CONTAMINANTS IN THE PREY OF THE PEREGRINE FALCON IN CANADA

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ABSTRACT

This report discusses contamination of the avian prey of the Peregrine Falcon in Canada and its significance for the recovery of the population. The contaminants of concern are the organochlorine compounds DDE, dieldrin, oxychlordane, heptachlor epoxide, alpha-HCH, mirex, hexachlorobenzene and PCBs, and mercury. The data reviewed were obtained for the main part from the National Registry of Toxic Chemical Residues of the Canadian Wildlife Service and were averaged by region (11 across the country) and by time period (1975-1979 and 1980-1985). More recent data were made available for prey collected in British Columbia, Alberta, New Brunswick, and Nova Scotia.

Concentrations of DDE, dieldrin, and PCBs can still be found in prey at levels associated with deleterious effects on the reproductive success of nesting Peregrines. The species with the highest concentrations were generally those which feed on aquatic organisms (such as herons and grebes), shorebirds, and swallows. The data did not allow for analysis of regional and temporal differences. Recently collected specimens from southern Ontario and evidence from the United States suggest that chemical "hot spots" are present in North America which may have significant effects, via the food chain, on the recovery of Peregrine populations.

An assessment of other potential sources of chemical contamination of Peregrines suggests that contamination or poisoning can also occur through the consumption of: (1) game birds with lead shot in their bodies; and (2) birds which are the subject of chemical control programs with the organophosphate fenthion and with strychnine.

Although the situation regarding organochlorine contamination of the environment has improved since the late 1960s, it is suggested that in planning releases of captive-bred Peregrines consideration should be given to potential contamination problems. Thorough surveys and analyses of samples should be carried out in areas where: (1) populations of species likely to have high levels of organochlorine contaminants are present; (2) organochlorine pesticides were used in large quantities in the past; (3) choice hunting sites and large concentrations of game birds are found; and (4) populations of rural or urban avian pests are likely to be the subject of chemical controls.

RÉSUMÉ

Ce rapport discute de la contamination des proies du Faucon pèlerin au Canada et des conséquences pour le rétablissement des populations. Les contaminants d'intérêt sont le mercure et les composés organochlorés tels le DDE, la dieldrine, l'oxychlordane, l'époxide d'heptachlore, l'alpha-HCH, le mirex, l'hexachlorbenzène et les BPC. Les données parviennent, en grande partie, du Registre national des résidus de produits chimiques toxiques et sont rassemblées par région (11 à travers le pays) et par intervalle de temps (1975-1979 et 1980-1985). Des données plus récentes pour des proies provenant de la Colombie Britannique, l'Alberta, le Nouveau Brunswick et la Nouvelle Ecosse sont aussi incluses.

Chez certaines proies, les concentrations de DDE, de dieldrine et de BPC se retrouvent toujours à des niveaux associés à des effets nocifs sur la reproduction des Faucons pèlerins. Les concentrations les plus élevées se retrouvent généralement chez les espèces qui se nourissent d'organismes aquatiques (telles les hérons, les oiseaux de rivage et les hirondelles). La nature disparate des données n'a pas permi l'analyse des différences régionales et temporelles. Certains spécimens provenant tout récemment du sud de l'Ontario et des études menées aux Etats-Unis suggérent l'existence de certaines "régions chaudes" en Amérique du nord. Celles-ci pourraient affecter, à travers la chaine alimentaire, le rétablissement des populations de Faucon pèlerin.

Un inventaire des autres sources potentielles de contamination des Faucons indique que la contamination peut aussi se faire à travers la consommation: (1) de gibier à plume contenant de la grenaille de plomb et (2) d'oiseaux dont les populations sont controlées à l'aide de substances chimiques telles la strychnine ou le fenthion, un organophosphate.

Bien que la contamination de l'environnement par les substances organochlorés a diminué depuis la fin des années 1960, on doit toujours tenir compte de ces problèmes durant la planification des programmes de réintroduction des Faucons pèlerins. Un inventaire minutieux devrait être entrepri dans les régions (1) où des proies du Faucon pèlerin seront probablement contaminées par des substances organochlorés, (2) où un usage important de pesticides organochlorés a eu lieu dans le passé, (3) où se trouvent des sites de chasse et des populations importantes de gibier à plume, et (4) où les populations d'oiseaux problèmes sont controlées à l'aide de substances chimiques.

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1.0 Introduction

In 1975 a survey of breeding populations of the Peregrine Falcon (*Falco peregrinus*) in North America revealed that arctic and boreal populations had declined by at least 50% of their maximum recorded size (Fyfe *et al.*, 1976). In regions south of the boreal forest populations of the *anatum* race had declined to the point that it was extirpated from many regions as a breeding bird. Of 1,090 known North American breeding sites of the *anatum* and *tundrius* races, only 317 were known or suspected to be occupied in 1975. This decline, observed both in North America and Europe, is now clearly linked to eggshell thinning induced by DDE, a metabolite of the organochlorine insecticide DDT (Peakall, 1976). Also, in England, the use of cyclodiene insecticides such as aldrin, dieldrin, and heptachlor as seed dressings was implicated in the death of Peregrines consuming contaminated prey (see Ratcliffe, 1980).

In Canada, a major effort to reintroduce captive-bred Peregrines into their former range has been underway since 1975 (Western Raptor Technical Committee, 1988). Since most organochlorine compounds had been banned or restricted in their use in the late 1960s and early 1970s, it was hoped the released birds would breed successfully in an environment where levels of contaminants were declining. One major obstacle to this aim, however, is the fact that Peregrine Falcons and many of their prey winter in Central and South America where the use of organochlorine compounds increased after their restriction in Canada and the United States. Furthermore, DDE was shown to persist in northern temperate soils for many years at biologically significant levels (Beyer and Gish, 1980). In North America, wildlife are still exposed to organochlorine compounds both from recent uses and historical sources (Fleming, Clark and Henny, 1983).

Recent surveys show encouraging trends (Murphy, 1989; White, Fyfe and Lemon, 1989). Captive-released birds are returning to Canada and in some instances are attempting to breed; however, concerns are still raised about contaminant levels in the food of the birds (Western Raptor Technical Committee, 1988). In the United States, where both wild and reintroduced Peregrines are making a comeback, and in many cases breeding successfully (for example see Barclay, 1988), the concentrations of organochlorine contaminants in many prey species are still at levels believed to interfere with reproduction in raptors (DeWeese *et al.*, 1986). In light of the major efforts presently expended by wildlife agencies in Canada toward reintroducing the Peregrine Falcon to its former range, it is now important to evaluate the extent of their exposure to organochlorine compounds known to affect breeding in raptors. It is, therefore, the aim of this report to: (1) review the data available on current contaminant concentrations in prey species of Peregrines in Canada, and (2) to assess the potential impact these levels may have on the success of individuals returning to their former range.

2.0 Methods

2.1 The Data Base

The data analysed in this review were obtained from two sources. First, the National Registry of Toxic Chemical Residues (Elliott et al., 1987), established in 1964 and managed by the Canadian Wildlife Service (CWS), consists of analytical results and pertinent information on wildlife specimens collected in Canada for toxic chemical analysis. Remains of both analysed and unanalysed specimens are stored in the CWS National Specimen Bank (Elliott, 1985). The Registry covers data collected from the early 1960s to the present and focuses on residue levels of organochlorine pesticides, PCBs, and mercury. Some data on levels of trace elements (such as lead and cadmium) and of organochlorine contaminants (such as dioxins) can also be found in the Registry. Due to the nature of the mandate of the Canadian Wildlife Service, the majority of species analysed consist of migratory birds.

Second, chemical residue data for Peregrine prey collected in Alberta from 1983-1987 by agencies of that province are included. This survey provides a more detailed look at one area of the country and samples were collected specifically for this purpose.

2.2 The Prey of Peregrine Falcons

A list of Canadian bird species known to be prey of the three races of North American Peregrines is found in Table 1. This list was established using the references provided in the Anatum Peregrine Falcon Recovery Plan (Western Raptor Technical Committee, 1988). Only birds known to reside in Canada were included in the table. The number of avian items consumed is large (188 species) and reflects both the hunting ability of the falcon and the diverse habitats in which it nests. The types of prey range from small passerines to geese. This variety is not uncommon and lists of over 100 prey species have been recorded at numerous sites in Europe and North America (see Hickey and Anderson, 1969; Ratcliffe, 1980; Cade, 1982). While the list in Table 1 is extensive, it is certainly not exhaustive, as identification of prey species during the hunt or from remains is difficult. For example, Bird and Aubry (1982) could only identify 40 of 71 birds captured by Peregrine Falcons in southern Quebec. Prey species composition reflects the habitat in which the Falcons are found (Hickey and Anderson, 1969) and therefore further feeding studies at more sites will certainly provide new additions. Table 1 clearly shows the feeding preferences for each of the three races. Whereas anatum Peregrines have a diverse diet, the pealei and tundrius races are often restricted to bird species found for the most part on the Pacific Coast and the arctic tundra respectively. The greater diversity in the diet of anatum Peregrines reflects the large variety of habitats within the distribution range of this race. Not only do prey species vary from region to region, they may also vary from one nest site to the next (Hickey and Anderson, 1969).

While Peregrines are opportunistic and catholic in their choice of prey, certain sizes and types are chosen more often, sometimes out of proportion to their relative abundance. Males tend to catch birds in the 20 to 200 g weight range whereas females catch more birds in the 100 to 1000 g range (Cade, 1982). It has been noted that species with conspicuous "flash"

Table 1. Avian prey of the Peregrine Falcon recorded in Canada.

SPECIES NAME	COMMON NAME	RACE OF PEREGRINE		
		ANATUM	PEALEI	TUNDRIUS
Gavia arctica	Arctic Loon			1
Podiceps grisegena	Red-necked Grebe	1		
Podiceps auritus	Horned Grebe	1		
Podiceps nigricolis	Eared Grebe	1		
Aechmophorus occidentalis	Western Grebe	1		
Oceanodroma furcata	Fork-tailed Storm-Petrel		2	
Oceanodroma leucorhoa	Leach's Storm-Petrel		2	
Butorides striatus	Green-backed Heron	1		
Bubulcus ibis	Cattle Egret	1		
Egretta thula	Snowy Egret	1		
Nycticorax nycticorax	Black-crowned Night-Heron	1		
Branta canadensis	Canada Goose			
Branta bernicla	Brant	1		
Anas platyrhynchos	Mallard	1	1	
Anas strepera	Gadwall	1		
Anas acuta	Northern Pintail	2	1	
Anas crecca	Green-winged Teal	2	2	
Anas discors	Blue-winged Teal	1		
Anas cyanoptera	Cinnamon Teal	1		
Anas americana	American Wigeon	2		
Anas clypeata	Northern Shoveler	2		
Aythya americana	Redhead	1		
Aythya valisineria	Canvasback	1		
Aythya marila	Greater Scaup	1		
Aythya affinis	Lesser Scaup	1		
Bucephala clangula	Common Goldeneye		1	
Bucephala albeola	Bufflehead	1		
Clangula hyemalis	Oldsquaw			
Histrionicus histrionicus	Harlequin Duck	1	1	
Melanitta fusca	White-winged Scoter	1		
Melanitta perspicillata	Surf Scoter	1		
Melanitta nigra	Black Scoter			
Oxyura jamaicensis	Ruddy Duck	1		
Mergus serrator	Red-breasted Merganser	1	1	
Falco sparverius	American Kestrel	1		
Dendragapus canadensis	Spruce Grouse	1		
Bonasa umbellus	Ruffed Grouse	1		
Lagopus lagopus	Willow Ptarmigan			
Lagopus mutus	Rock Ptarmigan	2		
Callipepla californica	California Quail	1		
Oreortyx pictus	Mountain Quail	1		
Phasianus colchicus	Ring-necked Pheasant	1		
Alectoris chukar	Chukar	1		

Table 1. (cont'd)

SPECIES NAME	COMMON NAME	RACE OF PEREGRINE		
		ANATUM	PEALEI	TUNDRIUS
Rallus elegans	King Rail	1		
Porzana carolina	Sora	1		
Fulica americana	American Coot	2		
Charadrius vociferus	Killdeer	1		
Pluvialis dominica	Lesser Golden-Plover	1	1	2
Pluvialis squatarola	Black-bellied Plover			1
Arenaria interpres	Ruddy Turnstone		1	
Arenaria melanocephala	Black Turnstone	1		
Gallinago gallinago	Common Snipe	2		2
Numenius phaeopus	Whimbrel	1		
Bartramia longicauda	Upland Sandpiper	1		
Actitis macularia	Spotted Sandpiper	2		1
Tringa solitaria	Solitary Sandpiper	1		
Heteroscelus incanus	Wandering Tattler	1	1	
Catoptrophorus semipalmatus	Willet	1		
Tringa melanoleuca	Greater Yellowlegs	1		
Tringa flavipes	Lesser Yellowlegs	2		1
Calidris canutus	Red Knot	1		
Calidris ptilocnemis	Rock Sandpiper		1	
Calidris melanotos	Pectoral Sandpiper	1		1
Calidris alpina	Dunlin	1		
Limnodromus scolopaceus	Long-billed Dowitcher	1		1
Calidris pusilla	Semipalmated Sandpiper	1		1
Limosa limosa	Black-tailed Godwit			1
Recurvirostra americana	American Avocet	2		
Himantopus mexicanus	Black-necked Stilt	1		
Phalaropus fulicaria	Red Phalarope		1	1
Phalaropus tricolor	Wilson's Phalarope	1		
Phalaropus lobatus	Red-necked Phalarope	1		1
Stercorarius pomarinus	Pomarine Jaeger			1
Stercorarius parasiticus	Parasitic Jaeger			2
Stercorarius longicaudus	Long-tailed Jaeger			1
Larus argentatus	Herring Gull	1		
Larus californicus	California Gull	1		
Larus delawarensis	Ring-billed Gull	1		
Larus canus	Mew Gull	1		
Larus ridibundus	Common Black-headed Gull		1	
Larus atricilla	Laughing Gull	1		
Larus pipixcan	Franklin's Gull	2		
Larus philadelphia	Bonaparte's Gull	2		
Rissa tridactyla	Black-legged Kittiwake		1	
Xema sabini	Sabine's Gull	1		1
Sterna hirundo	Common Tern	1		

Table 1. (cont'd)

SPECIES NAME	COMMON NAME	RACE OF PEREGRINE		
		ANATUM	PEALEI	TUNDRIUS
Sterna paradisaea	Arctic Tern	1	2	
Sterna maxima	Royal Tern	1		
Chlidonias niger	Black Tern	1		
Cepphus columba	Pigeon Guillemot		1	
Brachyramphus marmoratus	Marbled Murrelet	1		
Synthliboramphus antiquus	Ancient Murrelet	1	2	
Ptychoramphus aleuticus	Cassin's Auklet	1	1	
Cyclorrhynchus psittacula	Parakeet Auklet	1	2	
Cerorhinca monocerata	Rhinoceros Auklet	1		
Fratercula corniculata	Horned Puffin		1	
Fratercula cirrhata	Tufted Puffin		1	
Columba fasciata	Band-tailed Pigeon	2		
Columba livia	Rock Dove	2		
Zenaida asiatica	White-winged Dove	1		
Zenaida macroura	Mourning Dove	2		
Otus asio	Eastern Screech-Owl	1		
Surnia ulula	Northern Hawk-Owl	1		
Glaucidium gnoma	Northern Pygmy-Owl	1		
Asio flammeus	Short-eared Owl		1	
Aegolius funereus	Boreal Owl	1		
Caprimulgus vociferus	Whip-poor-will	1		
Chordeiles minor	Common Nighthawk	2		
Chaetura pelagica	Chimney Swift	1		
Chaetura vauxi	Vau's Swift	1		
Aeronautes saxatilis	White-throated Swift	2		
Ceryle alcyon	Belted Kingfisher	1		
Colaptes auratus	Northern Flicker	2		
Melanerpes erythrocephalus	Red-headed Woodpecker	1		
Melanerpes lewis	Lewis' Woodpecker	1		
Sphyrapicus varius	Yellow-bellied Sapsucker	1		
Picoides villosus	Hairy Woodpecker	1		
Picoides pubescens	Downy Woodpecker	1		
Tyrannus verticalis	Western Kingbird	1		
Sayornis saya	Say's Phoebe	1		
Contopus sordidulus	Western Wood-Pewee	1		
Eremophila alpestris	Horned Lark	1		
Tachycineta thalassina	Violet-green Swallow	1		
Tachycineta bicolor	Tree Swallow	1		
Riparia riparia	Bank Swallow	1		
Hirundo pyrrhonota	Cliff Swallow	1		
Progne subis	Purple Martin	1		
Perisoreus canadensis	Gray Jay	2		
Cyanocitta cristata	Blue Jay	2		

Table 1. (cont'd)

SPECIES NAME	COMMON NAME	RACE OF PEREGRINE		
		ANATUM	PEALEI	TUNDRIUS
Cyanocitta stelleri	Steller's Jay	1		
Pica pica	Black-billed Magpie	1		
Corvus brachyrhynchos	American Crow	1		
Nucifraga columbiana	Clark's Nutcracker	1		
Parus atricapillus	Black-capped Chickadee	1		
Parus hudsonicus	Boreal Chickadee	1		
Dumetella carolinensis	Gray Catbird	1		
Turdus migratorius	American Robin	2		1
Ixoreus naevius	Varied Thrush	2		
Catharus guttatus	Hermit Thrush	1		
Catharus ustulatus	Swainson's Thrush	1		
Catharus minimus	Gray-cheeked Thrush			2
Sialia mexicana	Western Bluebird	1		
Sialia currucoides	Mountain Bluebird	1		
Myadestes townsendi	Townsend's Solitaire	1		
Phylloscopus borealis	Arctic Warbler			1
Motacilla flava	Yellow Wagtail			1
Anthus spinoletta	Water Pipit			1
Bombycilla garrulus	Bohemian Waxwing	1		
Bombycilla cedrorum	Cedar Waxwing	1		
Lanius excubitor	Northern Shrike			1
Sturnus vulgaris	European Starling	2		
Vireo solitarius	Solitary Vireo	1		
Vermivora celata	Orange-crowned Warbler	1		
Dendroica petechia	Yellow Warbler	1		1
Dendroica coronata	Yellow-rumped Warbler	1		
Dolichonyx oryzivorus	Bobolink	2		
Sturnella neglecta	Western Meadowlark	2		
Xanthocephalus xanthocephalus	Yellow-headed Blackbird	1		
Agelaius phoeniceus	Red-winged Blackbird	2		
Icterus galbula	Northern Oriole	1		
Euphagus carolinus	Rusty Blackbird	1		
Euphagus cyanocephalus	Brewer's Blackbird	2		
Quiscalus quiscula	Common Grackle	1		
Molothrus ater	Brown-headed Cowbird	1		
Piranga ludoviciana	Western Tanager	1		
Pheucticus melanocephalus	Black-headed Grosbeak	1		
Passerina amoena	Lazuli Bunting	1		
Coccothraustes vespertinus	Evening Grosbeak	2		
Pinicola enucleator	Pine Grosbeak	1		
Leucosticte arctoa	Rosy Finch		1	
Carduelis hornemanni	Hoary Redpoll	3		1
Carduelis flamme	Common Redpoll	3		1

Table 1. (cont'd)

SPECIES NAME	COMMON NAME	RACE OF PEREGRINE		
		ANATUM	PEALEI	TUNDRIUS
Carduelis pinus	Pine Siskin	1		
Carduelis tristis	American Goldfinch	1		
Carduelis psaltria	Lesser Goldfinch	1		
Loxia curvirostra	Red Crossbill	1		
Loxia leucoptera	White-winged Crossbill	1		
Pipilo chlorurus	Green-tailed Towhee	1		
Passerculus sandwichensis	Savannah Sparrow			1
Junco hyemalis	Dark-eyed Junco	1		
Spizella arborea	American Tree Sparrow			2
Zonotrichia leucophrys	White-crowned Sparrow	1		1
Passerella iliaca	Fox Sparrow	1		2
Calcarius lapponicus	Lapland Longspur		2	2
Plectrophenax nivalis	Snow Bunting		1	1

Legend: 1 = known to be consumed by Peregrines
2 = common occurence as a prey
3 = only genus recorded; species unknown

patterns in flight, such as Flickers, Meadowlarks, Red-winged Blackbirds, and Blue Jays, are common prey items. In Table 1, the species commonly found as prey items constitute a much smaller subset, thereby indicating a certain degree of specialization by the predator or the greater vulnerability of some birds. It is interesting to note in this context that warblers and other small forest dwelling birds are conspicuously absent from the list of prey. Unlike accipiters, which prefer forests and woodlands, Peregrine Falcons are especially adapted to open country.

2.3 The Data

From the standpoint of the recovery program, it would be desirable to focus on residue concentrations in the most common prey species sampled close to historical nest sites, presently occupied nest sites and at release sites. Unfortunately, of the 188 prey species found in Table 1, recent residue data (i.e. post 1980) are available for only 28 species, a third of which are common items in the diet of the Peregrine Falcon. Furthermore, the data in the Registry is spotty, both in time and space. This is a reflection of the nature of the surveys which were designed to meet specific contaminant concerns in various regions of Canada. Also, after the late 1970s, fewer studies were carried out because of the perception that organochlorine compounds were a diminishing concern. Analytical costs forced a reduction in the number of samples taken and the pooling of samples. This often eliminated information on sample variability. For these reasons, the residue data for each of the 28 species was sorted by region and by time period.

The regions were arbitrarily chosen based on knowledge of the distribution of the three races of Peregrine, ecozones, and areas recognized as major sources of contamination. A total of 11 regions are shown in Figure 1 and delineated as:

(1) Atlantic: includes the maritime provinces, north shore region of Québec, the Gaspé peninsula and the St. Lawrence up to Québec City.

(2) Great Lakes: St. Lawrence from Québec City up to and including the Great Lakes.

(3) Boreal: boreal forest north of St. Lawrence valley and Great Lakes to Manitoba border in the west and the coast of Labrador in the East.

(4) Eastern Arctic: northern Québec north of the 57th parallel.

(5) Southern Prairies: Manitoba, Saskatchewan and Alberta south of the 54th parallel.

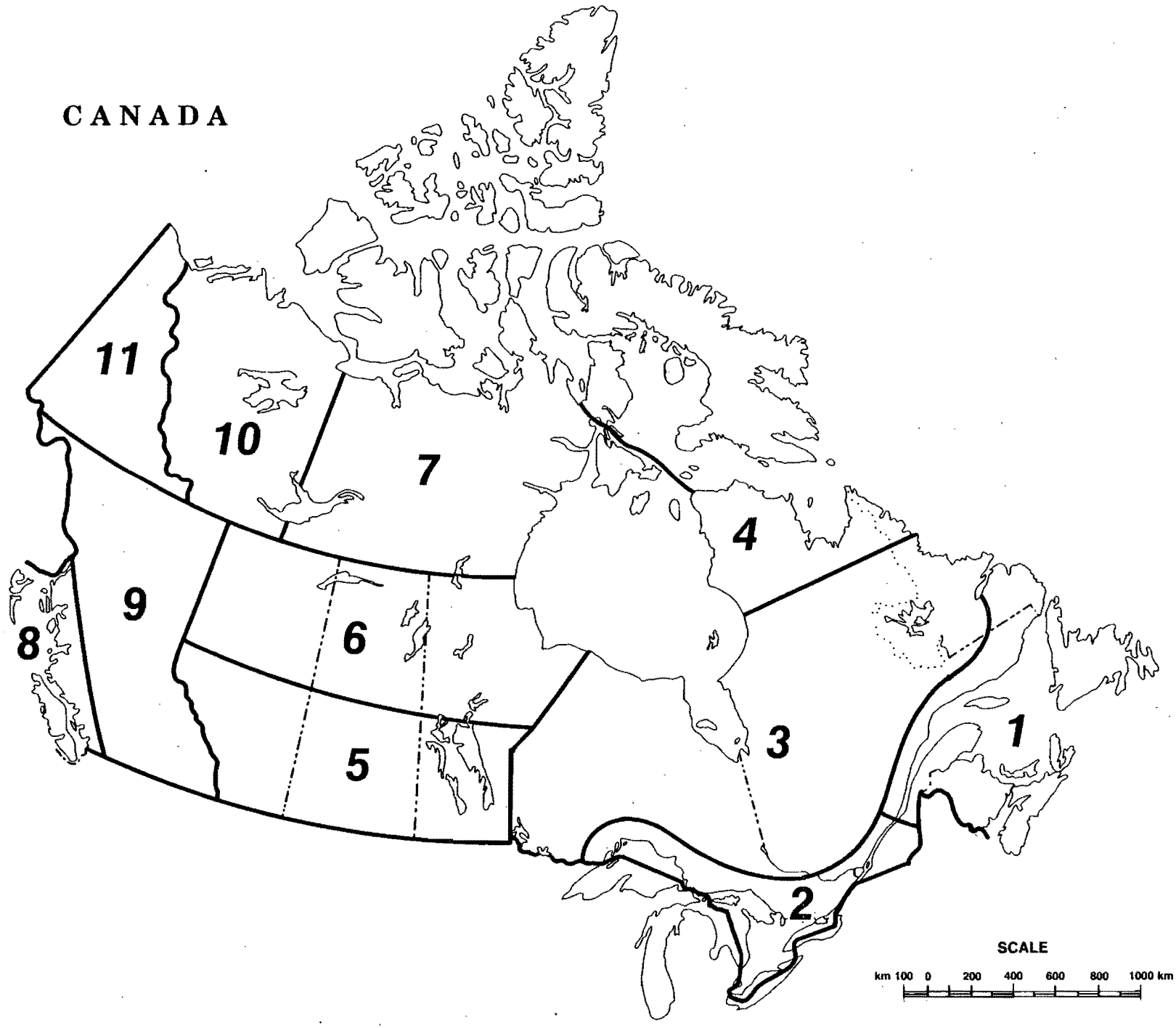
(6) Northern Prairies: Manitoba, Saskatchewan and Alberta north of the 54th parallel.

(7) Central Arctic: Northwest Territories east of 115^{o} longitude to Hudson Bay.

(8) West Coast: Pacific Coast of British Columbia.

Figure 1. Map of Canada showing the 11 regions selected for calculating regional averages:

(1) Atlantic
(2) Great Lakes
(3) Boreal
(4) Eastern Arctic
(5) Southern Prairies
(6) Northern Prairies
(7) Central Arctic
(8) Pacific Coast
(9) Rocky Mountains
(10) Western Arctic
(11) Yukon


CANADA
11
10
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9
8
6
5
3
1
2
SCALE
km 100 0 200 400 600 800 1000 km

(9) Rocky Mountains: interior of British Columbia.

(10) Western Arctic: Northwest Territories west of 115° longitude.

(11) Yukon: Yukon Territory.

The time over which residue concentrations in the registry are averaged cover the periods 1975 to 1979 and 1980 to 1985. While this study is concerned with present conditions, the paucity of data on current contaminant levels led to the pooling of all data from 1980 on. The five year interval from 1975 to 1979 was also analysed in order to provide some idea of trends over time in the contamination of Peregrine prey; many organochlorine compounds were either banned or restricted in their use during this time interval.

2.4 The Contaminants

This study focuses on residue levels of eight persistent organochlorine compounds. Some of these can have serious impacts on avian populations through their effects on reproduction (e.g. eggshell thinning, embryotoxicity).

DDE is a long-lived metabolite of DDT, an insecticide heavily used in the 1950s and 1960s, severely restricted in the 1970s, and discontinued in Canada since 1985. Dieldrin is one of the most persistent insecticides ever used. Oxychlordane is a persistent metabolite of the insecticide chlordane which is still registered as a termiticide. Heptachlor epoxide is a metabolite of heptachlor which was used as a seed treatment in the U.S.A. until 1982. Alpha-HCH is an isomer of hexachlorocyclohexane, the principal component of the insecticide Lindane. Hexachlorobenzene (HCB) was used as a fungicide until 1973 and is still found as a by-product of industrial processes and as a contaminant of pest control products. Mirex, a long lasting compound in soils was used industrially and, in the U.S.A., as an insecticide against fire ants. Finally, polychlorinated biphenyls (PCBs) are mixtures of many congeners with numerous uses (e.g. lubricants, heat-transfer systems). In 1976, PCBs were regulated under the United States Toxic Substances Control Act which effectively banned the manufacture, processing, distribution and use of PCBs except in totally enclosed systems such as electrical transformers, capacitors and electromagnets (Alford-Stevens, 1986). Similar regulatory limits on the use of PCBs were introduced in Canada in 1978 under the Environmental Contaminants Act which prohibited "open" uses but continued to permit existing "closed" applications (Strachan, 1988). As of 1980, under new amendments, no new PCBs could be put into service in Canada. The data on PCBs presented here refer to a 1:1 ratio mixture of Aroclor 1254 and Aroclor 1260.

In addition to the organochlorine compounds, mercury is included in this review because of its toxicity and close association with human activities. Lead is another metal of concern. Most Canadian releases of captive-bred Peregrines are currently conducted in cities. Unfortunately, there are practically no data in the Registry on current lead levels in the species of interest here.

Details about sample collection, preparation and chemical analysis along with more information on the history and patterns of chemical use can be found in a recent review of contaminants in Canadian seabirds (Noble and Elliott, 1986).

3.0 Results

The results are presented in three parts dealing with: (1) data from the registry over a 10 year period across Canada; (2) data from Alberta averaged by avian family for the period 1983-1987; and (3) data recently obtained on a small number of prey from British Columbia, Nova Scotia and New Brunswick.

3.1 The Registry Data

Mean contaminant levels in some prey of Peregrine Falcons are presented by contaminant, species, region and time interval in tables 1 to 10 of Appendix 1. Each table presents mean residue concentrations of one contaminant by region and time interval for some or all of the 28 species previously discussed.

Analysis of the data base reveals that contaminant levels in the prey are available for only six of the 11 regions defined in figure 1: the Atlantic, Great Lakes, Boreal, Southern Prairies, Rocky Mountains and Eastern Arctic regions. For some regions and species, data previous to 1980 are not available. Finally, it should be noted that different tissues were analysed in different species: eggs were collected for some, while for others muscle or whole body samples were taken. All contaminant concentrations are expressed on a wet weight basis.

3.1.1 DDE (Appendix 1, Table 1)

DDE concentrations greater than 1 ppm were found in the eggs of three species: Red-necked Grebes from the Southern Prairies, Western Grebes from the Rocky Mountains, and Black-crowned Night-Herons from the Great Lakes. The Red-necked Grebe eggs show the highest mean concentrations at 4.03 ppm. The three other species for which egg levels are available--American Kestrels, Leach's Storm-Petrels, and Eared Grebes--show mean values greater than 0.5 ppm. Eggs of the Black-crowned Night-Heron from the Great Lakes and Leach's Storm-Petrel from the Atlantic region show a 50% decrease in DDE concentrations between the late 70s and the 1980s.

Muscle DDE concentrations in six species of ducks are the highest in Bufflehead (1.56 ppm) and in Blue-winged Teal (1.76 ppm) collected respectively in the Great Lakes and Southern Prairie regions. In the Great Lakes, Greater Scaup and Lesser Scaup have concentrations above 0.1 ppm while in Mallard and Gadwall these are lower than 0.1 ppm. Over time, DDE concentrations in muscles of Greater and Lesser Scaup and Mallard from the Great Lakes seem to have increased.

Of 19 species analysed for whole body concentrations of DDE only four show mean levels greater than 1 ppm: Eared Grebe (2.02 ppm) from the Southern Prairies; Bank Swallow (1.65 ppm) from the Boreal region; Killdeer (1.17 ppm) from the Great Lakes; and American Robin (1.01 ppm) from the Atlantic region. These are closely followed by Brewer's Blackbirds (0.89 ppm) from the Southern Prairies and Dunlin (0.7 ppm) collected in the Central Arctic. Temporally, Rock Doves collected in the Great Lakes show a decrease between the late 70s and the 80s.

With regard to spatial patterns no trend emerges from the data. Concentrations about the 1 ppm value were found at least once in each region.

3.1.2 Dieldrin (Appendix 1, Table 2)

The eggs with the highest levels of dieldrin were those of Black-crowned Night-Herons collected from the Great Lakes (0.19 ppm), followed by those of Red-necked Grebes (0.11 ppm) sampled in the Southern Prairies. Egg concentrations of dieldrin were below 0.1 ppm for the other species, with concentrations of 0.058 and 0.038 ppm in eggs of Western Grebe (Rocky Mountains) and Leach's Storm-Petrels (Atlantic) respectively. Levels of dieldrin in Black-crowned Night-Heron eggs indicated a 70% decrease between the late 1970s and the 1980s.

None of the ducks analysed showed levels of dieldrin greater than 0.1 ppm in muscle. The highest concentrations measured were found in a Bufflehead (0.025 ppm) collected on the Great Lakes. In the same region, dieldrin levels showed a decline in Greater Scaup over the two time periods, but increased slightly in Mallard and Lesser Scaup.

Whole body levels of dieldrin were highest in Killdeer (Great Lakes), Semipalmated Plover (Central Arctic), and Bank Swallow (Boreal), with concentrations of 0.47, 0.21 and 0.11 ppm respectively. All other species for which whole body determinations were made showed levels below 0.1 ppm. No spatial pattern was evident in the concentrations of dieldrin in prey.

3.1.3 Oxychlordane (Appendix 1, Table 3)

Concentrations of oxychlordane in eggs were highest in Black-crowned Night-Herons (Great Lakes) and Red-necked Grebes (Southern Prairies), both showing approximately 0.14 ppm. Eggs from the other four species had levels between 0.01 and 0.1 ppm. This was also true for all species where whole body determinations were made. For the ducks, where muscle was analysed, levels were all below 0.01 ppm, except for the Bufflehead from the Great Lakes (0.05 ppm).

Temporally, in the Great Lakes, while Lesser Scaup showed a decrease over time, Greater Scaup, Black-crowned Night-Herons and Rock Doves showed an increase. No spatial trend was apparent.

3.1.4 Heptachlor Epoxide (Appendix 1, Table 4)

The highest levels of heptachlor epoxide in the eggs sampled were found in Red-necked Grebes (Southern Prairies) and Black-crowned Night-Herons (Great Lakes), with means of 0.08 and 0.04 ppm respectively. Eggs of the other species also had concentrations above 0.01 ppm, except for those from Eared Grebe (0.004) collected in Southern Prairies.

Muscle of Blue-winged Teal (Southern Prairies) and Bufflehead (Great Lakes) had concentrations of heptachlor epoxide of approximately 0.01 ppm, while the other three duck species from the Great Lakes had muscle levels below 0.01 ppm.

Whole body determinations showed that the six species of shorebirds all had levels greater than 0.01 ppm irrespective of region. Other species with whole body concentrations above 0.01 ppm were the Bank Swallow (Boreal) and the Eared Grebe (Southern Prairies). While Red-winged and Brewer's Blackbirds in the Southern Praries had whole body concentrations over 0.01 ppm, Red-winged Blackbirds collected in the Boreal or in the Atlantic regions did not.

With regard to spatial patterns, all five regions showed birds with concentrations above 0.01 ppm. Trends over time were confusing. Whereas concentrations in Rock Doves (Great Lakes) and the eggs of Leach's Storm-Petrels (Atlantic) increased over time, they decreased in muscle of Lesser Scaup and Mallard (both Great Lakes), and remained unchanged in Greater Scaup muscle and Black-crowned Night-Heron eggs (both Great Lakes).

3.1.5 Alpha-HCH (Appendix 1, Table 5)

Levels of alpha-HCH in the eggs of six species were all below 0.01 ppm. The highest concentrations were found in the eggs of Western Grebes (Rocky Mountains) and Red-necked Grebes (Southern Prairies), both with levels of 0.005 ppm. Whole body concentrations were the greatest in Semipalmated Plovers (0.04 ppm) from the Central Arctic and a Bank Swallow (0.03 ppm) from the Boreal region. Semipalmated Sandpipers showed whole body concentrations greater than 0.01 ppm in all regions where they were collected (Atlantic, Great Lakes and Central Arctic). A number of other species had whole body concentrations of alpha-HCH around 0.01 ppm. Determinations were not carried out on the duck samples and data previous to the 1980s were not available for any of these species.

While levels of alpha-HCH greater than 0.01 ppm were found in some specimens in all regions, it is interesting to note that birds collected from the Central Arctic all had levels above that mark.

3.1.6 HCB (Appendix 1, Table 6)

The highest concentrations of HCB measured in eggs were found in those of Red-necked Grebes (Southern Prairies) with an average of 0.11 ppm. Eggs from the other five species, except for the Eared Grebe (Southern Prairies), showed levels between 0.01 and 0.1 ppm. Muscle concentrations of HCB in three duck species from the Great Lakes--Greater Scaup, Lesser Scaup, and Bufflehead--were approximately 0.01 ppm. Blue-winged Teal from the Southern Prairies showed much lower levels in muscle at 0.001 ppm.

Of 16 species where whole body levels were determined, only seven showed mean values above 0.01 ppm. The highest of these were 0.025, 0.022 and 0.021 ppm for Bank Swallows (Boreal), Semipalmated Sandpipers (Central Arctic), and Dunlins (Central Arctic) respectively.

Once again, there did not appear to be any geographical trend. With regard to temporal patterns, Greater and Lesser Scaup (Great Lakes) showed increasing concentrations of HCB in muscle over time. These remained unchanged in eggs of Leach's Storm-Petrels (Atlantic) and Black-crowned Night-Herons (Great Lakes), and decreased in whole body samples of Rock Doves (Great Lakes).

3.1.7 PCBs (Appendix 1, Table 7)

Eggs with the highest levels of PCBs were those of Red-necked Grebes (Southern Prairies) and Black-crowned Night-Herons (Great Lakes) with means of 25.0 and 11.9 ppm respectively. Eggs from Leach's Storm-Petrels (Atlantic) and Western Grebes (Rocky Mountains) showed mean concentrations slightly over 2 ppm. Four duck species collected from the Great Lakes showed muscle concentrations of PCBs over 1 ppm; Bufflehead, Lesser Scaup,

Greater Scaup and Mallard had 44.4, 9.75, 8.75 and 1.28 ppm respectively. It should be noted that these same birds had much higher concentrations in the livers: 396, 19, 71 and 3.5 ppm respectively.

Of the species examined for whole body concentrations, five had levels close to or slightly above 1 ppm: Red-winged Blackbirds (0.92 ppm) and Bank Swallows (0.95 ppm) from the Boreal Region; Semipalmated Sandpipers (0.86 ppm) and Semipalmated Plovers (1.14 ppm) from the Central Arctic region; and Spotted Sandpipers (1.95 ppm) from the Atlantic region.

Again, birds with whole body, muscle, or egg concentrations of PCBs greater than 1 ppm were found in all six regions. Temporally, data from Rock Doves (Great Lakes), and eggs from Leach's Storm-Petrels (Atlantic) and Black-crowned Night-Herons (Great Lakes) showed no change between the late 1970s and 1980s. Concentrations were greater in the 1980s in muscle of Greater Scaup, Lesser Scaup and Mallard.

3.1.8 Mirex (Appendix 1, Table 8)

Of the species for which eggs were analysed, the Red-necked Grebe (Southern Prairies) showed the highest mean levels with 0.38 ppm of mirex. Except for eggs of Leach's Storm-Petrels (0.03 ppm) from the Atlantic region, mean concentrations in the eggs of the other species were below 0.01 ppm.

Of four duck species analysed, muscle concentrations were highest in the Bufflehead (Great Lakes) with a measurement of 0.13 ppm. Greater Scaup (Great Lakes) and Blue-winged Teal (Southern Prairies) showed muscle levels of 0.076 and 0.01 ppm respectively.

Whole body levels of mirex were highest in Northern Flicker (0.16 ppm) and American Robin (0.1 ppm), both collected from the Boreal region. Species with levels between 0.01 and 0.1 ppm were Spotted Sandpiper (Atlantic), Dunlin (Central Arctic), Bank Swallow (Boreal), and Willet and Killdeer (both Southern Prairies).

Two species showed an increase in concentrations over time: Greater Scaup and Rock Doves from the Great Lakes. Again, no regional trends were evident.

3.1.9 Mercury (Appendix 1, Table 9)

Mercury concentrations in the eggs of four species were highest in Leach's Storm-Petrel (Atlantic) with a mean of 0.41 ppm. Of the other three species, only Red-necked Grebes (Southern Prairies) showed mean egg concentrations above 0.1 ppm, with a mean of 0.11 ppm.

All five shorebird species showed mean whole body levels of mercury between 0.1 and 1 ppm, with the highest concentrations found in Semipalmated Sandpipers (0.4 ppm) from the Central Arctic region and Spotted Sandpipers (0.32 ppm) from the Atlantic region.

Of the other nine species analysed for whole body levels, seven had mean levels above 0.1 ppm. Common Grackle (Boreal), Red-winged Blackbird (Boreal), Bank Swallow (Boreal), and Lapland Longspur (Central Arctic) showed the highest mean concentrations, with values of 0.51, 0.35, 0.23 and 0.23 ppm respectively.

3.2 The Alberta Data

Levels of organochlorine contaminants in whole body homogenates of Peregrine prey collected in Alberta between 1983 and 1987 are summarized in Appendix 2. The data were averaged by avian family and are presented by habitat and geographic region. It appears that residue levels were on average higher in birds belonging to families associated with aquatic habitats and that concentrations were usually higher (except for heptachlor epoxide and HCB) in southern Alberta than in the northern half of the province. It should be noted, however, that the northern birds were collected in 1986 and 1987, whereas the southern birds cover an earlier period from 1983 to 1985. Also, the southern Alberta Anatidae included a Red-breasted Merganser which contained 20.9 and 7.1 ppm whole body of DDE and PCB respectively; when excluded from the data, the arithmetic means for this family are 0.15 ppm DDE and 0.14 ppm PCB. The highest mean levels reached in families associated with aquatic habitats are similar to those obtained from the National Registry. In southern Alberta, shorebirds of the family Scolopacidae, gulls (Laridae) and one Belted Kingfisher (Alcedinidae) showed the highest average levels for many contaminants. In Northern Alberta, Killdeers (Charadriidae) and gulls (Laridae) had the highest mean concentrations.

3.3 Other Data

Two other data sets were made available recently. First, whole body residues of five organochlorine compounds in four species of Peregrine prey collected in the Okanagan valley in 1983 were provided by the Ministry of Environment and Parks of the Province of British Columbia (Table 2). All concentrations were low except for DDE levels in Meadowlarks (1.2 ppm) and Robins (2.2 ppm) which were within the range of the highest values recorded elsewhere in Canada. Second, whole body residues of eight organochlorine compounds were determined for three species of shorebirds collected from the Bay of Fundy in August of 1986 (Table 3). Most residue concentrations were low. Semipalmated Plovers collected both in Nova Scotia and New Brunswick showed the highest levels of the three species, although well below the highest values recorded in Canada. For dieldrin, however, the value of 0.63 ppm measured in a pool of ten Semipalmated Plovers from Starr's Point, New Brunswick is the highest recorded for Peregrine prey in this report.

Table 2. Whole body residues (in ppm wet weight) of four organochlorine compounds in birds collected at Vasseux Lake, British Columbia, in the spring of 1983.

COMPOUND	SPECIES			
	Meadowlark	Mourning Dove	Rock Dove	Robin
DDE	1.2	0.046	0.008	2.2
HCB	0.004	0.0004		0.006
OXYCHLORDANE	0.039	0.001		0.005
alpha-HCH			0.0007	0.006
HEPTACHLOR EPOXIDE				0.004

Source: W.T. Munro, Ministry of Environment and Parks, Wildlife Branch, Province of British Columbia.

Table 3. Organochlorine residues in pooled samples of three bird species collected from the Bay of Fundy in August 1986.

SPECIES LOCATION	SAMPLE SIZE	RESIDUES (PPM WET WEIGHT)							
		HCB	DDE	MIREX	PCB	alpha-HCH	OXYCHLORDANE	HEPTACHLOR EPOXIDE	DIELDRIN
Short-billed Dowitcher									
Dorchester Cape, N.S.	5	0.005	0.033	ND	0.182	ND	0.002	0.002	0.005
Starr's Point, N.B.	5	0.004	0.098	ND	0.259	0.001	0.003	0.003	0.011
Semipalmated Sandpiper									
Dorchester Cape, N.S.	9	0.008	0.022	ND	0.17	0.002	0.007	0.003	0.008
Starr's Point, N.B.	10	0.008	0.1	ND	0.164	0.001	0.005	0.006	0.026
Semipalmated Plover									
Dorchester Cape, N.S.	10	0.01	0.791	0.002	0.311	0.006	0.009	0.005	0.013
Starr's Point, N.B.	10	0.013	0.456	ND	0.154	0.003	0.015	0.08	0.627

Source: Canadian Wildlife Service, Atlantic Region.

(ND = not detected)

4.0 Discussion

4.1 Contaminant Levels

The significance to Peregrine Falcons of contaminant levels in their prey in Canada is difficult to establish for most of the compounds discussed here. The effects on reproduction of dietary intakes of contaminants are not well documented, aside from DDE, dieldrin, and PCBs. Table 4 summarizes all the results, including the Alberta, British Columbia and Bay of Fundy data, by identifying species which show contaminant concentrations exceeding specific levels. For DDE, dieldrin, and PCBs, these levels were chosen on the basis of established toxicological effects. Since concentrations tend to be low for the other compounds and because there is little toxicological information for most of them, the threshold levels where chosen arbitrarily and correspond to the highest range of concentrations measured (on a logarithmic scale).

For DDE, ten species out of 29 showed levels in eggs, muscle or whole body samples of 1 ppm or above; the highest mean value being 4.03 ppm in eggs of Red-necked Grebes. These levels are significant and a cause for concern. Enderson and co-workers (1982) suggest that, in the breeding season, Peregrines feeding on prey exceeding about 1 ppm DDE could be expected to lay eggs containing 20 ppm DDE with shells thinned by more than 16%. This level of contamination of eggs is well within the range leading to reproductive failure (Peakall et al., 1975). Although DeWeese and co-workers (1986) cite a DDE concentration in food of about 3 ppm as causing significant eggshell thinning and reproductive failure, a more conservative value of 1 ppm is used here as a cut-off point. Body burdens close to 1 ppm were found in American Robin (2.2 ppm), Western Meadowlark (1.2 ppm), Dunlin (0.7 ppm), and Brewer's Blackbird (0.9 ppm). American Kestrel, Leach's Storm-Petrel and Eared Grebe had levels in eggs close to 1 ppm. While Peregrines do not consume the eggs of these species, the DDE contents reflect levels in the whole body approximately two times those in egg according to ratios based on experimental work with American Kestrels (Wiemeyer et al., 1986). This would suggest that the eggs of Red-necked Grebes sampled in the Southern Prairies came from birds with body burdens as high as eight ppm DDE.

Dieldrin concentrations of 0.1 ppm or greater were present in only five species, with the highest recorded in Semipalmated Plovers at 0.63 ppm (Tables 3 and 4). Dieldrin led to eggshell thinning in Mallards at dietary concentrations of 1.6 ppm, increased embryo death in Grey Partridges at 3 ppm, and decreased hatchability in Pheasants at 10 ppm (see Jefferies, 1973). More recent work shows that dietary levels of 0.5 ppm dieldrin do not reduce breeding success in Barn Owls in spite of a slight reduction in eggshell thickness (Mendenhall et al., 1983). It should also be noted that in those Owls, carcass residues averaged over 9 ppm. Such levels, in the brain, are associated with dieldrin-induced starvation in Brown-headed Cowbirds (Heinz and Johnson, 1981). While levels above 0.1 ppm in prey are not widespread, dieldrin has the same bioaccumulatory potential as DDE (Kan, 1978) and its presence may still be of concern in certain regions and prey species.

Twelve species had levels of PCBs of 1 ppm or above with three species showing levels over 10 ppm. Studies on the effect of PCBs on avian reproduction have shown that, in the chicken, dietary concentrations of 10 ppm of Aroclor 1248 caused severe embryonic mortality and concentrations of

Table 4. Mean levels (standard deviation/No. of values averaged) of contaminants in egg, muscle or whole body in Peregrine prey species. Only those means which are equal to or exceed specified threshold values are shown (see text). Blanks signify that the mean was lower than the threshold values and NA indicates that no values were available.

TISSUE / SPECIES / REGION	CONTAMINANT (THRESHOLD VALUE)									
	DDE	Dieldrin	Oxychl. (a)	HE (b)	alpha-HCH	HCB	PCBs (c)		Mirex	Mercury
	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>10.0 ppm)	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)
EGGS:										
Red-necked Grebe										
Southern Prairies	4.03	0.11	0.14	0.08		0.108	11.9		0.38	0.11
	(4.02/23)	(0.137/24)	(0.12/23)	(0.09/22)		(0.108/24)	(13.2/24)		(0.45/22)	(0.03/19)
Western Grebe										
Rocky Mountains	1.74			0.02		0.017		2.26		
	(2.74/9)			(0.01/9)		(0.004/9)		(1.9/9)		
Black-crowned Night-Heron										
Great Lakes	3.22	0.19	0.14	0.04		0.054	25.0		NA	NA
	(1.88/23)	(0.36/23)	(0.12/23)	(0.02/23)		(0.095/24)	(11.5/23)			
Eared Grebe										
Southern Prairies										
Leach's Storm-Petrel										
Atlantic				0.02		0.062		2.32		0.41
				(0.004/6)		(0.033/5)		(1.55/5)		
American Kestrel										
Rocky Mountains				0.02		0.011				NA
				(0.017/10)		(0.006/10)				
MUSCLE:										
Greater Scaup										
Great Lakes					NA	0.012		8.75		NA

Table 4. (cont'd)

TISSUE / SPECIES / REGION	CONTAMINANT (THRESHOLD VALUE)									
	DDE	Dieldrin	Oxychl. (a)	HE (b)	alpha-HCH	HCB	PCBs (c)		Mirex	Mercury
	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>10.0 ppm)	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)
Lesser Scaup										
Great Lakes					NA	0.011		9.75	NA	NA
Mallard										
Great Lakes					NA			1.28	NA	NA
Bufflehead										
Great Lakes	1.56			0.01	NA	0.029	44.4		0.13	NA
Gadwall										
Great Lakes					NA					NA
Blue-winged Teal										
Southern Prairies	1.76			0.01	NA					NA
WHOLE BODY:										
Killdeer										
Great Lakes	1.17	0.47		0.03	0.01					0.14
Southern Prairies				0.02	0.01					0.12
Semipalmated Sandpiper										
Great Lakes					0.02	0.012				0.14
Atlantic				0.02	0.02	0.014				
				(0.014/2)	(0/2)	(0.009/3)				
Central Arctic				0.03	0.01	0.022				0.40
Spotted Sandpiper										
Atlantic				0.01		0.018		1.95		0.32
				(0.004/15)		(0.046/15)		(2.18/15)		(0.29/15)

Table 4. (cont'd)

TISSUE / SPECIES / REGION	CONTAMINANT (THRESHOLD VALUE)									
	DDE	Dieldrin	Oxychl. (a)	HE (b)	alpha-HCH	HCB	PCBs (c)		Mirex	Mercury
	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>10.0 ppm)	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)
Semipalmated Plover										
Central Arctic		0.21		0.03	0.04	0.013		1.14		0.13
Atlantic		0.63		0.08		0.013				
Dunlin										
Central Arctic				0.02	0.02	0.021				0.18
Willet										
Southern Prairies				0.01	NA					NA
Bank Swallow										
Boreal	1.65	0.11		0.02	0.03	0.025		1.00		0.23
American Robin										
Rocky Mountains	2.2 (d)									
Atlantic	1.00		0.11	0.02	0.015					
	(0.89/2)		(0.071/2)	(0.028/2)	(0.007/2)					
Boreal					0.01				0.10	
Western Meadowlark										
Rocky Mountains	1.2 (d)	NA					NA	NA	NA	NA
Brewer's Blackbird										
Boreal					NA	NA			NA	NA
Southern Prairies				0.02	NA	NA			NA	NA
Red-winged Blackbird										
Atlantic									NA	0.10
										(0.03/2)
Great Lakes								1.00	NA	0.35
								(1.0/2)		
Southern Prairies				0.02					NA	0.10
				(0.028/2)						

Table 4. (cont'd)

TISSUE / SPECIES / REGION	CONTAMINANT (THRESHOLD VALUE)									
	DDE	Dieldrin	Oxychl. (a)	HE (b)	alpha-HCH	HCB	PCBs (c)		Mirex	Mercury
	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>0.01 ppm)	(>10.0 ppm)	(>1.0 ppm)	(>0.1 ppm)	(>0.1 ppm)
Common Grackle										
Boreal					0.01					0.51
Lapland Longspur										
Central Arctic					0.01	0.010				0.23
Horned Lark										
Central Arctic					0.02					0.10
Northern Flicker										
Boreal					0.01				0.16	0.10
Atlantic										0.10
Bobolink										
Atlantic										0.10
										(0.08/2)
Rock Doves										
Great Lakes										
Eared Grebe										
Southern Prairie	2.02			0.01	NA	0.013			NA	NA

(a): oxychlordane

(b): heptachlor epoxide

(c): 1:1 ratio mixture of Aroclor 1254 and Aroclor 1260 (see text)

(d): single pooled sample collected at Vasseux Lake, British Columbia (courtesy of W.T. Munro, Ministry of the Environment and Parks, Wildlife Branch, Province of British Columbia)

5 ppm of Aroclor 1254 decreased egg production (see Peakall 1975, 1986). Hatchability was markedly reduced in Ring Doves fed 10 ppm of Aroclor 1254 (Peakall and Peakall, 1973); this effect was ascribed to decreased parental attentiveness. Diets containing 3 ppm of Aroclor 1248 eight weeks prior to egg laying did not perceptibly affect reproduction in Screech Owls (McLane and Hughes, 1980): the number of eggs laid, eggs hatched, young fledged, and eggshell thickness were not affected. These studies show that while species differed substantially in their susceptibility to PCBs and that congeners differ appreciably in their effects, levels below 5 ppm in diet do not appear to affect reproduction in birds (see Peakall, 1986). Of the Peregrine prey analysed, only those collected from the Great Lakes showed whole body levels exceeding this value. Concentrations of 25 ppm in the eggs of Red-necked Grebes collected in the Southern Prairies are difficult to interpret with regard to their significance to Peregrines.

Oxychlordane did not exceed 0.1 ppm in any species except in the eggs of Red-necked Grebes and Black-crowned Night-Herons where they averaged 0.14 ppm, and in the American Robin (0.11 ppm). While 50% of European Starlings dosed with 1.5 ppm oxychlordane in their diet died within 60 days (Stickel et al., 1979), those dietary levels are two orders of magnitude greater than the concentrations found in the prey collected in Canada. It is not known what effects such low dietary concentrations may have on Peregrines.

Similarly, concentrations of heptachlor epoxide were generally low (< 0.1 ppm) in all prey sampled and the consequences to Peregrines of dietary exposure to these levels are not thought to be significant. Average residues of heptachlor epoxide in the brains of birds fed dietary levels of 50 ppm of heptachlor ranged from 13 ppm in European Starlings to 20 ppm in Red-winged Blackbirds. The times to 50% mortality for these two species were nine and 20 days respectively (Stickel et al., 1979). Alpha-HCH concentrations never exceeded 0.1 ppm and the bioaccumulation potential of this compound is low (Kan, 1978).

HCB concentrations exceeded 0.1 ppm only in eggs of Red-necked Grebes with a mean of 0.108 ppm, and in the liver of Bufflehead (0.176 ppm; see Table 6 of Appendix 1). While low, the significance of these concentrations to the Peregrines is not known. Based on an egg injection study, the LD_{50} of HCB to Herring Gull embryos was calculated to be 4.3 ppm (Boersma et al., 1986). Four species out of 23 analysed for mirex had levels equal to or exceeding 0.1 ppm, with the highest average concentration found in the eggs of Red-necked Grebes. Although generally low, the significance to Peregrines of these concentrations in prey is not known.

More than three-quarters of the 18 species analysed for total mercury showed levels above 0.1 ppm, with the highest value of 0.51 ppm found in Common Grackle. A recent review on the chronic toxicity of some metals to birds (Scheuhammer, 1987) suggests that methylmercury levels greater than 1 ppm dry weight (d.w.) in the diet have reproductive effects. Methylmercury is the most bioavailable and significant form of mercury. Pheasants (Phasianus colchicus) fed a diet containing 2-3 ppm (d.w.) MeHg for 12 weeks showed a significant decrease in the hatchability of eggs (Fimreite, 1971). Reduced egg output and hatching success were observed in Mallards dosed with dietary levels of 3 ppm (d.w.) methylmercury (Heinz, 1974). Diets containing 1.1 ppm inorganic Hg caused damage to various cell types in the kidneys of juvenile European Starlings (Nicholson and Osborn, 1984). Although the levels reported in prey of Peregrine Falcons in Canada represent total mercury and not the organic fraction, the evidence presented here suggests that present levels of mercury in Canadian prey may

exceed, in some cases, the threshold above which symptoms of toxicity may appear in their avian predators. The levels reported here are similar to those observed in Peregrine prey in Northern Sweden (Lindberg and Odsjo, 1983). These authors concluded that the reproductive output of the Peregrines feeding on these birds had not been affected by the mercury content. Barr (1986) found that reproduction in Loons breeding in Northwestern Ontario was impaired at mercury concentrations of 0.3-0.4 ppm wet weight in fish and invertebrate prey. It should be noted, however, that there is much variability between bird species in their sensitivity to mercury (Scheuhammer, 1987)

It appears that the nine contaminants discussed here were detected in most of the prey species analysed. While concentrations were low for most contaminants, three compounds were found at levels high enough to be of some concern for the health of Peregrine Falcons. Birds frequently consuming prey with some of the higher DDE, dieldrin, or PCB levels recorded here may be exposed to levels that diminish reproductive success. In addition, the effects of chronic exposure to low concentrations of mixtures of different organochlorine compounds are not known.

4.2 The Prey

Whereas most organochlorine compounds were detectable in practically all prey samples analysed, only a few species, Bank Swallows and certain species associated with aquatic life, showed high levels across a number of substances. The eggs of Red-necked Grebes and Black-crowned Night-Herons, the muscle of Bufflehead, and whole bodies of Killdeer and Semipalmated Plovers showed the greatest variety of contaminants (see Table 4) and often the highest levels. Dunlin and Semipalmated and Spotted Sandpipers may, to a lesser degree, be included in this group. Contaminant levels in the eggs of Red-necked Grebes from Alberta and of Black-crowned Night-Heron from the Great Lakes, and in muscle of Bufflehead from Lake Ontario were often among the highest recorded for many of the compounds. It should be noted that the highly contaminated Bufflehead (pool of 2 birds) were found dead on the shores of Windemere Basin in Hamilton Harbour, one of the most polluted sites on Lake Ontario.

These findings are in agreement with other studies showing that among the prey of Peregrine Falcons, aquatic species, shorebirds, and aerial insectivores (i.e. Swallows) contained the greatest variety and levels of organochlorines in the western United States (DeWeese et al., 1986), and of PCBs, DDT and mercury in northern Sweden (Lindberg et al., 1985). The more extensive collection of birds sampled and analysed in Alberta (Appendix 2) supports these trends. The plover, sandpiper and gull families showed consistently higher contaminant levels than other families for a number of compounds. Grebes showed relatively high levels of DDE. The studies cited above and the results presented here probably reflect the large biomagnification potential of aquatic food chains. In particular, the feeding habits of shorebirds, grebes, and herons in coastal areas and estuaries during migration, and in their winter range, leaves them particularly susceptible to large inputs of persistent contaminants present in sediments.

The hypothesis that migrant prey accumulate most of their body burdens of organochlorines in Central and South America could not be tested with the data at hand. Nevertheless, this hypothesis is supported by studies of contaminants in the prey of Peregrine Falcons (De Weese et al., 1986;

Lindberg et al., 1985; Enderson et al., 1982) showing higher levels of organochlorine compounds in migrant than in resident species. Henny et al. (1982), analysing blood samples of migrating Peregrine Falcons, found that juvenile Peregrines migrating south of the U.S. border accumulated most of their pesticide burden during their first winter in Latin America. It is, therefore, most likely that the migration of prey to the same wintering grounds would result in similar increases in body burdens of organochlorine contaminants.

This hypothesis, however, need not be the only explanation of the high levels shown here in shorebirds, herons, and grebes. The species showing some of the highest levels of contaminants in eggs, the Red-necked Grebe, does not migrate south of the United States. In the past nine years, evidence has grown concerning the presence of North American "hot spots" contributing to the contamination of birds by organochlorine compounds. Shorebirds sampled in the fall and winter months of 1979-1980 on mudflats at the outlets of agricultural drains along the south Texas coast were found to accumulate DDE during their stay to levels known to cause reproductive impairment (White et al., 1983). Wintering shorebirds collected from western Washington and at one site along the California coast between 1980 and 1983 showed highly variable whole body levels of DDE (Schick et al., 1987). The birds showing high levels do not migrate to Latin America, thereby indicating the presence of "hot spots" somewhere along the Pacific Coast of North America. A study of DDE and DDT contamination of prey species of the Peregrine Falcon in California and western Texas between 1980 and 1983 showed exceptionally high levels of DDE in the majority of Texas samples and a few of the California samples (Hunt et al., 1986). However, recent illegal uses or transport by birds migrating from Latin America were discounted as sources since p,p'-DDT was not detected in these samples. The authors suggested that the use of the pesticide Kelthane, a miticide containing the active ingredient dicofol, was probably the source of the contamination. Experiments have shown that, in Mallard Ducks, DDE is metabolically derived from technical Kelthane and that most of this metabolically formed DDE was derived from chloro-DDT (Risebrough et al., 1986). The latter was present as an impurity in the pesticide (2.6 to 3.0%), whereas p,p'-DDT was below the detection limit. It should be noted that the U.S. Environmental Protection Agency ordered DDT-related contaminants in Kelthane reduced to less than 0.1% by the end of 1988 (Dolan, 1986 in Schwarzbach et al., 1988). One hypothesis receiving more attention lately is that present contamination of wildlife may be attributed to past applications of technical DDT at very high rates in certain agricultural settings. Blus and co-workers (1987) analysed wildlife samples collected between 1979 and 1983 in the vicinity of fruit orchards in central Washington. Technical DDT had been applied at rates of 56 to 73 kg/ha, with some orchards receiving as much as 1000 kg/ha over the total period ending in the late 1960s to early 1970s. The study showed variability in the concentrations of DDT-related compounds measured, with some levels reaching as much as 150 ppm DDE and 13 ppm DDT in the brain of an American Robin found dead. These concentrations are within the lethal range. Although the data were not adequate to determine the exact source of the contamination, the presence of relatively high concentrations of contaminants in resident species suggests local sources. As there was little evidence of recent illegal uses of technical DDT or of applications of dicofol, the authors suggested that residues in certain samples may have originated from previous legal applications. Low DDE:DDT ratios (i.e. < 10) were common but do not necessarily indicate recent applications. The

authors cited studies which indicated that once an initial phase of rapid dissipation due to volatilization had passed, DDT and metabolites were estimated to have half-lives as high as 57.5 years and that the half-lives increased with concentration. In one case, soil samples taken in 1985 in California, many years after the last applications, revealed DDT residues exceeding concentrations of DDE in most samples (Mischke et al., 1985 in Blus et al., 1987).

For Canada, the data presented here may suggest the presence of similar "hot spots". With regard to regional distribution of contaminants in prey, most compounds were found in all six regions. Comparisons among regions are difficult to make since different species were collected in each region. Nevertheless, the samples with the highest concentrations were usually collected from either the Great Lakes or the Southern Prairie regions. The data did not permit discrimination among the various hypotheses about the source of the contamination. Shaw (1983) found in the analysis of eggs and nestlings of Tree Swallows nesting at various sites in Alberta in 1978 and 1979 that nestlings showed higher body burdens of DDE and PCBs than the eggs. This suggests that Tree Swallows were still obtaining some of their organochlorine burdens in Canada. Recently analysed egg samples from European Starlings and American Kestrels collected in Ontario showed high levels of DDE at the Niagara collection site (10.8 ppm wet weight for American Kestrels and 18.9 ppm for European Starlings). These values were higher than the highest levels recorded in the 1979 whole body samples of European Starlings, analysed as part of the United States Fish and Wildlife Service nationwide monitoring of organochlorine residues (Cain and Bunck, 1983). Since it is thought that these birds living in southern Ontario may not be migrating during the winter, the concentrations in the eggs may reflect the presence of local sources of DDE. Although DDE:DDT ratios could have been examined, their significance is unclear as can be seen in the studies cited above. Interpretation of the ratios may be significant in light of soil residue information obtained from the same collection sites.

Although the data were not analysed statistically, no consistent temporal difference was found between the two time periods for any of the compounds. One interpretation of the lack of differences may be that levels for most compounds were so low as to disguise any trend. Differences noted were often small when compared to the standard deviations and may not be significant.

4.3 Other Data Sets

Some reviews of contaminants in Canadian birds which are prey of Peregrines, not analysed herein, have been published. Mineau and co-workers (1984) reviewed the levels of contaminants in Herring Gull eggs from colonies in the Canadian Great Lakes. Trends indicate a general decline of DDT, DDE, PCB, mirex, HCB, and dieldrin between 1974 and 1979. In 1979, levels of DDE in Herring Gull eggs were generally below 10 ppm in Lakes Ontario, Erie, Huron, and Superior. In the same year, PCBs never exceeded 80 ppm in concentration. Although relatively high in 1979 (< 10 ppm DDE; < 80 ppm PCBs), levels were decreasing and reflected severe restrictions put on the use of certain pesticides and the production of PCBs in the late 1960s and early 1970s. Reductions in contaminant levels in the Great Lakes are thought to have resulted in a 56% annual increase in Double-crested Cormorant populations between 1974 and 1982 (Price and Weseloh, 1986).

Residues of DDE in Caspian Terns decreased from a mean of 13.8 to 5.2 ppm (wet weight) between 1972 and 1981 (Struger and Weseloh, 1985). These are clear signs of improving conditions in the Great Lakes.

Noble and Elliott (1986) reviewed trends in the level of contaminants in Canadian seabirds between 1968 and 1985. Some of the species analysed from the West Coast are important components in the diet of Peregrine Falcons of the pealei race. Eggs of Leach's and Fork-tailed Storm-Petrels sampled on the West Coast in the 1980s showed levels of DDE just slightly below or above 1 ppm; concentrations of other organochlorines were very low. The other species for which data are available for the 1980s, the Rhinoceros Auklet, had a mean level of 0.63 ppm DDE in eggs and very low levels of other organochlorines. Overall, the authors found that, between 1970 and the 1980s, most contaminants, especially DDE and PCBs, declined in seabirds on the Pacific Coast. A more detailed study of organochlorine contamination in seabird eggs from the West Coast (Elliott et al., 1988) confirmed this trend but showed that eggs of seabirds foraging offshore of British Columbia had higher levels of DDE and HCH than ecologically similar Atlantic Coast birds. This may point to continued use of DDT and Lindane in Asia. Eggs of seabirds from inshore locations were less contaminated than their counterparts on the East Coast. The significance of present levels to Peregrines is difficult to assess without more data, although the Pacific Coast population of the pealei race appears to be healthy and self-reproducing (Western Raptor Technical Committee, 1988).

4.4 Other Concerns

Most of the releases in Canada of captive-bred Peregrines have been carried out in urban areas using tall buildings as the site for the hack box. While this has many advantages with regard to lower predation, a good food supply, and lower costs, it raises some concerns with respect to contaminants associated with cities.

Lead levels found in inner cities are known to pose a major health hazard to children (Mielke et al. in DeMent et al., 1986). In birds, most absorbed lead accumulates in bone with reproductively active females accumulating Pb in bone at a greater rate than males and non-laying females (Scheuhammer, 1987). Dietary levels of 100 ppm Pb have few significant reproductive effects in most birds, although levels as low as 10 ppm in the diet of Quail did result in reductions in plasma Ca and egg production. In most studies, however, dietary levels greater than 90 ppm were required before effects such as decreases in the number of fledglings and lowered fledgling haematocrits and brain weights, which may be of significance for central nervous system development, were observed. Indications are, however, that urban-released Peregrines are not exposed to such levels in cities. In a recent study in Baltimore (DeMent et al., 1986) mean total concentration of lead in Rock Doves was found to be 4.6 ppm, more than ten fold greater than in control rural birds. The authors concluded that chronic dietary exposure to these urban levels by Peregrines did not pose a significant health risk. Since similar levels in urban Rock Doves have been reported from such major U.S. cities as Los Angeles and New York, there is no reason to believe that higher levels are to be expected in Canadian cities.

Of greater concern is the consumption, especially by females during the egg-laying period, of prey contaminated by lead shot. The accumulation and toxicity of lead is strongly influenced by dietary Ca levels. In

mammals, Pb absorption from the diet is easily doubled if the diet is Ca-deprived. All Mallards on a low-Ca diet died within 30 days of ingestion of one lead shot whereas 50% of those on an enriched Ca diet survived and recovered (Carlson and Nielson, 1985). Feeding heads of Mallards contaminated by lead shot to Prairie Falcons was identified as the cause of lead intoxication in these raptors (Benson et al., 1974). Lead poisoning has been recorded in a number of raptors and particularly well documented in Bald Eagles feeding on waterfowl (see Pattee and Hennes, 1983). This review indicated that ingestion of lead shot was more important than the consumption of tissue-bound lead as the primary cause of the poisonings. It is, therefore, likely that female Peregrines, during the egg-laying period, could be exposed to lead shot and subsequent lead poisoning when feeding on game birds next to areas of intense hunting.

An additional concern is the use of avicides registered for use in Canada for the control of pigeons, European Starlings, and House Sparrows. Presently, in Canada, six compounds are registered for use as bird control agents (Agriculture Canada, 1987). The effects of exposure of raptors to the two repellents and the chemosterilant azacosterol are not known. The three avicides registered are fenthion, 4-aminopyridine, and strychnine. Fenthion, an organophosphorus pesticide, is applied in the form of an emulsion released from specially designed perches. It is absorbed dermally through the feet and will lead to the death of the bird within a few hours. Obvious signs of distress on the part of the target bird combined with its inability to flee make it a particularly conspicuous and easy target for raptors. This compound was implicated in the secondary poisoning of a Great-horned Owl and a Red-tailed Hawk feeding on dead starlings which had been the target of an eradication program in Illinois (Wenneborg, 1986). In Iowa, five Bald Eagles were found dead after feeding on carcasses of piglets treated dermally with fenthion for control of lice (Henny et al., 1987). Famphur, another organophosphorus insecticide, used for the control of warbles on cattle, was implicated in the death of Black-billed Magpies in areas where the compound was used, and of Red-tailed Hawks feeding on the dead birds (Henny et al., 1985). In these cases of raptor mortality, ingestion of the insecticide was clearly identified as the cause of death. Although organophosphorus insecticides undergo relatively rapid degradation in the environment and tissues of homeotherms, they are highly toxic to birds for varying periods of time. Experimental work looking at the secondary poisoning of American Kestrels feeding on passerines exposed to sublethal doses of fenthion is now underway (P. Mineau, Canadian Wildlife Service, personal communication).

Aminopyridine, mixed in with corn as a bait, is used for the control of House Sparrows, blackbirds, and cowbirds, and is applied on or near buildings where birds nest or roost. Whereas it is lethal to most birds which ingest enough to cause flock-frightening behavior, laboratory studies on the secondary-poisoning of Sharp-shinned Hawks and American Kestrels indicate that the potential hazard appears to be low and that subacute or chronic exposure levels are tolerated by the raptors (Schafer et al., 1974; Holler and Schafer, 1982).

Strychnine is used similarly in the form of baited corn in areas frequented by pigeons. Secondary poisoning of raptors by strychnine has been documented (Redig, 1978). Although it is not accumulated and is excreted rapidly, it can cause secondary poisoning because its rapid toxic action can leave large amounts unabsorbed in the gut of dead prey (Schafer, 1981).

The extent of the use of avicides in Canadian cities, in particular fenthion and strychnine, is not known. The desired release of Peregrines in city cores where pigeon, sparrow, or starling populations are considered troublesome is a source of concern as these birds may be the target of control programs.

5.0 Conclusions

It appears from this review of contaminant concentrations in the prey of Peregrine Falcons in Canada that certain compounds, such as DDE, dieldrin, and PCBs, are still found at levels in prey which may have deleterious effects on the reproductive success of Peregrines nesting in the wild. This would be especially true of individuals feeding heavily on aquatic species (e.g. herons, grebes), shorebirds, and swallows. The finding in the 1980s of chemical "hot spots" in the United States, where avian prey of Peregrines are still known to accumulate significant body burdens of oganochlorine compounds during their migration, is particularly worrisome and points to either new sources of contamination or greater persistence in soils than was previously believed. Recent evidence of high levels of DDT in egg samples collected in the Niagara region, in birds thought to be residents, suggests that similar "hot spots" are likely to exist in Canada.

Another concern is the diversity of persistent organochlorine compounds found in some samples. The effect of chronic exposure of birds to low concentrations of such mixtures is still not known.

In spite of this potential for toxic effects, it is encouraging to find that a number of nesting attempts, although few, were successful in the 1980s in areas where they had been reintroduced (Murphy, 1989). This latest survey (1985-86) showed that Peregrines were returning to historical nesting sites and, in some cases, were attempting to breed. Populations in the Northwest Territories and Yukon were stable or increasing. The United States recovery program has recently shown greater success, possibly due to more intensive management efforts (Cade and Dague, 1986). In California, of 76 pairs occupying territories, 31 nests hatched at least one young. On the East Coast, the number of nesting pairs increased from 25 in 1985 to 30 in 1986, of which 25 where successful, producing 53 young.

Another encouraging trend is found in a recent overview of pesticide usage in Latin America (Burton and Philogene, 1986). In brief, the authors found that although pesticide use was forecast to increase, there was a shift toward the increased use of organophosphate and pyrethroid insecticides and away from organochlorine compounds. Most countries, certainly the biggest consumers, enacted legislation regulating the importation, production, and use of pesticides starting in the late 1970s. In Mexico, aldrin, endrin, dieldrin, chlordane, heptachlor, mirex, and DDT were either restricted in 1980 or canceled by the manufacturer. Many countries in South America now prohibit the use of organochlorine insecticides. While these trends are encouraging for Peregrines and their prey wintering in Latin America, the success of enforcement efforts by these countries is not known.

Finally, studies reviewed here indicate that the choice of release sites may be critical with respect to the potential for exposure to toxic chemicals, especially when mass hacks are involved. Releases should not take place in regions with levels of DDE, dieldrin and PCBs in prey substantially above the thresholds described in this paper. Releases in

proximity to choice hunting areas and large concentrations of game birds may expose the raptors to toxic levels of lead in prey contaminated by lead shot. The presence of lead in urban birds, however, is not known to have a significant impact on raptors and should not prohibit the choice of urban areas as sites for the release of captive-bred birds. The registered use of fenthion and strychnine for control of avian pests is of major concern due to evidence of secondary poisonings in raptors. It would be advisable that those managing the release programs should contact municipal authorities to inquire about the techniques used in controlling problem bird populations.

6.0 Recommendations

In light of the present strategy of using fewer release sites but larger numbers of releases at each site, the present review of contaminant levels in avian prey of the Peregrine Falcon in Canada and of related toxicological studies suggests that care should be taken in choosing the sites.

1. Surveys of potential sources of contamination should be undertaken and/or analyses of prey specimens for organochlorine contamination should be carried out when release sites are near: (a) important populations of species known to have particularly high body burdens of organochlorine contaminants; (b) areas where organochlorine pesticides were used in large quantities in the past; (c) choice hunting areas and large concentrations of game birds; and (d) populations of rural or urban avian pests which are likely to be the subject of population controls.

2. Efforts should be made to identify areas of Canada where intensive use of organochlorines took place in the past; those areas should be studied to determine their current contaminant levels especially in raptor prey items.

3. Pesticide use in Latin America should be further investigated and monitored.

4. Efforts should be made to monitor organochlorine levels in migrating raptors and their prey to follow long term trends.

5. Further work on "new pesticide" threats to Peregrines and other raptors is needed.

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REFERENCES

Agriculture Canada. 1987. Pest Control Products Registered in Canada. Pesticides Directorate, Agriculture Canada. Ottawa.

Alford-Stevens, A.L. 1986. Analysing PCBs. Environmental Science and Technology 20 (12): 1194-1199.

Barclay, J.H. 1988. Peregrine restoration in the eastern United States. In "Peregrine Falcon Populations. Their Management and Recovery." T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White (Eds.). The Peregrine Fund, Inc.. Boise Idaho. pp. 549-558.

Barr, J.F. 1986. Population dynamics of the Common Loon (Gavia immer) associated with mercury-contaminated waters in northwestern Ontario. Canadian Wildlife Service, Occasional Paper No. 56. 23 p.

Benson, W.W., B. Pharaoh and P. Miller. 1974. Lead poisoning in a bird of prey. Bulletin of Environmental Contamination and Toxicology 11: 105-108.

Beyer, W.N. and C..D. Gish. 1980. Persistence in earthworms and potential hazards to birds of soil applied DDT, dieldrin and heptachlor. Journal of Applied Ecology 17: 295-307.

Bird, D.M. and Y. Aubry. 1982. Reproduction and hunting behavior of Peregrine Falcons, Falco peregrinus, in southern Quebec. The Canadian Field-Naturalist 96:167-171.

Blus, L.J., C.J. Henny, C.J. Stafford and R.A. Grove. 1987. Persistence of metabolites in wildlife from Washington State orchards. Archives of Environmental Contamination and Toxicology 16: 467-476.

Boersma, D.C., J.A. Ellenton and A. Yagminas. 1986. Investigation of the hepatic mixed-function oxidase system in Herring Gull embryos in relation to environmental contaminants. Environmental Toxicology and Chemistry 5:309-318.

Burton, D.K. and B.J.R. Philogene. 1986. An overview of pesticide usage in Latin America. Unpublished Report. Canadian Wildlife Service. 122 p.

Cade, T.J. 1982. The Falcons of the World. Cornell University Press, Ithaca, New York. 188 p.

Cade, T.J. and P.R. Dague (Eds.). 1986. The Peregrine Fund Newsletter. Newsletter No. 14, Fall 1986. Cornell University Laboratory of Ornithology. 16 p.

Cain, B.W. and C.M. Bunck. 1983. Residues of organochlorine compounds in Starlings (Sturnus vulgaris), 1979. Environmental Monitoring and Assessment 3: 161-172.

Carlson, B.L. and S.W. Nielson. 1985. Influence of dietary calcium on lead poisoning in Mallard ducks (Anas platyrhynchos). American Journal of Veterinary Research 46: 276-282.

DeMent, S.H., J.J. Chisolm, Jr., J.C. Barber and J.D. Strandberg. 1986. Lead exposure in an "urban" Peregrine Falcon and its avian prey. J. Wildlife Diseases 22:238-244.

De Weese, L.R., L.C. McEwen, G.L. Hensler and B.E. Petersen. 1986. Organochlorine contaminants in passeriformes and other avian prey of the Peregrine Falcon in the western United States. Environmental Toxicology and Chemistry 5:675-693.

Elliott, J.E. 1985. Specimen banking in support of monitoring for toxic contaminants in Canadian wildlife. pp. 4-12 in "International Review of Environmental Specimen Banking.", Wise and Zeisler (Eds.). NBS Special Publication No. 706.

Elliott, J.E., W.J. Learning and Y. Ouellette. 1987. A guide to the Canadian Wildlife Service National Registry of Toxic Chemical Residues. Canadian Wildlife Service, Technical Report Series No. 27. 57 p.

Elliott, J.E., D.G. Noble, R.J. Norstrom and P.E. Whitehead. 1989. Organochlorine contaminants in seabird eggs from the pacific coast of Canada, 1971-1986. Environmental Monitoring and Assessment 12:67-82.

Enderson, J.H., G.R. Craig, W.A. Burnham and D.D. Berger. 1982. Eggshell thinning and organochlorine residues in rocky mountain Peregrines, Falco peregrinus, and their prey. The Canadian Field-Naturalist 96 (3):255-264.

Fimreite, N. 1971. Effects of Dietary methylmercury on Ring-necked Pheasants, with special reference to reproduction. Canadian Wildlife Service, Occasional Paper No. 9. 39 p.

Fleming, W.J., D.R. Clark, Jr., and C.J. Henny. 1983. Organochlorine pesticides and PCBs: a continuying problem for the 1980s. Transactions of the 48th North American Wildlife and Natural Resources Conference: 186-199.

Fyfe, R.W., S.A. Temple and T.J. Cade. 1976. The 1975 North American Peregrine Falcon survey. The Canadian Field-Naturalist 90:228-273.

Heinz, G. 1974. Effects of low dietary levels of methylmercury on Mallard reproduction. Bulletin of Environmental Contamination and Toxicology 11: 386-392.

Heinz, G.H. and R.W. Johnson. 1981. Diagnostic brain residues of dieldrin: some new insights. In "Avian and Mammalian Wildlife Toxicology: Second Conference, ASTM STP 757." D.W. Lamb and E.E. Kenaga (Eds.), American Society for Testing and Materials. pp. 172-92.

Henny, C.J., L.J. Blus, E.J. Kolbe and R.E. Fitzner. 1985. Organophosphate insecticide (Famphur) topically applied to cattle kills Magpies and Hawks. Journal of Wildlife Management 49 (3):648-658.

Henny, C.J., E.J. Kolbe, E.F. Hill and L.J. Blus. 1987. Case histories of Bald Eagles and other raptors killed by organophosphorus insecticides topically applied to livestock. Journal of Wildlife Diseases 23 (2):292-295.

Henny, C.J., F.P. Ward, K.E. Riddle and R.M. Prouty. 1982. Migratory Peregrine Falcons, Falco peregrinus, accumulate pesticides in Latin America during winter. The Canadian Field-Naturalist 96: 333-337.

Hickey, J.J. and D.W. Anderson. 1969. The Peregrine Falcon: life history and population literature. In "Peregrine Falcon Populations: Their Biology and Decline." J.J. Hickey (Ed.). University of Wisconsin Press, Madison. pp. 3-42.

Holler, N.R. and E.W. Schafer, Jr. 1982. Potential secondary hazards of AVITROL baits to Sharp-shinned Hawks and American Kestrels. Journal of Wildlife Management 46(2): 457-462.

Hunt, G.E., B.S. Johnson, C.G. Thelander, B.J. Walton, R.W. Risebrough, W.J. Jarman, A.M. Springer, J.G. Monk and W. Walker. 1986. Environmental levels of p,p'-DDE indicate multiple sources. Environmental Toxicology and Chemistry 5: 21-27.

Jefferies, D.J. 1973. The effects of organochlorine insecticides and their metabolites on breeding birds. Journal of Reproduction and Fertility, Suppl. 19:337-352.

Kan, C.A. 1978. Accumulation of organochlorine pesticides in poultry: a review. J. Agriculture and Food Chemistry 26 (5):1051-1055.

Lindberg, P. and T. Odsjo. 1983. Mercury levels in feathers of Peregrine Falcon Falco peregrinus compared with total mercury content in some of its prey species in Sweden. Environmental Pollution (series B) 5:297-318.

Lindberg, P., T. Odsjo and L. Reutergardh. 1985. Residue levels of polychlorinatedbiphenyls, DDT, and mercury in bird species commonly preyed upon by the Peregrine Falcon (Falco peregrinus Tunst.) in Sweden. Archives of Environmental Contamination and Toxicology 14:203-212.

McLane, M.A.R. and D.L. Hughes. 1980. Reproductive success of Screech Owls fed Aroclor 1248. Archives of Environmental Contamination and Toxicology 9:661-665.

Mendenhall, V.M., E.E. Klaas and M.A.R. McLane. 1983. Breeding success of Barn Owls (Tyto alba) fed low levels of DDE and dieldrin. Archives of Environmental Contamination and Toxicology 12:235-240.

Mineau, P., G.A. Fox, R.J. Norstrom, D.V. Weseloh, D.J Hallett and J.A. Ellenton. 1984. Using the Herring Gull to monitor levels and effects of organochlorine contaminants in the Canadian Great Lakes. In "Toxic Contaminants in the Great Lakes." J.O. Nriagu and M.S. Simmons (Eds.). Advances in Environmental Science and Toxicology Volume 14. pp. 425-452.

Murphy, J. 1989. The 1985-86 Canadian Peregrine Falcon survey. Submitted to The Canadian Field-Naturalist.

Nicholson, J.K. and D. Osborn. 1984. Kidney lesions in juvenile Starlings Sturnus vulgaris fed on a mercury-contaminated synthetic diet. Environmental Pollution (series A) 33:195-206.

Noble, D.G. and J.E. Elliott. 1986. Environmental contaminants in Canadian seabirds 1968-1985: trends and effects. Technical Report Series No. 13. Canadian Wildlife Service, Ottawa. 275 p.

Pattee, O.H. and S.K. Hennes. 1983. Bald Eagles and waterfowl: the lead shot connection. Forty-Eighth North American Wildlife Conference: 230-237.

Peakall, D.B. 1975. PCBs and their environmental effects. Critical Reviews in Environmental Control 5 (1):469-508.

Peakall, D.B. 1976. The Peregrine Falcon (Falco peregrinus) and pesticides. The Canadian Field-Naturalist 90:301-307.

Peakall, D.B. 1986. Accumulation and effects on birds. pp 31-47 in "PCBs and the Environment. Volume II." J. S. Waid (Ed.). CRC Press. Boca Raton, Florida. 191 p.

Peakall, D.B., T.J. Cade, C.M. White and J.R. Haugh. 1975. Organochlorine residues in Alaskan Peregrines. Pesticide Monitoring Journal 8:255-260.

Peakall, D.B. amd M.L. Peakall. 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. Journal of Applied Ecology 10:863-868.

Price, I.M. and D.V. Weseloh. 1986. Increased numbers and productivity of Double-crested Cormorants, Phalacrocorax auritus, on Lake Ontario. The Canadian Field-Naturalist 100 (4):474-482.

Ratcliffe, D.. 1980. The Peregrine Falcon. T and AD Poyser Ltd., Calton, England. 416 p.

Redig, D.V.M. 1978. Secondary poisoning from lead and strychnine. Abstract of Presented Papers at the 96th Meeting of the American Ornithological Union, Madison, Aug. 14-18, 1978. Abstract No. 132.

Risebrough, R.W., W.M. Jarman, A.M. Springer, W. Walker and W.G. Hunt. 1986. A metabolic derivation of DDE fom Kelthane^{R}. Environmental Toxicology and Chemistry 5: 13-19.

Schafer, E.W., Jr. 1981. Bird control chemicals. Nature, modes of action, and toxicity. In "CRC Handbook of Pest Management in Agriculture. Volume III." D. Pimentel (Ed.). CRC Press, Inc. pp. 129-139.

Schafer, E.W., Jr., R.B. Brunton and N.F. Lockyer. 1974. Hazards to animals feeding on Blackbirds killed with 4-aminopyridine baits. Journal of Wildlife Management 38(3): 424-426.

Scheuhammer, A.M. 1987. The chronic toxicity of aluminium, cadmium, mercury, and lead in birds: a review. Environmental Pollution 46: 263-295.

Schick, C.T., L.A. Brennan, J.B. Buchanan, M.A. Finger, T.M. Johnson and S.G. Herman. 1987. Organochlorine contamination in shorebirds from Washington State and the significance for their Falcon predators. Environmental Monitoring and Assessment 9: 115-131.

Schwarzbach, S.E., L. Schull and C.R. Grau. 1988. Eggshell thinning in Ring Doves exposed to p,p'-dicofol. Archives of Environmental Contamination and Toxicology 17: 219-227.

Shaw, G.G. 1983. Organochlorine pesticide and PCB residues in eggs and nestlings of Tree Swallows, Tachycineta bicolor, in central Alberta. The Canadian Field-Naturalist 98: 258-260.

Stickel, L. F., W.H. Stickel, R.D. McArthur and D.L. Hughes. 1979. Chlordane in birds: a study of lethal residues and loss rates. In "Toxicology and Occupational Medicine." Inter-American Conference on Toxicology and Occupational Medicine, 10th, Miami, Florida. pp. 387-396.

Strachan, W.M.J. 1988. Polychlorinated biphenyls (PCBs). Fate and effects in the Canadian environment. Environment Canada Report EPS 4/HA/2. May 1988.

Struger, J. and D.V. Weseloh. 1985. Great Lakes Caspian Terns: egg contaminants and biological implications. Colonial Waterbirds 8 (2):142-149.

Wenneborg, R. 1986. Rid-a-Bird. Hawk Chalk Vol. XXV No. 1:47-48.

Western Raptor Technical Committe. 1988. Anatum Peregrine Falcon recovery plan. Report of the Canadian Wildlife Service. Department of the Environment. Ottawa, Canada. 52 p.

White, C.M., R.W. Fyfe and D.B. Lemon. 1989. The 1980 North American Peregrine Falcon Survey. Submitted to The Canadian Field-Naturalist.

White, D.H., C.A. Mitchell and T.E. Kaiser. 1983. Temporal accumulation of organochlorine pesticides in shorebirds wintering on the south Texas coast, 1979-1980. Archives of Environmental Contamination and Toxicology 12: 241-245.

Wiemeyer, S.N., R.D. Porter, G.L. Hensler and J.R. Maestrelli. 1986. DDE, DDT + dieldrin: residues in American Kestrels and relations to reproduction. Fish and Wildlife Technical Report No. 6. U.S. Fish and Wildlife Service. 33 p.

APPENDIX 1

Residues of 8 organochlorine compounds (tables 1-8) and one metal (table 9) in some prey species of Peregrine Falcons in Canada (1975 to 1985).

Table 1. DDE residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1985				4.03 (4.02)		
					23		
Eared Grebe							
egg	1980-1985				0.65 (0.2)		
					2		
whole body	1980-1985				2.02		
					1		
Western Grebe							
egg	1980-1985						1.74 (2.74)
							9
Leach's Storm-Petrel							
egg	1980-1985	0.65 (0.38)					
		5					
	1975-1979	1.31 (0.65)					
		10					
Black-crowned Night-Heron							
egg	1980-1985		3.22 (1.88)				
			23				
	1975-1979	2.5 (1.4)	7.13 (6.37)				
		12	60				
Mallard							
liver	1980-1985		0.05				
			1				
muscle	1980-1985		0.037				
			1				
	1975-1979		0.015 (0.013)	0.006 (0.004)			
			14	4			

Table 1. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1985		0.029 (0.031)				
			2				
muscle	1980-1985		0.037 (0.038)				
			2				
Gadwall							
liver	1980-1985		0.045				
			1				
muscle	1980-1985		0.017				
			1				
Blue-winged Teal							
liver	1980-1985				1.88		
					1		
muscle	1980-1985				1.76		
					1		
Lesser Scaup							
liver	1980-1985		0.155				
			1				
muscle	1980-1985		0.134				
			1				
	1975-1979	0.01	0.015 (0.007)				
		1	2				
Greater Scaup							
liver	1980-1985		1.95				
			1				
muscle	1980-1985		0.27				
			1				
	1975-1979	0.007 (0.003)	0.05 (0.07)	0.005			
		2	7	1			

Table 1. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1985		5.41				
			1				
muscle	1980-1985		1.56				
			1				
American Kestrel							
egg	1980-1985						0.73 (0.46)
							10
Semipalmated Plover							
whole body	1980-1985					0.32	
						1	
Killdeer							
liver	1980-1985	0.09					
		1					
whole body	1980-1985		1.17		0.05		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	0.29 (0.44)					
		15					
Willet							
whole body	1980-1985				0.1		
					1		
Dunlin							
whole body	1980-1985					0.7	
						1	

Table 1. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1985	0.03 (0)	0.02			0.04	
		2	1			1	
Rock Dove							
whole body	1980-1985		0.05 (0.07)				
			3				
	1975-1979		0.393 (0.356)		0.366 (0.741)		
			10		5		
Northern Flicker							
whole body	1980-1985	0.11		0.1			
		1		1			
Horned Lark							
whole body	1980-1985					0.14	
						1	
Bank Swallow							
whole body	1980-1985			1.65			
				1			
American Robin							
whole body	1980-1985	1.01 (0.89)		0.6			
		2		1			
Bobolink							
whole body	1980-1985	0.15 (0.07)					
		2					
Red-winged Blackbird							
whole body	1980-1985	0.14 (0.02)	0.23 (0.17)		0.04 (0.03)		
		2	2		2		

Table 1. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Brewer's Blackbird							
whole body	1980-1985			0.18	0.89		
				1	1		
Common Grackle							
whole body	1980-1985			0.18			
				1			
Lapland Longspur							
whole body	1980-1985					0.02	
						1	

Table 2. Dieldrin residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1987				0.109 (0.137)		
					24		
Eared Grebe							
egg	1980-1987				0.004 (0.002)		
					2		
whole body	1980-1987				0.01		
					1		
Western Grebe							
egg	1980-1987						0.058 (0.121)
							9
Leach's Storm-Petrel							
egg	1980-1987	0.038 (0.022)					
		6					
	1975-1979	0.044 (0.012)					
		10					
Black-crowned Night-Heron							
egg	1980-1987		0.19 (0.36)				
			23				
	1975-1979	0.012 (0.018)	0.696 (1.333)				
		12	60				
Mallard							
liver	1980-1987		0.073				
			1				
muscle	1980-1987		0.007				
			1				
	1975-1979		0.003 (0.002)	0.003 (0.002)			
			14	4			

Table 2. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1987		0.002 (0.001)				
			2				
muscle	1980-1987		0.001 (0)				
			2				
Gadwall							
liver	1980-1987		0.021				
			1				
muscle	1980-1987		0.002				
			1				
Blue-winged Teal							
liver	1980-1987				0.02		
					1		
muscle	1980-1987				0.01		
					1		
Lesser Scaup							
liver	1980-1987		0.06				
			1				
muscle	1980-1987		0.011				
			1				
	1975-1979	0.005	0.005 (0)				
		1	2				
Greater Scaup							
liver	1980-1987		0.081				
			1				
muscle	1980-1987		0.006				
			1				
	1975-1979	0.005 (0)	0.025 (0.056)	ND			
		2	7	1			

Table 2. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1987		0.19				
			1				
muscle	1980-1987		0.025				
			1				
American Kestrel							
egg	1980-1987						0.007 (0.005)
							10
Semipalmated Plover							
whole body	1980-1987					0.21	
						1	
Killdeer							
liver	1980-1987	0.0025					
		1					
whole body	1980-1987		0.47		0.005		
			1		1		
Spotted Sandpiper							
whole body	1980-1987	0.034 (0.023)					
		15					
Willet							
whole body	1980-1987				0.01		
					1		
Dunlin							
whole body	1980-1987					0.04	
						1	

Table 2. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1987	0.02 (0)	0.02			0.02	
		2	1			1	
Rock Dove							
whole body	1980-1987		0.002 (0.001)				
			3				
	1975-1979		ND		ND		
			10		5		
Northern Flicker							
whole body	1980-1987	ND		ND			
		1		1			
Horned Lark							
whole body	1980-1987					ND	
						1	
Bank Swallow							
whole body	1980-1987			0.11			
				1			
American Robin							
whole body	1980-1987	0.02 (0.014)		ND			
		2		1			
Bobolink							
whole body	1980-1987	0.005 (0.007)					
		2					
Red-winged Blackbird							
whole body	1980-1987	0.005 (0.007)	0.006 (0.005)		0.005 (0.007)		
		2	2		2		

Table 2. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Brewer's Blackbird							
whole body	1980-1987			0.01	ND		
				1	1		
Common Grackle							
whole body	1980-1987			0.01			
				1			
Lapland Longspur							
whole body	1980-1987					0.01	
						1	

Table 3. Oxychlordane residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980–1985				0.136 (0.12) 23		
Eared Grebe							
egg	1980–1985				0.01 (0) 2		
whole body	1980–1985				0.02 1		
Western Grebe							
egg	1980–1985						0.018 (0.013) 9
Leach's Storm-Petrel							
egg	1980–1985	0.027 (0.008) 6					
	1975–1979	0.032 (0.011) 10					
Black-crowned Night-Heron							
egg	1980–1985		0.142 (0.122) 23				
	1975–1979		0.081 (0.089) 49				
Mallard							
liver	1980–1985		0.008 1				
muscle	1980–1985		0.001 1				
	1975–1979		0.001 (0.002) 14	0.003 (0.002) 4			

Table 3. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1985		0.005 (0.001)				
			2				
muscle	1980-1985		0.001 (0)				
			2				
Gadwall							
liver	1980-1985		0.009				
			1				
muscle	1980-1985		0.001				
			1				
Blue-winged Teal							
liver	1980-1985				0.01		
					1		
muscle	1980-1985				0.01		
					1		
Lesser Scaup							
liver	1980-1985		0.012				
			1				
muscle	1980-1985		0.003				
			1				
	1975-1979	0.005	0.005 (0)				
		1	2				
Greater Scaup							
liver	1980-1985		0.08				
			1				
muscle	1980-1985		0.007				
			1				
	1975-1979	0.005 (0)	0.003 (0.002)	ND			
		2	6	1			

Table 3. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1985		0.308				
			1				
muscle	1980-1985		0.052				
			1				
American Kestrel							
egg	1980-1985						0.015 (0.007)
							9
Semipalmated Plover							
whole body	1980-1985					0.03	
						1	
Killdeer							
liver	1980-1985	0.06					
		1					
whole body	1980-1985		0.07		0.04		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	0.021 (0.025)					
		15					
Willet							
whole body	1980-1985				0.03		
					1		
Dunlin							
whole body	1980-1985					0.01	
						1	

Table 3. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1985	0.017 (0.011)	0.02			0.02	
		3	1			1	
Rock Dove							
whole body	1980-1985		0.005 (0.004)				
			3				
	1975-1979		ND		ND		
			10		5		
Northern Flicker							
whole body	1980-1985	0.02		0.03			
		1		1			
Horned Lark							
whole body	1980-1985					0.01	
						1	
Bank Swallow							
whole body	1980-1985			0.03			
				1			
American Robin							
whole body	1980-1985	0.11 (0.071)		0.01			
		2		1			
Bobolink							
whole body	1980-1985	0.01 (0)					
		2					
Red-winged Blackbird							
whole body	1980-1985	0.01 (0)	0.015 (0.007)		0.025 (0.021)		
		2	2		2		

Table 3. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Brewer's Blackbird							
whole body	1980-1985			0.01	0.02		
				1	1		
Common Grackle							
whole body	1980-1985			0.01			
				1			
Lapland Longspur							
whole body	1980-1985					0.01	
						1	

Table 4. Heptachlor epoxide residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES		REGION					
Tissue/Time interval		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1987				0.081 (0.089)		
					22		
Eared Grebe							
egg	1980-1987				0.004 (0.002)		
					2		
whole body	1980-1987				0.01		
					1		
Western Grebe							
egg	1980-1987						0.021 (0.009)
							9
Leach's Storm-Petrel							
egg	1980-1987	0.018 (0.004)					
		6					
	1975-1979	0.009 (0.004)					
		10					
Black-crowned Night-Heron							
egg	1980-1987		0.044 (0.021)				
			23				
	1975-1979	0.007 (0.005)	0.043 (0.032)				
		12	60				
Mallard							
liver	1980-1987		0.007				
			1				
muscle	1980-1987		0.001				
			1				
	1975-1979		0.002 (0.002)	0.004 (0.002)			
			14	4			

Table 4. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1987		0.003 (0.001)				
			2				
muscle	1980-1987		0.001 (0)				
			2				
Gadwall							
liver	1980-1987		0.007				
			1				
Blue-winged Teal							
liver	1980-1987				0.03		
					1		
muscle	1980-1987				0.01		
					1		
Lesser Scaup							
liver	1980-1987		0.015				
			1				
muscle	1980-1987		0.003				
			1				
	1975-1979	0.005	0.005 (0)				
		1	2				
Greater Scaup							
liver	1980-1987		0.039				
			1				
muscle	1980-1987		0.007				
			1				
	1975-1979	0.01 (0)	0.006 (0.004)	ND			
		2	6	1			

Table 4. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1987		0.079				
			1				
muscle	1980-1987		0.012				
			1				
American Kestrel							
egg	1980-1987						0.019 (0.017)
							10
Semipalmated Plover							
whole body	1980-1987					0.03	
						1	
Killdeer							
liver	1980-1987	0.02					
		1					
whole body	1980-1987		0.03		0.02		
			1		1		
Spotted Sandpiper							
whole body	1980-1987	0.011 (0.004)					
		15					
Willet							
whole body	1980-1987				0.01		
					1		
Dunlin							
whole body	1980-1987					0.02	
						1	

Table 4. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1987	0.02 (0.014)				0.03	
		2				1	
Rock Dove							
whole body	1980-1987		0.002 (0.001)				
			3				
	1975-1979		ND		ND		
			10		5		
Northern Flicker							
whole body	1980-1987			ND			
				1			
Horned Lark							
whole body	1980-1987					ND	
						1	
Bank Swallow							
whole body	1980-1987			0.02			
				1			
American Robin							
whole body	1980-1987	0.02 (0.028)		ND			
		2		1			
Bobolink							
whole body	1980-1987	0.005					
		1					
Red-winged Blackbird							
whole body	1980-1987	ND	ND		0.02 (0.028)		
		1	2		2		

Table 4. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Brewer's Blackbird							
whole body	1980-1987			ND	0.02		
				1	1		
Common Grackle							
whole body	1980-1987			ND			
				1			

Table 5. Alpha-HCH residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1985				0.0048 (0.002)		
					11		
Eared Grebe							
egg	1980-1985				0.001 (0)		
					2		
Western Grebe							
egg	1980-1985						0.005 (0.003)
							9
Leach's Storm-Petrel							
egg	1980-1985	0.0044 (0.005)					
		6					
Black-crowned Night-Heron							
egg	1980-1985		0.0025 (0)				
			23				
American Kestrel							
egg	1980-1985						0.0035 (0.002)
							10
Semipalmated Plover							
whole body	1980-1985					0.04	
						1	
Killdeer							
liver	1980-1985	0.0025					
		1					
whole body	1980-1985		0.01		0.01		
			1		1		

Table 5. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Spotted Sandpiper							
whole body	1980-1985	0.0035 (0.003) 15					
Dunlin							
whole body	1980-1985					0.02 1	
Semipalmated Sandpiper							
whole body	1980-1985	0.02 (0) 2	0.02 1			0.01 1	
Rock Dove							
whole body	1980-1985		0.0033 (0.001) 3				
Northern Flicker							
whole body	1980-1985	0.005 1		0.01 1			
Horned Lark							
whole body	1980-1985					0.02 1	
Bank Swallow							
whole body	1980-1985			0.03 1			
American Robin							
whole body	1980-1985	0.015 (0.007) 2		0.01 1			

Table 5. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bobolink							
whole body	1980-1985	0.0075 (0.003) 2					
Red-winged Blackbird							
whole body	1980-1985	0.0075 (0.003) 2	0.0037 (0.002) 2		0.005 1		
Common Grackle							
whole body	1980-1985			0.01 1			
Lapland Longspur							
whole body	1980-1985					0.01 1	

Table 6. HCB residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980–1985				0.108 (0.108)		
					24		
Eared Grebe							
egg	1980–1985				0.007 (0.004)		
					2		
whole body	1980–1985				0.013		
					1		
Western Grebe							
egg	1980–1985						0.017 (0.004)
							9
Leach's Storm-Petrel							
egg	1980–1985	0.062 (0.033)					
		5					
	1975–1979	0.037 (0.018)					
		10					
Black-crowned Night-Heron							
egg	1980–1985		0.054 (0.095)				
			24				
	1975–1979	0.017 (0.009)	0.0865 (0.106)				
		12	60				
Mallard							
liver	1980–1985		0.002				
			1				
muscle	1975–1979		0.002 (0.002)	0.002 (0.002)			
			14	4			

Table 6. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1985		0.001 (0)				
			2				
muscle	1980-1985		0.001 (0)				
			2				
Blue-winged Teal							
liver	1980-1985				0.001		
					1		
muscle	1980-1985				0.001		
					1		
Lesser Scaup							
liver	1980-1985		0.014				
			1				
muscle	1980-1985		0.011				
			1				
	1975-1979	ND	0.005 (0)				
		1	2				
Greater Scaup							
liver	1980-1985		0.043				
			1				
muscle	1980-1985		0.012				
			1				
	1975-1979	ND	0.001 (0.002)	ND			
		2	6	1			
Bufflehead							
liver	1980-1985		0.176				
			1				
muscle	1980-1985		0.029				
			1				

Table 6. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
American Kestrel							
egg	1980-1985						0.011 (0.006)
							10
Semipalmated Plover							
whole body	1980-1985					0.013	
						1	
Killdeer							
liver	1980-1985	0.003					
		1					
whole body	1980-1985		0.003		0.005		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	0.018 (0.046)					
		15					
Willet							
whole body	1980-1985				0.004		
					1		
Dunlin							
whole body	1980-1985					0.021	
						1	
Semipalmated Sandpiper							
whole body	1980-1985	0.014 (0.009)	0.012			0.022	
		3	1			1	

Table 6. (cont'd)

SPECIES / Tissue	Time interval	REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Rock Dove							
whole body	1980-1985		ND				
			3				
	1975-1979		0.002 (0.002)		0.003 (0.002)		
			10		5		
Northern Flicker							
whole body	1980-1985	0.003		0.003			
		1		1			
Horned Lark							
whole body	1980-1985					0.007	
						1	
Bank Swallow							
whole body	1980-1985			0.025			
				1			
American Robin							
whole body	1980-1985	0.002 (0.001)		0.001			
		2		1			
Bobolink							
whole body	1980-1985	0.002 (0.001)					
		2					
Red-winged Blackbird							
whole body	1980-1985	0.0045 (0.002)	0.005 (0.001)		0.0025 (0.002)		
		2	2		2		
Common Grackle							
whole body	1980-1985			0.003			
				1			

Table 6. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Lapland Longspur							
whole body	1980-1985					0.01	
						1	

Table 7. PCB residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1985				11.9 (13.2)		
					24		
Eared Grebe							
egg	1980-1985				0.12 (0.1)		
					2		
whole body	1980-1985				0.29		
					1		
Western Grebe							
egg	1980-1985						2.26 (1.9)
							9
Leach's Storm-Petrel							
egg	1980-1985	2.32 (1.55)					
		5					
	1975-1979	3.62 (1.73)					
		10					
Black-crowned Night-Heron							
egg	1980-1985		25.0 (11.5)				
			23				
	1975-1979	14.6 (5.27)	24.9 (21.9)				
		12	60				
Mallard							
liver	1980-1985		3.51				
			1				
muscle	1980-1985		1.28				
			1				
	1975-1979		0.103 (0.16)	0.008 (0.015)			
			14	4			

Table 7. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Black Duck							
liver	1980-1985		0.051 (0.016)				
			2				
muscle	1980-1985		0.046 (0.001)				
			2				
Gadwall							
liver	1980-1985		1.46				
			1				
muscle	1980-1985		0.51				
			1				
Blue-winged Teal							
liver	1980-1985				0.07		
					1		
muscle	1980-1985				0.04		
					1		
Lesser Scaup							
liver	1980-1985		19.0				
			1				
muscle	1980-1985		9.75				
			1				
	1975-1979	0.04	0.125 (0.12)	0.0005			
		1	6	1			
Greater Scaup							
liver	1980-1985		70.9				
			1				
muscle	1980-1985		8.75				
			1				
	1975-1979	ND	0.384 (0.731)	ND			
		2	6	1			

Table 7. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1985		395.7				
			1				
muscle	1980-1985		44.4				
			1				
American Kestrel							
egg	1980-1985						0.193 (0.089)
							10
Semipalmated Plover							
whole body	1980-1985					1.14	
						1	
Killdeer							
liver	1980-1985	0.06					
		1					
whole body	1980-1985		0.14		0.13		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	1.95 (2.18)					
		15					
Willet							
whole body	1980-1985				0.18		
					1		
Dunlin							
whole body	1980-1985					0.17	
						1	

Table 7. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1985	0.4 (0.13)	0.19			0.86	
		2	1			1	
Rock Dove							
whole body	1980-1985		0.353 (0.159)				
			3				
	1975-1979		0.254 (0.227)		0.774 (1.37)		
			10		5		
Northern Flicker							
whole body	1980-1985	0.12		0.09			
		1		1			
Horned Lark							
whole body	1980-1985					0.11	
						1	
Bank Swallow							
whole body	1980-1985			0.95			
				1			
American Robin							
whole body	1980-1985	0.265 (0.134)		0.14			
		2		1			
Bobolink							
whole body	1980-1985	0.085 (0.007)					
		2					
Red-winged Blackbird							
whole body	1980-1985	0.125 (0.064)	0.925 (1.08)		0.095 (0.078)		
		2	2		2		

Table 7. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Brewer's Blackbird							
whole body	1980-1985			0.12	0.06		
				1	1		
Common Grackle							
whole body	1980-1985			0.12			
				1			
Lapland Longspur							
whole body	1980-1985					0.13	
						1	

Table 8. Mirex residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1985				0.377 (0.448)		
					22		
Eared Grebe							
egg	1980-1985				0.0037 (0.002)		
					2		
Western Grebe							
egg	1980-1985						0.0047 (0.002)
							9
Leach's Storm-Petrel							
egg	1980-1985	0.03 (0.01)					
		5					
Gadwall							
liver	1980-1985		0.003				
			1				
Blue-winged Teal							
liver	1980-1985				0.01		
					1		
muscle	1980-1985				0.01		
					1		
Greater Scaup							
liver	1980-1985		0.518				
			1				
muscle	1980-1985		0.076				
			1				
	1975-1979	ND	ND	ND			
		2	6	1			

Table 8. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Bufflehead							
liver	1980-1985		0.175				
			1				
muscle	1980-1985		0.129				
			1				
American Kestrel							
egg	1980-1985						0.0075 (0.007)
							10
Semipalmated Plover							
whole body	1980-1985					ND	
						1	
Killdeer							
liver	1980-1985	0.0025					
		1					
whole body	1980-1985		ND		0.06		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	0.01 (0.007)					
		15					
Willet							
whole body	1980-1985				0.01		
					1		
Dunlin							
whole body	1980-1985					0.01	
						1	

Table 8. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1985	0.01	ND			ND	
		2	1			1	
Rock Dove							
whole body	1980-1985		0.0018 (0.001)				
			3				
	1975-1979		ND				
			10				
Northern Flicker							
whole body	1980-1985	0.04		0.16			
		1		1			
Horned Lark							
whole body	1980-1985					ND	
						1	
Bank Swallow							
whole body	1980-1985			0.03			
				1			
American Robin							
whole body	1980-1985	0.03 (0)		0.1			
		2		1			
Bobolink							
whole body	1980-1985	0.0005 (0)					
		2					
Common Grackle							
whole body	1980-1985			ND			
				1			

Table 8. (cont'd)

SPECIES		REGION					
Tissue/Time interval		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Lapland Longspur							
whole body	1980-1985					ND	
						1	

Table 9. Mercury residues in prey of the Peregrine Falcon by region, tissue and time interval. Data are arithmetic means (S.D.) in ppm wet weight and sample size (number of samples or pooled samples). ND = non-detectable.

SPECIES / Tissue	Time interval	REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Red-necked Grebe							
egg	1980-1985				0.106 (0.028)		
					19		
Eared Grebe							
egg	1980-1985				0.03		
					1		
Western Grebe							
egg	1980-1985						0.053 (0.017)
							9
Leach's Storm-Petrel							
egg	1980-1985	0.41					
		1					
Semipalmated Plover							
whole body	1980-1985					0.13	
						1	
Killdeer							
whole body	1980-1985		0.14		0.12		
			1		1		
Spotted Sandpiper							
whole body	1980-1985	0.32 (0.29)					
		15					
Dunlin							
whole body	1980-1985					0.18	
						1	

Table 9. (cont'd)

SPECIES Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Semipalmated Sandpiper							
whole body	1980-1985		0.14			0.4	
			1			1	
Rock Dove							
whole body	1980-1985		0.007 (0.003)				
			3				
	1975-1979		0.005 (0)		0.366 (0.741)		
			10		5		
Northern Flicker							
whole body	1980-1985	0.09		0.09			
		1		1			
Horned Lark							
whole body	1980-1985					0.1	
						1	
Bank Swallow							
whole body	1980-1985			0.23			
				1			
American Robin							
whole body	1980-1985	0.07 (0)		0.6			
		2		1			
Bobolink							
whole body	1980-1985	0.1 (0.08)					
		2					
Red-winged Blackbird							
whole body	1980-1985	0.095 (0.035)	0.35 (0.4)		0.1		
		2	2		1		

Table 9. (cont'd)

SPECIES / Tissue/Time interval		REGION					
		Atlantic	Great Lakes	Boreal Forest	Southern Prairie	Central Arctic	Rocky Mountains
Common Grackle							
whole body	1980-1985			0.51			
				1			
Lapland Longspur							
whole body	1980-1985					0.23	
						1	

APPENDIX 2

Residues of 8 organochlorine compounds in some prey species of Peregrine Falcons in Alberta (1983 to 1985).

Table 1. Mean organochlorine residues (ppm) in whole body homogenates of avian families associated with aquatic habitats in southern Alberta, 1983-1985.

FAMILY	N (1)	HCB	alpha-HCH	DDE	Oxychl. (2)	HE (3)	Dieldrin	Mirex	PCB
Podicipedidae	2	0.028	0.002	2.8	0.021	0.001	0.001	0.014	0.34
SD		0.007	0.001	3.01	0.008	0	0	0.001	0.01
Anatidae	13	0.056	0.001	1.75	0.01	0.013	0.005	0.001	0.66
SD		0.19	0.004	5.77	0.021	0.041	0.015	0.002	1.93
Rallidae	1	0.001	0.001	0.04	0.003	0.001	0.007	0.002	0.05
Charadriidae	5	0.017	0.003	2.88	0.03	0.072	0.453	0.03	0.22
SD		0.03	0.003	2.44	0.028	0.089	0.603	0.045	0.31
Scolopacidae	7	0.006	0.001	2.84	0.011	0.103	0.06	0.06	0.88
SD		0.011	0.001	2.5	0.007	0.216	0.055	0.055	1.6
Laridae	11	0.043	0.001	2.1	0.018	0.045	0.077	0.001	2.31
SD		0.126	0.001	2.46	0.028	0.069	0.126	0.001	2.58
Alcedinidae	1	0.011	0.017	0.6	0.177	0.032	0.054	0.054	1.59
Hirundinidae	5	0.005	0.009	1.37	0.019	0.044	0.013	0.039	0.42
SD		0.005	0.008	0.93	0.018	0.059	0.013	0.039	0.32

(1): N = number of pooled samples per avian family mean
(2): oxychlordane
(3): heptachlor epoxide

Table 2. Mean organochlorine residues (ppm) in whole body homogenates of avian families associated with terrestrial habitats in southern Alberta, 1983-1985.

FAMILY	N (1)	HCB	alpha-HCH	DDE	Oxychl. (2)	HE (3)	Dieldrin	Mirex	PCB
Phasianidae	1	0.001	0.001	0.004	0.001	0.001	0.002	0.003	0.05
SD									
Columbidae	2	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.03
SD		0	0	0.002	0	0	0	0.001	0.04
Picidae	1	0.001	0.001	0.03	0.011	0.008	0.007	0.002	0.05
Corvidae	2	0.01	0.002	0.08	0.006	0.065	0.006	0.002	0.2
SD		0.001	0	0.009	0.004	0.083	0.001	0	0.21
Mimidae	1	0.002	0.004	0.051	0.008	0.015	0.006	0.002	0.05
Turdidae	10	0.003	0.004	0.152	0.017	0.039	0.062	0.002	0.06
SD		0.002	0.003	0.142	0.017	0.073	0.158	0.001	0.04
Sturnidae	1	0.013	0.005	0.983	0.009	0.007	0.036	0.002	0.05
Ploceidae	1	0.005	0.001	0.002	0.001	0.001	0.001	0.002	0.05
Icteridae	10	0.001	0.001	0.186	0.003	0.006	0.002	0.001	0.13
		0.001	0.001	0.309	0.002	0.004	0.003	0.001	0.23
Fringillidae	3	0.017	0.002	0.142	0.006	0.02	0.003	0.001	0.04
SD		0.027	0.001	0.1	0.006	0.025	0.003	0.001	0.02
Passerines	3	0.003	0.008	0.106	0.003	0.004	0.002	0.001	0.06
SD		0.004	0.007	0.098	0.004	0.005	0.003	0.001	0.01

(1): N = number of pooled samples per avian family mean
(2): oxychlordane
(3): heptachlor epoxide

Table 3. Species composition of family-group samples pooled from avian prey associated with aquatic habitats in southern Alberta (1983-1985).

AVIAN FAMILY	SAMPLE		SPECIES
Anatidae (13)	1		1 Green-winged Teal
	2	*	1 Red-breasted Merganser
	3		2 Green-winged Teal
			1 Mallard
	4		1 Green-winged Teal
	5		1 Mallard
	6		1 Common Merganser
	7		1 Mallard
	8		2 Gadwalls
	9		2 Mallards
	10		2 Mallards
	11		2 Gadwalls
	12		1 Green-winged Teal
			2 Blue-winged Teal
	13		3 Mallards
Charadriidae (5)	1	*	4 Killdeers
	2	*	3 Killdeers
	3		4 Killdeers
	4		9 Killdeers
	5		4 Killdeers
Laridae (11)	1		7 Franklin Gulls
	2		5 Black Terns
	3	*	3 California Gulls
	4		5 Franklin Gulls
	5		3 Franklin Gulls
			2 Black Terns
	6	*	4 Ring-billed Gulls
	7	*	2 Ring-billed Gulls
	8	*	1 Ring-billed Gulls
			1 Bonaparte Gull
	9	*	2 Ring-billed Gulls
	10	*	2 Ring-billed Gulls
	11		2 Ring-billed Gulls
Rallidae (1)	1		5 American Coots
Scolopacidae (7)	1	*	14 Spotted Sandpipers
	2		1 Lesser Yellowlegs
			11 Spotted Sandpipers
	3	*	3 Willets
	4	*	2 Marbled Godwits
	5		6 Spotted Sandpipers
	6	*	1 Lesser Yellowlegs
			1 Greater Yellowlegs
	7	*	2 Western Sandpipers
			3 Spotted Sandpipers
			1 Semi-palmated Sandpiper
			1 Solitary Sandpiper

Table 3. (cont'd)

AVIAN FAMILY	SAMPLE	SPECIES
Alcedinidae (1)	1 *	1 Belted Kingfisher
Podicipedidae (2)	1	1 Horned Grebe
	2 *	1 Western Grebe
Hirundinidae (5)	1	9 Bank Swallows
		1 Rough-winged Swallow
	2 *	5 Bank Swallows
		2 Bank Swallows
		3 Rough-winged Swallows
	3 *	5 Bank Swallows
		1 Rough-winged Swallow
		2 Cliff Swallows
	4 *	6 Cliff Swallows
	5	6 Barn Swallows

*: indicates samples with DDE > 1.0 ug/g

Table 4. Species composition of family-group samples pooled from avian prey associated with terrestrial habitats in southern Alberta (1983-1985).

AVIAN FAMILY	SAMPLE	SPECIES
Icteridae (10)	1	9 Red-winged Blackbirds
	2	9 Meadowlarks
	3	5 Red-winged Blackbirds
	4	2 Red-winged Blackbirds
		2 Red-winged Blackbirds
		2 Red-winged Blackbirds
		1 Common Grackle
		2 Baltimore Orioles
	5	5 Red-winged Blackbirds
	6	5 Red-winged Blackbirds
	7	3 Brewers Blackbirds
		5 Brown-headed Cowbirds
		2 Common Grackles
	8	8 Meadowlarks
		3 Baltimore Orioles
	9	5 Red-winged Blackbirds
	10	2 Red-winged Blackbirds
		2 Baltimore Orioles
		1 Brown-headed Cowbird
Columbidae (2)	1	3 Rock Doves
	2	4 Mourning Doves
Corvidae (2)	1	4 crows
	2	1 crow
		3 Black-billed Magpies
Ploceidae (1)	1	7 House Sparrows
Sturnidae (1)	1	4 Starlings
Phasianidae (1)	1	1 Hungarian Partridge
Picidae (1)	1	1 Hairy Woodpecker
Mimidae (1)	1	1 Brown Thrasher
		6 Catbirds

Table 4. (cont'd)

AVIAN FAMILY	SAMPLE	SPECIES
Turdidae (10)	1	7 American Robins
(includes some	2	5 kingbirds
Tyrannidae)	3	10 American Robins
	4	5 American Robins
	5	3 American Robins
		1 bluebird
	6	5 American Robins
	7	6 American Robins
	8	9 kingbirds
	9	9 bluebirds
	10	4 American Robins
Passeriformes (3)	1	7 Cedar Waxwings
(various families)		2 chickadees
	2	1 Tennessee Warbler
		1 Yellow Breasted Chat
		1 Wilson's Warbler
		2 Yellow Warblers
		2 Cedar Waxwings
		1 Horned Lark
		2 chickadees
	3	1 Swamp Sparrow
		4 flycatchers
		1 Wood Peewee
Fringillidae (3)	1	2 White-crowned Sparrows
		6 Vesper Sparrows
	2	5 Savannah Sparrows
		1 Vesper Sparrow
		3 Song Sparrows
		1 Clay-colored Sparrow
	3	1 Savannah Sparrow
		4 Vesper Sparrows
		6 Song Sparrows
		5 Clay-colored Sparrows

Family names correspond to those found in:
Godfrey, W.E.. 1979. The birds of Canada. Natural Museum of Natural Sciences. National Museums of Canada. Ottawa, Canada. 428 p.

Table 5. Mean organochlorine residues (ppm) in whole body homogenates of avian families associated with aquatic habitats in northern Alberta, 1986-1987.

FAMILY	N (1)	HCB	alpha-HCH	DDE	Oxychl. (2)	HE (3)	Dieldrin	Mirex	PCB
Anatidae	11	0.009	0.005	0.86	0.019	0.019	0.015	0.002	0.5
SD		0.019	0.009	2.24	0.024	0.025	0.024	0.003	0.54
Rallidae	2	0.001	0.001	0.13	0.012	0.009	0.029	0.001	0.31
SD		0	0	0.07	0.006	0.006	0.004	0	0.27
Charadriidae	1	0.001	0.001	1.52	0.045	0.261	0.058	0.005	0.64
Scolopacidae	6	0.001	0.001	0.3	0.009	0.017	0.049	0.008	0.37
SD		0	0	0.41	0.007	0.015	0.062	0.018	0.3
Laridae	12	0.081	0.001	1.59	0.03	0.109	0.165	0.018	1.3
SD		0.241	0	1.22	0.02	0.132	0.214	0.018	0.69

(1): N = number of pooled samples per avian family mean
(2): oxychlordane
(3): heptachlor epoxide

Table 6. Mean organochlorine residues (ppm) in whole body homogenates of avian families associated with terrestrial habitats in northern Alberta, 1986-1987.

FAMILY	N (1)	HCB	alpha-HCH	DDE	Oxychl. (2)	HE (3)	Dieldrin	Mirex	PCB
Tetranidae	1	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.05
Picidae	4	0.001	0.001	0.194	0.041	0.029	0.016	0.01	0.21
SD		0	0	0.158	0.07	0.031	0.017	0.017	0.14
Turdidae	1	0.001	0.001	0.171	0.012	0.01	0.005	0.012	0.38
Icteridae	3	0.001	0.001	0.259	0.008	0.008	0.005	0.004	0.26
SD		0	0	0.165	0.008	0.002	0.006	0.006	0.14
Passerines	4	0.001	0.001	0.158	0.011	0.007	0.003	0.001	0.19
SD		0	0	0.187	0.008	0.005	0.002	0	0.13

(1): N = number of pooled samples per avian family mean
(2): oxychlordane
(3): heptachlor epoxide

Table 7. Species composition of family-group samples pooled from avian prey associated with aquatic habitats in northern Alberta (1986-1987).

AVIAN FAMILY	SAMPLE		SPECIES
Anatidae (11)	1		1 Mallard
	2		1 Shoveler
	3	*	1 Shoveler
	4		1 Shoveler
	5		1 Lesser Scaup
	6		1 Green-winged Teal
			1 Blue-winged Teal
	7		2 Blue-winged Teals
	8		1 Mallard
	9		1 Common Merganser
	10		1 Common Merganser
	11		1 Common Merganser
Charadriidae (1)	1	*	1 Killdeer
Laridae (12)	1	*	3 Common Terns
	2		4 Black Terns
	3	*	4 Black Terns
	4	*	3 Black Terns
	5		2 Black Terns
	6	*	2 Franklin's Gulls
	7	*	2 Franklin's Gulls
	8	*	3 Franklin's Gulls
	9	*	3 Ring-billed Gulls
	10	*	2 Ring-billed Gulls
	11		1 California Gull
	12		1 California Gull
Rallidae (2)	1		2 American Coots
	2		2 American Coots
Scolopacidae (6)	1	*	4 Spotted Sandpipers
	2		3 Wilson's Phalaropes
	3		4 Semipalmated Sandpipers
	4		3 Lesser Yellowlegs
	5		2 Spotted Sandpipers
	6		3 Spotted Sandpipers

*: indicates samples with DDE > 1.0 ug/g.

Family names correspond to those found in:
Godfrey, W.E.. 1979. The birds of Canada. Natural Museum of Natural Sciences. National Museums of Canada. Ottawa, Canada. 428 p.

Table 8. Species composition of family-group samples pooled from avian prey associated with terrestrial habitats in northern Alberta (1986-1987).

AVIAN FAMILY	SAMPLE	SPECIES
Icteridae (3)	1	5 Yellow-headed Blackbirds
	2	7 Red-winged Blackbirds
	3	2 Common Grackles
Passeriformes (4) (various families)	1	3 Yellow-rumped Warbler
		1 Western Tanager
		1 Slate-colored Junco
	2	7 Chipping Sparrows
		1 Song Sparrow
	3	1 Red-eyed Vireo
		1 Eastern Phoebe
		1 Traill's Flycatcher
		1 Catbird
	4	1 Red-winged Blackbird
		1 Grosbeak
Picidae (4)	1	1 Common Flicker
	2	2 Common Flickers
	3	2 Common Flickers
	4	2 Common Flickers
Tetraonidae (1)	1	1 Spruce Grouse
Turdidae (1)	1	1 American Robin
		1 Hermit Thrush

Family names correspond to those found in:
Godfrey, W.E.. 1979. The birds of Canada. Natural Museum of Natural Sciences. National Museums of Canada. Ottawa, Canada. 428 p.