.	--	--	--
	299	--	--	0.06	N.D.	N.D.	N.D.	N.D.	2.80	N.D.	N.D.
	501	--	--	0.20	N.D.	N.D.	N.D.	0.08	3.20	N.D.	N.D.
Geo. Mean				0.122							

[a] No residues of p,p'-DDT, dieldrin, heptachlor epoxide, oxychlordane, *cis*-nonachlor, endrin, toxaphene, HCB, or mirex were detected.

[b] -- = Not analyzed, N.D. = No residue detected. Detectable concentrations (ppm): organochlorines = 0.01; mercury = 0.02, lead = 0.2. Detectable concentration of cadmium for samples 1 and 231 = 0.1 ppm. Detectable concentration of cadmium = 0.005 ppm for remaining samples.

[c] Percent of recent, successive nesting attempts which successfully produced young. -- = No history, N.A. = no attempts.

residue in blood from a Wickiup Reservoir adult was 0.10 ppm. Low concentrations of chlordane or nonachlor were found in blood of three of the Upper Klamath Lake adults, and in one from Wickiup Reservoir.

Concentrations of DDE in blood of the three sub-adults that were sampled were higher than the residues in blood of nestlings, and were comparable to the moderate concentrations found in the blood of adult eagles from Wickiup Reservoir. PCBs were detected only in one sub-adult blood sample (0.08 ppm), from a bird entering a near-adult plumage.

Residues of contaminants in the fresh carcasses of an adult male bald eagle (illegally shot) and a 5-week old nestling, provide some comparisons for interpreting blood residues (Appendix 2). The carcass of the adult contained 34.0 ppm DDE and 28.0 ppm PCBs, and the liver had a concentration of 0.97 ppm of mercury. Residues in the carcass of the nestling were 1.1 ppm DDE and 0.7 ppm PCBs; 1.6 ppm of mercury and 0.67 ppm lead were detected in the liver. The carcass of the adult also contained residues of DDD, dieldrin, heptachlor epoxide, oxychlordane, _cis_-chlordane, _cis_-nonachlor, _trans_-nonachlor, and HCB ranging from 0.15 to 0.75 ppm. The carcasses of five additional adults found in the vicinity of Upper Klamath Lake were too decomposed for residue analysis or detailed necropsy.

CAUSES OF MORTALITY

Shooting was the known or implicated cause of death in 6 of the 8 adult mortalities identified in the vicinity of Upper Klamath Lake during this study; cause of death was unknown in the other 2 eagles. Death of a sub-adult going into its adult plumage was due to electrocution. Two of the eagle mortalities were ascertained by radio tracking or observations without retrieval of carcasses for confirmation. Four nestlings were found dead or moribund at nest sites: one death caused by pneumonia, one from injuries suspected of being sustained during a maiden flight, and two unknown. Eleven mortalities of banded young which dispersed from nest sites were reported: four from electrocution or wire impact, one shooting, one from perforation of the intestinal tract by fish bones, and five unknown.

On Upper Klamath Lake 10 bald eagle territories were monitored regularly due to their occupation by, or proximity to, radioed eagles. During 1979-80 at least five adults from five nest sites were replaced by new adults. Replacement was determined by reoccupation of a nest site at which known mortalities had occurred or the occupation of an established nest site by an eagle in a late sub-adult plumage. All the sites were reoccupied by the following breeding season, but failed to produce young. On two occasions single adult eagles were observed entering occupied nesting territories, apparently soliciting one of the adults, and two pairs of eagles were monitored which did not occupy territories. In 1982, an adult female at an established territory was displaced by another adult prior to the egg laying period. The nest failed to produce young that year, but was successful in 1983.

RESIDUES IN BALD EAGLE EGGS

The contents of 13 addled bald eagle eggs which were intact contained low concentrations of mercury (Table 13). The highest residues of mercury were in the four intact eggs from Upper Klamath Lake ($\overline{x}$ = 0.161 ppm) and one egg from the outer Klamath Basin (0.25 ppm), but these values were fairly low considering the elevated levels of mercury detected in the blood samples. Only one intact egg was collected from the Cascades, and six of the eight eggs from the outer Klamath Basin were from one nest site (Kittridge Ranch), so comparisons between areas were not possible.

The Kittridge Ranch site has never successfully produced young; and no embryo development was detected in any of the six collected eggs. Contaminants in the eggs were quite low with very consistent levels of DDE, PCBs, and mercury. The mean concentration of DDE in the six eggs was 1.58 ppm (range: 1.5-1.7 ppm); mean concentration of PCBs was 0.189 ppm (range: 0.18-0.22 ppm); and mean mercury concentration was 0.040 ppm (range: 0.034-0.054).

The only intact egg from the Cascade Lakes analyzed for contaminants had very low concentrations of organochlorines; only DDE and PCBs were detected. The concentration of DDE was comparable to the low residues in the Kittridge Ranch eggs, and the residues of PCBs, though higher than in the Kittridge Ranch eggs, was considerably lower than in the other eggs from the outer Klamath Basin or from Upper Klamath Lake.

The four intact eggs from Upper Klamath Lake and the Thompson and Drews Reservoirs eggs from the outer Klamath Basin contained the widest array and highest concentrations of organochlorine compounds detected (Table 13). No parent DDT was detected in the eggs, but DDE concentrations ranged from 6.3 to as high as 20.0 ppm ($\overline{x}$ = 9.43), and DDD was detected in all but one of the eggs ($\overline{x}$ = 0.224 ppm). Concentrations of the other organochlorines were fairly low, but exposure to the contaminants was evident. Estimated concentrations of PCBs ranged as high as 12.0 ppm ($\overline{x}$ = 6.54 ppm).

The mean shell thickness of addled eggs (Table 13) and of shell fragments collected at nest sites (Table 14) was 11% thinner than the pre-DDT norm, although these values must be regarded as approximate. Shell thickness was highly variable with thinning apparent in some eggs from all three areas, although the shell thickness of one unhatched egg from the Round Swamp nest in the Cascade Lakes was approximately 10% thicker than the pre-DDT norm. All of the nests which had evidence of shell thinning in the eggs greater than or equal to 20% were located on Upper Klamath Lake. Measurements on shell fragments collected from nests tended to give much lower estimates of shell thickness than measurements from intact or nearly intact eggs. The mean thickness of shell fragments was 17% thinner than the pre-DDT norm while mean shell-thinning in the unhatched eggs was only 9%. The mean of the average percent thinning of unhatched eggs for each nest was 9% (N = 6) on Upper Klamath Lake, 11% (N = 3)

Table 13. Shell thickness and concentrations of organochlorines and mercury detected[a] in unhatched bald eagle eggs from southcentral Oregon.

Area Site-Year	Success History[b]	Embryo age (days)	Shell Thickness[c] (mm)	% Thin[d]	p,p'-DDE	p,p'-DDD	Dieldrin	Heptachlor Epoxide	Oxychlordane	cis-Chlordane	trans-Nonachlor	cis-Nonachlor	HCB	Estimated PCBs[f]	Mercury
					ppm wet weight[e]										
UPPER KLAMATH LAKE															
Plantation - 1980	50.0	20+	0.55	-10	7.9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.03	3.6	0.14
Doak Mt. - 1981A	0	0	0.59	-3	9.8	0.38	0.05	N.D.	0.04	0.13	0.22	0.05	N.D.	7.7	0.18
Doak Mt. - 1981B	0	0	0.59	-3	7.2	0.27	0.04	N.D.	0.03	0.08	0.16	0.03	N.D.	5.7	0.14
Photographer-1981	33.3	24	0.59	-3	20.0	0.32	0.10	0.03	0.10	0.15	0.32	N.D.	N.D.	12.0	0.19
Malone S. - 1979[g]	80.0	16	0.49	-20	--	--	--	--	--	--	--	--	--	--	--
Doak Ridge - 1980[g]	0	25	0.54	-11	--	--	--	--	--	--	--	--	--	--	--
OUTER KLAMATH BASIN															
Thompson - 1979	0	0	0.53	-13	6.3	0.21	N.D.	0.08	0.04	N.D.	0.18	N.D.	N.D.	5.6	0.031
Kittridge - 1980A	0	0	[0.55]	-10	1.6	0.03	N.D.	0.16	N.D.	N.D.	0.03	N.D.	0.02	0.18	0.036
Kittridge - 1980B	0	0	[0.56]	-8	1.5	N.D.	N.D.	0.15	N.D.	N.D.	N.D.	N.D.	N.D.	0.18	0.040
Kittridge - 1980C	0	0	[0.59]	-3	1.7	N.D.	N.D.	0.20	0.02	N.D.	N.D.	0.03	N.D.	0.18	0.040
Kittridge - 1981A	0	0	[0.60]	-1	1.6	N.D.	0.04	0.13	N.D.	N.D.	N.D.	N.D.	N.D.	0.22	0.054
Kittridge - 1981B	0	0	—[h]	--	1.5	N.D.	0.04	0.13	N.D.	N.D.	0.02	N.D.	N.D.	0.18	0.034
Kittridge - 1981C	0	0	0.52	-15	1.6	N.D.	0.06	0.18	N.D.	N.D.	0.03	N.D.	N.D.	0.20	0.044
Drews Res. - 1981	0	0	[0.53]	-13	10.0	0.74	0.05	0.06	0.07	0.23	0.47	0.18	N.D.	7.4	0.25
CASCADE LAKES															
Benchmark - 1979	66.7	—	0.57	-6	1.6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.4	0.059
Round Swamp -1980[i]	50.0	--	[0.67]	+10	--	--	--	--	--	--	--	--	--	--	--
Odell Lake - 1980[j]	0	--	0.50	-18	--	--	--	--	--	--	--	--	--	--	--
Lemolo Lake -1980[i]	50.0	0	[0.58]	-5	--	--	--	--	--	--	--	--	--	--	--

Table 13. Continued

[a] Concentrations in table corrected for dehydration to fresh wet weight. No residues of p,p'-DDT, endrin, toxaphene or mirex detected.

[b] Percent of recent, successive nesting attempts which produced young.

[c] Figures in brackets are approximate.

[d] Percent change from pre-DDT norm.

[e] N.D. = no residue detected. -- = not analyzed. Detectable concentrations (ppm) before correction for dehydration: organochlorine insecticides and metabolites = 0.05; PCBs = 0.25; Mercury = 0.02.

[f] PCBs = polychlorinated biphenyls.

[g] Egg contained pinholes.

[h] Rough thickened areas in shell. Thickness ranged from 0.40 to 0.59 mm.

[i] Egg was found cracked or broken in nest.

[j] Egg had been broken into by a scavenger.

Table 14. Shell thickness of egg fragments collected at bald eagle nest sites.

Area/ Site	Year	Success[a]	Success History[b]	Shell Thickness (mm)[c]	% Thin[d]
UPPER KLAMATH LAKE					
Eagle Ridge N.	1979	2	50.0	[0.44]	-28
Eagle Ridge N.	1981	2	50.0	[0.52]	-15
Doak Ridge	1980	0	0	[0.57]	-6
Long Lake N.[e]	1981	0	66.7	0.44	-27
Malone N.[f]	1981	0	33.3	0.42	-32
Highway[e]	1981	0	0	0.52	-15
Odessa Dump	1981	0	25.0	[0.58]	-5
Photographer	1981	0	33.3	0.53	-13
OUTER KLAMATH BASIN					
Thompson Res.	1981	0	0	0.53	-13
CASCADE LAKES					
Bates Butte	1981	2	85.7	0.52	-15

[a] Number of young produced in year shells were collected.

[b] Percent of recent, successive nesting attempts which produced young.

[c] Figures in brackets are approximate.

[d] Percent change from pre-DDT norm.

[e] Shell thickness is mean of measurements from two groups of fragments.

[f] Shell thickness is mean of measurements from three groups of fragments.

in the outer Klamath Basin, and 5% (N = 4) in the Cascade Lakes. Excluding the Round Swamp egg from the calculations, shell thinning in the eggs from the Cascade Lakes was 10% (N = 3).

PRODUCTIVITY

Annual productivity of bald eagles fluctuated markedly from 1978 to 1983 in the three breeding areas (Table 15); nesting success for the southcentral Oregon population ranged from a low of 49% in 1982 to as high as 76% in 1978. The annual increases in the number of sites surveyed in each area reflect increased information and efforts in locating nests rather than an increase in the number of breeding pairs (Isaacs et al. 1983).

Yearly changes in breeding success were fairly consistent from area to area indicating that a common factor, such as widespread inclement weather may have an overiding influence on overall breeding success. The low productivity in all three areas in 1982 may have been due to unusually cold weather and snow storms occurring in late March during the incubation period (Isaacs et al. 1983). While there was large variability in nesting success from year to year, the mean percent of nest sites successfully producing young was similar for the three areas: 59% in the Cascade Lakes, 57% in the outer Klamath Basin, and 61% on Upper Klamath Lake.

The mean number of young produced per successful site is generally a more consistent figure than other productivity statistics, largely being a function of the reproductive potential of the species. However, annual changes in young per successful nest

Table 15. Productivity data for bald eagles in Southcentral Oregon, 1978-83.

	Breeding sites surveyed[a]	% Breeding sites occupied[b]	% Occupied breeding sites successful[c]	Young produced	Young/occupied site	Young/successful site
UPPER KLAMATH LAKE						
1978	33	48	75	17	1.06	1.42
1979	36	58	67	21	1.00	1.50
1980	39	62	50	18	0.75	1.50
1981	43	58	60	25	1.00	1.67
1982	44	61	52	19	0.70	1.36
1983	44	68	67	32	1.07	1.60
OUTER KLAMATH BASIN						
1978	6	83	80	7	1.40	1.75
1979	15	80	67	14	1.17	1.75
1980	18	78	50	15	1.07	2.14
1981	21	86	61	17	0.94	1.55
1982	23	83	47	13	0.68	1.44
1983[d]	24	92	57	19	0.90	1.58
CASCADE LAKES						
1979	24	67	62	15	0.94	1.50
1980	28	68	63	16	0.84	1.33
1981	30	70	76	27	1.29	1.69
1982	31	61	47	12	0.63	1.33
1983	31	68	48	11	0.52	1.10

[a] Breeding Site - a breeding site may have more than one nest.

[b] Occupied Site - a site at which one or more adults and some evidence of nesting was observed during the breeding season.

[c] Successful Site - a site at which one or more young were produced.

[d] One active site with unknown outcome used only in calculation of sites surveyed and % occupied.

may reflect factors which could vary by area, such as prey abundance and fratricide interactions (Ingram 1959, Stinson 1979) and parental ability, which may be a function of nesting history and adult turnover rates. The mean annual number of young per successful site in the Cascade Lakes (1.39, 95% C.I. = ± 0.27) was lower than the same figures for the outer Klamath Basin (1.70 ± 0.26) and Upper Klamath Lake (1.51 ± 0.12); however, variance was high and the number of years with data too low for statistical significance.

Number of young produced per occupied site is a good index of overall productivity. This statistic tended to be lowest in the Cascade Lakes area. Mean annual young per occupied site was 0.84 ± 0.29 in the Cascade Lakes, 0.93 ± 0.17 in the outer Klamath Basin, and 1.03 ± 0.26 on Upper Klamath Lake.

Mean annual occupancy of breeding sites was 84% in the outer Klamath Basin, 59% on Upper Klamath Lake, and 67% in the Cascade Lakes. The occupancy rate of nest sites was significantly higher in the outer Klamath Basin than in either the Cascade Lakes ($P < 0.003$) or on Upper Klamath Lake ($P < 0.001$), which did not differ significantly from each other ($P = 0.26$). The outer Klamath Basin has a lower density of nesting territories than the other two areas; mean minimum distance between nest sites on Upper Klamath Lake was 3.2 km (range: 0.93–10.6 km, N = 31), and on Wickiup Reservoir and Crane Prairie Reservoir, the mean minimum distance was 2.8 km (2.1–5.5 km, N = 12). The lower nest occupancy rates in the Cascade Lakes and on Upper Klamath Lake may be a function of intraspecific interactions, territoriality and spacing of nest sites, or disturbance.

The relationship (r = 0.14) between the nesting success of a nesting territory and the shell thickness of unhatched eggs from the site was not significant (Tables 13 and 14). The unhatched egg with the thinnest shell (-20%) was collected from a nest site with a history of 80% breeding success, and all the eggs with shell thinning less than or equal to 5% came from nests that produced young during only half or less of the annual nesting attempts. Degree of shell thinning, as determined by measurement of shell fragments, also did not correspond well to success history (r = -0.43).

Sample size was low, but none of the eggs with high residues of environmental contaminants came from nests with a history of nesting success greater than 50%. However, mean annual nesting success for all the nests in southcentral Oregon was only approximately 60%, and the relationship between nesting success and DDE residues in eggs was not significant (r = -0.04).

The relationship (DDE:r = -0.37; PCBs:r = -0.44; Hg:r = -0.15) between contaminant residues in eight adult blood samples and the history of nesting success at their territories was not significant (Table 12). Sample size was low; however, the two females from Upper Klamath Lake with the highest concentrations of environmental contaminants have not attempted to nest recently or have no record of attempting to nest. The nest site occupied by the adult male with the highest blood residues of DDE has a history of successfully producing young during 50% of the annual nesting attempts; however, the reproductive capabilities of males would be expected to be less sensitive to contaminants than females (Locke et al. 1966). The other two females from Upper Klamath Lake had similar residue concentrations in their blood samples; however, one had not successfully produced young during the last three nesting attempts, while the other had produced young successfully in 6 consecutive years.

Comparisons of residues in the blood of nestlings to the history of nesting success of their parent's nest site also have no clear trends (DDE:r = 0.14; PCBs:r = 0.07; Hg:r = 0.12) (Appendices 4, 5, and 6). Some of the nestlings with the highest residues of DDE, PCBs, or mercury in their blood come from nest sites with good histories of producing young.

DISCUSSION

FOOD HABITS

Fish generally comprise the major component of the diets of bald eagles in inland breeding populations (Herrick 1924, Wright 1953, Dunstan and Harper 1975, McEwan and Hirth 1980, Todd et al. 1982, and others). Although they show a preference for fish, bald eagles are considered opportunistic and feed on a broad prey base including a large number of bird, mammal, reptile, and invertebrate species (Sherrod 1978). Studies of some coastal populations of bald eagles have shown a higher importance of birds (Murie 1940, Sherrod et al. 1976, Todd et al. 1982) and mammals (Retvalvi 1970) in the diet. Avian prey of bald eagles are generally seabirds in coastal populations and mostly ducks and gulls in inland populations.

In this study bald eagles had a highly diverse and variable diet. Diets changed seasonally and differed markedly with geographic region. Fish species were a major component of the diet in all three areas; however, salmonid fish were a major component of the diet of the eagles only in the Cascade Lakes. The availability of salmonids may be lower at the lower elevation and in the shallower waters of the outer Klamath Basin and Upper Klamath Lake where trout may be in deeper, colder water. Avian prey were more important in the diets of the eagles in the outer Klamath Basin and on Upper Klamath Lake than in the Cascade Lakes. These differences are probably a result of varying abundance and availablity due to habitat suitability and the timing of movements of the migratory birds through the area. The

Cascade Lakes are mostly frozen over during the winter and open up later than the other areas because of their higher elevation. The shallower water bodies in the outer Klamath Basin favor dabbling ducks, and extensive marsh areas in the vicinity of Upper Klamath Lake attract a wide variety of waterbirds. Avian prey are especially important during the winter and early spring just prior to and during the early nesting season; the importance of grebes in the diets also increases with their arrival from their wintering areas in early spring. Todd et al. (1982) also reported regional and, in inland populations, seasonal differences in the diets of populations of bald eagles in Maine that they believed corresponded to changes in prey availability. They also reported that Salmonidae were common throughout the state but were of low dietary importance to the eagles.

The wide variety of bird species taken as prey, including a number of passerines, shows the opportunistic foraging habits of the eagles. However, prey species which are of low dietary importance to the eagles as a population, such as gulls and herons, may be more important to specific nesting pairs of eagles which key in on these species.

The variability in the diet of bald eagles in this study and the prey specialization by some individual eagles has implications regarding the uptake of environmental contaminants. The broad prey base of the eagles in general should result in moderate levels of contamination. By utilizing a wide variety of prey the eagles increase the chances of encountering highly contaminated food items and increasing their total body burden through accumulation of the organochlorines and heavy metals. However, by not feeding exclusively on prey species which tend to be highly contaminated, the overall diet has lower levels of environmental contaminants. Eagles which tend to specialize on certain prey species may increase or decrease their pollutant uptake markedly. Eagles feeding exclusively on fish would have low levels of organochlorines in their diets; and eagles nesting in the vicinity of Belding's ground squirrel colonies could lower their dietary intake of organochlorines even more by switching to ground squirrels when they emerge in the spring. In contrast, the eagles which prey on grebes, gulls, herons, or bitterns markedly increase their uptake of environmental contaminants. Variability in diets, as well as age and past exposures, probably accounts for the wide range of contaminant levels observed in this study.

Foraging behavior of the eagles may influence the uptake of environmental contaminants. Pirating and scavenging by bald eagles has been reported (Bent 1937, Kalmbach et al. 1964, Erskine 1968, Edwards 1969, Grubb 1971, Servheen 1975, Dunstan and Harper 1975, Ogden 1975, Sherrod et al. 1976, Todd et al. 1982). However, Southern (1963) reported that eagles wintering in Illinois preferred live fish despite the availablity of quantities of dead fish. The incidence of environmental contaminants in dead and dying prey, which are scavenged by eagles or pirated from gulls and other scavengers, may be higher than in healthy prey. However, the incidence of scavenging by breeding bald eagles in this study was low. Eagles were observed utilizing carrion on occasion, but the high density of eagles and other scavengers such as gulls made the availability of carrion too low to be relied on as a major component of the diet. The vast majority of pirating observed in this study was theft from ospreys, and the environmental contaminant levels in fish taken by osprey should be expected to be similar to those in fish taken live by eagles. The sub-adults observed in this study scavenged more prey than the adults. Taking live prey and pirating from osprey are apparently high skill behaviors which require experience to acquire proficiency.

RESIDUES IN PREY SPECIES AND BALD EAGLES

The environmental contaminants in the mammalian prey species sampled in this study were quite low compared to the other species sampled, with the exception of lead residues in Belding's ground squirrels. The extremely low concentrations of mercury and organochlorines in the mammalian samples indicates that these prey are not contributing significantly to the body burdens of the bald eagles. Herbivorous small mammals generally accumulate only very low residues (Turner 1965, Dimond and Sherburne 1969, U.S.D.A. 1969) and species utilizing terrestrial habitats have a lower potential for bioaccumulation (Keith and Hunt 1966, Saha 1972, Bevenue 1976).

The fish species which composed a major component of the eagles' diets also had fairly low residues of environmental contaminants. Concentrations of lead in the fish samples in this study were all below the concentrations of lead in control diets reported by Pattee and Hennes (1983) for bald eagles sampled by Hoffman et al. (1981), which resulted in blood levels in the eagles below the 0.1 ppm detection limit. Mercury residues, while low compared to levels reported for fish associated with contaminated areas (Wobeser et al. 1970), indicate that the aquatic system is the source of mercury contamination in eagles in southcentral Oregon (Peakall and Lovett 1972, Saha 1972).

The mean concentrations of organochlorines in the fish samples were low in comparison to concentrations in fish samples from watersheds throughout the United Stâtes (Henderson et al. 1971, Veith et al. 1979) and similar to or lower than concentrations in fish samples from other areas in Oregon (Claey et al. 1975). Fish from the Rogue River had mean concentrations of 0.097 ppm DDE and 0.125 ppm PCBs, and fish from the Columbia River had mean concentrations of 0.038 ppm DDE and 0.48 ppm PCBs. Henderson et al. (1971) also reported that fish from the Klamath River drainage (originating from Upper Klamath Lake) had organochlorine residues lower than fish from the Columbia River or the Rogue River drainages of Oregon. These higher residues in the bald eagles' food chain indicate potential environmental contaminant hazards to bald eagles in those areas. Henny et al. (1981a) reported that concentrations of PCBs in mink (_Mustela vision_) and river otters were higher in the Columbia River drainage than in other areas in Oregon.

The concentrations of organochlorines and mercury in the ducks and coots sampled in this study are low in comparison to levels reported throughout the United States (Vermeer et al. 1973, Heath and Hill 1974, White and Heath 1976, White 1979). American coots were among the most important of the eagles' avian prey but had relatively low residues of environmental contaminants. Diving ducks in this study had the highest residues of the Anatidae sampled, but were of lower dietary importance to the eagles. Dindal and Peterle (1968) reported higher levels of DDT in scaup than mallards exposed to the same treatment. Baskett (1975) reported higher mercury levels in divers compared to dabbling ducks and that the highest levels of mercury were from areas with known contamination, indicating mercury levels were largely due to local contamination despite the mobility of waterfowl. The presence of mercury in the fish samples in this study suggests that mercury contamination in southcentral Oregon is local, and the greater concentrations in the higher trophic levels represent bioaccumulation rather than translocation.

Lead concentrations in waterfowl samples were fairly low and as such should not represent a major threat to the health of bald eagles; however, lead in the form of embedded shot may pose the greatest threat to bald eagles (Pattee and Hennes 1983). Pattee and Hennes concluded that repeated exposure of bald eagles to embedded shot in waterfowl was the primary source of lead poisoning in bald eagles. The presence of embedded shot and lead poisoning in waterfowl is extensive (Bellrose 1953, 1964, Elder 1950, 1955, Stout and Cornwell 1976, Perry and Geissler 1980, Griffin et al. 1982). Lead shot have been reported in over 50% of bald eagle castings collected from some wintering areas (Dunstan 1974, Platt 1976). Pattee et al. (1981) reported that five of six bald eagles experimentally fed 10 to 156 lead shot died in 10 to 133 days, while the sixth went blind.

The bald eagles in southcentral Oregon, especially in the outer Klamath Basin and on Upper Klamath Lake, are undoubtedly being exposed to lead shot through the waterfowl and western grebes in their diet. The nestling bald eagles have relatively fewer waterfowl in their diet compared to adults, but exposure to lead was evident in some of their blood samples. The occurrence of lead residues in the blood samples from adult eagles is low; however, the tissue lead in the eagles' prey would not be expected to elevate levels in the eagle blood markedly (Pattee and Hennes 1983). Eagles with high lead contamination after repeated exposure to lead shot would be difficult to sample as they probably die in a fairly short period of time.

The high residues in the grebes and gulls sampled in this study demonstrate the bioaccumulation of environmental contaminants in aquatic systems. Residues of organochlorines and mercury in fish-eating birds are generally higher than in other bird species from the same areas (Dustman and Stickel 1969, Stickel 1973, Vermeer et al. 1973, Fimreite 1974, Hesse et al. 1975, Hoffman and Curnow 1979). The scavenging habits of gulls may also augment their uptake of contaminants. Gulls, herons, bitterns and cormorants were not a major component of the diet of the eagles in southcentral Oregon, but they were consistently found among the prey remains at nesting territories. Herons, bitterns and cormorants were not sampled for environmental contaminants in this study; however, other studies have reported high levels of contaminants in the heron family and cormorants (Moore and Tatton 1965, Prestt et al. 1970, Fimreite 1974, Hesse et al. 1975, Hoffman and Curnow 1979, Ohlendorf 1981).

The grebes and gulls sampled in this study may have accumulated organochlorines from their wintering areas. Samples of most species from southcentral Oregon show higher residues of organochlorines from Upper Klamath Lake than from the Cascade Lakes. The higher DDE residues in western grebes from Upper Klamath Lake than in the Cascade Lakes fit the general pattern of contamination seen in samples from the lower trophic levels. However, DDE concentrations in the eared grebes samples from the Cascade Lakes were higher than samples from Upper Klamath Lake, and the biomagnification factor from fish sampled in the areas was almost 50 times greater for the eared grebes from the Cascade Lakes than in eared grebes from Upper Klamath Lake. Concentration factors of DDE residues from the fish samples to the gull species were over 2.5 times greater for the gull samples from the Cascades, despite greater concentrations of DDE in fish samples from Upper Klamath Lake. Differences in the environmental contamination of the populations' wintering grounds may account for the relatively higher body burdens of organochlorines in the eared grebes and gulls in the Cascade Lakes during the summer months. The much higher residues of DDE in the fish-eating birds compared to the fish sampled from the areas (over 430 times greater in the gulls and a factor of over 160 for the eared grebes from the Cascade Lake, and factors over 200 for western grebes from both areas) seem too high for only local accumulation (Stickel 1973, Bevenue 1976); especially since the fish sampled were in a size range ($\bar{x}$ = 287.5 g) typical of eagle prey items and much larger than food items of grebes.

The concentrations of environmental contaminants in the avian prey of the bald eagles in this study are comparable to the levels in prey items of osprey populations that have had reproductive failures associated with environmental contaminants. Ames (1966) reported levels of ΣDDT from 1.3 to 5.5 ppm in fish prey of a declining osprey population in Connecticut and 0.05 to 0.3 ppm in fish prey of a more stable population from Maryland. Similar differences between the two states for both levels of DDE and PCBs were found by Wiemeyer, et al. (1975). Dietary concentrations of 2.8 and 3.0 ppm DDE have experimentally caused significant eggshell thinning in kestrels (Wiemeyer and Porter 1970, Lincer 1975); the mean concentrations of DDE in some of the grebe and gull species in this study approach or exceed this concentration, notably in western grebes which are a common prey item of eagles on Upper Klamath Lake.

Wiemeyer et al. (1978) reported residues of environmental contaminants in potential prey items of bald eagles in Maine and speculated that avian prey, particularly gulls, were the major dietary source of contaminants. Similarly, Koivusaari et al. (1976) reported high residues of organochlorines in white-tailed eagles (Haliaeetus albicilla) in Finland that had reproductive failures. They postulated that the elevated residues were acquired from the fish-eating birds in their diet because residues in fish were low.

The outer Klamath Basin and Upper Klamath Lake would be expected to have relatively higher levels of organochlorines than the Cascade Lakes because of their proximity to resident human populations and agriculture; however, the source of mercury in the areas in southcentral Oregon and the basis for any regional differences in concentrations are not immediately clear. The mercury contamination appears local, being detected in low levels in fish samples from both Upper Klamath Lake and the Cascade Lakes. Mercury concentrations appear slightly higher in the prey species from Upper Klamath Lake than from the Cascade Lakes; this pattern holds true at the higher trophic levels even in the species with aberrant organochlorine residues.

The contamination of the majority of the prey base of the bald eagles in southcentral Oregon is fairly low for most of the organochlorine compounds and heavy metals analyzed. However, PCBs are obviously present in the system, and DDE and mercury are consistently detected at moderate levels, showing definite biomagnification in the food chain. Though the eagles are not subsisting on a steady diet of birds during the entire year, the avian prey are apparently the source of their elevated concentrations of environmental contaminants. The eagles are also feeding on the largest number of avian prey during the winter and spring, just prior to and during the eagles' early nesting season. The outer Klamath Basin and Upper Klamath Lake have a high potential for accumulation of environmental contaminants in bald eagles because of the relatively higher contamination of the prey base in those areas and the greater incidence of avian prey in the bald eagles' diets. Because the nesting bald eagles are resident birds and the local contamination of organochlorines appears fairly low, translocation of contaminants by migratory birds may be an important factor. Lead as embedded shot also poses a potential hazard in the entire Klamath Basin because of the large numbers of wintering waterfowl, heavy hunting pressure by humans, and the high incidence of these species in the diets of the bald eagles in the breeding areas.

RESIDUES IN BALD EAGLE BLOOD

Concentrations of organochlorines in whole blood, plasma, and serum have been used to estimate body burdens in man and some birds (Radomski et al. 1971, Edmundson et al. 1972, Friend et al. 1979, Capen and Leiker 1979, Henny and Meeker 1981). However, concentrations in circulating blood may be influenced by the physical condition of the animal, metabolism of fat reserves (Stickel 1973), or the contaminant levels in a recent meal. The relations of organochlorine concentrations in the brains of bald eagles, lipid levels, and whole carcass residues have been studied (Barbehenn and Reichel 1981), but their relationship to residues in whole blood are uncertain. Blood samples of two captive bald eagles from Patuxent Wildlife Research Center were taken just prior to sacrificing the birds for analysis of organochlorines; concentrations of DDE in the carcasses of the two eagles were between 60 and 75 times the residues in the blood (S.N. Wiemeyer, pers. comm.).

Stafford and Stickel (1982) reported lower residues of DDT and DDE in avian blood which had been frozen compared to blood preserved with formalin. Wiemeyer et al. (1984b) reported a 35% loss of DDE in blood frozen and stored for 2 months; there was no additional loss after 8 months of storage. There was no detectable loss of metal residues in the frozen and stored samples. The eagle blood in this study was frozen and stored for several months prior to analysis; the reported concentrations of organochlorines are undoubtedly lower than if the samples had been analyzed fresh.

The occurrence of DDE, PCBs, and mercury in the blood samples from nestling bald eagles in this study suggest contamination of the prey base, as the nestlings only had approximately 9 weeks to accumulate contaminants. The majority of food items of the nestlings prior to fledging are fish which contain low concentrations of environmental contaminants. The relatively higher levels of environmental contaminants in the nestlings from the outer Klamath Basin and Upper Klamath Lake, compared to the Cascade Lakes, fit the general pattern of available contaminants in the prey bases of the areas and differences in diets. The lowest residues were in the nestlings from the Cascade Lakes which have the lowest number of birds in their diet and reside in the area with the lowest contamination. The relatively higher PCB levels in the nestlings from the widespread and diverse outer Klamath Basin are indicative of the area's potential for local contaminant problems.

Mercury residues in blood samples of the bald eagles in this study appear high compared to levels reported in studies of the effects of dietary methylmercury on mallards (Heinz 1974, 1976, 1979). Three generations of mallards were fed a diet of 0.5 ppm methylmercury in dry mash, equivalent to approximately 0.1 ppm in a natural succulent diet. The dietary mercury resulted in blood mercury residues of about 0.5 to 0.6 ppm (Heinz 1980). Blood residues of adult eagles in this study contained a mean of 2.33 ppm mercury; only some eagle prey items such as grebes and gulls contained concentrations of mercury as high as the concentration in the equivalent succulent diet fed Heinz's experimental mallards. Bald eagles may have different physiological responses to mercury than other species which have been studied. Blood samples from five bald eagles, which had been held in captivity from 1-13 years at Patuxent Wildlife Research Center, contained 0.17 to 0.31 ppm mercury, which are higher background levels than in control ducks at the Research Center (S.N. Wiemeyer, pers. comm.); yet, these blood residues are considerably lower than the blood mercury in either nestling or adult eagles from this study that were analyzed using the same methodology.

The high levels of mercury in the blood of the adult eagles and the lower levels in nearly all the nestlings, demonstrates the accumulative nature of the metal and indicates that it's presence is widely distributed in southcentral Oregon. The much higher concentrations of organochlorines in the blood of the adults from Upper Klamath Lake, compared with the Wickiup Reservoir adults, reflects the higher contamination of their prey base and greater accumulation due to the greater incidence of birds in their diet.

If the DDE residues in the blood samples are 35% low due to freezing and storage, and a conversion factor of 60 is used to estimate the concentrations in the eagles bodies, the estimated residues in the bodies of the five adult eagles captured on Upper Klamath Lake range from 63 to 129 ppm DDE. The mean estimated concentration of 88 ppm DDE in the bodies of the adult eagles from Upper Klamath Lake is about 20 times the mean DDE residue in the western grebe samples from the area. The one actual adult eagle carcass from Upper Klamath Lake contained 34 ppm DDE (Appendix 2), approximately 8 times the mean DDE residues in the western grebes. The carcass of the 5-week-old nestling contained 1.1 ppm DDE (Appendix 2); mean DDE residues in the bodies of the 9-week-old nestlings from Upper Klamath Lake, as estimated using their blood levels, was approximately 2.1 ppm.

Residues of organochlorines from carcasses of bald eagles found dead or moribund throughout the United States have been reported periodically (Reichel et al. 1969a, 1969b, Coon et al. 1970, Mulhern et al. 1970, Belisle et al. 1972, Cromartie et al. 1975, Prouty et al. 1977, Kaiser et al. 1980). Comparisons with their data suggest sublethal accumulations in the adult eagles sampled from Upper Klamath Lake, but they provide no indications of the possible effects on reproductive success of the birds. Grier (1974) pointed out the extreme variation in published residue levels from bald eagle carcasses and the difficulty in making meaningful comparisons between carcass data, egg data, and productivity in his study of reproduction and environmental contaminants in bald eagles in Northwestern Ontario.

Few studies have been conducted which allow a comparison of the environmental contaminants in whole blood of bald eagles to productivity. Residues of DDE in the eggs of four species of raptors have been estimated from DDE residues in blood plasma by regression analysis (Henny and Meeker 1981). The pre-laying and post-laying plasma-egg relationships seemed to be species independent for the American kestrels and the three species of North American accipiters studied. Henny et al. (1981b) used residues in blood plasma samples of bald eagles wintering in Colorado and Missouri in the Henny and Meeker regression models to estimate organochlorine residues in potential eggs of the eagles; but, they noted that the plasma-egg residue relationship had not been studied specifically in bald eagles.

By applying the residues of DDE in the whole blood (adjusted for 35% loss) of the bald eagles sampled in this study to the Henny and Meeker models (depending on sampling date), we estimated the mean concentration of DDE in eggs from these eagles at 1.5 ppm for the one female from the Cascade Lakes, and 5.2, 9.4, 6.5, and 3.6 ppm from the four females from Upper Klamath Lake. Running the blood residues of the adult male eagles through the pre-laying model (since the males had not decreased their body burdens through egg-laying), estimates DDE residues in eggs laid by females with those residue levels at 4.6 ppm for the eagle from Upper Klamath Lake, and 0.38 and 0.95 ppm for the two males from Wickiup Reservoir. If the plasma-egg residue relationship holds true for bald eagles, these estimated egg residues should still be conservative because residues in whole blood rather than plasma were used. Adjusting for dilution by red blood cells (40-50% plasma yield), the estimated residue concentrations could more than double, depending upon the proportion of lipids and thus the lipophilic organochlorines in the plasma fraction of the whole blood. Doubling the residue levels to account for the dilution factor in whole blood estimates the mean DDE residue at 11.3 ppm in eggs from the adults from Upper Klamath Lake, and 1.7 ppm for eggs from Wickiup Reservoir; these values correspond surprisingly well to the actual DDE residues in the four addled eggs collected from Upper Klamath Lake ($\bar{x}$ = 10.3 ppm) and the one egg from the Cascade Lakes (1.6 ppm).

BALD EAGLE EGGS

Contaminant residues in addled eggs of bald eagles have been reported for a number of breeding populations (Stickel et al. 1966, Krantz et al. 1970, Wiemeyer et al. 1972, Grier 1974, Gilbertson and Reynolds 1974, Grubb and Rubink 1978, Grier 1982) and have been associated with varying reproductive success. However, the relationship between contaminant levels and productivity has been clouded by extreme variability and biases associated with collection of unhatched eggs. Addled eggs may be unrepresentative of the eggs in the entire population because eggs may not have hatched because of elevated contaminant levels, and eggs with extreme residue concentrations and shell-thinning may have not survived intact to be collected.

Wiemeyer et al. (1984a) compared the residues in 126 unhatched bald eagle eggs to shell thickness and the reproductive history of individual nest sites. Productivity and shell-thickness were negatively correlated to concentrations of eight contaminants in eggs. Levels of DDE provided the strongest relationships to these factors, and the other significant contaminants were highly correlated with DDE. Wiemeyer et al. also provided equations for estimating shell-thinning and mean 5-year productivity at individual nest sites from DDE residues in unhatched eggs. For example, a DDE residue of 5 ppm in eggs was associated with 10% shell-thinning, and productivity of one young per occupied site was associated with 1.3 ppm DDE in eggs. Application of the equations to DDE residues in the intact eggs collected in this study (Table 13) provides estimates of mean 5-year production of 0.44, 0.43, and 0.16 young per year for the three nest sites on Upper Klamath Lake; 0.94, 0.51, and 0.37 young per year at the three nest sites in the outer Klamath Basin; and 0.94 young per year at the one site in the Cascade Lakes which provided an addled egg. The mean DDE residues in the eggs from Upper Klamath Lake would be associated with a mean annual production of 0.36 young for those sites. Actual productivity at the three nests on Upper Klamath Lake during the year of egg collection and the previous 4 years was 0.20 young per year (0.60 at the Plantation nest and no young produced at the other territories). The three nesting territories in the outer Klamath Basin from which eggs were collected had failed to produce young in all nesting attempts. The Cascade Lakes nest had a mean 5-year production of 0.40 young per year. Mean DDE residues in potential eggs, as estimated from the blood samples from adult eagles from Upper Klamath Lake, would be associated with a mean productivity depressed to 0.55 young per site (as low as 0.33 young per site if the residue concentrations are adjusted for dilution in whole blood).

Concentrations of DDE in intact eggs and blood provide strong evidence that the reproductive success of specific nest sites in the outer Klamath Basin and on Upper Klamath Lake was reduced. The contamination of the prey base is not causing total reproductive failures of the populations; productivity has ranged from 0.70 to 1.07

young/occupied site. The total effect of contamination in the Klamath Basin is depression of productivity of the areas' population, and probably recurrent reproductive failure of some nesting pairs. In contrast, the residues in the intact egg and the adult blood samples from the Cascade Lakes suggest that productivity is not being significantly depressed by organochlorines. This is supported by the relatively uncontaminated prey base in the Cascade Lakes and the lower incidence of avian prey in their diet.

While the concentrations of mercury in the blood of the eagles appear high and show accumulation with age of the birds, the concentrations in the eagle eggs appear quite low -- only slightly above background levels and considerably less than levels associated with adverse effects on reproduction in pheasants (Borg et al. 1969, Fimreite 1971, Spann et al. 1972). Fimreite and Karstad (1971) reported that dietary concentrations of 7-10 ppm methylmercury were lethal to red-tailed hawks (Buteo jamaicensis).

Heinz (1979, 1980) reported that mallards fed a diet equivalent to 0.1 ppm methylmercury in a succulent diet laid fewer eggs and produced fewer young than control birds. Blood mercury in the ducks on the mercury diet was 0.5 to 0.6 ppm and mercury in eggs ranged from 0.79 to 1.49 ppm. Mercury in the livers of the experimental female mallards ranged from 0.89 to 1.62 ppm, while residues in the livers of males from the same experiment ranged from 2.75 to 6.44 ppm; apparently the females were reducing total body burdens by depositing mercury in their eggs.

Blood of adult eagles in this study contained a mean of 2.33 ppm mercury. Yet, the mean concentration of mercury in the four intact eagle eggs from Upper Klamath Lake was only 0.16 ppm, and the nine other eagle eggs analyzed all contained less than half that concentration, except for one from the outer Klamath Basin containing 0.25 ppm. Bald eagles may not readily deposit mercury in egg tissues; mercury residues in blood samples of adult males in this study were comparable to or, in most cases, less than residues in the blood samples from adult females. Concentrations of mercury in eggs of bald eagles from other populations are also generally fairly low (Grier 1982, Wiemeyer 1972, 1984a). Only eggs from Maine appeared to have mercury residues having the potential for adverse effects on reproduction (Wiemeyer et al. 1984a).

Mercury residues have varying effects on hatching rates in different species of birds (Vermeer et al. 1973) and the effects of mercury on reproductive success of bald eagles and other birds of prey in the wild are difficult to assess because organochlorine contamination is nearly always also present. The effects of mercury on reproduction may become more clear with decreasing organochlorine residues in the environment (Newton 1979, p. 255-56; Wiemeyer et al. 1984a).

The eggshell thickness measurements in this study should only be regarded as approximate. Eggshell thickness and physiological responses to contaminants are variable (Krantz et al. 1970). Disruption of shell membranes can cause unreliable thickness measurements, and if an egg is broken it is often difficult to ascertain from which part of the egg the fragments originated. Thinning may also occur during late embryonic development from a normal uptake of calcium (Kreitzer 1972). Extrapolations of shell thickness measurements to the population level are also subject to the biases of non-random sampling in the collection of addled eggs (Grier 1974, 1982, Henny et al. 1981b, Wiemeyer et al. 1984a). Despite these draw backs, shell thickness measurements can cautiously be used for purposes of general comparison.

Populations of raptors with mean shell-thinning of 15-20% have shown noticeable declines in numbers (Anderson and Hickey 1972; Newton 1979, p. 243). The eggshell thickness of addled eggs in this study show moderate thinning; eggs from the entire study were 8% thinner and eggs from Upper Klamath Lake and the outer Klamath Basin area were 9% thinner than the pre-DDT norm. Inclusion of measurements of shell fragments in the calculations indicates shell thinning of approximately 11% in southcentral Oregon. The DDE residues in the addled eggs is associated with mean shell thinning of 13% for Upper Klamath Lake (n = 3), 9% for the outer Klamath Basin (n = 3), and 6% for the one site with an unhatched egg from the Cascade Lakes (Wiemeyer et al. 1984a). This degree of thinning is not associated with complete reproductive failure and declines at the population level, but it indicates contamination at individual nest territories. The nest sites with the greatest shell thinning were located on Upper Klamath Lake, consistent with the data on diets and residues in the prey base, blood samples, and eggs.

PRODUCTIVITY

The degree of eggshell thinning at a nest site has been strongly correlated to DDE contamination in bird eggs (Wiemeyer and Porter 1970, Blus et al. 1972, Cooke 1973, Wiemeyer et al. 1984a) and has been associated with impaired reproduction in bald eagles (Hickey and Anderson 1968, Postupalsky 1971, Anderson and Hickey 1972, Wiemeyer et al. 1972, Grier 1974, 1982). In contrast, Grier (1982) reported no statistical correlation between shell thickness and DDE in eggs although the relationship was evident at higher concentrations of DDE. In general, productivity of individual nest sites in this study did not consistently correspond to levels of environmental contaminants in eggs or blood of adults and young. Our results indicated that reproductive problems may have existed at specific nesting territories. Contamination was low to moderate; and, due to high variability, the effects of reproduction may be masked by other influences and interactions.

It is difficult to assess the effects of low to moderate levels of contamination which are not having drastic effects at the population level. Adult eagles with severe contaminant burdens, but still occupying territories, may never produce young that can be sampled for blood or lay eggs that can be evaluated. When comparing nestling blood residues to nest success, one can only evaluate the environmental contaminants at nests which are successfully producing young. Residues in nestlings have only limited accumulation time and give little indication of past exposure in the adults. Reproductive histories of nesting territories or individual eagles may also be difficult to assess because of shifting nest sites and replacement of birds in mated pairs (Hensel and Troyer 1964, Krantz et al. 1970).

The relative productivity of bald eagles in the geographical areas in this study do not correspond to the environmental contamination in the breeding eagles and their prey base. The Cascade Lakes area, which had the lowest levels of environmental contaminants, had a somewhat lower and more variable productivity than Upper Klamath Lake and the Klamath Basin. The annual fluctuations in productivity appeared fairly consistent between these areas. Other studies have also documented large annual fluctuations in reproductive success and differing productivity patterns in different regions (Chrest 1964; Grier 1974, 1982; Hensel and Troyer 1964). Weather has been considered a major factor influencing bald eagle populations in many areas (Postupalsky 1967, Sprunt et al. 1973, Grier 1974, Leighton et al. 1979, Isaacs et al. 1983, Lehman 1983). It appears that the Cascade Lakes area is subject to some factors other than environmental contaminants which are depressing reproduction and increasing fluctuations in productivity, such as effects of weather or increased human disturbances from outdoor recreationists and logging.

The mean productivities of the bald eagles in this study compare favorably with values reported from other populations (Sprunt et al. 1973, Grubb et al. 1975, Nesbitt et al. 1975, Todd 1979, Grier 1982, Isaacs et al. 1983). However, most of these populations have also been exposed to organochlorine contamination to some degree. Sprunt et al. (1973) estimated the minimum productivity required for population stability in bald eagles at 50% nesting success with at least 0.70 young per occupied site. However, these estimates were arrived at by comparison of productivity figures of bald eagle populations from six regions which variously appeared to be declining or stable. Productivity of healthy populations with minimal influences of environmental contaminants is usually near or above 1.0 young per occupied site (Sprunt et al. 1973, Leighton et al. 1979, Madsen 1979, Wiemeyer et al. 1984a). The production of young necessary for stable bald eagle populations may vary with time and area, depending upon the particular set of factors influencing the various aspects of population dynamics. Very little information is available regarding the influence of different components of population dynamics in bald eagles (Grier 1974, 1979, 1980, 1982); and the apparent stability of a population as determined by productivity and the number of adult pairs in an area or other similar censuses may actually be a function of immigration, emmigration, and the number of non-breeding adults in the population. Critical declines in recruitment could be masked for extended periods of time due to the longevity of adults, traditional nesting habits, and adults in the population not occupying territories.

Productivity is only one aspect of population dynamics of bald eagles and may be of less importance to stability of a population than other factors (Grier 1979, 1980). Grier (1979) cautioned against using productivity statistics alone when making inferences about population health. Adult mortality may be of greater importance than annual productivity in the population dynamics of long lived species

(Young 1968, Mertz 1971, Grier 1974, 1979). Grier (1980) concluded that survival was far more critical to population stability of bald eagles. Small decreases in annual productivity may be overshadowed by extremely low survival to adulthood. Considering the low reproduction rates, high immature mortality, and longevity of bald eagles, the loss of adult breeders could have overriding influences on populations. Sherrod et al. (1976) estimated annual adult mortality rates on Amchitka Island in Alaska at only about 5.4%.

The adult mortality of bald eagles in the populations in southcentral Oregon may be quite high. The turnover of adults in this population, as evidenced by rapid replacement of adults at nest sites and non-breeding adults in the population, would largely go undetected by casual observation or productivity surveys visiting nest sites only two or three times per season. The non-breeding and replacement eagles in the population probably do not represent a surplus of breeding age birds as a result of high production of young and low mortality rates; but, more likely, are largely comprised of adults displaced from habitat loss or death of a mate. The close proximity of over 500 wintering bald eagles in the Klamath-Tule basin (Keister and Anthony 1983) may also be a source of replacement birds during the winter and early breeding season. Grier (1982) suspected that the rapid recovery of reproductive success in northwestern Ontario following the decline in use of DDT may have been due to high turnover of adults.

Human related factors constitute the vast majority of causes of death reported from autopsy studies on bald eagles; and, though the incidence of shooting deaths appears to be declining, it remains the primary cause of mortality (Reichel et al. 1969a, Coon et al. 1970, Belisle et al. 1972, Cromartie et al. 1975, Prouty et al. 1977, Todd 1979, Kaiser et al. 1980). This increase beyond natural mortalities, especially of adults, would be particularly devastating to a species which evolved at the top of a food chain with few enemies, and in the absence of the plethora of pressures humans now produce. Human factors are probably a major source of mortality in bald eagles in southcentral Oregon, especially shooting. Bald eagles are shot in acts of pure vandalism, supposed protection of livestock, and by hunters; but, perhaps the majority of shooting in the Klamath Basin takes place for illegal sale of eagle feathers and body parts (K. Harrington, pers. comm.). Occasional mortalities of eagles in the population due to lead poisoning (Jacobson et al. 1977, Todd 1979, Kaiser et al. 1980, Pattee and Hennes 1983) undoubtedly occurs due to the high incidence of waterfowl in the diet of the eagles in the outer Klamath Basin and on Upper Klamath Lake, especially during the winter. The turnover of adults may be a cause of the so-called intermittant breeding reported in other studies (Broley 1947, Chrest 1964, Brown and Amadon 1968, Lehman 1983) due to disruption of breeding cycles and an adjustment period during pair bond formation.

The contributing influences of other factors on population dynamics, such as habitat loss and disturbance, may be substantial though difficult to assess. Nesting habitat of bald eagles in Oregon also has a high value for use by recreationists and the timber and housing industries (Anthony and Isaacs 1981). The effects of disturbance on nesting bald eagles have been discussed with varying conclusions (Broley 1947, Hensel and Troyer 1964, Mathisen 1968, Gerrard et al. 1975), but it is generally acknowledged that human disturbance can have detrimental effects on productivity. Bald eagles have shifted locations of nest sites apparently in response to human disturbance (Broley 1947, Murphy 1965, Gerrard et al. 1975, Anthony and Isaacs 1981). Anthony and Isaacs (1981) examined the characteristics of bald eagle habitat in Oregon and quantified human disturbance factors and productivity at nest sites. Their data suggested that human disturbance, particularly logging and major roads, negatively affected nesting success.

The major pesticide-related declines in populations of raptors have been associated with decreased reproductive performance, primarily from eggshell thinning and embryo death rather than direct mortalities (Henny 1972), though direct mortalities of bald eagles have been reported, especially from dieldrin poisoning (Reichel et al. 1969, Mulhern et al. 1970, Belisle et al. 1972, Cromartie et al. 1975, Prouty et al. 1977, Kaiser et al. 1980). However, the sublethal effects of a variety of environmental contaminants, may also increase the impact of other factors affecting bald eagles, such as disturbance and inclement weather. The organochlorine and mercury compounds have been shown to cause neuro-excitability at sub-lethal concentrations in a variety of species, both experimentally and in the wild (Dustman and Stickel 1969, Friend and Trainer 1970, Jefferies 1973, Kreitzer and Heinz 1974, Fox et al. 1978, Fyfe et al. 1976, Henny 1977, Heinz 1979, 1980, Fox and Donald 1980).

Predation is a high skill activity and the energy requirements of foraging, disturbance flights (Stalmaster 1983), and rearing of young can be demanding. The sublethal effects of environmental contaminants which affect neural activity (e.g. pesticides, PCBs, and mercury) or the uptake of oxygen in the blood (i.e. lead) may all be subtle, but their additive or synergistic effects, in combination with other factors, may have profound effects on reproductive success. This may, in part, account for some of the fluctuations in productivity observed in this study.

While levels of organochlorines have reportedly been decreasing in the environment and somewhat in other bald eagle populations, DDE and PCBs are extremely persistent, as are lead and mercury. Improvements in DDE contamination of environments are slow due to its long half-life (Beyer and Gish 1980, Fleming and Cromartie 1981). Large accumulations in bottom sediments of the area may be providing a steady supply of residues to the water column as they are continually taken up by organisms in the lower levels of the aquatic food chain (Keith 1966; Johnson et al. 1967, cited in Dustman and Stickel 1969). Translocation of contaminants to the area by fish-eating birds increases the accumulations at the top of the food chain.

Reproductive success of bald eagles in the Cascade Lakes appears to be affected by factors other than organochlorine contamination.. Residues of DDE, PCBs, and mercury in the Klamath Basin and Klamath Lake are common in the eagles' prey base and show definite biomagnification in the food chain and accumulations in the eagles. Lead poisoning from ingesting lead shot in prey items probably contributes to already high mortality rates and needs to be investigated further. DDE appears to be having a direct adverse effect on productivity of specific pairs of bald eagles from Upper Klamath Lake and outer Klamath Basin, and along with other contaminants may be indirectly increasing the impact of other influences. Although environmental contaminants in the outer Klamath Basin and Upper Klamath Lake are not at levels associated with critical population declines in other bald eagle populations, their effects should not be discounted, especially considering the number and severity of other factors impinging on reproductive success in southcentral Oregon.

FOOD HABITS AND ENVIRONMENTAL CONTAMINANTS OF BALD EAGLES WINTERING IN THE KLAMATH BASIN, OREGON AND CALIFORNIA

ABSTRACT

Diets of bald eagles wintering in the Klamath Basin of northern California and southern Oregon were assessed by identification of remains of 913 prey items found at perches, examination of 341 castings collected from communal night roosts, and direct observations of foraging by eagles. Levels of organochlorine compounds, lead, and mercury in the bald eagles and their prey base were determined by residue analyses of 21 blood samples from captured bald eagles, 9 carcasses of eagles found dead in the study area, and 58 pooled samples of eight major prey species. Bald eagles fed largely on waterfowl, usually scavenging on cholera killed ducks and geese. However, this wintering concentration was unique in that microtine rodents were also a major dietary component. Residues of organochlorines in prey species were low; DDE residues were below detectable levels in mammalian prey, and were detected in low concentrations in 80% of the waterfowl samples. PCBs were detected in low concentrations in only five prey samples; and heptachlor epoxide was only detected in three samples. Mean mercury concentrations in prey species were all below 0.08 ppm, and mean lead concentrations in prey samples ranged from 0.15 to 4.79 ppm. Concentrations of organochlorines in blood samples from bald eagles were low ($\overline{x}$ DDE = 0.039 ppm; $\overline{x}$ PCBs = 0.017 ppm). Mercury was detected in all of the

eagle blood samples ($\overline{x}$ = 2.25 ppm). Lead residues were detected in 31% of the bald eagle blood samples. Organochlorine residues in whole carcass tissue of necropsied eagles were also low ($\overline{x}$ DDE = 2.734 ppm, $\overline{x}$ PCBs = 2.125 ppm). Mean concentration of mercury in the livers of the necropsied eagles was 1.89 ppm; mean lead concentration was 1.52 ppm. Bald eagles did not appear to have elevated body burdens of organochlorines associated with reproductive problems. Prey of the eagles were relatively clean with the possible exception of lead shot in waterfowl which may present a potential for lead poisoning of eagles. The extent and impact of this exposure is difficult to determine and requires further study.

INTRODUCTION

Major declines in many populations of bald eagles (*Haliaeetus leucocephalus*) from 1950 to 1975 (Broley 1958, Sprunt and Ligas 1966, Abbott 1967) 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 and Wildlife Service 1979). Many of the declines have been attributed to lowered rates of reproduction (Henny 1972) associated with eggshell thinning induced by the DDT-metabolite, DDE (Stickel et al. 1966, Hickey and Anderson 1968, Krantz et al. 1970, Postupalsky 1971, Anderson and Hickey 1972, Wiemeyer et al. 1972, Sprunt et al. 1973, Grier 1974, Newton 1979, p. 239, Wiemeyer et al. 1984a). Residue levels in autopsied eagles have also been reported periodically (Reichel et al. 1969a, 1969b, Mulhern et al. 1970, Belisle et al. 1972, Cromartie et al. 1975, Prouty et al. 1977, Kaiser et al. 1980), but few studies have evaluated pollutants specifically in the prey of bald eagles (Wiemeyer et al. 1978).

The Klamath Basin of southcentral Oregon and northern California hosts one of the highest densities of wintering bald eagles in the 48 contiguous states with peak counts of over 500 eagles during January and February (Keister and Anthony 1983). The Klamath-Tule Lake Basin has a history of pesticide use and contaminant problems (Pillmore 1961, Godsil and Johnson 1968, Federal Water Quality Administration 1970), including die-offs of fish-eating birds associated with organochlorine compounds (Keith 1966, D.J. Lehnhart pers. comm.).

Organochlorines such as DDE are extremely persistent both in the environment and in the bodies of birds (Longcore and Stendell 1977, Beyer and Gish 1980, 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 (U.S. Fish and Wildlife Service 1980); and heavy use of the basin by waterfowl hunters increases the potential for exposure of eagles to lead shot (Pattee and Hennes 1983).

The objectives of this study were to determine the food habits of bald eagles wintering in the Klamath Basin and determine levels of organochlorine compounds and heavy metals in the bald eagles and their prey base. The study was funded by the Patuxent Wildlife Research Center, U.S. Fish and Wildlife Service and conducted through the Oregon Cooperative Wildlife Research Unit with the U.S. Fish and Wildlife Service, Oregon State University, Oregon Department of Fish and Wildlife, and the Wildlife Management Institute cooperating.

STUDY AREA

The Klamath Basin lies at about 1200 m. The climate is characterized by wet, moderately cold winters and dry summers with a fairly short growing season of three to four months; annual precipitation throughout the area ranges from approximately 40 to 130 cm, most of which falls as snow between October and March, or rain at the lower elevations. Air temperatures at Upper Klamath Lake range from -30 to 40° C, with an annual mean of about 9° C (unpublished data, U.S. Forest Service). Water bodies variously freeze and thaw throughout winters depending upon the severity of the weather.

The Klamath Basin contains approximately 15,000 ha of wetlands; and much of the large expanses of agricultural lands are reclaimed marshes or lake bottom. In non-cultivated areas the upland plant communities range 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*).

Over 1,000,000 waterfowl utilize the wetlands of the Klamath Basin during autumn and spring migrations (U.S. Fish and Wildlife Service 1980). Many of the wintering waterfowl concentrate in the southern portion of the basin on Lower Klamath Lake and Tule Lake, part of the Klamath Basin National Wildlife Refuge. Increased bald eagle use of the Klamath Basin has been correlated to increased incidences of waterfowl die-offs due to avian cholera (Pasteurella multocida) which provide an abundant food source for the eagles (Keister 1981). Keister (1981) documented shifts in use of the foraging areas of bald eagles and their associated communal night roosts with changes in prey concentrations and availability. Bald eagle foraging was usually concentrated in wetlands and flooded fields (Keister 1981, Keister and Anthony 1983). Waterfowl distribution in the wetlands was affected by temperatures which determined the location and extent of open water. Montane voles (Microtus montanus) became available in abundance in conjunction with flooding of agricultural fields generally beginning in January.

METHODS

AGE ESTIMATION

Ages of bald eagles were estimated by examination of plumage (Southern 1964, 1967, Servheen 1975). For the purposes of this paper eagles were classified as sub-adults (hatching year to maturity) or adults (maturity). Sub-adults with essentially an adult plumage, but still having some dark feathers in the head and/or tail, were noted as near-adults.

FOOD HABITS

Diets of bald eagles were assessed by observations of eagle foraging, examination of castings from communal roosts, and identification of prey remains at foraging areas. Regurgitated castings of bald eagles were collected from the bases of perch trees in four of the major communal night roosts. Fur and feather materials 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 the winter months, 1979-82. Prey items were either identified at the feeding sites or collected for comparisons to reference collections. Remains of prey items were identified to species when possible. Fresh prey items were recorded and collected for residue analyses; all old remains of prey were cleared from the vicinity of the perches to ensure that items would not be re-examined on subsequent visits. A composite diet of waterfowl eaten by the bald eagles was estimated by frequency of occurrences of the minimum number of individuals of each taxon identified (Mollhagan et al. 1972).

CONTAMINANT ANALYSES

Levels of environmental contaminants of bald eagles were determined by residue analyses of samples of whole blood from captured adult and sub-adult 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; liver, brain, and whole carcass tissues were forwarded to Patuxent Wildlife Research Center (P.W.R.C.). Blood samples were collected from live-trapped eagles using heparinized glass syringes which were washed and rinsed three times with residue grade acetone. The 6 to 12 cc samples were stored in glass vials which had been washed with nitric acid and rinsed with residue grade acetone and covered with teflon lined lids. Blood samples were frozen and stored 8 to 24 months prior to residue analyses.

Blood samples and eagle carcasses were analyzed by the P.W.R.C. Chemistry Section. Sample preparation, extraction, and Florisil cleanup for organochlorine analysis were as described by Cromartie et al. (1975). For the blood samples, special precautions were taken in rinsing glassware and procedural blanks were run with every 20th sample since the lower limit of sensitivity for blood was 0.01 ppm for pesticides. Silica gel or silicic acid was used for the separation of pesticides from polychlorinated biphenyl compounds (PCBs) and is described in detail in Kaiser et al. (1980). After the separation of pesticides from PCBs, all fractions were quantified by electron-capture gas-liquid chromatography (GLC) using a 1.83 m x 4 mm id glass column packed with 1.5% SP-2250/1.95% SP-2401 on 100/120 mesh Supelcoport. Residues in approximately 10% of the samples were confirmed by gas-liquid chromatography/mass spectrometry (GLC/MS). The lower limits of reportable residues were 0.01 ppm for pesticides and 0.05 ppm for PCBs for blood samples and 0.05 ppm for pesticides and 0.25 ppm for PCBs in other tissues. Residues were corrected for procedural blank background for blood samples only.

Atomic absorption was used for analysis of heavy metals. All mercury analyses were as described by Monk (1961) and Hatch and Ott (1968). Lead and cadmium were run as described by Haseltine et al. (1981) or Hinderberger et al. (1981) with slight modifications.

Levels of environmental contaminants in prey of the eagles were determined by residue analysis of whole carcass homogenates. Prey species were collected during 1979 to 1982 from established foraging areas of bald eagles in the wintering area. Actual prey items of bald eagles were also retrieved when possible. Collected animals were wrapped in clean 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 were pooled into groups of five individuals per sample prior to grinding; birds and rabbits were pooled into groups of three individuals per sample. Specimens were skinned and had gastrointestinal tracts removed. All accessible fat was removed from skins and included in pooled samples. The feet of mammalian species, and beak, tips of wings, and the tarsi and feet of bird species were removed prior to grinding. Pooled samples were homogenized using a large blender/grinder with blades and container made of stainless steel with teflon washers. Actual eagle kills were not pooled but were prepared separately. Samples were stored in chemically cleaned vials with teflon lids and frozen prior to residue analyses.

Prey samples were analyzed for organochlorine compounds by Hazelton Raltech, Inc., Madison, Wisconsin, by gas chromatography. Residues in seven samples which had relatively high concentrations of a large number of contaminants were confirmed by GLC-MS; residues of _gamma_-chlordane, dieldrin, oxychlordane, and HCB could not be confirmed and therefore are not reported. Percent lipid of samples was calculated by solvent extraction. Prey samples were analyzed for lead and mercury by Analytical Bio Chemistry Laboratories, Inc., Columbia, Missouri, by atomic absorption spectrophotometry.

STATISTICAL PROCEDURES

All concentrations in this paper are presented in ppm on a wet-weight basis unless otherwise noted. Residue concentrations were transformed to common logarithms prior to statistical procedures to correct for skewed distributions; values below detection limits were arbitrarily given values of 1/2 the lower limit of detection to eliminate values of zero prior to transformation. Means presented for residue data are geometric. Two way analysis of variance (ANOVA) was used to determine significant differences between age and area for residues in blood of wintering eagles and eagles on the Upper Klamath

Lake and Cascade Lakes breeding areas in southcentral Oregon (Part 1); other differences in residue concentrations were compared using one way ANOVA (Kim and Kohout 1975). Differences in frequencies of occurrences were tested using a chi-square test for proportions (Dixon and Massey 1969, p. 249). A Bonferroni technique (Snedecor and Cochran 1980, p. 116) was used to adjust significance levels for multiple comparisons. All statistical hypotheses were tested at the 0.05 level of significance.

RESULTS

FOOD HABITS

Examination of material found in castings of bald eagles from communal night roosts provided the best estimation of the relative importance of avian and mammalian prey in the overall diet. Prey remains at perch sites along foraging areas on the refuges provided an estimate of the composition of the avian prey, but gave no indication of prey taken from the flooded fields or other areas. Examination of material in castings tends to downplay the importance of fish (Kalmbach et al. 1964); however, all of the 211 observed instances of successful foraging by bald eagles were on avian or mammalian prey, and no foraging attempts on fish were observed during the study.

Waterfowl feathers were found 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. These results indicate that voles were a major component of the wintering eagles diet during some periods. The incidence of fur of other mammals was fairly low. Rabbit (Lepus californicus and Sylvilagus nuttallii) fur was detected in 9.4% of the castings, deer (Odocoileus hemionus) fur in 1.5%, and fur of Belding's ground squirrels (Spermophilus beldingi) in 0.9%.

Montane voles were captured by eagles on agricultural fields that were flooded for rodent control and preparation for spring planting. These fields were flooded annually in mid-winter to early spring by diversion of irrigation water over a 2 to 6 day period (depending on size of the field) until the field was covered with water, forcing voles out of their burrows. Animals observed foraging on voles in flooded fields included 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*). However, bald eagles were the most numerous predator attracted to the fields. Numbers of eagles foraging on voles increased during the first few days a field was flooded and peaked with as many as 200 eagles in a single 250 ha field before tapering off as the flooding was completed. Bald eagles would usually forage for voles by perching on the ground near the leading edge of the flooding water and capture voles as they emerged from their burrows. Pirating of voles from gulls, ravens and other eagles was also common.

The eagles fed almost entirely on waterbirds when not mousing on the flooded fields. Over 99% of the 913 prey items found at perches were avian (Table 16), and over 94% of the prey remains were waterfowl (Anseriformes). An additional 4% were coots (*Fulica americana*).

Dabbling ducks (Anatini) were the major component of the diet, comprising over 66% of the prey remains (Table 16). Mallards (*Anas platyrhynchos*) comprised 25% of the prey items; American wigeon (*A. americana*) comprised 23%, and northern pintails (*A. acuta*) comprised 15%. The other duck species appeared far less important; divers (Aythyini) and Mergini combined comprised less than 2%. However, ruddy ducks (*Oxyura jamaicensis*) as a single species comprised over 9%

Table 16. Prey items found at bald eagle hunting perches on Lower Klamath and Tule Lake National Wildlife Refuges, 1979-82.

Species	Number of Individuals	Percent of 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 (Chen caerulescens)	69	7.6
Ross' goose (C. rossii)	28	3.1
Mallard (Anas platyrhynchos)	231	25.3
Northern pintail (A. acuta)	135	14.8
Gadwall (A. strepera)	4	0.4
American wigeon (A. americana)	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 (Bucephala clangula)	3	0.3
Bufflehead (B. albeola)	1	0.1
Common merganser (Mergus merganser)	5	0.6
Ruddy duck (Oxyura jamaicensis)	86	9.4
Ring-necked pheasant (Phasianus colchicus)	2	0.2
American coot (Fulica americana)	37	4.1
Killdeer (Charadrius vociferus)	1	0.1
California gull (Larus californicus)	3	0.3
MAMMALS		
Montane vole (Microtus montanus)	2	0.2
Muskrat (Ondatra zibethica)	3	0.3
REPTILES		
Gartersnake (Thamnophis sirtalis)	1	0.1
TOTAL	913	

of the prey remains. Geese and swans were also an important component of the diet, totaling 17% of the identified prey. This group was probably underrepresented in the prey remains, because their large size may have discouraged eagles from carrying the carcasses back to perches, and their relatively higher biomass would increase their dietary importance.

Most of the observed foraging on waterfowl by bald eagles was scavenging. Only 9% of the 55 observations of successful foraging on waterfowl on the refuges was of birds taken alive. Waterfowl deaths caused by avian cholera and, to a lesser degree, lead poisoning (J. Hainline, pers. comm.) made large numbers of carcasses available to eagles. During late February and early March, 1981, large numbers of snow geese (Chen caerulescens) congregated in four sections surrounding Alkali Lake in the Klamath Basin. During this period 128 observations of bald eagles feeding on cholera killed snow geese were recorded. Young (1983) reported that approximately 90 bald eagles roosted nightly in small groups in the vicinity of the area during this time. Larger carcasses, such as those of swans or geese, were often fed on by more than one eagle, and eagles often displaced each other from carcasses. Eagles which fed while perched in trees often dropped less edible portions of prey to the ground, as evidenced by large numbers of heads, beaks, wings and gizzards scattered below perches. Eagles were capable of consuming an entire carcass while perched on the ground. Gizzards were observed less frequently among prey remains where eagles perched on irrigation dikes to feed than beneath perch trees.

ENVIRONMENTAL CONTAMINANTS IN PREY SPECIES

No residues of organochlorine compounds were detected in the black-tailed jack rabbit (*Lepus californicus*) or montane vole samples analyzed for environmental contaminants (Table 17). Low concentrations of mercury ($\overline{x}$ = 0.007 ppm) were detected in 40% of the vole samples (Tables 17 and 18), while mercury was not detected in any of the jack rabbit samples. Residues of lead were detected in 50% of the jack rabbit samples ($\overline{x}$ = 0.146 ppm), and all of the vole samples contained detectable lead residues ($\overline{x}$ = 0.724 ppm).

DDE was detected in generally low concentrations in 80% of the waterfowl samples (Tables 17 and 18). Samples from ruddy ducks contained the highest concentrations of DDE ($\overline{x}$ = 0.252 ppm), and the only occurrence of DDT was in one of the ruddy duck samples (0.29 ppm). PCBs and heptachlor epoxide were the only other organochlorines detected in any waterfowl samples. PCBs were detected in four (57%) of the ruddy duck samples ($\overline{x}$ = 0.124 ppm) and one (14%) northern pintail (0.12 ppm); heptachlor epoxide was detected in low concentrations in two of the ruddy duck samples (0.01 and 0.02 ppm) and one northern pintail sample (0.02 ppm). Residues in actual prey items taken from bald eagles were also low (Table 19), comparable to the potential prey items sampled.

Mercury was detected at generally low concentrations in 52% of the waterfowl samples (Tables 17 and 18). All of the ruddy duck samples contained detectable residues of mercury at higher concentrations than in the other waterfowl ($\overline{x}$ = 0.071 ppm). Lead residues were detected in

Table 17. Frequency of occurrence of organochlorines, mercury and lead detected in prey species collected from foraging areas of bald eagles wintering in the Klamath Basin.

		Percent of samples with detectable residue levels[a]					
Species	Sample[b] Size	DDT	DDE	PCBs	Heptachlor epoxide	Mercury	Lead
Snow goose	7	0.0	71.4	0.0	0.0	28.6	100.0
Ross' goose	7	0.0	85.7	0.0	0.0	14.3	100.0
Mallard	7	0.0	85.7	0.0	0.0	57.1	100.0
Northern pintail	7	0.0	100.0	14.3	14.3	85.7	100.0
American wigeon	5	0.0	40.0	0.0	0.0	20.0	60.0
Ruddy duck	7	14.3	85.7	57.1	28.6	100.0	100.0
Black-tailed jack rabbit	8	0.0	0.0	0.0	0.0	0.0	50.0
Montane vole	10	0.0	0.0	0.0	0.0	40.0	90.0

a Detectable concentrations of toxaphene, PCBs and lead = 0.1 ppm, detectable concentration of all other organochlorines and mercury = 0.01 ppm.

b Three animals per sample.

c PCBs resembled Aroclor 1254.

Table 18. Concentrations of organochlorines, mercury, and lead detected in prey species collected from foraging areas of wintering bald eagles in the Klamath Basin.

Species	Sample[a] size	Mean % lipid wet weight	Mean[b] ppm wet weight (95% C.I. in parentheses) [range[c] in brackets]			
			DDE	PCBs[d]	Mercury	Lead
Snow goose	7	6.3	0.011 (0.006-0.020)	N.D.	0.006 [N.D.-0.01]	1.220 (0.786-1.893)
Ross' goose	7	8.8	0.010 (0.007-0.014)	N.D.	0.006 [N.D.-0.01]	1.172 (0.409-3.354)
Mallard	7	9.1	0.027 (0.011-0.068)	N.D.	0.009 (0.005-0.016)	4.788 (1.890-12.13)
Northern pintail[e]	7	10.9	0.059 (0.027-0.129)	0.057 [N.D.-0.12]	0.012 (0.008-0.020)	0.643 (0.198-2.085)
American wigeon	5	8.7	0.008 [N.D.-0.02]	N.D.	0.006 [N.D.-0.01]	0.197 (0.031-1.270)
Ruddy duck[f]	7	5.8	0.252 (0.036-1.759)	0.124 (0.052-0.300)	0.071 (0.034-0.148)	1.878 (0.439-8.042)
Black-tailed jack rabbit	8	2.1	N.D.	N.D.	N.D.	0.146 (0.038-0.559)
Montane vole	10	3.6	N.D.	N.D.	0.007 [N.D.-0.02]	0.724 (0.235-2.225)

[a] Three animals per sample.

[b] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration of toxaphene, PCBs, and lead = 0.1 ppm. Detectable concentration of other organochlorines and mercury = 0.01 ppm. N.D. = no residue detected.

[c] Range presented instead of confidence interval if frequency of occurrence in samples < 50%, which produces unreliable variance estimates.

[d] PCBs resembled Aroclor 1254.

[e] One sample also contained 0.02 ppm heptachlor epoxide.

[f] One sample also contained 0.29 ppm DDT. Two samples also contained 0.02 and 0.01 ppm heptachlor epoxide.

Table 19. Concentrations of organochlorines, mercury, and lead detected[a] in prey items taken from bald eagles wintering in the Klamath Basin.

Species	Weight (g)	Percent Lipid of wet weight	ppm wet weight				
			p,p'-DDE	PCBs[b]	Endrin	Mercury	Lead
Snow goose	1139	6.6	N.D.	N.D.	N.D.	N.D.	0.78
Snow goose	1239	7.8	N.D.	N.D.	N.D.	N.D.	0.18
Snow goose	830	9.3	N.D.	N.D.	N.D.	N.D.	0.42
Snow goose	1089	4.7	N.D.	N.D.	N.D.	0.02	0.88
Greater white-fronted goose	1414	22.4	N.D.	N.D.	0.02	N.D.	0.72
Mallard	711	7.5	0.02	N.D.	N.D.	N.D.	2.80
Northern pintail	463	18.1	N.D.	N.D.	N.D.	0.02	0.26
American wigeon	426	12.9	N.D.	N.D.	N.D.	N.D.	0.16
American wigeon	399	11.6	N.D.	N.D.	N.D.	N.D.	0.35
American wigeon	391	14.5	N.D.	N.D.	N.D.	N.D.	0.32
Common goldeneye	382	5.6	0.06	0.16	N.D.	0.05	17.60
Ruddy duck	347	6.1	0.04	N.D.	N.D.	0.01	0.22

[a] Detectable concentrations of toxaphene, PCBs, and lead = 0.1 ppm, detectable concentrations of all other organochlorines and mercury = 0.01 ppm. N.D. = no residue detected.

[b] PCBs resembled Aroclor 1254.

95% of the waterfowl samples; only two wigeon samples contained no detectable residues. The highest concentrations of lead were detected in mallards ($\bar{x}$ = 4.79 ppm) and ruddy ducks ($\bar{x}$ = 1.88 ppm), which were important eagle food items. Some extreme lead levels (10.6-16.5 ppm) in 12.5% of the waterfowl samples were probably the result of embedded lead shot in the whole carcass homogenates.

ENVIRONMENTAL CONTAMINANTS IN BALD EAGLES

Blood samples of the 21 bald eagles that were captured and released on the wintering area contained low concentrations of organochlorine compounds (Table 20). DDE was detected in all but one of the eagle blood samples, but in fairly low concentrations. PCBs were detected in less than half of the blood samples, and the only other organochlorine detected in eagle blood was *trans*-nonachlor in one sub-adult.

Mercury was detected in all of the blood samples from the bald eagles analyzed for heavy metals (Table 21). The 5 sub-adult blood samples contained a mean of 2.166 ppm mercury, very similar to the mean of 2.285 ppm detected in the 15 adult samples; residues of lead in the blood samples were more variable. Lead residues were detected in 4 of the 13 adult blood samples and 3 of the 4 sub-adult samples analyzed. Concentrations of lead in the blood of adults ranged as high as 0.25 ppm with a mean of 0.038 ppm; sub-adult blood samples contained lead residues as high as 0.62 ppm with a mean of 0.129 ppm.

The carcasses of nine bald eagles found in the vicinity of the wintering area contained a wider array of organochlorines than were

Table 20. Frequency of occurrence and concentrations of organochlorines detected[a] in blood of bald eagles wintering in the Klamath Basin.

Area	Sample Size	p,p'-DDE Percent Occurrence	p,p'-DDE Mean[c] ppm wet weight (95% C.I.)	PCBs[b] Percent Occurrence	PCBs[b] Mean[c] ppm wet weight (95% C.I.)
Adults	16	93.8	0.042 (0.028-0.064)	50	0.018 (0.009-0.036)
Sub-adults[d]	5	100	0.030 (0.007-0.126)	40	0.014 [N.D.-0.08][e]

[a] No residues of p,p'-DDT, p,p'-DDD, dieldrin, heptachlor epoxide, oxychlordane, *cis*-chlordane, *cis*-nonachlor, endrin, toxaphene, HCB, or mirex were detected in any samples.

[b] PCBs = polychlorinated biphenyls.

[c] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration = 0.01 ppm.

[d] One sample also contained 0.01 ppm *trans*-nonachlor.

[e] Range presented instead of confidence interval because frequency of occurrence <50%, which produced unreliable variance estimates. N.D. = no residue detected.

Table 21. Frequency of occurrence and concentrations of mercury and lead detected in blood of bald eagles wintering in the Klamath Basin.

	Mercury			Lead		
Age	Sample Size	Percent occurrence	Mean[a] ppm wet weight (95% C.I.)	Sample Size	Percent occurrence	Mean[a] ppm wet weight (95% C.I.)
Adults	15	100	2.285 (1.762-2.964)	13	30.8	0.038 [N.D.-0.25][b]
Sub-adults	5	100	2.166 (1.586-2.960)	4	75.0	0.129 (0.012-1.360)

[a] Means are geometric, 1/2 of lower limit of detectable concentrations used for zeros. Detectable concentration of mercury = 0.02 ppm. Detectable concentration lead = 0.05 ppm.

[b] Range presented instead of confidence interval because frequency of occurrence < 50%, which produces unreliable variance estimates. N.D. = no residue detected.

Table 22. Concentrations of organochlorines and heavy metals detected[a] in tissues of bald eagles found dead in the vicinity of the Klamath Basin wintering area, 1979-82.

		Contaminant													
		p,p'-DDE		p,p'-DDD		Dieldrin		Heptachlor epoxide		Oxychlor-dane		*cis*-Chlordane		*trans*-Nonachlor	
Age and Sex	Cause of death	C[b]	B	C	B	C	B	C	B	C	B	C	B	C	B
adult	undetermined	0.45	--	0.06	--	--	--	--	--	--	--	--	--	0.05	--
adult male	emaciation	3.8	2.1	--	--	--	--	--	--	0.06	--	--	--	0.13	--
adult male	undetermined	5.5	0.23	0.07	--	0.12	--	--	--	0.06	--	--	--	--	--
adult male	emaciation	8.3	24.0	0.15	0.37	0.12	0.39	0.05	0.15	0.14	0.48	--	0.13	0.10	0.08
adult female	pneumonia	9.0	1.4	0.10	--	0.06	--	0.08	--	0.07	--	--	--	0.09	--
adult female	drowning	4.8	0.61	--	--	0.07	--	0.22	--	--	--	--	--	--	--
adult female	emaciation	3.8	17.0	--	0.24	--	0.38	--	0.06	--	0.18	--	--	0.15	0.70
sub-adult female	electrocution	3.5	0.13	0.15	--	0.09	--	--	--	0.05	--	0.09	--	0.23	--
sub-adult female	head trauma	0.19	--	--	--	0.11	--	--	--	--	--	--	--	--	--

Table 22. (Continued)

		Contaminant												
		cis-Nonachlor		Estimated Toxaphene		HCB		Mirex		Estimated PCBs		Lead	Cadmium	Mercury
Age and Sex	Cause of death	C	B	C	B	C	B	C	B	C	B	L	L	L
adult	undetermined	--	--	0.15	--	--	--	--	--	0.30	--	2.3	--	1.4
adult male	emaciation	0.05	--	--	--	N.A.	N.A.	N.A.	N.A.	8.8	2.2	5.4	N.A.	N.A.
adult male	undetermined	--	--	--	--	--	--	--	--	3.8	0.22	0.89	--	2.2
adult male	emaciation	--	0.24	--	--	--	0.08	0.05	0.10	10.0	23.0	2.8	0.13	8.0
adult female	pneumonia	0.06	--	--	--	0.09	--	0.07	--	6.0	1.1	0.32	--	2.9
adult female	drowning	--	--	--	--	N.A.	N.A.	N.A.	N.A.	1.3	--	1.5	--	1.6
adult female	emaciation	--	0.19	--	0.10	--	0.08	--	0.13	3.0	35.0	N.A.	N.A.	N.A.
sub-adult female	electrocution	--	--	0.13	--	0.06	--	0.05	--	3.0	0.10	2.0	0.85	1.0
sub-adult female	head trauma	--	--	--	--	0.05	--	--	--	--	--	0.94	--	0.76

[a] Residues are in ppm wet weight. No residues of p,p'-DDT or endrin detected. -- = no residue detected. N.A. = not analyzed. Detectable concentrations (ppm): pesticides = 0.05, PCBs = 0.25, cadmium and lead = 0.1, mercury = 0.02.

[b] Tissue analyzed: C = carcass, B = brain, L = liver.

detected in the blood samples (Table 22); however, most of the contaminants were in relatively low concentrations. The highest concentrations were of DDE and PCBs in brains of the three eagles which died of emaciation. These elevated residues in the brain were probably the result of mobilization of contaminants in the metabolized fat reserves (Stickel 1973) and do not indicate critical levels (Stickel et al. 1984). Mean DDE concentration in whole carcass tissues of the nine eagles was 2.734 ppm (95% C.I. = 0.98-7.58); mean concentration of PCBs in the carcasses was 2.124 ppm (95% C.I. = 0.67-6.77). All other organochlorines were detected at less than 0.8 ppm with means below 0.05 ppm.

Concentrations of heavy metals in the livers of the necropsied eagles were moderate to low (Table 22). Cadmium was detectable in only two of the seven samples analyzed for that metal (0.85 and 0.13 ppm). Mean concentration of mercury in the livers was 1.89 ppm (95% C.I. = 0.92-3.90); lead concentrations ranged as high as 5.4 ppm with a mean of 1.52 ppm (95% C.I. = 0.74-3.11).

DISCUSSION

FOOD HABITS

Wintering concentrations of bald eagles are often associated with a particularly abundant food source such as fish (McClellend 1973, Shea 1973, Servheen 1975, Stalmaster 1976, Steenhoff 1976, Young 1983), road-killed jack rabbits (Edwards 1969, Platt 1976), or waterfowl concentrations (Wright 1953, Southern 1964, Swisher 1964, Hancock 1964). The concentrations of bald eagles in this study were associated with wintering and staging waterfowl concentrations and increasing incidences of avian cholera providing carcasses for scavenging (Keister 1981). The eagles can subsist solely on cholera kills during periods when waterfowl are concentrated and waterfowl mortalities due to avian cholera increase (Bellrose 1976, p. 70, Keister 1981). However, this area also appears unique in that the bald eagles were periodically utilizing microtine rodents as a major dietary component. The avian prey of the eagles wintering in the Klamath Basin were largely dabbling ducks and geese. Dabbling ducks were also important prey of resident bald eagles which nest in the Klamath Basin (Part 1). However, the avian portion of the resident eagles' diets contained a wider variety of species; and grebes and, to a lesser extent, diving ducks were major dietary components. The dietary importance of mammals to the resident eagles was relatively low, especially in comparison to the voles in the wintering eagles' diet. Scavenging and pirating habits of bald eagles in this study were similar to those reported in other studies (Bent 1937, Kalmbach et al. 1964, Erskine 1968, Edwards 1969, Grubb 1971, Servheen 1975, Dunstan and Harper 1975, Ogden 1975, Sherrod et al. 1976, Todd et al. 1982). This was in contrast to the resident bald eagles which nest in the Klamath Basin (Part 1). Resident eagles also fed largely on waterbirds during the winter months; but it was estimated that over 70% of the avian prey were taken live. By scavenging on dead and dying birds the wintering eagles may increase the number of hunter-crippled and lead poisoned waterfowl in their diet and increase their exposure to lead. Mortalities of bald eagles due to avian cholera have been reported, and it has been suggested that extensive outbreaks of avian cholera in waterfowl concentrations could pose a threat to bald eagles (Locke et al. 1972, Rosen 1972). The number of reported eagle mortalities due to avian cholera appears low considering that eagles often feed directly on the carcasses of cholera-killed waterfowl; however, incidences of bald eagles contracting avian cholera and their impact may be difficult to assess.

ENVIRONMENTAL CONTAMINANTS

The extremely low concentrations of organochlorines and mercury in voles and jack rabbits in this study indicate that these prey are not contributing significantly to contamination of wintering bald eagles. Species in terrestrial habitats have a lower potential for bioaccumulation (Keith and Hunt 1966, Saha 1972, Bevenue 1976) and herbivorous small mammals generally accumulate only very low residues (Turner 1965, Dimond and Sherburne 1969, U.S.D.A. 1969). Lead residues in the montane vole samples were comparable to some of the concentrations in the waterfowl samples. These concentrations appear relatively high considering that the lead was tissue-bound rather than in the form of embedded shot. However, Pattee and Hennes (1983) reported that the control diets of eagles sampled by Hoffman et al. (1981) contained 0.7-3.7 ppm lead. Yet, lead in the blood of the control eagles was not elevated above the 0.1 ppm detection limit.

The concentrations of organochlorines and mercury in the dabbling ducks and geese sampled in this study were low in comparison to levels reported throughout the United States (Vermeer et al. 1973, Heath and Hill 1974, White and Heath 1976, White 1979) and were similar to levels in samples of the same species collected from foraging territories of resident bald eagles in southcentral Oregon (Part 1). Dabbling ducks typically have lower contaminant levels than divers (Dindal and Peterle 1968, Baskett 1975). The presence of DDT, the parent material of DDE, in one sample indicates that the source of some of the contaminants may be translocation rather than local accumulation in the Klamath Basin. However, even the residue levels in the ruddy duck samples were far lower than residue levels in western grebes (*Aechmophorus occidentalis*) and California gulls (*Larus californicus*) collected from the Klamath Basin which were implicated as the dietary source of elevated contaminant levels in the resident nesting eagles (Part 1).

Mean lead concentrations in waterfowl in this study were fairly low. As tissue-bound lead, the residues in waterfowl in this study should not represent a major threat to the health of bald eagles. However, the extreme levels of lead detected in some of the waterfowl sampled indicate the presence of lead as embedded shot. Lead shot may pose the greatest threat to bald eagles wintering in the Klamath Basin, as repeated exposure to embedded shot in waterfowl is a major source of lead poisoning in bald eagles (Pattee and Hennes 1983). The presence of embedded shot and lead poisoning in waterfowl is extensive (Bellrose 1953, 1964, Elder 1950, 1955, Stout and Cornwell 1976, Perry and Geissler 1980, Griffin et al. 1982), and lead shot have been found in over 50% of bald eagle castings from some wintering areas (Dunstan 1974, Platt 1976). Pattee et al. (1981) reported that five of six bald eagles experimentally force fed 10 to 156 lead shot died in 10 to 133 days, while the sixth went blind.

Besides embedded lead, waterfowl may carry numerous lead shot in their gastrointestinal tract (Pattee and Hennes 1983). In this study gizzards were removed from waterfowl samples along with the entire gastrointestinal tract prior to residue analyses. Bald eagles which consume the gizzard of avian prey may ingest numerous lead shot in one feeding.

The bald eagles wintering in the Klamath Basin are undoubtedly being exposed to lead shot through the waterfowl in their diet. Past exposure was evident in some elevated levels of lead in blood samples of the bald eagles, especially those of sub-adults. The occurrence of lead residues in the blood samples of adult eagles was 31%; however the tissue lead in the eagles' prey would not be expected to markedly elevate levels in the eagle blood (Pattee and Hennes 1983). Eagles with high lead contamination may be difficult to sample as they probably die in a fairly short period of time and decreased appetites and lethargy (Hoffman et al. 1981) may diminish the eagles' chances of being trapped. The extent and impact of exposure of eagles to lead in the Klamath Basin is difficult to determine and requires further study.

Mercury residues in blood samples of bald eagles in this study were high compared to levels in experimental mallards; Heinz (1974, 1976, 1979, 1980) reported that dietary mercury of approximately 0.1 ppm resulted in blood residues of about 0.5 to 0.6 ppm. Mercury in blood of wintering bald eagles in this study were comparable to residues in resident adult eagles in southcentral Oregon (Part 1). However, the prey species analyzed contained relatively low mercury concentrations. Bald eagles may have different physiological responses to mercury than other species which have been studied (Borg et al. 1969, Fimreite 1971, Spann et al. 1972, Vermeer et al. 1973). Blood samples from five bald eagles which had been held in captivity from 1-13 years at Patuxent Wildlife Research Center contained 0.17 to 0.31 ppm mercury, which were higher background levels than in control ducks at the Research Center (S.N. Wiemeyer, pers. comm.). However, these blood residues were considerably lower than the blood mercury in eagles from this study.

The eagle blood in this study was frozen and stored for several months prior to analysis; therefore concentrations of organochlorines were undoubtedly lower (approximately 35%) than if the samples had been analyzed fresh (Stafford and Stickel 1982, Wiemeyer et al. 1984b). However, the residues of organochlorines in the blood of the wintering eagles in this study were still quite low.

Blood samples of adult and sub-adult bald eagles from the breeding territories in southcentral Oregon (Part 1) contained a wider array of environmental contaminants than the wintering eagles. The blood of the resident eagles had much higher concentrations of DDE ($P = 0.001$) and PCBs ($P = 0.001$). Henny et al. (1981) also reported low concentrations of organochlorines in blood plasma of wintering adult bald eagles in Colorado and Missouri.

Few studies have been conducted which allow a comparison of the environmental contaminants in whole blood of bald eagles to productivity. Henny and Meeker (1981) developed regression models for estimating DDE residues in eggs of raptors from residues in blood plasma; and Henny et al. (1981) used the models to estimate organochlorine residues in potential eggs of eagles wintering in Colorado and Missouri. By applying the residues of DDE in the whole blood of the adult bald eagles sampled in this study (adjusted for 35% loss due to freezing) to the Henny and Meeker pre-laying model, we estimated the mean concentration of DDE in eggs from these eagles at 0.13 ppm. If the plasma-egg residue relationship holds true for bald eagles, these estimated egg residues should be conservative because residues in whole blood rather than plasma were used. Adjusting for dilution by red blood cells (40-50% plasma yield), the estimated residue concentrations could more than double, depending upon the proportion of lipids and thus the lipophilic organochlorines in the plasma fraction of the whole blood. However, doubling the residue levels to account for the dilution factor in whole blood still estimates the mean DDE residues in potential eggs at low levels. This concentration in bald eagle eggs is not associated with measurable shell thinning, and is well below the level of DDE associated with a productivity of one young per occupied site in a healthy population (1.3 ppm DDE, 95% C.I. = 0.36-2.4) (Wiemeyer et al. 1984a).

The concentrations of residues detected in the carcasses of the necropsied eagles found on the wintering area were consistent with the low levels found in the blood samples. Residues of organochlorines in the carcass of an illegally shot resident adult male found on a nesting territory in the Klamath Basin (Part 1) were all considerably higher than concentrations in the carcasses of any of the wintering eagles, with the exception of toxaphene; toxaphene was not detected in the carcass of the resident bird, but was estimated at low levels in two of the necropsied wintering eagles.

The wintering birds in the Klamath Basin do not appear to nest in Oregon. Resident eagles in southcentral Oregon usually remain in the vicinity of their nesting territories, apparently even at the higher elevations in the High Cascade Mountains, despite their close proximity to the wintering congregation of bald eagles (Part 1). 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 1981). 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. Bald eagles captured from a wintering group of eagles on the Skagit River in northern Washington have been re-located among the wintering congregation in the Klamath Basin later the same winter (G. Hunt, pers. comm.). Young (1983) radio-marked and tracked an adult male from Glacier National Park to the Klamath Basin during the winter and then north to the Taltson River in the Northwest Territories. Henny et al. (1981) hypothesized that bald eagles wintering in Colorado and Missouri migrated from the Great Lakes region, northern Saskatchewan, and other parts of Canada; they attributed low ΣDDT residues in plasma of the eagles to a general improvement of the environment in the nesting areas.

The bald eagles sampled from the Klamath Basin wintering area did not appear to have elevated body burdens of organochlorines that would be associated with reproductive problems. This is probably a function of the wintering eagles' diet; the prey base of the eagles appeared to be relatively clean, with the possible exception of lead shot in waterfowl which may present a potential for lead poisoning of eagles. These low organochlorine levels are in contrast to reported residues in blood and eggs of the resident bald eagles in the Klamath Basin (Part 1), where it was concluded that DDE was having a direct impact on reproductive success of some nesting pairs. The bald eagles which only winter in the Klamath Basin apparently nest in areas which have a relatively clean prey base or any contaminated prey species in the areas are of low dietary importance.

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APPENDICES

Appendix 1. Prey items found at bald eagle nests in southcentral Oregon, 1979-83.

	Upper Klamath Lake[1]				Outer Klamath Basin[2]				Cascade Mountains[3]			
	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of Prey items	Greatest Number at one nest	Percent of Nests with item
BIRDS												
Pied-billed grebe	1	0.1	1	1.0	4	0.6	2	6.8	--	--	--	--
Eared and horned grebes	69	6.6	7	54.6	19	2.8	3	31.8	14	4.5	2	22.4
Western grebe	88	8.5	5	66.7	16	2.4	2	34.1	18	5.7	3	27.6
Grebe Chick	1	0.1	1	1.0	1	0.1	1	2.3	1	0.3	1	1.7
Double-crested cormorant	7	0.7	2	5.0	2	0.3	1	4.6	1	0.3	1	1.7
American bittern	4	0.4	2	3.0	1	0.1	1	2.3	2	0.6	1	3.4
Great blue heron	7	0.7	1	7.1	4	0.6	1	9.1	7	2.2	1	12.1
Black-crowned night-heron	20	1.9	5	10.1	1	0.1	1	2.3	2	0.6	1	3.4
White-fronted goose	4	0.4	1	4.0	1	0.1	1	2.3	2	0.6	1	3.4
Snow goose	1	0.1	1	1.0	2	0.3	1	4.6	1	0.3	1	1.7
Canada goose	18	1.7	2	17.2	11	1.6	2	22.7	6	1.9	1	10.3
Gosling	3	0.3	1	3.0	--	--	--	--	--	--	--	--
Wood duck	7	0.7	3	5.0	3	0.4	1	6.8	4	1.3	1	6.9
Green-winged teal	6	0.6	1	6.1	7	1.0	1	15.9	2	0.6	1	3.4
Mallard	35	3.4	2	31.3	35	5.2	5	54.6	13	4.1	1	22.4
Northern pintail	24	2.3	2	23.2	29	4.3	3	47.7	4	1.3	1	6.9
Cinnamon and blue-winged teal	20	1.9	2	17.2	33	4.9	5	31.8	3	1.0	1	5.2
Northern shoveler	16	1.5	2	15.2	8	1.2	2	15.9	1	0.3	1	1.7
Gadwall	7	0.7	1	7.1	12	1.8	2	25.0	1	0.3	1	1.7
American wigeon	10	1.0	2	9.1	13	1.9	2	27.3	--	--	--	--
Unidentified dabbler	7	0.7	4	4.0	2	0.3	1	4.6	8	2.5	1	13.8
Canvasback	9	0.9	1	9.1	2	0.3	1	4.6	2	0.6	1	3.4
Redhead	2	0.2	1	2.0	5	0.7	1	11.4	1	0.3	1	1.7
Ring-necked duck	--	--	--	--	2	0.3	2	2.3	--	--	--	--
Lesser scaup	63	6.1	4	50.5	14	2.1	2	29.6	11	3.5	2	17.2
Common goldeneye	--	--	--	--	--	--	--	--	1	0.3	1	1.7
Bufflehead	29	2.8	4	24.2	6	0.9	1	13.6	2	0.6	1	3.4
Common merganser	--	--	--	--	--	--	--	--	2	0.6	1	3.4
Ruddy duck	87	8.4	7	54.6	11	1.6	2	22.7	5	1.6	1	8.6
Duckling	3	0.3	1	3.0	--	--	--	--	1	0.3	1	1.7
Unidentified waterfowl	12	1.2	6	4.0	5	0.7	4	4.6	6	1.9	1	10.3
American coot	89	8.6	14	47.5	135	20.1	14	77.3	31	9.9	2	50.0
Wilson's phalarope	--	--	--	--	1	0.1	1	2.3	--	--	--	--
California and ring-billed gulls	17	1.6	2	15.2	4	0.6	1	9.1	12	3.8	4	13.8
Caspian tern	1	0.1	1	1.0	--	--	--	--	--	--	--	--
Forster's tern	--	--	--	--	1	0.1	1	2.3	2	0.6	1	3.4
Barn owl	1	0.1	1	1.0	--	--	--	--	--	--	--	--

Appendix 1. (Continued)

	Upper Klamath Lake[1]				Outer Klamath Basin[2]				Cascade Mountains[3]			
	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of Prey items	Greatest Number at one nest	Percent of Nests with item
Great horned owl	1	0.1	1	1.0	--	--	--	--	--	--	--	--
Belted kingfisher	--	--	--	--	1	0.1	1	2.3	1	0.3	1	1.7
Northern flicker	2	0.2	1	2.0	1	0.1	1	2.3	--	--	-	--
Steller's jay	7	0.7	2	6.1	1	0.1	1	2.3	1	0.3	1	1.7
Black-billed magpie	1	0.1	1	1.0	2	0.3	1	4.6	--	--	--	--
American robin	1	0.1	1	1.0	1	0.1	1	2.3	1	0.3	1	1.7
Western bluebird	--	--	--	--	1	0.1	1	2.3	--	--	--	--
European starling	--	--	--	--	1	0.1	1	2.3	--	--	--	--
Red-winged blackbird	2	0.2	1	2.0	3	0.4	1	6.8	--	--	--	--
Yellow-headed blackbird	2	0.2	1	2.0	1	0.1	1	2.3	--	--	--	--
Brewer's blackbird	1	0.1	1	1.0	--	--	--	--	2	0.6	1	3.4
Western meadowlark	1	0.1	1	1.0	5	0.7	2	9.1	1	0.3	1	1.7
Σ (BIRDS)	687	66.1%			407	60.6%			172	54.8%		
FISH												
Mountain whitefish	--	--	--	--	2	0.3	1	4.6	43	13.7	6	60.3
Kokanee	--	--	--	--	--	--	--	--	9	2.9	4	6.9
Rainbow trout	16	1.5	1	16.2	6	0.9	2	11.4	13	4.1	11	5.2
Unidentified Salmonid	--	--	--	--	4	0.6	1	9.1	20	6.4	2	32.8
Tui and blue chub	126	12.1	6	73.7	8	1.2	1	18.2	24	7.6	4	36.2
Suckers	78	7.5	4	62.6	22	3.3	3	40.9	3	1.0	1	5.2
Black and brown bullhead	34	3.2	6	24.2	132	19.6	54	38.6	--	--	--	--
White crappie	--	--	--	--	4	0.6	2	6.8	--	--	--	--
Largemouth bass	--	--	--	--	4	0.6	2	6.8	--	--	--	--
Unidentified sunfish	--	--	--	--	4	0.6	1	9.1	--	--	--	--
Yellow perch	3	0.3	1	3.0	2	0.3	2	2.3	--	--	--	--
Σ (FISH)	257	24.7%			188	28.0%			112	35.7%		

Appendix 1. (Continued)

	Upper Klamath Lake[1]				Outer Klamath Basin[2]				Cascade Mountains[3]			
	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of prey items	Greatest Number at one nest	Percent of Nests with item	Number of individuals	Percent of Prey items	Greatest Number at one nest	Percent of Nests with item
MAMMALS												
Black-tailed jack rabbit	16	1.5	2	14.1	7	1.0	1	15.9	--	--	--	--
Snowshoe hare	--	--	--	--	--	--	--	--	2	0.6	1	3.4
Nuttall's cottontail	4	0.4	1	4.0	1	0.1	1	2.3	--	--	--	--
Unidentified rabbit	3	0.3	1	3.0	--	--	--	--	3	1.0	1	5.2
Yellow-bellied marmot	15	1.4	4	10.1	2	0.3	1	4.6	1	0.3	1	1.7
Belding's ground squirrel	13	1.3	1	13.1	15	2.2	2	31.8	5	1.6	1	8.6
Beechey's ground squirrel	2	0.2	1	2.0	--	--	--	--	--	--	--	--
Golden-mantled ground squirrel	--	--	--	--	1	0.1	1	2.3	--	--	--	--
Douglas squirrel	1	0.1	1	1.0	--	--	--	--	--	--	--	--
Northern flying squirrel	1	0.1	1	1.0	--	--	--	--	1	0.3	1	1.7
Pocket gopher	--	--	--	--	2	0.3	1	4.6	--	--	--	--
Meadow mouse	11	1.1	2	8.1	6	0.9	5	4.6	1	0.3	1	1.7
Muskrat	16	1.5	2	15.2	24	3.6	7	27.3	1	0.3	1	1.7
Porcupine	1	0.1	1	1.0	2	0.3	1	4.6	--	--	--	--
Coyote	--	--	--	--	1	0.1	1	2.3	--	--	--	--
Long-tailed weasel	2	0.2	1	2.0	--	--	--	--	--	--	--	--
Bobcat	1	0.1	1	1.0	--	--	--	--	--	--	--	--
Mule deer	5	0.5	1	5.0	7	1.0	1	15.9	7	2.2	1	12.1
Cow	1	0.1	1	1.0	3	0.4	1	6.8	1	0.3	1	1.7
Sheep	--	--	--	--	3	0.4	1	6.8	--	--	--	--
Pig	--	--	--	--	--	--	--	--	1	0.3	1	1.7
Unidentified Mammal	--	--	--	--	1	0.1	1	2.8	1	0.3	1	1.7
Σ (MAMMALS)	92	8.9%			75	11.2%			24	7.6%		
INVERTEBRATES												
Crayfish	1	0.1	1	1.0	--	--	--	--	6	1.9	4	5.2
Freshwater clams	3	0.3	3	1.0	2	0.3	2	2.3	--	--	--	--

[1] 27 nest sites sampled a total of 99 times.
[2] 16 nest sites sampled a total of 44 times.
[3] 22 nest sites sampled a total of 58 times.

Appendix 2. Concentrations of organochlorines and heavy metals detected[a] in tissues of bald eagles found dead in the vicinity of Klamath Lake.

		Contaminant													
		p,p'-DDE		p,p'-DDD		Dieldrin		Heptachlor epoxide		Oxychlor-dane		*cis* Chlordane		*trans*-Nonachlor	
Age and Sex	Cause of death	C[b]	B	C	B	C	B	C	B	C	B	C	B	C	B
adult male	shot	34.0	2.4	0.63	—	0.17	—	0.28	—	0.25	—	0.30	—	0.75	—
5 weeks female	pneumonia	1.1	2.3	—	—	—	—	—	—	—	—	—	—	—	—
near-adult[c]	electrocuted	9.8	1.1	0.30	0.05	0.06	—	—	—	0.07	—	0.09	—	0.45	—

Appendix 2. (Continued)

		Contaminant												
		cis-Nonachlor		Estimated Toxaphene		HCB		Mirex		Estimated PCBs		Lead	Cadmium	Mercury
Age and Sex	Cause of death	C	B	C	B	C	B	C	B	C	B	L	L	L
adult male	shot	0.28	—	—	—	0.15	—	—	—	28.0	2.2	—	—	0.97
5 weeks female	pneumonia	—	—	—	—	—	—	—	—	0.70	1.8	0.67	0.23	1.6
near-adult[c]	electrocuted	0.11	—	0.10	—	—	—	—	—	8.5	0.96	—	—	1.6

[a] Residues are in ppm wet weight. No residues of p,p'-DDT or endrin detected. — = no residue detected.

[b] Tissue analyzed: C = carcass, B = brain, L = liver.

[c] Probably a wintering transient.

Appendix 3. Concentrations of organochlorines, mercury, and lead detected[a] in prey items recovered from bald eagles in south-central Oregon.

Area and Species	Weight (g)	Percent Lipid of wet weight	ppm wet weight			
			p,p'-DDE	PCBs[b]	Mercury	Lead
CASCADE LAKES						
Mountain whitefish	561	6.4	N.D.	N.D.	0.03	0.26
Mountain whitefish	844	4.4	N.D.	N.D.	0.03	0.05
Mountain whitefish	438	4.1	N.D.	N.D.	0.02	0.18
Mountain whitefish	175	9.8	0.02	0.13	0.03	0.16
Mountain whitefish	470	5.9	N.D.	N.D.	0.02	0.05
Mean[c]	498	6.1	--	--	0.026	0.113
95% C.I.					0.019-0.034	0.044-0.294
Kokanee	517	9.8	N.D.	N.D.	0.03	0.05
Brown trout[d]	2051	0.7	0.02	N.D.	0.15	0.05
KLAMATH LAKE						
Eared grebe	317[e]	55.3	0.10	N.D.	0.10	0.13

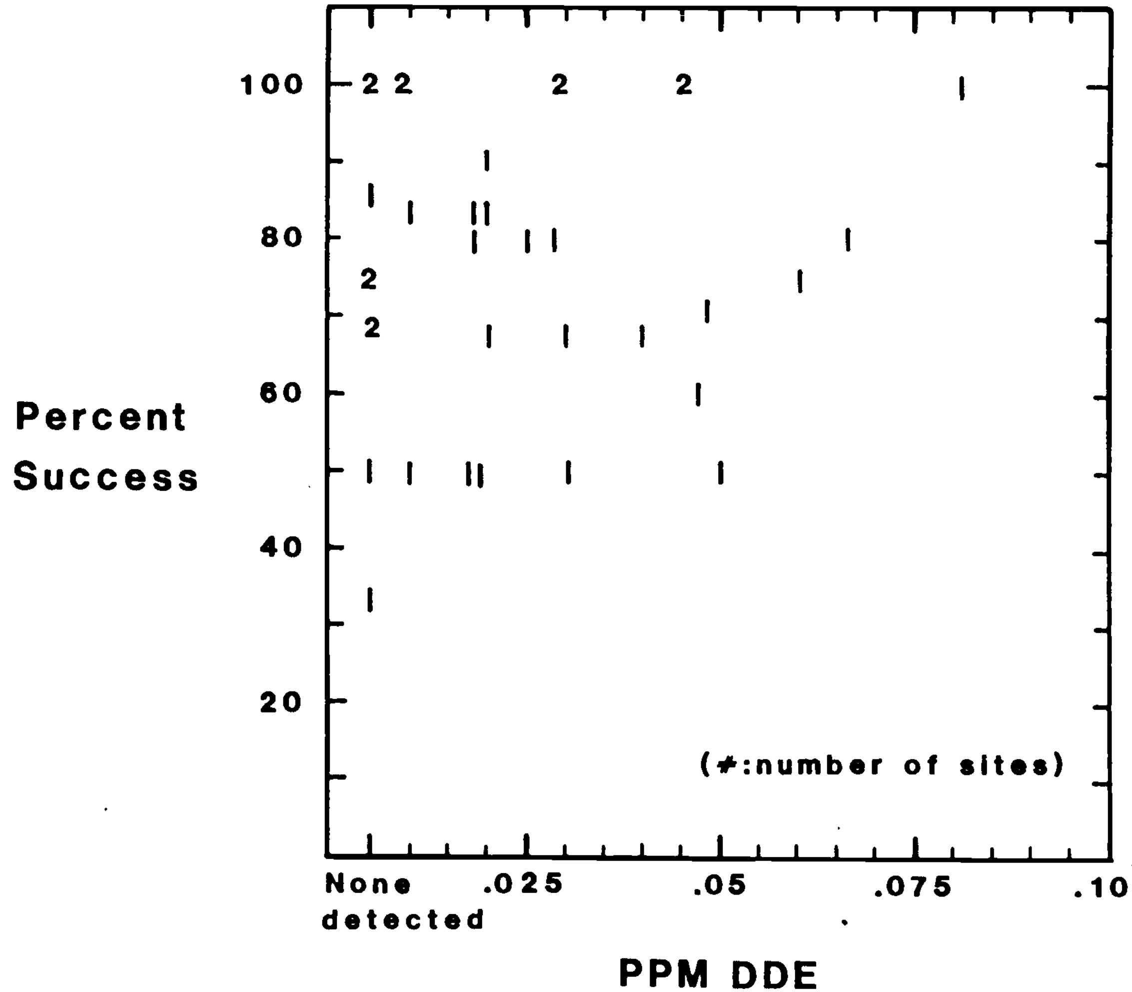
a Detectable concentrations of lead, toxaphene and PCBs = 0.1 ppm, detectable concentrations of all other organochlorines and mercury = 0.01 ppm.

b PCBs resembled Aroclor 1254.

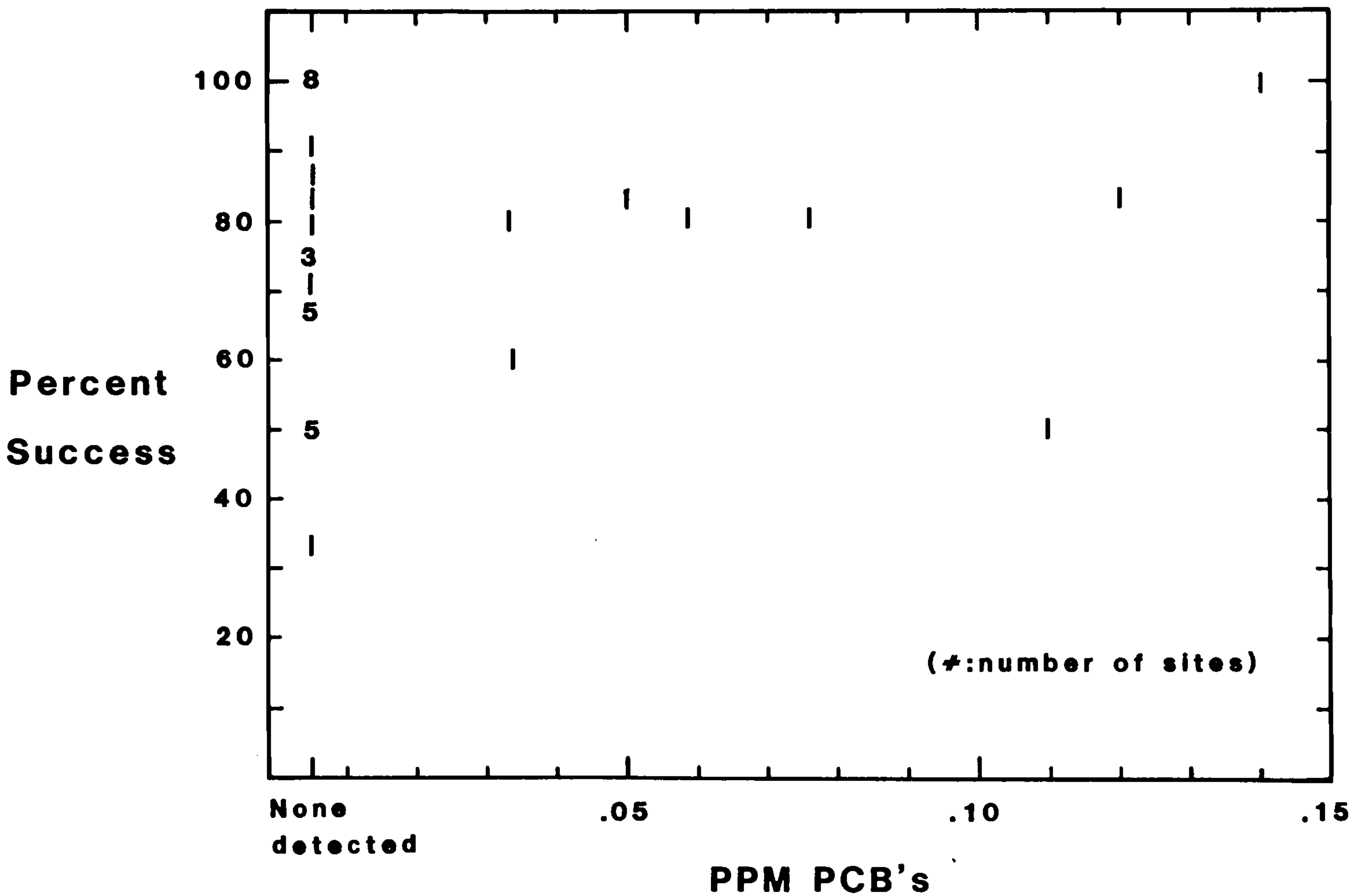
c Means of contaminants are geometric, using 1/2 of lower limit of detectable concentrations for zeros.

d Entire head of the fish had been eaten.

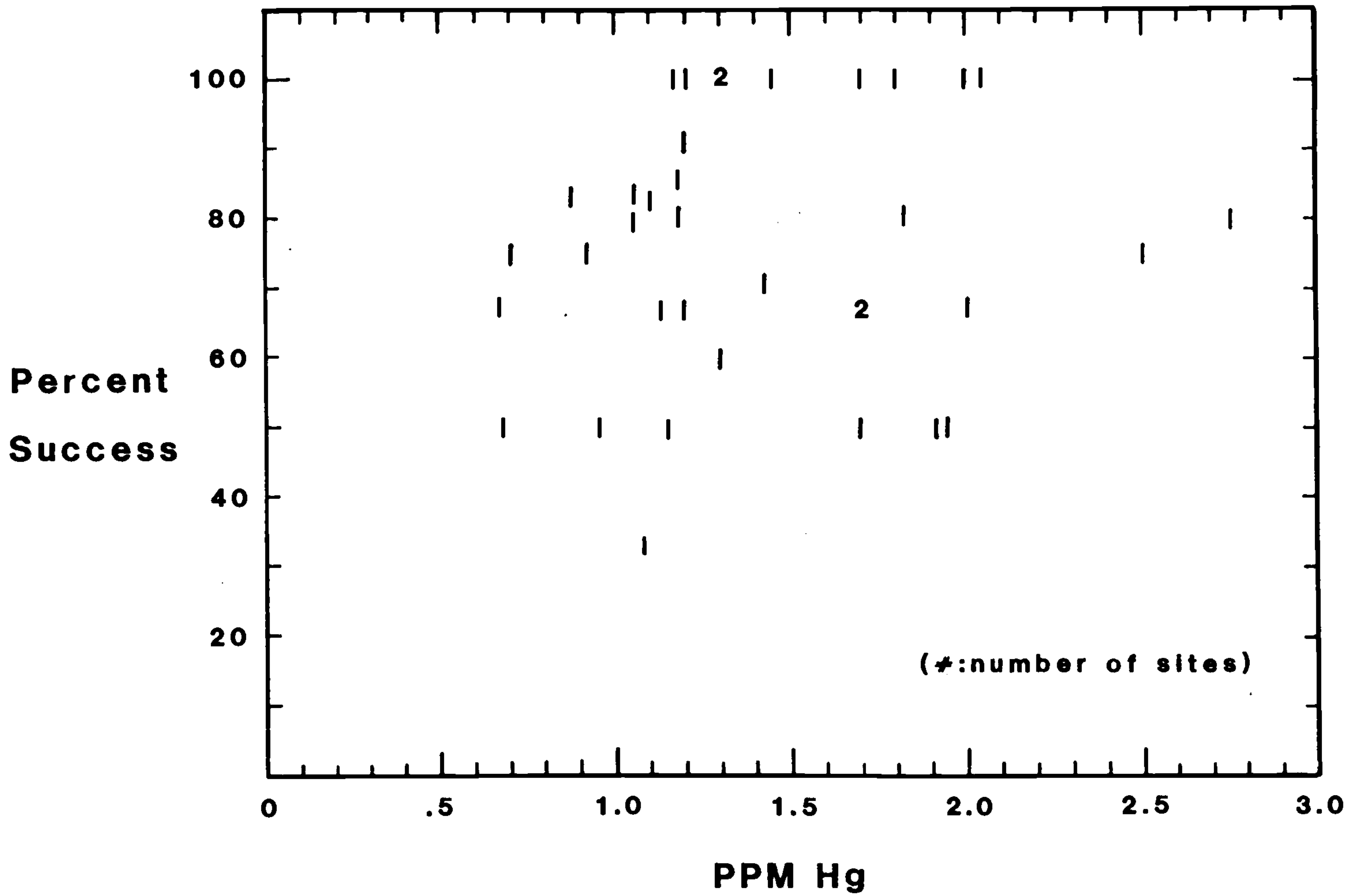
e Dressed weight after lab preparation.



Appendix 4. Success history of bald eagle nest sites vs mean concentration (ppm wet weight) of DDE in blood of nestlings.



Appendix 5. Success history of bald eagle nest sites vs mean concentration (ppm wet weight) of PCBs in blood of nestlings.



Appendix 6. Success history of bald eagle nest sites vs mean concentration (ppm wet weight) of mercury in blood of nestlings.