



BIOLOGICAL AND ECOTOXICOLOGICAL CHARACTERISTICS OF TERRESTRIAL VERTEBRATE SPECIES RESIDING IN ESTUARIES



Osprey



(Photo by

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Biological Characteristics

Species

Pandion haliaetus ranges from 53-61 cm in length and has a wingspan of 1.4-1.8 m. Females tend to have a greater average mass (1.6 kg) than males (1.4 kg) (Dunning, 1993). Ospreys are white on their ventral surface and brown on the dorsal surface. When in flight, the wing has an obvious bend at the "wrist" (Bull and Farrand, 1977; McVey et al., 1993).

Status in Estuaries	Osprey are mainly found near marine environments, but large inland rivers, lakes, and reservoirs may also provide suitable habitat (McVey et al., 1993). Nesting occurs on natural or artificial structures such as flat-topped wooden platforms, channel markers, and radio towers located near shallow waters supporting a plentiful supply of fish (Poole, 1989; McVey et al., 1993). Colonies may arise in secure areas such as islands or lakes, but most pairs tend to be solitary nesters, separated from other nests by tens to hundreds of kilometers (McVey et al., 1993). Typical clutch size is 2-4 eggs (Bull and Farrand, 1977). Young are altricial (Ehrlich et al., 1988). The maximum age of an osprey recorded in nature 23 years (Clapp et al., 1982).
Abundance and Range	The osprey occurs along the Pacific northwest and the eastern seaboard of North America from South Carolina to Maine and can be found as a year-round resident on the Gulf Coast (Bull and Farrand, 1977). Migration to wintering grounds in Central and South America mainly follows the coastline (McVey et al., 1993). Eight thousand active nests have been found in the United States, and about 50% of the North American population is estimated to be located along the Atlantic Coast or the Gulf of Mexico (Poole, 1989).
Site Fidelity	Ospreys typically pair for life and use the same nest site in successive years.
Ease of Census	Moderate
Feeding Habits	Specialists. This species forages by hovering over water and diving feet first for prey. The osprey feeds almost exclusively on medium sized (11-30 cm) live fish that remain in shallow waters or near the water's surface. It has occasionally been observed taking birds, frogs, crustaceans, and fresh dead fish (McVey et al., 1993). The osprey is known to feed specifically on menhaden, channel catfish, white perch, shad, sunfish, largemouth bass, winter flounder, herrings, and silversides, and will travel up to 10-15 km to find food (Clark, 1995; McVey et al., 1993).

Osprey Contaminant Exposure Data

I. Organochlorine Contaminants

A. Concentrations in Adults and Nestlings

1. From 1964 to 1973, adults and occasional nestlings were collected along the East coast (Wiemeyer et al., 1980). Organochlorine residues were measured in brain and carcass and a summary of the results is listed below.

Florida (N=5): **DDE** concentrations ranged from ND-11 $\mu\text{g/g}$ wet weight in brain and 0.60-38 $\mu\text{g/g}$ in carcass. **DDD** concentrations ranged from ND-2.8 $\mu\text{g/g}$ in brain and from ND-8.4 $\mu\text{g/g}$ in carcass. Concentrations of **DDT** were <1 $\mu\text{g/g}$ in both brain and carcass, with the exception of one bird from Merritt Island with a concentration of 5.7 $\mu\text{g/g}$ in carcass. **Dieldrin** and **heptachlor epoxide** were detected at concentrations <1 $\mu\text{g/g}$. **PCBs** ranged from ND-50 $\mu\text{g/g}$ in brain and 1.1-20 $\mu\text{g/g}$ in carcass.

South Carolina (N=2): **DDE** concentrations were 16 and 3.7 $\mu\text{g/g}$ in brain, and 5.1 and 0.69 $\mu\text{g/g}$ in carcass. **DDD** and **DDT** values were <1 $\mu\text{g/g}$ in brain and neither were detected in carcass. **Dieldrin** was detected at a concentrations of 3.8 and 0.02 in brain. **Heptachlor epoxide** was not detected. **PCBs** concentrations were 9.0 and 3.0 $\mu\text{g/g}$ in brain, and 4.0 and 6.0 $\mu\text{g/g}$ in carcass.

Maryland, mainly along the Chesapeake Bay (N=14): **DDE** concentrations ranged from 0.12-30 $\mu\text{g/g}$ in brain and 0.36-43 $\mu\text{g/g}$ in carcass. **DDD** values ranged from ND-12 $\mu\text{g/g}$ in brain and 0.14-18 $\mu\text{g/g}$ in carcass. **DDT**, **dieldrin**, **heptachlor epoxide**, **oxychlordane**, **cis-chlordane**, **trans-nonachlor**, and **cis-nonachlor** were detected at concentrations <1 $\mu\text{g/g}$ for both matrices. **PCB** concentrations ranged from <0.05 -12 $\mu\text{g/g}$ in brain and 1.0-46 $\mu\text{g/g}$ in carcass.

New Jersey (N=2): **DDE** concentrations were <1 $\mu\text{g/g}$ in brain, and 14 and 0.27 $\mu\text{g/g}$ in carcass. **DDD** values were <1 $\mu\text{g/g}$ in brain and 2.8 and 0.06 $\mu\text{g/g}$ in carcass. **DDT**, **dieldrin**, **heptachlor epoxide**, **oxychlordane**, **cis-chlordane**, **trans-nonachlor**, and **cis-nonachlor** concentrations were <1 $\mu\text{g/g}$ in both matrices. **PCB** concentrations were 1.2 and <0.05 $\mu\text{g/g}$ in the brain and 24 and 0.25 $\mu\text{g/g}$ in the carcass.

New York (N=1): **DDE** and **PCB** were the only compounds detected at concentrations >1 $\mu\text{g/g}$. **DDE** occurred at a concentration of 2.0 $\mu\text{g/g}$ in brain and 0.68 $\mu\text{g/g}$ in carcass. **PCB** values were 2.5 $\mu\text{g/g}$ in brain and 0.95 $\mu\text{g/g}$ in carcass.

Ohio (N=2): **DDE** and **PCB** were the only compounds detected at concentrations >1 $\mu\text{g/g}$. Neither was detected in the brain, but **DDE** occurred in both carcasses at concentrations of 0.19 and 4.5 $\mu\text{g/g}$ and **PCB** was detected in one carcass at 2.3 $\mu\text{g/g}$.

2. In 1968 and 1969, ospreys either moribund or dead were collected from Connecticut and Virginia (Wiemeyer et al., 1975).

Of the four birds from Connecticut (three adults and one nestling), contaminant concentrations ranged from 2.0-20 $\mu\text{g/g}$ wet weight in brain and 2.8-38 $\mu\text{g/g}$ in carcass for **DDE**, 0.24-5.5 $\mu\text{g/g}$ in brain and 1.7-12 $\mu\text{g/g}$ in carcass for **DDD**, ND-1.3 $\mu\text{g/g}$ in brain and <1 $\mu\text{g/g}$ in carcass for **DDT**, and 0.19-7.5 $\mu\text{g/g}$ in brain and 1.0-9.5 $\mu\text{g/g}$ in carcass for **dieldrin**. Concentrations of **heptachlor epoxide** were <1 $\mu\text{g/g}$ in both matrices. **PCB** concentrations ranged from 4.8-21 $\mu\text{g/g}$ in brain and 5.0-40 $\mu\text{g/g}$ in carcass.

The two Virginia adults were collected from Currioman Bay and Great Falls. **DDE** concentrations were 0.63 and 12 $\mu\text{g/g}$ in brain and 11 and 4.4 $\mu\text{g/g}$ in carcass. **DDD** was detected at values of 0.11 and 1.0 $\mu\text{g/g}$ in brain and 2.6 and 0.52 $\mu\text{g/g}$ in carcass. Concentrations of **DDT**, **dieldrin**, and **heptachlor epoxide** were <1 $\mu\text{g/g}$ in both matrices. **PCBs** concentrations were 2.0 and 33 $\mu\text{g/g}$ in brain, and 20 and 15 $\mu\text{g/g}$ in carcass.

3. Ospreys (N=2) collected from Ontario between 1969 and 1972 contained the following geometric mean concentrations of **DDE** and **PCB**, respectively: 0.87 and 2.40 $\mu\text{g/g}$ dry weight in brain; 1.33 and 3.79 $\mu\text{g/g}$ in liver; 1.92 and 10.9 in breast muscle; and 23.7 and 70.7 $\mu\text{g/g}$ in whole body (Gilbertson and Reynolds, 1974).
4. One osprey chick found dead in the Persian Gulf, Bahrain, between 1971-1975, contained 0.25 **DDE** $\mu\text{g/g}$ wet weight and 0.95 $\mu\text{g/g}$ **PCB** in whole body (Bourne and Bogan 1976).
5. In 1974, a juvenile osprey was collected from Florida (Johnston, 1976). Contaminant concentrations detected in adipose tissue were 0.13 $\mu\text{g/g}$ wet weight for **DDE**, and 0.26 $\mu\text{g/g}$ for **total DDT**. In uropygial glands, values were 1.55 $\mu\text{g/g}$ for **DDE** and 1.79 $\mu\text{g/g}$ for **total DDT**. **PCB** and **dieldrin** were not detected.
6. Three adult and one juvenile osprey were found dead or moribund in Florida from 1974-75 (Sundlof et al., 1986). Contaminants were measured in brain, fat, liver, and muscle of two of the adults, and in brain only of the remaining two birds. In adults, concentrations of **DDE**, **DDT**, and **dieldrin** were <1 $\mu\text{g/g}$ wet weight in all tissues analyzed. Other contaminant concentrations in adults exceeded 1 $\mu\text{g/g}$ only in the fat, at the following values: 1.30 $\mu\text{g/g}$ **DDD**, 1.50 and 2.10 $\mu\text{g/g}$ **total DDT**, and 1.00 and 1.20 **PCB**. Organochlorine concentrations were higher in the brain of the juvenile, detected at the following levels: 3.60 $\mu\text{g/g}$ **DDE**, 0.00 $\mu\text{g/g}$ **DDD**, 3.80 $\mu\text{g/g}$ **DDT**, 7.40 $\mu\text{g/g}$ **total DDT**, and 4.00 $\mu\text{g/g}$ **DDT equivalents**.

7. From 1975 to 1982 organochlorine contaminants were measured in the carcasses of ospreys found either moribund or dead from locations along the east coast and at sites in Wisconsin and Iowa (Wiemeyer et al., 1987). A summary of the results for each state are listed below:

Tillman, South Carolina (N=1): **DDE** was detected at a concentration of 8.8 $\mu\text{g/g}$ wet weight and **PCBs** at 140 $\mu\text{g/g}$. Concentrations of **DDD** and **oxychlordane** were $<1 \mu\text{g/g}$.

Pea Island National Wildlife Refuge, North Carolina (N=1): Concentrations of **DDE** and **PCBs** were $<1 \mu\text{g/g}$.

Pine Hall and Cape Charles, Virginia (N=2): **DDE** was detected at concentrations of 4.8 and 17 $\mu\text{g/g}$, **DDD** at 2.0 and 1.6 $\mu\text{g/g}$, and **DDT** at 1.30 $\mu\text{g/g}$ in the bird from Pine Hall. **Dieldrin**, **heptachlor epoxide**, **oxychlordane**, **cis-chlordane**, **trans-nonachlor**, and **cis-nonachlor** were detected only in the bird collected from Cape Charles at concentrations $<1 \mu\text{g/g}$. **PCB** concentrations were 8.8 and 25 $\mu\text{g/g}$.

Maryland (N=10): **DDE** concentrations ranged from 0.63-4.5 $\mu\text{g/g}$ in 9 of the birds and occurred at 48 $\mu\text{g/g}$ in an osprey collected from Easton. **DDD** was detected in 9 birds, at concentrations of 0.15-3.8 $\mu\text{g/g}$. **Dieldrin** was detected in 5 birds, at concentration of 0.17-2.2 $\mu\text{g/g}$. Concentrations of **DDT**, **heptachlor epoxide**, **oxychlordane**, **trans-nonachlor**, **cis-chlordane**, and **cis-nonachlor** were $<1 \mu\text{g/g}$.

New Jersey (N=4): **DDE** was detected in 3 birds at concentrations of 31, 0.11, and 0.60 $\mu\text{g/g}$. **DDD**, **dieldrin**, **oxychlordane**, **cis-chlordane**, **trans-nonachlor**, and **cis-nonachlor** were only detected in a single bird from Brigantine National Wildlife Refuge at values of 13, 0.30, 0.17, 0.48, 0.28, and 0.28 $\mu\text{g/g}$, respectively. **PCBs** concentrations in two birds were 24 and 1.1 $\mu\text{g/g}$.

Massachusetts (N=3): **DDE** was detected in all 3 birds at concentrations $<1 \mu\text{g/g}$. **DDD** was detected in one bird at a concentration of 0.21 $\mu\text{g/g}$. **PCBs** were detected in 2 birds at concentrations of 0.95 and 1.2 $\mu\text{g/g}$.

Janesville, Wisconsin (N=1): **DDE** was detected at a concentration of 1.5 $\mu\text{g/g}$. Concentrations of **DDD**, **dieldrin**, **cis-chlordane**, **cis-nonachlor**, and **PCBs** were $<1 \mu\text{g/g}$.

Missouri Valley, Iowa (N=1): **DDE** was the only organochlorine contaminant detected in this bird at a concentration of 0.20 $\mu\text{g/g}$.

8. In 1990, one adult osprey from Kangaroo Island, Australia, had brain, liver, and fat concentrations of the following: $<0.02 \mu\text{g/g}$ **dieldrin**, $<0.02 \mu\text{g/g}$ **DDD**, $0.15 \mu\text{g/g}$ **DDE**, and $<0.02 \mu\text{g/g}$ **DDT** (Falkenberg et al., 1994).
9. Dead and partly decayed osprey were collected in October of 1993 (N=8). The carcasses were found at the mouth of Tabbs Creek in Virginia (Hale et al., 1996). All concentrations are given in ng/g, probably most comparable to dry weight because of desiccation before collection of the birds, but samples were not dried in the lab. Concentrations of **total PCBs** in mesenteric materials ranged from 11,300 to 45,300. Congeners detected tended to be highly chlorinated. Concentrations of **DDT** ranged from 73.0 to 385. Concentrations of **DDE** ranged from 5,320 to 12,900. Concentrations of **DDD** ranged from 37.5 to 182. The osprey samples were too degraded to make assumptions about the significance of the concentrations of the **DDE** and **PCBs**.
10. In 1995 and 1996, 54 eggs were collected from nests along the Columbia and Fraser Rivers in British Columbia, Canada, and Washington and Oregon, USA, of which 38 were hatched (Elliott et al., 2001). For all seven sites, mean concentrations of **2,3,7,8-TCDD**, **1,2,3,7,8-PnCDD**, **1,2,3,6,7,8-HxCDD**, **1,2,3,7,8,9-HxCDD**, **2,3,7,8-PnCDF**, **1,2,3,6,7,8-HxCDF**, **1,2,3,4,6,7,8-HpCDF** in the chicks were below 2930, 365, 1420, 960, 1200, 348, 203, and 1650 ng/kg lipid weight, respectively. Mean (ranges) **PCDDs** and **PCDFs** concentrations at Nechako River, Pitt River, Thompson River, Upper Columbia, Castlegar, Portland, and Lower Columbia, respectively, were: 2540 (663-11,600), 413 (141-6070), 13400 (9130-21,600), 1280 (249-10,100), 1690 (662-4490), 990 (215-9030), and 1210 (103-6750) pg/g **1,2,3,4,6,7,8-HpCDD** and 12,200 (4130-39,100), 645 (129-8790), 40,400 (18,900-57,000), 3280 (297-79,600), 6530 (2510-29,100), 1900 (112-54,300), 4010 (326-20,400) pg/g **1,2,3,4,6,7,8,9-OCDD**.

Geometric mean (range) **PCB** concentrations in chicks from Nechako River (N=3), Pitt River (N=5), Thompson River (N=4), Upper Columbia (N=7), Castlegar (N=5), Portland (N=7), and Lower Columbia (N=7) sites, respectively, were: 24.3 (8.09-46.5), 29.0 (9.87-49.5), 22.8 (9.79-50.9), 52.2 (25.6-93.1), 138 (105-176), 109 (36.8-426), and 149 (89.4-207) $\mu\text{g/g}$ lipid weight **total PCBs**; 1.27 (0.34-4.62), 1.50 (0.40-3.20), 1.61 (0.69-5.06), 1.76 (0.88-3.71), 3.59 (2.92-4.59), 8.10 (1.90-34.5), and 10.9 (6.14-17.3) $\mu\text{g/g}$ **congener 101**; 0.99 (0.29-2.88), 1.16 (0.30-2.17), 0.98 (0.47-1.62), 1.57 (0.67-3.43), 3.05 (2.66-3.90), 5.27 (1.34-22.6), and 6.81 (3.40-11.1) $\mu\text{g/g}$ **congener 99**; 2.09 (0.63-6.70), 2.77 (0.85-4.86), 1.87 (0.86-3.85), 2.97 (1.21-6.49), 6.67 (5.56-7.37), 10.0 (2.18-46.4), and 14.8 (8.72-21.4) mg/kg **congener 118**; 3.68 (1.23-6.47), 4.35 (1.72-7.61), 3.39 (1.73-6.40), 8.89 (4.26-14.7), 19.7 (14.9-25.7), 15.2 (4.96-65.2), and 21.5 (14.5-31.3) $\mu\text{g/g}$ **congener 153**; 0.35 (0.10-1.05), 0.47 (0.15-0.76), 0.24 (0.13-0.47), 0.47 (0.20-1.09), 1.19 (1.03-1.45), 2.18 (0.55-9.55), and 2.68 (1.46-4.43) $\mu\text{g/g}$ **congener 105**; 3.66 (1.12-7.81),

4.59 (1.42-8.25), 3.48 (1.62-6.92), 7.23 (3.39-11.9), 17.8 (14.8-20.1), 16.0 (5.06-67.0), and 21.6 (13.2-30.6) $\mu\text{g/g}$ **congener 138**; 1.07 (0.36-3.01), 1.52 (0.49-2.59), 1.18 (0.52-2.10), 4.00 (1.92-6.14), 9.08 (5.92-11.4), 5.31 (1.87-20.3), and 7.84 (4.91-10.8) $\mu\text{g/g}$ **congener 182**; 2.03 (0.71-4.78), 2.87 (1.18-5.72), 1.76 (0.89-3.49), 6.33 (2.95-11.4), 23.3 (15.2-36.6), 8.04 (2.83-30.6), and 12.2 (8.70-18.1) mg/kg **congener 180**; 0.84 (0.28-1.76), 1.10 (0.39-2.25), 0.74 (0.35-1.64), 2.24 (1.20-3.69), 9.66 (6.48-14.3), 3.38 (1.25-13.0), and 4.94 (3.02-6.52) $\mu\text{g/g}$ **congener 170**.

For all seven sites, concentrations of **congener 81** and **congener 189** in osprey chicks were below 8.310 and 0.174 ng/g , respectively. Geometric mean (ranges) **non-ortho PCB** concentrations at Nechako River, Pitt River, Thompson River, Upper Columbia, Castlegar, Portland, and Lower Columbia, respectively, were: 3660 (762-5780), 2560 (844-7320), 4040 (852-32,600), 5750 (845-23,300), 6070 (3920-8500), 13,500 (4790-31,400), and 18,000 (9970-28,300) pg/g **congener 77**; 7860 (2150-20,500), 8630 (2470-13,800), 7880 (2560-17,500), 14,200 (2880-60,100), 28,000 (25,200-34,900), 24,400 (11,500-100,000), and 46,400 (23,000-67,800) pg/g **congener 126**; 2040 (730-3870), 921 (312-1690), 836 (487-1810), 3920 (538-14,100), 7010 (5590-9750), 1760 (810-8240), and 2310 (1270-3350) pg/g **congener 169**.

For all seven sites, geometric mean concentrations of **HCB**, **DDT**, **mirex**, **p-mirex**, **β -HCH**, **HE**, **dieldrin**, **TCPM**, and **chlordanes**- (sum of **oxychlordanes**, **trans-chlordane**, **cis-chlordane**, **trans-nonachlor**, and **cis-nonachlor**) in chicks were below 0.26, 1.61, 0.58, 1.55, 0.15, 0.65, 0.29, 0.89, and 1.16 $\mu\text{g/g}$, respectively. Geometric means (ranges) of organochlorine concentrations at Nechako River, Pitt River, Thompson River, Upper Columbia, Castlegar, Portland, and Lower Columbia, respectively, were: 179 (133-307), 82.7 (41.0-237), 54.5 (24.6-85.7), 122 (51.7-402), 196 (99.7-496), 316 (185-588), and 258 (145-389) $\mu\text{g/g}$ **DDE** and 6.81 (2.44-16.2), 4.42 (1.84-21.2), 3.38 (0.96-9.32), 4.28 (0.74-53.9), 6.27 (1.27-43.2), 18.3 (6.67-37.8), and 16.8 (4.96-57.6) $\mu\text{g/g}$ **DDD**.

Geometric mean (range) in unhatched and hatched egg concentrations, were, respectively: 3.33 (0.81-22.9) and 2.62 (0.40-9.22) $\mu\text{g/g}$ **DDE**, 1.08 (0.15-10.0) and 0.83 (0.14-6.67) $\mu\text{g/g}$ **PCBs**, 2.93 (27.3-2760) and 210 (37.0-1570) pg/g **CB-126**, 2.21 (0.17-25.5) and 4.34 (0.20-59.4) pg/g **2,3,7,8-TCDD**, and 45.8 (8.63-450) and 61.7 (6.03-254) pg/g **TEQs**. These concentrations were not significantly different between the unhatched eggs and hatched eggs.

B. Concentrations in Eggs

1. In the mid-1960s an unhatched egg from Gardiners Island located in the Long Island Sound had a concentration of 13.8 $\mu\text{g/g}$ **DDT and other metabolites** (Puleston, 1975). Eggs collected in 1967 and 1969 contained similar concentrations. In 1974, **DDT** in an unhatched egg contained a concentration of 3.59 $\mu\text{g/g}$.
2. In 1968 and 1969, eggs were collected from osprey nests in Connecticut and Maryland after documenting a difference in productivity between locations (Wiemeyer et al., 1975). In Connecticut, mean contaminant concentrations were 8.9 $\mu\text{g/g}$ wet weight **DDE**, 1.3 $\mu\text{g/g}$ **DDD**, and 15 $\mu\text{g/g}$ **PCB**. Concentrations of **DDT**, **dieldrin** and **heptachlor epoxide** were, on average, <1 $\mu\text{g/g}$. Concentrations in Maryland were lower, at means of 2.4 $\mu\text{g/g}$ **DDE**, 2.6 $\mu\text{g/g}$ **PCB** and <1 $\mu\text{g/g}$ **DDD**, **DDT**, **dieldrin**, and **heptachlor epoxide**.
3. Nine osprey eggs collected from Ontario between 1969 and 1972 contained geometric mean concentrations of **DDE** and **PCB** of 22.0 and 19.4 $\mu\text{g/g}$ dry weight, respectively (Gilbertson and Reynolds, 1974).
4. From 1969 to 1976 unhatched osprey eggs were collected from Connecticut and eastern Long Island (Spitzer et al., 1978). Within this time period, **DDE** concentrations were found to decrease fivefold and **PCB** concentrations showed no significant change. The geometric mean concentration of **DDE** in unhatched eggs from nests in which no young were produced was higher (113 $\mu\text{g/g}$ dry weight) than in unhatched eggs from nests that produced one (59.6 $\mu\text{g/g}$) or two (29.1 $\mu\text{g/g}$) young. Similarly, **PCB** concentrations were highest in nests in which no young were produced (144 $\mu\text{g/g}$) than in nests where one (130 $\mu\text{g/g}$) or two (83.8 $\mu\text{g/g}$) young were produced. **Dieldrin** was detected at a maximum concentration of 1.05 $\mu\text{g/g}$ in a nest in which one young was produced.
5. In 1970 and 1972, 8 eggs were collected from Avalon-Stone Harbor, New Jersey (Wiemeyer et al., 1978). The mean (range) **DDE** concentration was 14 (6.5-26) $\mu\text{g/g}$ wet weight and mean **DDD** was 2.9 (1.2-6.8) $\mu\text{g/g}$. Mean concentrations of **DDT**, **dieldrin**, **heptachlor epoxide**, **mirex**, and **cis-chlordane** were <1 $\mu\text{g/g}$. **PCB** concentrations averaged 8.8 (2.5-13) $\mu\text{g/g}$.
6. Between 1970 and 1979, osprey eggs were collected from 14 states (Wiemeyer et al., 1988). Eggs were analyzed for the following contaminants: **DDE**, **DDD**, **DDT**, **dieldrin**, **heptachlor epoxide**, **oxychlordane**, **cis-chlordane**, **trans-nonachlor**, **cis-nonachlor**, **toxaphene**, and **PCBs**. Listed below are only those contaminants detected at geometric mean concentrations >1 $\mu\text{g/g}$ wet weight.

From 1970 to 1978, 112 eggs were collected from 13 locations throughout Maryland. Concentrations ranged from 1.9-6.7 $\mu\text{g/g}$ for **DDE**, 0.51-1.6 $\mu\text{g/g}$ for **DDD**, and 2.7 to 12 $\mu\text{g/g}$ for **PCBs**. Mean **kepone** concentrations were <1 $\mu\text{g/g}$.

From 1971 to 1977, 33 eggs were collected from 8 locations in Virginia. Mean concentrations ranged from 1.8-6.2 $\mu\text{g/g}$ **DDE** and 3.8-14 $\mu\text{g/g}$ **PCBs**.

Concentrations of **kepone** ranged from 0.05-1.5 $\mu\text{g/g}$ in all eggs collected in 1976 and 1977, except those from Chickahominy River, Virginia (5.0 $\mu\text{g/g}$ in 1977).

In 1972 and 1973, 11 eggs were collected from Coeur d'Alene Lake in Idaho. **DDE** was detected at a mean concentration of 7.4 $\mu\text{g/g}$.

From 1972 to 1973, 10 eggs were collected from Northeastern Michigan. **DDE** was detected at a mean concentration of 5.1 $\mu\text{g/g}$ and **PCBs** at a mean of 4.2 $\mu\text{g/g}$.

From 1972 to 1975, 4 eggs were collected from coastal Maine. **DDE** was detected at a mean concentration of 4.1 $\mu\text{g/g}$ and **PCBs** at a mean of 4.9 $\mu\text{g/g}$.

From 1972 to 1973, 7 eggs were collected from the Westport River in Massachusetts. **DDE** was detected at a mean concentration of 4.2 $\mu\text{g/g}$ and **PCBs** at a mean of 8.3 $\mu\text{g/g}$.

In 1973 and 1975, eggs were collected in collected in Indianola (n=1), and Everglades National Park (n=10), Florida. **DDE** concentrations ranged from 0.35-3.2 $\mu\text{g/g}$ and **PCBs** concentrations ranged from 0.45-3.0 $\mu\text{g/g}$.

In 1974, 1 egg was collected from Prime Hook, Delaware. **DDE** was detected at a concentration of 5.0 $\mu\text{g/g}$ and **PCBs** at a mean of 4.6 $\mu\text{g/g}$.

In 1974, 10 eggs were collected randomly and from failed nests in Lake Mattamuskeet, North Carolina. **DDE** was detected at concentrations ranging from 0.51-5.4 $\mu\text{g/g}$ and **PCBs** from 0.86-3.1 $\mu\text{g/g}$.

From 1974 to 1979, 52 eggs were collected from five locations in New Jersey. Mean concentrations at these locations ranged from 3.7-13 $\mu\text{g/g}$ **DDE**, 0.36-2.5 $\mu\text{g/g}$ **DDD**, and 5.0-16 $\mu\text{g/g}$ **PCB**.

From 1976 to 1977, 6 eggs were collected from Flathead Lake, Montana. **DDE** was detected at a mean concentration of 11 $\mu\text{g/g}$ and **PCBs** at a mean of 2.7 $\mu\text{g/g}$.

From 1976 to 1978, 8 eggs were collected from the Adirondack Mountains and coastal areas of New York. **DDE** was detected at mean concentrations of 1.7 and 3.7 $\mu\text{g/g}$, respectively, and **PCBs** at means of 2.3 and 8.2 $\mu\text{g/g}$.

One egg was collected from Trumbull Airport in Connecticut in 1977. **DDE** was detected at a concentration of 2.1 $\mu\text{g/g}$ and **PCBs** at 11 $\mu\text{g/g}$.

- In 1978, 1 egg was collected from Watts Bar Lake in Tennessee. **DDE** was detected at a concentration of 4.0 µg/g and **PCBs** at 21 µg/g.
7. In 1971 and 1972, 6 eggs were collected from Eagle Lake California (Littrell, 1986). **DDE** concentrations ranged from 1.13 to 9.6 µg/g wet weight, and **DDD** from ND-3.3 µg/g. Concentrations of *p,p'*-**DDT** were <1 µg/g and *o,p'*-**DDT** was not detected. Concentrations of **PCB (Aroclor 1254)** ranged from 1.8-5.7 µg/g.
 8. From 1971 and 1974, 9 unhatched eggs were collected from Barnegat Bay, New Jersey (Wiemeyer et al., 1978). **DDE** was detected at a mean (range) concentration of 16 (7.6-40) µg/g wet weight, and **DDD** at a mean of 11 (0.49-42) µg/g. Concentrations of **DDT, dieldrin, heptachlor epoxide, mirex and cis-chlordane** were <1 µg/g. Mean **PCBs** concentrations were 9.0 (3.6-36) µg/g.
 9. In 1972, 3 eggs were collected from Seahorse Key, Florida (Szaro, 1978). Each of the eggs contained a developed embryo, but had failed to hatch. **DDE** was detected at an average concentration of 8.34 µg/g lipid weight and **DDD** at 3.55 µg/g. Concentrations of **DDT and dieldrin** were <1 µg/g. **PCBs (Aroclor 1254)** occurred at an average concentration of 29.9 µg/g.
 10. Eleven fresh osprey eggs collected from 1972 to 1973 at Coeur d'Alene watershed contained mean organochlorine concentrations of 8.53 µg/g **DDE**, 10.25 µg/g **total DDT** and 1.18 µg/g **PCB** (Johnson et al., 1975).
 11. From 1972 to 1977, ospreys nesting in Yellowstone National Park were studied (Swenson, 1979). In 4 osprey eggs which failed to hatch (3 late embryos and 1 addled), **DDE** was detected at a mean concentration of 7.20 µg/g wet weight and concentrations of **PCBs, DDD, DDT, dieldrin, endrin, HCB, and BHC** were <1 µg/g.
 12. Non-viable eggs were collected from Eagle Lake, California from 1973 to 1984 (Littrell, 1986). **DDE** concentrations ranged from 0.82-22 µg/g wet weight, and **DDD** from 0.05-2.9 µg/g. Concentrations of **DDT**, several **DDT-metabolites, HCB, BHC, trans-nonachlor, cis-chlordane, heptachlor epoxide, dieldrin, and oxychlordane** were <1 µg/g. **PCB (Aroclor 1260)** was detected at a concentration of 5.3 µg/g in one egg and <1 µg/g in all others.
 13. Between 1973 and 1987, osprey eggs were collected from Maryland, Virginia, and Massachusetts (Audet et al., 1992).

In 1973, 11 eggs from Glenn L. Martin National Wildlife Refuge in Maryland contained a median **DDE** concentration of 3.4 µg/g wet weight and a median **PCB** concentration of 2.8 µg/g. Median concentrations of **DDD, DDT, and dieldrin** were <1 µg/g. In 1986, median concentrations of 5 eggs collected from the same location in Maryland were lower at 2.3 µg/g **DDE** and 1.0 µg/g **PCB**. **DDD, DDT, and dieldrin** were not detected.

In 1986, 4 osprey eggs were collected between Narragansett Bay and Buzzards Bay,

Massachusetts. Median concentrations of **DDE**, **DDD**, **DDT**, and **dieldrin** were <1 µg/g, and **PCBs** were 2.4 µg/g.

In 1987, 5 eggs were collected from the York River area, Mobjack Bay, and Rappahannock River, Virginia. Median concentrations of **DDE**, **DDD**, **DDT**, and **dieldrin** were <1 µg/g, and **PCBs** were 3.7 µg/g.

14. Osprey eggs (N=17) collected from the Rappahannock and York Rivers, Virginia in 1976 contained a median (range) **kepone** concentration of 0.32 (0.05-1.5) µg/g wet weight based on total egg volume (Stafford et al., 1978).
15. From 1980-1989, non-viable eggs were collected from nests of known-age ospreys breeding at two sites in Michigan: Fletcher Pond in Alpena and Montmorency Counties, and Houghton Lakes in Roscommon County (Ewins et al., 1999). Organochlorine concentrations in 25 eggs did not differ significantly among age classes (3-4 years old, N=8; 5-9 years old, N=9; 10-15 years old; N=8). Mean organochlorine concentrations for all age classes combined were 1.16 µg/g wet weight **DDE**, 1.33 µg/g **total DDT**, 1.842 **total PCBs**, and <0.02 µg/g **mirex**, **photo-mirex**, **oxychlordane**, **cis-chlordane**, **trans-chlordane**, **cis-nonachlor**, **trans-nonachlor**, **heptachlor epoxide**, **dieldrin**, **octachlorostyrene**, **α-HCH**, **β-HCH**, **γ-HCH**, **1,2,3,4-TeCB**, **1,2,4,5-TeCB**, and **HCB**. Concentrations of **PCB congeners 28** and **49** were <0.1 µg/g, and **congener 180** ranged from approximately 0.1-0.5 µg/g.
16. From 1985 to 1989, addled eggs were collected and, in 1989, normal eggs were randomly collected from three osprey populations in New Jersey: Delaware Bay, Atlantic Coast, and Maurice River (Steidl et al., 1991). The geometric mean concentrations of **DDE** and **PCBs** in the Atlantic Coast population, which had been reproducing well, were 1.4 and 4.2 µg/g wet weight, respectively. Only randomly collected eggs were analyzed from Maurice River where geometric mean concentrations were 1.9 µg/g for **DDE** and 5.7 µg/g for **PCBs**. Random and addled eggs from Delaware Bay contained geometric mean concentrations of 3.1 µg/g **DDE** and 8.4 µg/g **PCBs**. Concentrations of **DDD**, **dieldrin**, **heptachlor epoxide**, **oxychlordane**, and **trans-nonachlor** were <1 µg/g at all three sites.
17. Between 1987 and 1988, nine osprey eggs were collected from South and West Australia (Falkenberg et al., 1994). In all nine samples, concentrations of **dieldrin** were 0.04 mg/kg or less, **DDD** were 0.08 µg/g or less, and **DDE** were 0.08 µg/g or less. Concentrations of **DDT** in the samples were: <0.04, 0.18, 0.22, 0.01, ND, 0.02, 0.01, and 0.04 µg/g. Five of the eggs had traces of **heptachlor epoxide**.

18. From 1992-1996, osprey eggs were collected from 3 areas along the Wisconsin River: one site downstream from bleached kraft-mill facilities (Castle Rock and Petenwell Flowages (CR/P)), and two upstream reference sites (Rainbow Flowage and Mead Wildlife Area) (Woodford et al., 1998). **TCDD** concentrations were significantly higher in eggs from CR/P (29-148 pg/g wet weight) than Rainbow Flowage (ND-24 pg/g) or Mead Wildlife Area (<1-3 pg/g). Concentrations of **PCDDs/PCDFs (TCDD-Eq)** were also significantly higher at CR/P (52-171 pg/g) than Rainbow Flowage (0.4-28 pg/g) or Mead Wildlife Area (7-9 pg/g). Concentrations of **coplanar PCBs (TCDD-Eq)**, measured at CR/P and Mead Wildlife Area only, were similar between sites and ranged from 17-87 pg/g. Concentrations of **DDT** (0.5-18 ng/g) and **DDE** (79-939 ng/g) were measured in eggs collected in 1992 and 1993 from CR/P and Rainbow Flowage only, and were similar between sites. Concentrations of **total PCBs**, also measured in eggs from 1992 and 1993, were significantly greater at CR/P (809-2745 ng/g) than Rainbow Flowage (200-1694 ng/g). No significant differences were found among years for any compound.
19. Between 1991 and 1997, 111 osprey eggs were collected from nests in the Fraser and Columbia River drainage basins, in British Columbia, Washington, and Oregon (Elliott et al., 2000). Eggs from 1995 and 1996 were collected and incubated, but did not hatch. Contaminant concentration ranges and ranges of geometric means (in parentheses) are given in ng/g wet weight. There was no difference in organochlorine content among years within study areas, therefore values are reported together. **Chlordane** values are for the sum of *cis-nonachlor*, *trans-nonachlor*, *oxychlordane*, *cis-chlordane*, and *trans-chlordane*. Not all measurements were taken for every year at each site.

Fraser River:

Nechako River 1992 and 1996 (N=7): **HCB** 0.5-3.8 (ND – 1.1), **DDE** 382-6890 (1380 – 2360), **mirex** 0.6-1.5 (0.8 – ND), **β -HCH** ND - 42.7 (0.5 – 3.2), **r-chlordane** 2.0-13.0 (3.5 – 6.0), **DDD** 8.9-585 (86.5 – 106), **DDT** 2.8-106 (10.3 – 20.2), **heptachlor epoxide** 1.4-4.8 (2.8 – 3.4), **dieldrin** ND-6.6 (0.5 – 3.5), and **total PCBs** 45.4-690 (104 – 351).

Fraser River (below Quesnel) 1991 and 1992 (n=9): **HCB** ND-1.7 (0.1 – 0.2), **DDE** 246-5590 (1010 – 1310), **mirex** ND-15.9 (NC – 2.0), **β -HCH** ND-12 (NA – 0.4), **r-chlordane** ND-8.6 (ND – 6.1), **DDD** 8.9-298 (NA – 53.6), **DDT** ND-43.6 (NA – 3.1), **heptachlor epoxide** 0.8-5.1 (1.8 – 3.0), **dieldrin** ND-7.4 (0.1 – 5.2), and **total PCBs** 55.1-1,104 (273 – 291).

South Thompson River 1991, 1992, 1997 (n=16): **HCB** ND-29.9 (0.5 – 3.0), **DDE**

110-13,900 (1170 – 1800), **mirex** 1.0-9.2 (NA – 3.3), **β -HCH** ND-18.1 (NA – 1.3), **r-chlordane** ND-14.9 (ND – 7.2), **DDD** 8-513 (NA – 32.9), **DDT** 1.0-433 (NA – 27.6), **heptachlor epoxide** ND-5.0 (0.5 – 2.4), **dieldrin** ND-11.4 (0.1 – 1.5), and total **PCBs** 132-1010 (251 – 380).

Thompson River 1991, 1992, 1995, 1997 (n=16): **HCB** ND - 6.1 (ND – 2.6), **DDE** 336 -10,600 (706 – 3170), **mirex** ND - 26.1 (ND – 2.8), **β -HCH** ND - 107 (ND – 5.8), **r-chlordane** ND - 20.1 (0.1 – 9.0), **DDD** 3.0 - 1140 (NA – 411), **DDT** ND-682 (NA – 17.6), **heptachlor epoxide** ND - 9.7 (0.4 – 4.1), **dieldrin** ND - 9.6 (ND – 2.2), and total **PCBs** 85 - 962 (199 – 297).

Pitt River 1996 (n=3): **HCB** ND, **DDE** 3,067 - 10,000 (5430), **mirex** ND, **β -HCH** ND - 4.4 (0.2), **r-chlordane** 1.9 - 12.8 (5.0), **DDD** 441 - 1,230 (663, significantly higher than South Thompson), **DDT** ND (significantly lower than all sites except Kootenay), **heptachlor epoxide** ND - 10.6 (1.4), **dieldrin** ND - 6.3 (0.3), and total **PCBs** 305 - 648 (436).

Columbia River:

East Kootenay (upper) 1991 (n=8): **HCB** 1.9 - 3.8 (7.8), **DDE** 800 - 8,800 (2180), **r-chlordane** ND - 39 (0.2), **heptachlor epoxide** 1.0 - 74 (6.4), **dieldrin** ND - 11 (2.2), and total **PCBs** 149 - 1,316 (507).

East Kootenay (lower) 1991 (n=8): **HCB** ND - 2.7 (0.1), **DDE** 320 - 20,000 (2060), **mirex** ND - 3.0 (0.1), **β -HCH** 1.9 - 88.5 (9.0), **r-chlordane** ND - 13.8 (0.8), **DDD** 13.5 - 218 (34.7), **DDT** 1.5 - 24.4 (3.5), **heptachlor epoxide** 1.9 - 12 (3.3), **dieldrin** ND - 18 (0.4), and total **PCBs** 169 - 2,540 (441).

West Kootenay 1991, 1993, 1995 (n=16): **HCB** ND - 6.8 (0.3 – 5.9), **DDE** 560 - 11,100 (1,010 – 3,470), **mirex** ND - 76.5 (2.0 – 6.7), **β -HCH** ND - 200 (ND – 3.3), **r-chlordane** 5.1 - 123 (12.0 – 30.2), **DDD** 8.3 - 666 (49.6 – 107), **DDT** ND - 81.9 (ND – 18.3), **heptachlor epoxide** 0.7 - 102 (5.1 – 6.3, significantly higher than South Thompson), **dieldrin** ND - 35.1 (ND – 5.4, significantly higher than South Thompson), and total **PCBs** 155 - 2,028 (343 – 996).

Columbia River 1991, 1992, 1993, 1997 (n=22): **HCB** ND-1888 (1.0 – 2.4), **DDE** 434-6,403 (1100 – 3770), **mirex** ND-24 (3.1 – 4.9), **β -HCH** ND-109 (ND – 1.0), **r-chlordane** 7.1-59.3 (9.3 – 34.4), **DDD** 3-484 (9.7 – 83.5), **DDT** ND-263 (2.7 – 38.9), **heptachlor epoxide** ND-22.2 (0.3 – 7.0), **dieldrin** ND-28.7 (0.3 – 4.4), and total **PCBs** 581 - 4,310 (1,220 – 2,360).

Lower Columbia River 1995 and 1996 (n=6): **HCb** ND - 12.1 (0.6 – 6.8), **DDE** 1,160 - 22,900 (1,850 – 13,800), **mirex** ND - 41.7 (ND – 1.4), **β-HCH** ND-13.2 (0.2 – 6.1), **r-chlordane** 10.2 - 93.7 (18.8 – 47.6), **DDD** 49-1,485 (119 – 1,376), **DDT** 3.3 - 108 (8.7 – 89.7), **heptachlor epoxide** 3.6 - 33.2 (4.9 – 19.6), **dieldrin** ND-20.6 (0.2 – 15.2), and total **PCBs** 1,190 - 11,952 (1,470 – 4,620).

From the complete set of 111 eggs, 22 eggs had **DDE**>5,000 ng/g, 9 eggs had **DDE** >10,000 ng/g, and 2 eggs had **DDE** >20,000 ng/g. **DDT** was detected in 95% of eggs, **DDD** in all eggs, **mirex** and **β-HCH** in most eggs, **photomirex** in 20% of eggs, and **α-HCH** and **γ-HCH** were not detected in any eggs. Eggs were analyzed for 42 **PCB congeners**, with **153, 138, 180, 182, 118, 99, and 101** making up 60% of total **PCBs**. **PCB congeners 66, 60, 101, 99, 87, 110, and 118** were elevated in the lower Columbia, and **183, 172, 180, 170, 203, and 204** were elevated in the upper Columbia.

20. Between 1991-1997, 5 osprey eggs were collected in Norway (Herzke et al., 2002). Concentrations in ng/g wet weight were **ΣPCBs** 5458 average, and 12927 max, sum of pesticides 2530 average and 5065 max, **Σ chlorobornanes** 144 average and 616 max.
21. In New Jersey, osprey eggs were collected in 1998, from the Atlantic coast, Delaware Bay, and the Maurice River area (Clark et al., 2001). Mean concentrations of the following (in µg/g fresh wet weight) for all three regions were: 0.93 **DDE**, 0.11 **DDD**, 0.01 **DDT**, 0.02 **heptachlor epoxide**, 0.01 **oxychlordane**, 2.53 **total PCBs**, 0.70 **PCB-1254**, 1.179 **PCB-1260**, 0.01 *trans* **-nonachlor**, 0.01 *cis* **-nonachlor**, and 0.01 **dieldrin**. Contaminant concentrations were similar among regions, except for **PCB-1260**, which was found highest in Delaware Bay eggs. **DDE, DDD, total PCBs, oxychlordane, heptachlor epoxide, and trans -nonachlor** were significantly lower in 1998.

Geometric means for **PCB congeners** and **TCDD-EQs** in osprey eggs for Delaware Bay (N=6), Maurice River (N=5), and the Atlantic coast (N=6) were (in pg/g), respectively: 321.7, 328.8, and 583.4 **PCB 77**; 97.9, 73.9, and 50.8 **PCB 81**; 474.2, 685.0, and 574.2 **PCB 126**; 161.3, 142.8, and 59.7 **PCB 169**; 125,331.2, 67,903.6, and 65,214.3 **PCB 105**; 179,305.8, 131,584.4, and 131,724.1 **PCB 118**; 15,510.8, 10,537.4, and 13,025.3 **PCB 123**; 63,960.5, 34,057.8, and 30,346.6 **PCB 156**; 5992.8, 3603.8, and 3933.2 **PCB 157**; 29,045.2, 17,161.5, and 14,994.0 **PCB 167**; 4955.6, 2613.4, and 2307.9 **PCB 189**; 93.88, 109.14, and 75.53 **total TCDD-EQs**. **PCB 114** was not detected.

II. Cholinesterase-Inhibiting Pesticides

No direct exposure data available

III. Trace Elements, Metals, and Metalloids

A. Concentrations in Adults, Juveniles, and Nestlings

1. From 1975 to 1982, hepatic metal concentrations were determined in osprey found dead or moribund from the East Coast, Iowa, and Wisconsin (Wiemeyer, 1987). Concentrations of **Cr** and **As** were generally $<1 \mu\text{g/g}$, except in New Jersey where values reached 1.70 and 3.20 $\mu\text{g/g}$, respectively. Concentrations of **Cu** ranged from 1.5-55 $\mu\text{g/g}$, the greatest values occurring in Maryland. **Zinc** concentrations ranged from 19-150 $\mu\text{g/g}$, the greatest values in New Jersey and Virginia. Concentrations of **Cd** and **Ni** were $<1 \mu\text{g/g}$. Concentrations of **Hg** ranged from 0.28-35 $\mu\text{g/g}$, the greatest value occurring in Massachusetts. Birds from Wisconsin, Maryland, and Virginia also had high concentrations of **Hg** (11, 21, 13 $\mu\text{g/g}$, respectively). **Lead** concentrations ranged from ND-4.6 $\mu\text{g/g}$, and **Fe** from 320 to a high of 2800 $\mu\text{g/g}$ in Virginia.
2. In 1986, 3 ospreys found dead were collected in Idaho and Oregon: one adult male from the Coeur d'Alene River, one adult male shot on the Santiam River and one hatching year male shot on the Santiam River (Henny et al., 1991). Concentrations of **Cd** in the kidney were 2.7, 1.0, and 0.02 $\mu\text{g/g}$ wet weight, respectively. Hepatic metal concentrations were 2.7, 4.4 and 4.8 $\mu\text{g/g}$ for **Cu**, 21, 23, and 39 $\mu\text{g/g}$ for **Zn**, and $<1.0 \mu\text{g/g}$ for all birds for **Pb** and **As**. **Mercury** was analyzed in the liver of the male from Coeur d'Alene River (0.42 $\mu\text{g/g}$) and the hatchling (2.1 $\mu\text{g/g}$).
3. In 1986 and 1987, adult and nestling ospreys were collected from the Coeur d'Alene River (area of concern), the Coeur d'Alene Lake and Saint Joes River which served as an intermediate site, and the Pend Oreille and Flathead Lakes which served as a control site (Henny et al., 1991).

Concentrations of **Pb** in blood were highest in adults from the Coeur d'Alene River, (ND-0.82 $\mu\text{g/g}$ wet weight), and lower at the intermediate site (ND-0.34 $\mu\text{g/g}$) and the reference site (ND-0.16 $\mu\text{g/g}$). A significant increase in the geometric mean concentration occurred from 1986-87 at the intermediate site (0.04 $\mu\text{g/g}$ to 0.05 $\mu\text{g/g}$) and the reference site (0.03 $\mu\text{g/g}$ to 0.04 $\mu\text{g/g}$), though not at the Coeur d'Alene River.

In nestlings, concentrations of **Pb** in blood were also highest at the Coeur d'Alene River, (ND-0.42 $\mu\text{g/g}$), and lower at the intermediate site (ND-0.26 $\mu\text{g/g}$) and the reference site (ND-0.06 $\mu\text{g/g}$). A significant decrease in the geometric mean concentration occurred at the reference site from 1986-87 (0.03 $\mu\text{g/g}$ to 0.02 $\mu\text{g/g}$), though no difference was observed at the other two sites.

4. Mean **Hg** content ranged from 6.05-15.58 $\mu\text{g/g}$ dry weight in samples of 14-19 osprey primaries and tail feathers collected in Germany (Hahn et al., 1993).

5. From 1989-1991, feathers were collected from osprey nestlings (35-45 days old) in 118 nests, and nestlings were taken from 23 nests in the James Bay and Hudson Bay regions of Quebec for **Hg** analysis (DesGranges et al., 1998). Adult feathers were collected opportunistically around the nesting areas. In collected nestlings, the proportion of **MeHg/total Hg** was greater than 90% in stomach contents, blood, brain, and muscle, compared to 74% and 76% in the liver and kidneys, respectively. Nestlings living near reservoirs tended have to higher **Hg/Se** tissue ratios when compared to those in "natural habitats". Concentrations of **Hg** in all tissues were significantly higher in ospreys from reservoirs than from "natural" areas: 3.61 and 0.72 $\mu\text{g/g}$ wet weight in liver, respectively, 5.28 and 0.91 $\mu\text{g/g}$ in kidneys, 1.01 and 0.23 $\mu\text{g/g}$ in brain, 1.79 and 0.36 $\mu\text{g/g}$ in muscle, 0.76 and 0.19 in stomach content, 1.94 and 0.39 in blood, 37.35 and 6.96 $\mu\text{g/g}$ dry weight in nestling feathers, and 58.09 and 16.47 $\mu\text{g/g}$ in adult feathers. The mean number of young fledged did not differ between nests near reservoirs and those near "natural" habitats.
6. Elemental profiles were determined in flight feathers collected from adult osprey at Clear Lake, California (N=12) and juvenile osprey from four locations--Clear Lake (N=12), Couer d'Alene, Idaho (N=18), St. Joe, Idaho (N=18), and Bahia de Los Angeles, Baja California (N=5) (Cahill et al., 1998). Mean concentrations for adults and juveniles, respectively, at Clear Lake were 32,396 and 34,099 $\mu\text{g/g}$ **S**, 3547 and 1030 $\mu\text{g/g}$ **Ca**, 36.7 and 6.48 $\mu\text{g/g}$ **Ti**, 424 and 96.6 $\mu\text{g/g}$ **Fe**, trace and 1.01 $\mu\text{g/g}$ **Ni**, 173 and 151 $\mu\text{g/g}$ **Zn**, 3.20 and 3.38 $\mu\text{g/g}$ **Se**, 8.90 and 76.5 $\mu\text{g/g}$ **Br**, 28.4 and 1.26 $\mu\text{g/g}$ **Sr**, 20.0 and 5.25 $\mu\text{g/g}$ **Hg**, and 0.87 $\mu\text{g/g}$ and trace **Pb**. Concentrations of **V**, **Cr**, **As**, and **Rb** were not detected or detected in trace amounts only. Mean concentrations for juveniles at other sites were similar and ranged from 34,255-34,901 $\mu\text{g/g}$ **S**, 881-1219 $\mu\text{g/g}$ **Ca**, 2.06-15.4 $\mu\text{g/g}$ **Ti**, 26.0-87.9 $\mu\text{g/g}$ **Fe**, 133.6-148 $\mu\text{g/g}$ **Zn**, 2.61-5.21 $\mu\text{g/g}$ **Se**, 15.7-32.5 $\mu\text{g/g}$ **Br**, ND-0.43 $\mu\text{g/g}$ **Rb**, 0.81-2.44 $\mu\text{g/g}$ **Sr**, ND-2.25 $\mu\text{g/g}$ **Hg**, and trace-7.78 $\mu\text{g/g}$ **Pb**. Concentrations of **V**, **Cr**, **Ni**, and **As** were not detected or detected in trace amounts only at these sites. Concentrations of **Hg** were significantly greater in juveniles at Clear Lake compared to other sites, though reproduction was not depressed at this site. Concentrations of **Pb** at Coeur d'Alene were approximately seven times higher than other sites.
7. In 1988-1989, feathers were collected from osprey nestlings (n=17), mostly from within 50 km of Helsinki in Uusimaa, southern Finland, (Solonen et al., 1999). Analysis of the secondary flight feathers gave the following median (and range) of concentrations in $\mu\text{g/g}$ dry weight: **Al** 58 (33-110), **Cu** 6.8 (5.6-8.6), **Zn** 110 (98-140), **Cd** 0.26 (0.04-1.10), and **Pb** 0.8 (0.6-2.7).

8. Between 1991 and 1994, adult and nestling osprey feathers were collected from St. Marys River, Georgian Bay, Kawartha Lakes, and Ogoki Reservoir in Ontario, Canada, and from Delaware Bay, New Jersey (Hughes et al., 1997).

In 1991, mean (range) **Hg** concentrations (in $\mu\text{g/g}$ dry weight) of osprey chick feathers were: 7.86 (5.90-10.10) at St. Marys River (N=7), 4.63 (2.60-6.80) at Georgian Bay (N=8), and 2.81 (1.10-5.00) at Kawartha Lakes (N=9). In 1992, mean (range) **Hg** concentrations (in $\mu\text{g/g}$) of osprey chick feathers were: 6.77 (5.8-8.33) at St. Marys River (N=5), 4.46 (1.57-5.66) at Georgian Bay (N=5), 3.67 (2.66-5.18) at Kawartha Lakes (N=10), 10.98 (7.61-17.00) at Ogoki Reservoir (N=5), and 2.26 (1.81-2.73) at Delaware Bay (N=4). In 1991 and 1992, there were significant differences between **Hg** concentrations in chick feathers among Ontario and New Jersey study areas.

Between 1991 and 1994, 14 chick feather samples from Delaware Bay had a mean **Hg** concentration of 2.14 $\mu\text{g/g}$ and 7 samples from along the Atlantic Coast in New Jersey averaged 3.35 $\mu\text{g/g}$. The **Hg** concentrations in the chicks were significantly related to the concentrations in the eggs collected from the same years.

In 1991, mean (range) **Hg** concentrations (in $\mu\text{g/g}$ dry weight) of adult osprey feathers from the Great Lakes area were: 28.8 (17.3-40.2) at St. Marys River (N=2), 21.1 (7.5-47.9) at Georgian Bay (N=5), and 6.7 (5.3-7.6) at Kawartha Lakes (N=4). St. Marys River, Ontario, adult osprey feathers had significantly higher levels of **Hg** than did those from Kawartha Lakes, Ontario. Mean **Hg** concentrations in adult osprey feathers were 2.4-4.6 times higher than those of chick feathers.

B. Concentrations in Eggs

1. In 1969, **Hg** was determined in osprey eggs from Maryland (0.14 $\mu\text{g/g}$ wet weight) and Connecticut (0.13 $\mu\text{g/g}$) (Wiemeyer et al., 1975).
2. In 1972, six fresh osprey eggs collected from Coeur d'Alene contained a mean **Hg** concentration of 0.090 $\mu\text{g/g}$ (Melquist, 1974).
3. In 1973 and 1978, concentrations of **Hg** were <1 $\mu\text{g/g}$ wet weight in osprey eggs collected from Idaho, New Jersey, Maryland, and Florida (Wiemeyer et al., 1988).
4. In 1973, 1986, and 1987, median **Hg** concentrations ranged from 0.03-0.24 $\mu\text{g/g}$ wet weight in eggs collected from Maryland, Virginia, and Massachusetts (Audet et al., 1992).
5. From 1985 and 1989, **Hg** concentrations were low in osprey eggs collected from the Atlantic Coast (0.17 $\mu\text{g/g}$ wet weight), the Maurice River (0.10 $\mu\text{g/g}$), and Delaware Bay (0.09 $\mu\text{g/g}$) (Steidl et al., 1991).

6. **Mercury** exposure was measured in osprey eggs collected between 1989-1991 from nests in the James Bay and Hudson Bay regions of Quebec (DesGranges et al., 1998). Concentrations of **Hg** were similar in eggs collected from nests near reservoirs (0.22 µg/g wet weight, N=18) and eggs collected from "natural" areas (0.18 µg/g, N=33).
7. In 1991 and 1992, osprey eggs were collected from St. Marys River, Georgian Bay, Kawartha Lakes, and Ogoki Reservoir in Ontario, Canada, and from Delaware Bay, New Jersey (Hughes et al. 1994).

In 1991, mean (range) **Hg** concentrations (in µg/g dry weight) of osprey eggs were: 0.63 (0.50-0.76) at St. Marys River (N=2), 0.89 (0.33-2.19) at Georgian Bay (N=10), 0.53 (0.11-0.95) at Kawartha Lakes (N=13). Mean **Hg** concentrations in osprey eggs from Ontario were not significantly different in 1991. In 1992, mean (range) **Hg** concentrations (in µg/g) of osprey eggs were: 0.64 (0.45-1.10) at St. Marys River (N=6), 0.61 (0.26-1.75) at Georgian Bay (N=7), 0.32 (0.15-0.78) at Kawartha Lakes (N=9), 1.40 (0.70-2.15) at Ogoki Reservoir (N=8), 0.42 (0.19-0.71) at Delaware Bay (N=5). Differences in **Hg** concentrations were found in 1992 when two more areas were added to the study. When data from both years were pooled, the eggs from Ogoki Reservoir had significantly higher **Hg** concentrations than the other sites except for Georgian Bay.

8. Between 1991 and 1997, 111 osprey eggs were collected from nests in the Fraser and Columbia River drainage basins, in British Columbia, Washington, and Oregon (Elliott et al., 2000). Eggs from 1995 and 1996 were collected and incubated, but did not hatch. **Hg** concentrations in the eggs did not vary between sites or years, with the exception of significantly lower **Hg** at Quesnel in 1992. Contaminant concentration are given in ng/g dry weight. Ranges and range of geometric means across years (in parentheses) of **Hg** concentrations were: Nechako River 16.0 – 216 (74.7), Fraser River below Quesnel 27.2 – 57.6 (34.1), South Thompson River 32.0 – 243 (95.3 - 97.4), Thompson River 30.0 – 238 (56.5 – 118), Kootenay River west 22.8 – 164 (66.4 – 70.1), Columbia River 39.6 – 184 (57.5 – 96.0). Not all measurements were taken for every year at each site.
9. In New Jersey, 1998, six osprey eggs were collected from the Atlantic coast, six from Delaware Bay, and five from the Maurice River area (Clark et al., 2001). Mean **Hg** concentrations for all three areas were 0.12 µg/g fresh wet weight and **Pb** concentrations were 0.30 µg/g.

IV. Petroleum

No residue data available

Osprey Contaminant Response Data

I. Organochlorine Contaminants

1. Compared to 1947 values, eggshell thinning occurred in eggs collected between 1967 and 1969 in Maryland (12%) and Connecticut (15%) (Wiemeyer et al., 1975).

2. From 1969 to 1976, a correlation was found between eggshell thickness and **DDE** concentration in eggs from eastern Long Island and Connecticut (Spitzer et al., 1978). As the concentration of **DDE** fell, specifically below 60 µg/g dry weight, productivity was found to increase.
3. Compared to pre-1947 values, eggshell thinning occurred in osprey eggs collected from Barnegat Bay, New Jersey, in 1971 (4%) and 1974 (19%) (Wiemeyer et al., 1978). In the Avalon-Stone Harbor Area, eggshell thinning was 12%. Osprey populations from both locations declined due to poor reproduction between 1970 and 1974
4. In 1972, eggshell thickness was 8-9% thinner than "established normal values" for this species in 7 eggs collected from Seahorse Key, Florida (Szaro, 1978).
5. Mean thickness of 11 eggs collected from the Coeur d'Alene watershed in 1972 and 1973 was 17% thinner than shells collected from 1880-1932 (Johnson et al., 1975).
6. In Yellowstone National Park, brood size in ospreys was found to decrease after the application of chlorinated hydrocarbon pesticides (Swenson, 1979). Brood size dropped from a mean of 2.36 in 1896-1940, to 1.60 in 1947-1954 and 1.67 in 1972-1977. An average thickness index of 2.19 was found in five osprey eggs collected from 1972 to 1977 in this area which was comparable to an index of 2.15 from a stable osprey population in Idaho.
7. Sixteen out of 22 eggs collected from Eagle Lake California from 1973 to 1984 were below the established "normal level for thickness" (Littrell, 1986).
8. From 1980-1989, non-viable eggs were collected from nests of known-age ospreys breeding at two sites in Michigan: Fletcher Pond in Alpena and Montmorency Counties, and Houghton Lakes in Roscommon County (Ewins et al., 1999). Eggshell thickness in 27 eggs did not differ significantly among age classes (3-4 years old, 5-9 years old, 10-15 years old) or among years. Mean shell thickness for the entire period was 0.481 mm, 4.8% thinner than pre-**DDT** thickness. Only a marginally significant relationship was found between shell thickness and **DDE** concentrations in eggs.
9. From 1985 to 1988, eggs were collected from Delaware Bay, the north portion of the Cape May peninsula in New Jersey, and the Maurice River in New Jersey (Steidl et al., 1991). **DDE** and **PCBs** concentrations were greatest in samples from Delaware Bay. The percent nest success, the mean number of young fledged per pair, and the number of eggs hatched were lower for the Delaware Bay osprey population compared to the Cape May peninsula and Maurice River populations. In Delaware Bay, 1.08 young fledged per pair, while 1.61 and 1.33 young per pair fledged on the Cape May peninsula and the Maurice River, respectively. Eggshells thickness, compared to pre-1947 values, decreased 10.4% in Delaware Bay, 4.7% on the Cape May peninsula and 5.5% at the Maurice River.

10. Between 1987 and 1988, nine osprey eggs were collected from South and West Australia (Falkenberg et al., 1994). Total **DDT** concentrations were low in the osprey eggs, below levels associated with reproductive failure. There was no significant difference between pre-1947 and post-1947 egg measurements. Some of the embryos failed to develop despite the eggs being incubated beyond full term.
11. In 1995 and 1996, on the Wisconsin River, osprey eggs were exchanged between nests from an area contaminated with **TCDDs** and **PCDFs/PCDDs** (Castle Rock and Petenwell Flowages), and two reference sites (Rainbow Flowage and Mead Wildlife Area) (Woodford et al., 1998). Egg hatching and chick fledging rates were not significantly different for nests that had been switched compared to those which had not been manipulated. Chicks that were switched to Castle Rock and Petenwell Flowages as eggs had a lower mass increase rate than chicks at reference sites, despite greater levels of parental nest attentiveness and food provisioning at the contaminated site.
12. Osprey eggs collected in 1995 and 1996 were hatched and then measured for biochemical parameters (Elliott et al., 2001). There were no significant differences in the parameters from Nechako River, Pitt River, Thompson River, Upper Columbia, Castlegar, Portland, and Lower Columbia for CYP1A, EROD, plasma dehydro-retinol, or liver dehydro-retinol. For kidney dehydro-retinol, kidney ester 1, kidney ester-2, and liver ester-2, the Nechako and Portland sites had the lowest concentrations.
13. In New Jersey, 1998, osprey eggs were collected from the Atlantic coast, Delaware Bay, and the Maurice River area (Clark et al. 2001). Mean (range) eggshell thickness was (in mm): 0.470 (0.43-0.54) in Delaware Bay (N=6), 0.506 (0.43-0.59) in Maurice River (N=5), and 0.496 (0.44-0.54) in Atlantic coast (N=6) eggs. Eggshell thickness was inversely correlated with **total PCB** and **DDE** concentrations and was not different between regions.

II. Cholinesterase-Inhibiting Pesticides

No response data available

III. Trace Elements, Metals, and Metalloids

1. A negative correlation was found between ALAD and the concentration of **Pb** in blood of adult ospreys nesting in Idaho (Henny et al., 1991). Protoporphyrin concentration was positively correlated with **Pb** concentration in blood.

IV. Petroleum

No response data available

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