ENVIRONMENTAL CONTAMINANTS IN CANADIAN SEABIRDS 1968 - 1985: TRENDS AND EFFECTS

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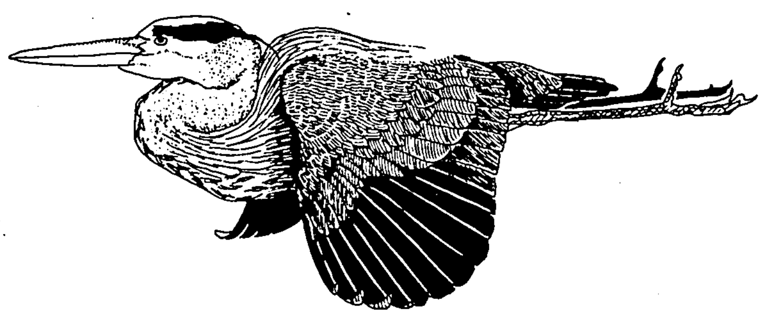

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SUMMARY

Environmental pollutants, including organochlorine pesticides, industrial chemicals and heavy metals, have been reported in biological organisms worldwide. Persistent organochlorine compounds such as PCBs, DDE (the main breakdown product of DDT), hexachlorobenzene (HCB), dieldrin and chlordane have been found not only near industrialized locations, but in regions as remote as the Antarctic, High Arctic and mid-ocean. Increasing input of heavy metals into the environment as a result of man's activities continues to be a cause for concern.

As top predators in the marine food chain, seabirds can accumulate toxic burdens of persistent environmental contaminants. Pesticide poisoning has resulted in several instances of seabird mortality in Europe and North America since the late 1960s. Eggshell thinning and reproductive failure associated with elevated DDE residues have been documented in Brown Pelicans, Northern Gannets and Double-crested Cormorants from coastal colonies of North America. On the Great Lakes, PCBs and other organochlorines have been implicated in mortality of embryos, a high incidence of congenital abnormalities in chicks, and a number of physiological alterations found in fish-eating birds.

This review was carried out to: 1) assess the current levels of pollutants in Canadian marine birds; 2) determine whether pollutants had affected or are continuing to affect seabird health; and 3) evaluate the reliability of seabirds as indicators of the health of the marine ecosystem. Seabird samples from locations in British Columbia, the Atlantic coast and Arctic from 1968 to 1985 were analyzed for organochlorines, PCBs, and in certain cases, mercury, lead and cadmium.

The main conclusions are as follows:

1. Levels of organochlorines found in Canadian seabirds between 1968 and 1985 were not high enough to cause direct mortality. Nevertheless, the levels were in some cases high enough to cause adverse effects on reproduction.

2. Mercury levels in Double-crested Cormorants from the Baie des Chaleurs in the early 1970s were as high as levels found to have toxic effects on birds in other studies.

3. Elevated concentrations of DDE in eggs were associated with eggshell thinning, low productivity and population declines in Northern Gannets at Bonaventure Island, Quebec, from 1968 to 1971. Eggshell thinning to a degree that reproductive impairment might be expected was recorded in eggs of Double-crested Cormorants from the St. Lawrence estuary, and a lesser degree of thinning was recorded for the Leach's Storm-petrels from the Bay of Fundy, during the early 1970s. Since that time, the levels of DDE declined at most locations sampled, gannet and cormorant populations are growing and reproductive success has increased to normal rates.

4. Mercury, PCBs and organochlorine compounds (DDE, DDD, DDT, mirex, dieldrin, heptachlor epoxide, HCB, HCH, oxychlordane and other chlordane metabolites) were, and continue to be, present in seabirds from all regions of Canada.

The current ranking of regions in terms of highest overall levels is: St. Lawrence estuary and gulf; Bay of Fundy; Strait of Georgia; Vancouver Island; Newfoundland, Lancaster Sound and the Queen Charlotte Islands.

5. Levels of pollutants were intermediate on a global scale and lower than in industrial freshwater systems. In the Gulf of St. Lawrence, levels are about three times lower than levels in the Great Lakes and similar to levels found along the northeastern

coast of the USA. Contaminant levels from Newfoundland and the Arctic were similar to levels found in Norway, but generally higher than concentrations in seabird eggs from Alaska.

6. Sufficient data were available to establish long-term trends of contaminant levels in five Atlantic coast species. The overall picture is of declining levels of contaminants everywhere, except in the St. Lawrence estuary, following the restrictions placed on use of organochlorines in North America. Use of DDT, dieldrin, PCBs, HCB, and HCH was initially restricted around 1970 and further restricted to minor uses by the mid-1970s. The restrictions on chlordane date from 1978. Less complete data sets from several Pacific coast species also show decreases.

PCBs declined significantly at all locations between 1968 and 1984, except in Double-crested Cormorants from the St. Lawrence estuary and Razorbills from the Gulf of St. Lawrence between 1972 and 1978.

DDE, the most persistent metabolite of DDT, showed the most significant decreases at all locations except in the St. Lawrence estuary where levels in Double-crested Cormorants did not decline significantly between 1972 and 1984. Oxychlordane, the most persistent metabolite of technical chlordane, showed no consistent trend, declining only in Atlantic Puffins between 1976 and 1984. HCB concentrations in gannets at Bonaventure Island and in puffins and cormorants in the Bay of Fundy have declined since 1976. Levels were stable or increased significantly in all other east coast species during the same period. Heptachlor epoxide levels, although always low, increased until 1980 in most species, probably as a result of increased use of chlordane during the 1970s. Levels started to decline by 1984. Dieldrin levels declined significantly in seabird eggs everywhere between 1968 and 1984, except in the St. Lawrence estuary and in Razorbills from the Gulf of St. Lawrence.

Recommendations for continued monitoring and research include:

1. Certain areas should be investigated in greater detail, in terms of both chemical residue levels and biological effects on seabirds:

a) The St. Lawrence estuary and nearby gulf is the most polluted marine water system in Canada, probably because of continued input of pollutants into the St. Lawrence basin. We recommend a more compehensive survey of the impact of the continuing high levels of some organochlorines, industrial chemicals and heavy metals on seabirds of this region, particularly those breeding in the estuary.

b) In the Strait of Georgia, there are potential hazards from industrial chemicals, heavy metals and microcontaminants such as dioxins.

c) In the Arctic between 1969 and 1984, most organochlorine compounds were stable in seals and polar bears, but chlordane compound increased. Trends in seabirds, which have not been sampled for contaminants since 1977, should be determined.

d) Mercury levels in seabirds and waterfowl from the Baie des Chaleurs and near the mouth of the Fraser River in B.C. were very high in the early 1970s. Re-examination of these sites should be carried out to determine long-term trends and reassess the potential impact of mercury.

2. The seabird egg monitoring program should be continued with the same species (Double-crested Cormorant, Atlantic Puffin, Northern Gannet and Leach's Storm-petrel) on the Atlantic coast and expanded to include comparable species on the Pacific (Double-crested Coormorant, Leach's Storm-petrel and Rhinoceros Auklet) and arctic (Thick-billed Murre) coasts. Consideration should also be given to monitoring of widespread resident species like the Black or Pigeon Guillemot as indicators of local pollution. These monitoring programs should be further coordinated with other seabird research to maximize the relevant

biological information and minimize costs.

3. A survey of the levels of heavy metals, including radionuclides, should be carried out on seabirds from the Atlantic, Pacific and Arctic regions in order to determine the background levels and geographic variation in levels.

4. Greater coordination with other biomonitoring agencies is required in order to integrate data on pollutants in many components of the marine ecosystem, i.e. water, zooplankton, fish, seabirds and marine mammals.

SOMMAIRE

Des polluants de l'environnement, dont des pesticides organochlorés, des produits chimiques industriels et des métaux lourds, ont été retrouvés dans les organismes vivants du monde entier. Des composés organochlorés persistants, tels les BPC, le DDE (principal produit de dégradation du DDT), l'hexachlorobenzène (HCB), la dieldrine et le chlordane, ont été decelés non seulement près de zones industrielles mais dans des régions aussi éloignées que l'Antarctique, le Haut-Arctique et le milieu des océans. Des apports accrus de métaux lourds dans l'environnement, causé par les activités humaines, continuent d'être une source de préoccupations.

Prédateurs situés au sommet de la chaîne alimentaire marine, les oiseaux de mer peuvent accumuler, à des concentrations toxiques, des contaminants persistants de l'environnement. Plusieurs cas de mortalité d'oiseaux de mer attribuable à des pesticides ont été signalés en Europe et en Amérique du Nord depuis la fin des années 1960. En Amérique du Nord, on a observé un amincissement de la coquille des oeufs et des échecs de la reproduction associés à des teneurs élevées en résidus du DDE chez des colonies côtières de Pélicans bruns, de Fous de Bassan et de Cormorans à aigrettes. Dans les Grands Lacs, des BPC et d'autres organochlorés ont été mis en cause dans la mortalité d'embryons, la fréquence élevée d'anomalies congénitales chez les oisillons, et un certain nombre d'altérations physiologiques observées chez des oiseaux piscivores.

Cette étude avait pour but: 1) d'examiner les concentrations actuelles de polluants chez les oiseaux de mer du Canada; 2) de déterminer si les polluants avaient porté atteinte ou continuaient de porter atteinte à la santé des oiseaux de mer; et 3) d'évaluer si les oiseaux de mer constituaient des indicateurs fiables de l'état de l'écosystème marin. Des analyses des teneurs en organochlorés, en BPC et, dans certains cas, en mercure, en plomb et en cadmium, ont été effectuées sur les échantillons

d'oiseaux de mer provenant de la Colombie Britannique, de la côte Atlantique et de l'Arctique, entre 1968 et 1985.

Voici les principales conclusions de ces analyses:

1. Les concentrations d'organochlorés chez les oiseaux de mer au Canada entre 1968 et 1985 n'étaient pas assez élevées pour être une cause directe de mortalité. Cependant, dans certaines cas, elles pouvaient être suffisantes pour nuire à la reproduction.

2. Au début des années 1970, les concentrations de mercure chez les Cormorans à aigrettes de la baie des Chaleurs étaient comparables à celles ayant eu des effets toxiques chez des oiseaux ayant fait l'objet d'autres ètudes.

3. Les concentrations élevées de DDE dans les oeufs des Fous de Bassan de l'île Bonaventure, au Québec, entre 1968 et 1971, ont été reliées à un amincissement de la coquille, à une diminution de la productivité et à des baisses du niveau de la population. Au début des années 1970, des oeufs de Cormorans à aigrettes de l'estuaire du Saint-Laurent présentaient un amincissement de la coquille qui faisait douter de la réussite de la reproduction; un amincissement de la coquille, à un degré moindre, a également été observé pour les Pétrels cul-blanc de la baie de Fundy. Depuis, les concentrations de DDE ont diminué à la plupart des endroits échantillonnés, les populations de Fous de Bassan et de cormorans s'accroissent et leur productivité a atteint un niveau normal.

4. Chez les oiseaux de mer de toutes les régions du Canada, on a trouvé et on continue de trouver du mercure, des BPC et des composés organochlorés (DDE, DDD, DDT, mirex, dieldrine, heptachlore époxyde, HCB, HCH, oxychlordane et autre produits de dégradation du chlordane).

Le classement actuel des régions présentant les plus fortes concentrations de produits toxiques, est le suivant: estuaire et golfe du Saint-Laurent; baie de Fundy; détroit de Georgia; île de Vancouver; Terre-Neuve, détroit de Lancaster et îles de la Reine-Charlotte.

5. Les concentrations des polluants étaient intermédiaires à l'échelle globale et plus faibles que dans les bassins d'eau douce des régions industrielles. Dans le golfe du Saint-Laurent, les concentrations étaient environ trois fois plus faibles que dans les Grands lacs et elles étaient analogues aux concentrations mesurées le long de la côte nord-est des États-Unis. Les concentrations de contaminants à Terre-Neuve et dans l'Arctique étaient similaires à celles mesurées en Norvège, mais elles étaient généralement plus élevées que celles mesurées dans les oeufs d'oiseaux de mer de l'Alaska.

6. Les données étaient suffisantes pour nous permettre d'établir les tendances à long terme en ce qui concerne les concentrations de contaminants chez cinq espèces de la côte atlantique. En général, les concentrations ont diminué partout, sauf dans l'estuaire du Saint-Laurent, après des restrictions imposées quant à l'utilisation des organochlorés en Amérique du Nord. C'est vers 1970 qu'on a commencé à imposer des restrictions concernant l'utilisation du DDT, de la dieldrine, des BPC, de l'HCB et de l'HCH. Au milieu des années 1970, ces restrictions sont devenues plus sévères. Dans le cas du chlordane, l'imposition de restrictions date de 1978. Les données pour plusieurs espèces d'oiseaux de la côte du Pacifique, bien que moins complètes, indiquent également des diminutions.

Entre 1968 et 1984, les teneurs en BPC ont diminué de façon significative à tous les endroits, sauf dans l'estuaire du Saint-Laurent pour les Cormorans à aigrettes et dans le golfe du Saint-Laurent pour les Godes, entre 1972 et 1978.

Le DDE, le plus persistant des produits de dégradation du DDT, est le polluant dont les concentrations ont le plus baissé, partout sauf dans l'estuaire du Saint-Laurent où ses concentrations chez les Cormorans à aigrettes n'ont pas diminué de façon significative entre 1972 et 1984. Dans le cas de l'oxychlordane, produit de dégradation le plus persistant du chlordane technique, aucune tendance constante n'a été observée, ses concentrations ayant diminué seulement chez les Macareux moines entre 1976 et 1984. Quant à l'HCB, ses concentrations diminuent depuis 1976 chez les Fous de Bassan de l'île Bonaventure ainsi que chez les macareux et les cormorans de la baie de Fundy. Chez toutes les autres espèces de la côte est, ses concentrations durant la même période sont demeurées stables ou ont augmenté de façon significative. Les concentrations d'heptachlore époxyde, bien que toujours faibles, ont augmenté jusqu'en 1980 chez la plupart des espèces, en raison probablement de l'utilisation accrue du chlordane au cours des années 1970. Elles ont commencé à diminuer vers 1984. Enfin, les concentrations de dieldrine ont diminué partout de façon significative dans les oeufs des oiseaux de mer entre 1968 et 1984, sauf dans l'estuaire du Saint-Laurent et pour les godes dans le golfe du Saint-Laurent.

Nos recommandations quant à la poursuite de la surveillance et de la recherche en ce domaine sont les suivantes:

1. Effectuer des études plus détaillées dans certaines régions, notamment pour déterminer les concentrations de résidus de produits chimiques et leurs effets biologiques chez les oiseaux de mer:

a) L'estuaire du Saint-Laurent et la partie avoisinante du golfe constituent le système marin le plus pollué au Canada en raison, probablement, du déversement sur une base continue de polluants dans le bassin du Saint-Laurent. Nous recommandons de mener une étude plus complète sur les effets de concentrations élevées et soutenues de certains organochlorés, de produits chimiques industriels et de métaux lourds sur les oiseaux de mer de cette région, et particulairement sur ceux qui se reproduisent dans l'estuaire.

b) Dans le détroit de Georgia, il existe des risques de contamination par des produits chimiques industriels, des métaux lourds, et des micropolluants comme les dioxinnes.

c) Dans l'Arctique, de 1969 à 1984, la plupart des composés organochlorés sont demeurés stables chez les phoques et les ours polaires, mais les composés du chlordane se sont accrus. Il faudrait déterminer les tendances chez les oiseaux de mer n'ayant pas été échantillonnés pour l'analyse des contaminants depuis 1977.

d) Au début des années 1970, les concentrations de mercure chez les oiseaux de mer et la sauvagine étaient très élevées dans la baie des Chaleurs et près de l'embouchure du Fraser, en Colombie Britannique. Une nouvelle étude des concentrations à ces endroits devrait être effectuée afin de déterminer les tendances à long terme et réévaluer les effets possibles du mercure.

2. Poursuivre le programme de surveillance des oeufs des oiseaux en étudiant les même espèces (Cormoran à aigrettes, Macareux moine, Fou de Bassan et Pétrel cul-blanc) sur la côte atlantique et en l'étendant à des espèces comparables de la côte du Pacifique (Cormoran à aigrettes, Pètrel cul-blanc et Alque à bec-cornu) et des côtes de l'Arctique (Marmette de Brunnich). On devrait aussi considérer d'utiliser des espèces résidantes répandues, tel le Guillemot noir ou le Guillemot du Pacifique, comme indicateurs de la pollution locale. On devrait coordonner davantage les programmes de surveillance avec les autres projets de recherche sur les oiseaux de mer de manière à tirer le maximum d'informations biologiques pertinentes et réduire les coûts au minimum.

3. Effectuer une étude des concentrations des métaux lourds, dont les radionucléides, chez les oiseaux de mer de l'Atlantique, du Pacifique et de l'Arctique afin d'en déterminer les concentrations selon les sources et les différences géographiques.

4. Établir une coopération plus étroite avec les autres organismes effectuant des travaux biologiques de surveillance de manière à intégrer les données sur les polluants des différentes composantes de l'écosystème marin (eau, zooplancton, poissons, oiseaux de mer ou mammifères marins).

ABSTRACT

This report reviews CWS data on environmental contaminants in Canadian seabirds. Tissues and eggs of 24 species collected from the Atlantic, Pacific and arctic coasts, between 1968 and 1985, were analyzed for organochlorine and mercury content. A small sample of east coast seabirds were analyzed for lead and cadmium. In order of concentrations, PCB's, DDE, dieldrin, mercury, HCB, oxychlordane, DDT, DDD, heptachlor epoxide, alpha and beta HCH, mirex, cis-chlordane, nonachlor and endrin were detected in most samples.

The St. Lawrence River estuary and nearby gulf was, and is the most contaminated region, followed by the Bay of Fundy, the Strait of Georgia and western Vancouver I. Residues in the arctic, Newfoundland and northern B.C. were relatively low. The overall temporal pattern was of declining residues of most contaminants (particularly PCB's, DDE and dieldrin) everywhere except the St. Lawrence estuary.

Potential toxic effects are assessed for each species in terms of population status, productivity and comparison with toxicity studies. Differences in contaminant levels between species, locations and years are discussed with reference to feeding ecology, seasonal movements and metabolic capacity. We evaluate the current seabird contaminant monitoring program, and make recommendations for improvements and further research.

RÉSUMÉ

Les données du Service canadien de la faune sur la contamination des oiseaux de mer canadiens sont passées en revue. Des échantillons de tissus et d'oeufs de 24 espèces, obtenus sur les côtes de l'Atlantique, du Pacifique et de l'Arctique entre 1968 et 1985, ont été analysés pours leurs teneurs en organochlorés et en mercure. Les teneurs en plomb et en cadmium ont également été déterminées chez un petit nombre d'oiseaux de mer de la côte Est. La plupart des échantillons renfermaient, par ordre d'importance de leurs concentrations, des BPC, du DDE, de la dieldrine, du mercure, de 'HCB (hexachlorobenzène), de l'oxychlordane, du DDT, du DDD, de l'heptachlore époxyde, de l'HCH (formes alpha et beta), du mirex, du cis-chlordane, du nonachlore et de l'endrine.

L'estuaire du Saint-Laurent et la golfe avoisinant étaient et continuent d'être la région où la contamination est la plus élevée. Viennent ensuite la baie de Fundy, le détroit de Georgia et l'ouest de l'île de Vancouver. Dans l'Arctique, à Terre-Neuve et dans le nord de la Colombie Britannique, les concentrations de résidus étaient relativement faibles. La diminuation des résidus de la plupart des contaminants (et plus particulièrement des BPC, du DDE et de la dieldrine) est la tendance générale observée partout, sauf dans l'estuaire du Saint-Laurent.

Les auteurs évaluent les effets toxiques potentiels pour chaque espèce compte tenu de l'état des populations, de la productivité et des résultats d'études sur la toxicité. Ils examinent les différences des concentrations des contaminants suivant les espèces, les emplacements et les années, en considérant l'écologie alimentaire, les déplacements saisonniers et la capacité du métabolisme. Ils évaluent également le programme actuel de surveillance des contaminants chez les oiseaux de mer et formulent des recommandations en ce qui concerne les améliorations à apporter et la recherche future.

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DISCUSSION

1. INTRODUCTION

Synthetic organochlorine compounds and heavy metals have been reported in wildlife, including seabirds, since the mid 1960's. By 1970, there was an alarming increase in reports of wildlife mortality due to chemical poisoning, and some fish-eating species were found to be laying eggs so thin-shelled that productivity was essentially zero (Ohlendorf et al, 1978). The persistence of organochlorines in the ecosystem was confirmed by their discovery in biota in regions as remote as the Antarctic (Ballschmiter et al, 1981).

Eventually, enough conclusive evidence was accumulated to force legislative action. Use of DDT, PCBs, dieldrin and heptachlor was restricted in North America and most of Europe, around 1970. Use in most other parts of the world, particularly tropical developing countries, has not yet been restricted, and in fact has probably increased since the early 1970's.

Growing public concern about use and disposal of hazardous substances and the health of the environment, provided the impetus for environmental contaminant monitoring programs. For example, the Herring Gull (Larus argentatus) has been used successfully to monitor pollution in the Great Lakes (Mineau et al, 1984).

Since the oceans are the ultimate sink of most manmade persistent substances, there is concern about the health of the marine environment and the impact of contaminants on its denizens. Seabirds, as top predators in the marine food chain, can accumulate significant amounts of these chemicals, and are likely to be the most affected. The DDE-induced crash of American Brown Pelican (Pelecanus occidentalis) populations fifteen years ago (Blus et al, 1971), is evidence that the effects can be very serious.

This report results from a project by the Canadian Wildlife Service (CWS) to review its data on environmental contaminants in Canadian seabirds. Available data on organochlorine and heavy metal levels were examined in order to:

1) determine if toxic chemicals have affected or are continuing to affect the health of Canadian seabird individuals or populations

2) consider the utility of seabird species as indicators of contamination of marine ecosystems by persistent environmental pollutants

3) determine what future monitoring and surveillance of environmental contaminants in Canadian seabirds is necessary.

Table 1 is a summary of organochlorine analyses conducted on seabirds by CWS. The number of analyses for each tissue and species is provided on a yearly basis according to geographic regions. Publications containing some of the data for each species are noted.

Certain sections of this report are organized geographically into east coast, arctic and west coast regions. Maps of collection locations are provided in Appendix 2. A detailed summary of all organochlorine and mercury residue data is available in Appendix 6.

2. METHODS

2.1 General Approach:

Seabirds included in this report are those species which breed on the coasts of Canada and spend their time outside the breeding season in the marine environment. Species such as loons, grebes and phalaropes which breed in freshwater and winter in marine areas were excluded. A search for data on the selected species was made on the CWS National Registry of Toxic Chemical Residues (Elliott et al, 1986), a computerized repository for information on environmental contaminants in Canadian wildlife. Data was available on twenty-four species, as listed in Table 1.

All data on these species were retrieved and a separate data

Table 1

Summary of Canadian Wildlife Service data on organochlorine chemicals in seabirds.
The number of samples analyzed each year is given, according to tissue and area of collection.
Publications including at least part of the data for each species are noted.

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
Northern Fulmar	Whole body	Atlantic				19																38	Peakall and Nettleship, in press
	Liver	Arctic								10	9												
Leach's Storm-petrel	Eggs	Atlantic	19				10				10				10				10		80	22	Pearce *et al*, 1979
		Pacific			1	5												6		9			Ohlendorf *et al*, 1978
	Whole body	Atlantic					9				5												Pearce *et al*, in prep.
	Miscellaneous	Pacific				8																	Elliott *et al*, in prep. b
Fork-tailed Storm-petrel	Eggs	Pacific			2													3			5		Ohlendorf *et al*, 1978 Elliott *et al*, in prep. b
Northern Gannet	Eggs	Atlantic	9	20	6			10	30		6								6		87	44	Keith and Gruchy, 1972 Elliott *et al*, in prep. a
	Miscellaneous	Atlantic	40		2		2																Chapdelaine *et al*, in prep.
Double-crested Cormorant	Eggs	Atlantic			15		40	15		14	25			11	10				10		163	6	Pearce *et al*, 1978
		Pacific			3									10						10			Ohlendorf *et al*, 1978
	Liver	Atlantic		4						2													Pearce *et al*, in prep. Elliott *et al*, in prep.
Pelagic Cormorant	Eggs	Pacific			20			6												11	37	5	Ohlendorf *et al*, 1978 Elliott *et al*, in prep. b
	Liver	Pacific	5																				
Common Eider	Eggs	Atlantic					24														24	1	Pearce *et al*, 1979
	Muscle	Atlantic			1																		

Table 1 (continued)

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
King Eider	Eggs	Arctic									1										1		
Glaucous-winged Gull	Eggs	Pacific			63							10						35			108	20	Ohlendorf et al, 1978
	Miscellaneous	Pacific	20																				Elliott et al, in prep. b
Ivory Gull	Eggs	Arctic									10										10		
Black-legged Kittiwake	Eggs	Arctic									6										6	20	Peakall and Nettleship, in press
	Liver	Arctic								10	10												
Common Tern	Eggs	Atlantic		4	10	3	10	25		10											62	4	Pearce et al, 1979
	Liver	Atlantic		4																			
Razorbill	Eggs	Atlantic					10	3					20								33	2	Pearce et al, 1979 Chapdelaine and Laporte, 1982
	Muscle	Atlantic			2																		
Common Murre	Eggs	Atlantic	10			4															14	7	Pearce et al, 1979
	Miscellaneous	Atlantic Pacific			2 5																		
Thick-billed Murre	Eggs	Arctic								12	10	10									32	42	Peakall and Nettleship, in press
	Liver	Arctic								10	22	20											

Table 1 (continued)

SPECIES	TISSUE	GEOGRAPHICAL REGION	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	TOTALS Eggs	TOTALS Tissues	PUBLICATIONS
Dovekie	Muscle	Atlantic	9																			9	
Black Guillemot	Eggs	Atlantic						3													3	1	Pearce et al, 1979
	Muscle	Atlantic			1																		
Pigeon Guillemot	Eggs	Pacific			13																13		Ohlendorf et al, 1978 Elliott et al, in prep. b
Marbled Murrelet	Miscellaneous	Pacific	6	12																		18	Ohlendorf et al, 1978 Elliott et al, in prep. b
Ancient Murrelet	Eggs	Pacific	5																		5	72	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific	28	2	2	4	36																
Cassin's Auklet	Eggs	Pacific			4																4	4	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific			2	2																	
Rhinoceros Auklet	Eggs	Pacific			11															6	17	10	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Miscellaneous	Pacific		8	2																		
Atlantic Puffin	Eggs	Atlantic	20				36	1			10				10				10		87	12	Pearce et al, 1979 Pearce et al, in prep.
	Miscellaneous	Atlantic	5		2		5																
Tufted Puffin	Eggs	Pacific			1																1	2	Ohlendorf et al, 1978 Elliott et al, in prep. b
	Whole body	Pacific			2																		

file was created. A hardcopy of the contents was produced and the whole dataset verified by hand against the original documents, such as field collection sheets, laboratory notebooks and analysis reports. The incidence of errors was very low (<0.01%). The few detected errors were corrected and the data declared ready for use. Results of recent analyses and re-analyses were added to the file.

2.2 Sample Collection:

Field collection procedures varied. The report covers eighteen years of work during which, collectors, reasons for collecting and methodologies changed. Egg collections were the most standardized. Fresh eggs were collected early in the nesting season at most sites. For species such as terns and cormorants which lay a multiple egg clutch, a single egg was removed from the first clutch. Nests to be sampled were selected at random from the central area of the colony. Late season collecting of unhatched eggs was more opportunistic and involved collection of whatever eggs were available. Eggs for pesticide analysis were removed by hand and refrigerated temporarily. As soon as possible, egg contents were removed and placed into chemically cleaned (acetone and hexane) glass jars with a chemically cleaned foil liner between the lid and the jar. Egg contents were then frozen at -20 C or colder until time of analysis. The collection of Ivory Gull (Pagophila eburnea) eggs from Seymour Island, North West Territories diverged from this general method. Due to the isolated circumstances, egg contents were placed into chemically cleaned glass jars containing formalin as a preservative agent. Collection of adult and juvenile birds was normally by shooting or netting. Carcasses were wrapped in solvent rinsed aluminum foil and/or placed into polyethylene bags then frozen at -20 C.

2.3 Sample preparation:

Tissues were dissected using chemically cleaned (acetone and hexane) instruments. Soft tissues including eggs were homogenized in a Waring blender or Sorvall Omnimixer. Whole body samples were prepared by removing digestive tract and hard body parts such as feet and beak, homogenizing in a commercial meat grinder, followed by further homogenization in a Waring blender as required.

2.4 Chemical Analysis:

Data included in this report dates from 1968. For data prior to 1969, only p,p'-DDE and dieldrin levels are presented. The presence of other compounds such as p,p'-DDT, p,p'-DDD and o,p'-DDT was confirmed in many samples; however, quantitative information was unreliable as the confounding influence of PCBs had not been removed. An early method for separating PCB peaks from those of the common pesticides was developed on behalf of CWS in 1969 (Reynolds, 1969). Quantitative results for PCBs and other organochlorines are included for samples analyzed subsequent to this date. A methodology review in 1978 revealed losses of DDD, DDT, HCB and oxychlordane of up to 50% during vacuum oven drying. The losses were found to be reproducible, so correction factors were added to the registry and are applied to all pre-1978 data.

Organochlorine chemicals included in the report are listed in Appendix 4. Prior to 1984, all analyses were carried out at the Ontario Research Foundation of Missassauga, Ontario under contract to CWS. Quality of contract analyses is controlled by the inclusion of blind-numbered samples of an in-house egg reference material. Analytical procedures are described in Reynolds and Cooper (1975) and Norstrom et al (1980). Some 1984 samples were analyzed at the National Wildlife Research Center, Ottawa-Hull, using similar procedures (Peakall et al,1986). PCBs were quantified by capillary gas chromatography against an

Aroclor 1260 standard or a 1:1 mixture of Aroclors 1254 and 1260. The latter standard provides a more consistant if slightly higher value for residues in wildlife tissues (Reynolds, 1971; Norstrom et al 1978; Won and Norstrom, 1980).

Total mercury was determined by wet digestion followed by flameless atomic absorption spectrophotometry (AAS) (Fimreite and Reynolds, 1973). Methodology for lead and cadmium involved freeze-drying followed by low temperature ashing and treatment with nitric acid/hydrogen peroxide. Elements were then determined by flame or flameless AAS depending on the concentration. NBS bovine liver Standard Reference Material was used to standardize procedures.

2.5 Sample storage:

The remains of most of the CWS specimens included in this review are still retained in the CWS National Specimen Bank (Elliott, 1984). Samples were stored at -25 to -30 C until 1981 at which time the collection was transferred to -40 C storage. Some recent material is stored at -80 C.

A variety of specimen bank samples have recently been re-analyzed, including some seabird samples (Elliott, 1985). Re-analysis of samples from previous years provides data on many chemicals that were formerly not identified or for which accurate methods were not available at the time of collection.

2.6 Data Analysis:

Data in the report are presented in the form of parts per million (ppm) on a wet weight basis (i.e. mg/kg wet weight). Reporting of residue levels on a wet weight basis is preferred for eggs as moisture content is less variable than lipid content during embryonic development (Peakall and Gilman, 1979). Residues in other tissues are also reported on a wet weight basis, as moisture content is generally less variable than lipid.

Residue concentrations generally exhibit a log normal distribution; therefore, data are presented in the form of geometric means. Means were calculated from samples collected for the same species, tissue, year and location. Data are also included from single analyses of pooled samples. The ratio of the number of analyses over the number of samples pooled is indicated for each case in the tables of Appendix 6.

Means were calculated from individual sample values which were transformed to common logarithms. Zero values were eliminated from the data. Zeros are present in the database dating from an earlier era when a complete suite of chemicals were routinely added to the registry whether they had been analyzed for or not. When a chemical was analyzed for and not detected in a sample, a value of one half the detection limit was entered (generally 0.0005 for most organochlorines). The mean and the 95% confidence interval were calculated on the transformed values, the anti log of the mean was then taken to obtain the derived (geometric) mean and confidence interval.

Statistical analysis was conducted using either SPSS routines on a mainframe computer or by modified versions of NWA Statpak routines on a micro computer.

Where possible, residues in eggs were further analyzed for differences between sites and years for the same species. A one way analysis of variance was performed on the log-transformed data; Tukey's range test was then used to detect significant differences ($p \leq 0.05$) between mean concentrations of the same chemical at different sites and for different years. Trends over time were determined for each chemical at the same location.

3. RESULTS

3.1 Atlantic Coast Seabirds

3.1.1 Organochlorine Residues

Table 1 in Appendix 5 summarizes organochlorine residues in eggs of Atlantic coast seabirds with respect to locality and year of collection. More detailed information (geometric means, ranges, confidence intervals) are provided in Table 1 of Appendix 6 for all organochlorines and mercury in eggs or tissues of east coast seabirds, 1968 to 1984.

DDE and DDT were detected in all east coast samples; DDD was present in most samples except where overall DDT levels were very low. DDE egg levels ranged from 30.0 ppm in a collection of 10 unhatched Northern Gannet (Sula bassana) eggs from Bonaventure Island, Quebec in 1969 to 0.283 ppm in eggs of Common Eiders (Somateria mollissima) collected in 1972 at Watshishu, Quebec. DDE levels in other tissues ranged from a low value of 0.014 in Dovekie (Alle alle) breast muscle collected in 1968 from the Davis Strait to 49.5 ppm wet weight, in the brain of a gannet collected from the Baie des Chaleurs in 1970.

PCBs were detected in all samples from 1969 on, when functional analytical methods were implemented. Highest PCB residues were found in eggs of Double-crested Cormorants (Phalacrocorax auritus), from the Iles Razades in 1979, 23.4 ppm, from the Magdalen Islands in 1973, 22.4 ppm and from Gros Pelerin in 1975, 22.1 ppm. Lowest PCB egg residues, 0.572 ppm, were in Common Eider eggs from the Ste. Marie Islands in 1972. PCB levels in other tissues ranged from 0.302 ppm in breast muscle of Common Murres (Uria aalge) from Newfoundland, in 1970, to 81.4 ppm in gannet brain tissue from the Baie des Chaleurs in the same year.

Dieldrin was found in all samples; mean egg levels ranged from 1.16 ppm in addled gannet eggs from Bonaventure Island in 1969 to 0.01 ppm in Common Eiders from Watshishu, 1972. Residues in other tissues varied from 1.44 ppm in brain of an adult gannet found dead at Janeville, New Brunswick in 1970 to 0.003 ppm in Dovekie breast muscle from the Davis Strait in 1968.

Endrin was detected in the range of 0.01 to 0.1 ppm in eggs of Leach's Storm-petrel (Oceanodroma leucorhoa) ,Double-crested Cormorant, Common Eider, Common Tern (Sterna hirundo), Razorbill (Alca torda), Common Murre and Atlantic Puffin (Fratercula arctica) collected from 1968 to 1973. Highest levels of endrin, (0.231 ppm) were detected in addled gannet eggs from Bonaventure Island in 1974. Since endrin was not reported in Atlantic seabird eggs after 1973, it may have been mistakenly identified in earlier chromatograms, possibly for some of the chlordane compounds discovered later.

Heptachlor epoxide was detected in the range 0.01 to 0.1 ppm in most east coast seabird egg samples. The highest value, 0.394 ppm was recorded in Leach's Storm-petrel eggs from Great Island in 1976. Values less than 0.01 ppm were detected in 1971 from Northern Fulmar (Fulmaris glacialis) whole bodies collected in the Labrador Sea and Common Tern eggs from Harrington Harbour, Quebec.

Routine reporting of chlordane-related compounds began in 1975. Detectable levels of oxychlordane were found in all east coast seabird eggs analyzed after this date, as well as in all retrospective analyses of stored samples from earlier years. Oxychlordane levels between 1.0 and 0.1 ppm were found in eggs of Bonaventure Island gannets in 1976, Pelerin and Ste. Marie Island razorbills in 1978 and Great Island and Machias Seal Atlantic Puffins in 1976, 1980 and 1984. Oxychlordane residues between 0.1 and 0.01 were reported in eggs of Leach's Storm-petrel at both Great and Machias Seal Islands in 1976, 1980 and 1984, in all samples of Double-crested Cormorants collected after 1976 and in eggs of Common Terns from Tabusintac, 1975. 0.001 ppm of oxychlordane was detected in Double-crested Cormorant liver from Gros Pelerin Island in 1975. Cis-chlordane was found within the same range though slightly lower than oxychlordane in most samples. Razorbill eggs from the Pelerin Islands in 1978 were an exception as they contained cis-chlordane levels which were consistently higher than oxychlordane.

Samples collected after 1978 were analyzed for mirex/photomirex. Mirex levels between 0.1 and 0.01 ppm were found in eggs of Leach's Storm-petrel from Great Island and Kent Island, Double-crested Cormorants from Ile Blanche, Ile Razades and Manawagonish Island and Atlantic Puffins from Great Island and Machias Seal Islands. Photomirex residues were present at lower levels but within the same range.

Samples collected after 1978 were also analyzed for hexachlorocyclohexane (HCH). Levels between 0.1 and 0.01 were detected in Double-crested Cormorant eggs from Isle Blanche, Iles Razades, Ile aux Pommes and Manawagonish Island in 1979 and 1980, and in Razorbill eggs from Pelerin Island and Ste. Marie Islands in 1978. HCH residues between 0.01 and 0.001 were found in Leach's Storm-petrel eggs from Great and Kent Islands and in Atlantic Puffin eggs from Great and Machias Seal Islands in 1980 and 1984. The beta-HCH isomer was sometimes higher than the alpha-HCH isomer, but generally the residues were about the same for each.

Hexachlorobenzene (HCB) was reported in all samples analyzed by 1970. HCB was also found in all retrospective determinations of samples from earlier years. With few exceptions, HCB residues in east coast seabirds were in the range of 0.1 and 0.01 ppm. Higher levels in the range 1.0 to 0.1 were found in gannet brain (0.26 ppm) from Janeville, N.B. in 1970, in both fresh and addled Razorbill eggs from the Pelerin (0.162 ppm) and Ste. Marie Islands (0.195 ppm) in 1976 and in fresh eggs from Brion Island in 1973 (0.127 ppm), also in Atlantic Puffin eggs from Machias Seal Island in 1976 (0.188 ppm). The lowest value, 0.008 ppm HCB was reported in Double-crested Cormorant eggs from the Ste. Marie Islands in 1972.

3.1.1 Geographic Differences:

Mean egg residues for each species were compared between locations for DDE, dieldrin, heptachlor epoxide, oxychlordane, HCB, beta-HCH and PCB (Table 1. Appendix 5). Significant differences between sites occured for each species; however, the pattern of geographic variation was complex and often changed with time.

Details are discussed below for species which were sampled at more than more location for each of the seven chemicals tested. DDE and PCB levels were generally higher and often significantly so in samples from the Bay of Fundy than from other locations. However, mean levels of these chemicals are about equal or higher, in some instances significantly, in Double-crested Cormorant eggs from colonies in the St. Lawrence River estuary than from those in the Bay of Fundy.

DDE

DDE levels in Leach's Storm-petrel were consistently higher, significantly in 1976, in eggs from the Bay of Fundy than from the Newfoundland shelf. Significant differences in DDE egg levels were not found amongst any of the Double-crested Cormorant colonies tested. Neither was there a clear pattern of geographic differences for this species. Significantly higher levels of DDE were present in eggs of Common Eider from Bay of Fundy than Gulf of St. Lawrence colonies. There were higher levels of DDE in Common Tern eggs in 1973 from Northumberland Strait colonies than from those further north in the Gulf of St. Lawrence. Levels of DDE in Atlantic Puffins were consistently and significantly higher from the Bay of Fundy than from the Newfoundland Shelf. In a 1972 survey of 7 colonies, levels in puffin eggs from the north shore of the St. Lawrence were intermediate. DDE levels were consistently but not significantly higher in razorbill eggs from the St. Lawrence estuary than in the gulf.

Dieldrin

Dieldrin levels in eggs of Leach's Storm-petrel were consistently higher from the Newfoundland Shelf than the Bay of Fundy. Dieldrin levels in Double-crested Cormorants displayed neither significant regional differences nor a consistent pattern of variation. Dieldrin levels in Common Eider eggs were significantly higher in the Bay of Fundy than in two out of three Gulf of St. Lawrence north shore colonies. Dieldrin levels in Common Tern eggs were higher in Gulf of St. Lawrence colonies than in those from the Baie des Chaleurs or along the north shore. Dieldrin levels in Atlantic Puffin eggs were highest from the Bay of Fundy, intermediate from the north shore and lowest from the continental shelf. Dieldrin levels in razorbill eggs showed neither significant nor consistent variation between St. Lawrence estuary and gulf colonies.

Heptachlor epoxide

Heptachlor epoxide levels in Leach's Storm-petrel eggs were consistently higher, significantly so in 1980, from the continental shelf than in the Bay of Fundy. Levels in eggs of both Double-crested Cormorants and Common Eiders showed no consistent pattern of variation. Levels of Heptachlor epoxide in Common Tern eggs were very similar from all sampled colonies. Heptachlor epoxide levels in Atlantic Puffin eggs were significantly higher in 1972 from some continental shelf colonies than some from the St. Lawrence north shore; in 1976 levels were significantly higher in eggs from the Bay of Fundy than from the continental shelf. Heptachlor epoxide levels in razorbill eggs were similar between the St. Lawrence estuary and gulf colonies.

Oxychlordane

Oxychlordane levels in eggs of Leach's Storm-petrel were consistently but not significantly higher in Bay of Fundy than Newfoundland shelf colonies. Levels of this chemical in Double-crested Cormorant eggs showed no particular pattern of regional differences. Oxychlordane levels in Atlantic Puffin eggs were significantly higher in the Bay of Fundy than the Newfoundland shelf in 1976, 1980 and 1984. Levels in Razorbill eggs were similar in both St. Lawrence estuary and gulf colonies.

Hexachlorobenzene

Levels of HCB were consistently but not significantly higher in Leach's Storm-petrel eggs from the Newfoundland shelf than in the Bay of Fundy. No significant differences in HCB levels were found between monitor colonies of Double-crested Cormorant in the St. Lawrence River and the Bay of Fundy. Statistically significant variation in HCB levels in eggs of this species during the early 1970's displayed no geographical pattern. HCB levels in Common Eider eggs in 1972 were similar at each location. There were significant differences in HCB levels in Common Tern eggs from 1973, but no geographic pattern was evident.

HCB levels in Atlantic Puffin eggs in 1972 displayed significant regional variation. However, eggs from neighbouring Betchouane and Ste. Marie Island colonies on the St. Lawrence north shore were significantly different while eggs from Great Island on the continental shelf contained the same amount of HCB as those from Machias Seal Island in the Bay of Fundy. In 1976, Atlantic Puffin eggs from Machias Seal contained more than twice the amount of HCB than those from Great Island; in 1980 there were no significant differences in HCB content in eggs from the two colonies. In 1972, HCB levels in razorbill eggs from a Gulf of St. Lawrence colony were significantly higher than those from a colony further upstream. In 1978, HCB levels in eggs from the gulf colony were higher than in eggs from a second razorbill colony in the estuary, but not significantly so.

Hexachlorocyclohexane

Beta-HCH levels in Leach's Storm-petrel eggs were similarly low in both the Bay of Fundy and Newfoundland shelf colonies. Double-crested Cormorant eggs from the St. Lawrence River estuary contained significantly higher levels of beta-HCH in 1980 than those from the Bay of Fundy. Beta-HCH in eggs of Atlantic Puffins were consistently low at both the Newfoundland shelf and Bay of Fundy colonies. Levels of beta-HCH in eggs of Razorbills were significantly higher in the St. Lawrence estuary than in the gulf.

PCBs

PCB levels in Leach's Storm-petrel eggs were significantly higher in 1972 in Bay of Fundy than in Newfoundland shelf colonies; levels remained higher in the Fundy colony but have not been significantly different in subsequent collection years. There were no significant differences in PCB levels in eggs from Double-crested Cormorant colonies in 1972. In 1976, eggs from the St. Lawrence monitor colony, Ile aux Pommes, contained significantly more PCB than those from the Bay of Fundy monitor colony, Manawagonish Island. By 1980, eggs from the Fundy cormorant colony contained more PCB than the St. Lawrence River colony, but the difference was small and not significant. PCB levels in Common Eider eggs in 1972 were significantly higher from the Bay of Fundy than from two St. Lawrence north shore colonies, but were not higher than levels in eggs from a third colony in the area, Inner Birch Island. PCB levels in Common Tern eggs in 1973 were similar in all sampled colonies. PCB levels in Atlantic Puffin eggs were consistently and significantly higher from the Bay of Fundy than from continental shelf colonies; eggs from St. Lawrence north shore colonies contained intermediate levels of PCB. Significantly higher levels of PCB were found in Razorbill eggs from colonies upstream in the St. Lawrence estuary than from the St. Marie Islands on the north shore of the gulf.

3.1.3 Temporal Trends:

Long-term temporal trends can be determined for several east coast seabird species at selected monitor colonies. The general picture is of declining levels of most chemicals in the Bay of Fundy colonies, slower rates of decline or no change at colonies on the outer continental shelf, and no change or increases in the St. Lawrence estuary and some parts of the gulf.

Residues of most organochlorines (ie. PCBs, DDE, dieldrin and oxychlordane) declined most rapidly in eggs of Double-crested Cormorants from Manawagonish I. in the Bay of Fundy, than in cormorants, petrels or puffins collected elsewhere. In contrast, in eggs of cormorants breeding at Ile aux Pommes in the St. Lawrence River, no chemicals decreased significantly. Organochlorine compounds in these samples were stable or increasing. Razorbill eggs collected from the Ste. Marie Islands in the Gulf of St. Lawrence in 1972 and 1978 also showed a significant decline only in DDE. Dieldrin and PCB levels were stable while heptachlor epoxide and HCB increased significantly between 1972 and 1978.

In eggs of Atlantic Puffins and Leach's Storm-petrels from colonies in the Bay of Fundy, residues of most organochlorines were initially lower in 1972 than in cormorant eggs, and declined more slowly. At Great Island, concentrations of PCBs, DDE and dieldrin in eggs of these species were consistently lower and declining at a slower rate than residues in eggs from the Bay of Fundy. HCB and oxychlordane levels did not change significantly at Great Island between 1972 and 1984, and heptachlor epoxide levels appear to have increased.

Organochlorine concentrations in eggs of gannets from Bonaventure Island (in the Gulf of St. Lawrence) show similar temporal trends. DDE, DDD, DDT and dieldrin declined significantly between 1968 and 1984, HCB, PCBs and mirex showed some evidence of declines, and HCH, oxychlordane and cis-chlordane remained stable.

In Bathurst Harbour (Baie des Chaleurs), in eggs of Common Tern collected from 1970 to 1973, only DDE decreased significantly.

3.2. Pacific Coast Seabirds

Organochlorine and mercury residues (geometric means, ranges and confidence intervals) in tissues and eggs of west coast seabirds are contained in Table 3 of Appendix 6. A summary of organochlorine residues in fresh eggs, organized by collection site, is provided in Table 2 of Appendix 5. Nineteen (19) of these samples are from a 1970 survey involving single analyses of egg pools. DDE and PCB data from this survey were discussed by Ohlendorf et al (1978).

3.2.1 Organochlorine Residues:

DDE and DDT were found in all west coast seabird samples analyzed. DDD was present in most samples, except where overall DDT levels were very low. DDE residues ranged from 0.029 ppm in brain tissue of Glaucous-winged Gull (Larus glaucescens) from Boundary Bay in 1968 to 10.7 ppm in fat tissue of the same species from Langara Island in 1969. DDE residues in eggs ranged from 0.224 ppm in a sample of Glaucous-winged Gulls from Northwest Rocks in 1970 to 4.07 ppm in Double-crested Cormorants from Mandarte Island in the same year.

PCBs were detected in all samples from 1969 on, when functional analytical methods were implemented. PCB residues ranged from 0.040 ppm in brain of Leach's Storm-petrel from Graham Island in 1971 to 16.4 ppm in Ancient Murrelet (Synthliboramphus antiquus) fat from Langara Island in the same year. PCB egg levels varied between 0.364 ppm in Glaucous-winged Gulls from Northwest Rocks in 1970 to 14.0 ppm in Double-crested Cormorants from Mandarte Island in the same year.

Dieldrin was detected in all but one sample. Egg levels ranged from 0.007 ppm in Cassin's Auklet (Ptychoramphus aleuticus) from Moore Island in 1970 to 0.082 ppm in Pelagic Cormorant (Phalacrocorax pelagicus) eggs in the same year. Measured dieldrin levels in other tissues ranged from 0.001 ppm in brain of Ancient Murrelets from Langara Island in 1968 to 0.080 ppm in fat of Marbled Murrelet (Brachyramphus marmoratus) from the same colony in 1969.

Endrin was reported in only one egg sample, at a value of 0.022 ppm in Leach's Storm-petrel from Graham Island in 1971. Endrin was found more commonly in tissue samples, where it ranged from 0.010 ppm in breast muscle of Cassin's Auklet from Langara Island to 0.24 ppm in fat of Ancient Murrelet from the same island and year. As mentioned before, the identification of endrin in samples from the early 1970's may not be reliable.

Heptachlor epoxide was reported in about 25% of egg samples (N = 22) between 1968 and 1979 (Table 2, Appendix 5) and ranged in value from 0.010 ppm in eggs of Leach's Storm-petrel from Graham Island in 1971 to 0.040 in those of Double-crested Cormorants from Mandarte Island in 1979. Heptachlor epoxide was reported slightly more often in other tissues, ranging from 0.021 ppm in brain of Ancient Murrelet from Langara Island in 1968 to 0.050 ppm in liver from the same species and location in 1972.

Routine reporting of chlordane related compounds began in 1975. All west coast seabird egg samples analyzed after that date had detectable levels. Oxychlordane values of 0.01 ppm were present in a pool of 10 Double-crested Cormorant eggs from Mandarte Island in 1979 and a mean value of 0.001 ppm was detected in 10 Glaucous-winged Gulls from Tsawwassen in 1977. Alpha-chlordane values were 0.060 ppm and 0.001 ppm respectively in the same samples.

The beta isomer of hexachlorocyclohexane (HCH) was reported at 0.007 ppm in eggs of Glaucous-winged Gulls from Tsawwassen in 1977 and at 0.030 in eggs of Double-crested Cormorants from Mandarte Island in 1979. Tissue levels of beta-HCH ranged from 0.020 ppm in Ancient Murrelet brain from 1972 at Langara Island to 0.968 ppm in whole body of the same species and location in 1969.

Hexachlorobenzene (HCB) residues were reported in all but one egg sample. Levels varied from 0.006 ppm in Glaucous-winged gulls from Mittlenatch Island in 1970 to 0.304 ppm in Double-crested Cormorants from Mandarte Island in the same year. Detectable levels of HCB were reported in about 40% of the other tissues analyzed. Levels ranged from 0.004 in whole body of Ancient Murrelet from the Queen Charlotte Islands in 1970 to 0.198 ppm in fat of Leach's Storm-petrel from Graham Island in 1971.

3.2.2 Geographic Differences:

Only egg data was examined for geographical variation. Statistical analysis was not done due to pooled analyses. Ohlendorf et al (1978) noted that DDE and PCB levels and the PCB/DDE ratios were generally higher in birds nesting in the Strait of Georgia than in more remote locations.

The highest PCB levels were found in the Strait of Georgia, in Double-crested and Pelagic cormorants. However, levels in Pelagic cormorants were higher at Mittlenatch Island further to the north and more remote from the city of Vancouver and the Fraser Estuary than at the more southerly Mandarte Island. Levels of PCB in Pigeon Guillemots (*Cepphus columba*) were also much higher at Mittlenatch Island than in eggs from Skedans Island in the Queen Charlottes. PCB levels in eggs of Glaucous-winged Gulls, however, were slightly higher from both Queen Charlotte Strait (2.83 ppm) and from Cleland Island (2.58 ppm), off the west coast of Vancouver Island, than at Mandarte Island (2.49 ppm) or Mittlenatch Island (1.53 ppm).

The PCB/DDE ratio generally decreases in eggs collected outside the Strait of Georgia, due both to drops in PCB levels and some increases in DDE levels. DDE levels in Glaucous-winged gulls followed a similar pattern to PCB, being highest at Skedans Island and the Stevenson Islets. Lower levels were found in Strait of Georgia colonies and still lower levels from colonies further north in the Queen Charlotte Islands. DDE levels in Pigeon Guillemots were highest at Cleland Island, but this is from a single egg. DDE levels in this species, from pools of 10 eggs, were higher (0.604 ppm) at Mittlenatch Island than at Skedans Island, (0.163 ppm). DDE levels in Leach's Storm-petrel eggs were higher at Cleland Island than from Langara Island in the Queen Charlottes.

Dieldrin levels in Glaucous-winged Gull eggs from the 1970 survey were highest in the Strait of Georgia, 0.046 ppm at Mandarte Island and 0.045 ppm at Mittlenatch Island. Levels outside the strait were lower and variable with no clear geographic pattern. Levels in Leach's Storm-petrel eggs were higher, 0.045 ppm, from Cleland Island in 1970 than at Langara Island a year later, 0.013 ppm.

Heptachlor epoxide levels in 1970 Glaucous-winged Gull eggs exhibited no clear geographic pattern. Hexachlorobenzene (HCB) levels in 1970 were highest in Glaucous-winged Gull eggs from Cleland Island, 0.046 ppm; HCB levels in eggs from other gull colonies showed no pattern.

3.2.3 Temporal Differences:

Data permitting any comparison of residue changes with time are very limited. Pools of Double-crested Cormorant eggs from Mandarte Island were analyzed in 1970 (N = 3) and 1979 (N = 10), and a sample of 5 eggs in 1985. DDE levels dropped during this time period from 4.07 ppm to 0.501 ppm, PCBs from 14.0 ppm to 3.79 ppm and HCB from 0.304 ppm to 0.030 ppm. Dieldrin levels rose from 0.040 in 1970 to 0.050 in 1979, but were only 0.006 ppm in 1985. Heptachlor epoxide and HCH were not measured for in 1970 but declined between 1979 and 1985. Total chlordane compounds decreased between the last two samples although oxychlordane increased slightly. In eggs of Pelagic Cormorants from Mandarte Island in 1970, 1973 and 1985, DDE, PCBs, dieldrin, heptachlor epoxide and oxychlordane decreased, HCH increased slightly, and HCB showed no consistent trend.

Glaucous-winged Gull eggs collected in 1977 from Tsawwassen and individually analyzed (N = 10) can be compared with caution to the 1970 pool of 10 from Mandarte Island. Residues of DDE, dieldrin, heptachlor epoxide and PCB were all lower in the 1977 samples. HCB levels were higher in 1977 than in 1970.

Between 1970 and 1985, DDE in Rhinoceros Auklet (*Cerorhinca monocerata*) eggs from Lucy Island in Hecate Strait decreased from 2.84 ppm to 0.631 ppm; HCB remained about the same; and PCBs decreased from 2.01 ppm to 0.607 ppm.

Breast muscle, fat, liver and brain of Ancient Murrelets from Langara Island were analyzed in 1968, 1971 and 1972. Mean DDE and dieldrin levels were higher, although not significantly so, in all tissues in 1972 than in 1968.

3.3 Organochlorine Residues in Arctic Seabirds

A summary of organochlorine residues in tissues and eggs of arctic seabirds is contained in Table 2, Appendix 5. More detailed information, including geometric means, ranges and confidence intervals are provided in Table 3 of Appendix 6.

Arctic seabird samples consisted of livers and eggs of Thick-billed Murres (Uria lomvia) and Black-legged Kittiwakes (Rissa tridactyla), livers of Northern Fulmars from Prince Leopold Island, and eggs of Ivory Gull and King Eider (Somateria spectabili) from Seymour Island, 1975 to 1977.

PCBs were the major contaminant in tissues of all species. Egg concentrations ranged from 0.06 ppm wet weight in the King Eider to 5.73 ppm in the eggs of Black-legged Kittiwakes, in 1976. Liver levels were similar, from 0.09 ppm in livers of young Thick-billed Murres to 3.30 ppm in livers of adult kittiwakes.

DDE, the dominant pesticide metabolite, was present in all samples. The highest egg levels (0.464 ppm) occurred in the eggs of Ivory Gulls, compared to 0.02 ppm in the eider egg. Liver values ranged from 0.035 in the livers of young murres to 0.605 ppm in livers of adult fulmars. DDD (and some DDT) were found in most samples, at concentrations less than 0.05 ppm except for one sample of fulmar livers with 0.245 ppm DDD, in 1976.

Residues of dieldrin were low, always less than 0.03 ppm, with highest levels occurring in the eggs of Ivory Gulls.

Chlordane compounds were represented mainly by oxychlordane, at concentrations less than 0.03 ppm in eggs of murres and eiders, and between 0.05 and 0.10 ppm in eggs of Ivory Gulls and kittiwakes. Liver concentrations were less than 0.05 ppm in murres and kittiwakes, but much higher (0.11 to 0.26 ppm) in fulmars. Another chlordane compound, cis-chlordane, was present at very low levels (0.01 ppm or less) in eggs and livers of all species. Heptachlor epoxide occurred at levels less than 0.015 in eggs of all species except the kittiwake, which had egg concentrations of 0.04 ppm. All liver values were 0.01 ppm or less.

HCB concentrations varied greatly in eggs (from 0.01 ppm in eiders to 0.13 ppm in murres and kittiwakes) and livers (from 0.02 ppm to 0.13 ppm in livers of murres). Liver HCB levels in kittiwakes and fulmars were intermediate within this range.

The beta-isomer of HCH was recorded in most samples at concentrations of 0.01 ppm or less. Mirex occurred at levels between 0.01 and 0.02 ppm in livers and eggs of kittiwakes and fulmars, and at even lower levels in eggs of Ivory Gulls and murres.

Since different species (and often different tissues) were sampled at the two locations, no examination of geographic trends was possible.

Data from Prince Leopold Island allows some comparison of variation between years, but the sampling years are too close (1975 to 1977) to show significant temporal trends. Examination of the data revealed increases in most organochlorine residues between 1975 and 1976 in the livers of fulmars,kittiwakes and adult murres, and murre eggs (except for PCBs in the latter). Changes in organochlorine residues between 1976 and 1977 were not consistent in the eggs, nestling livers and adult livers of Thick-billed Murres sampled. Livers concentrations of all compounds decreased while egg concentrations of DDE and PCBs increased.

3.4 Heavy Metals in Canadian Seabirds

3.4.1 Introduction

CWS data on heavy metal levels in seabirds includes:

1) A survey of mercury levels in tissues and eggs of seabirds

collected in 1968 and 1969 near sites of industrial mercury contamination.

2) Analysis of mercury in Common Tern eggs from Bathurst Harbour, 1969-73.

3) A survey of mercury levels in eggs of east coast species in 1972 and 1976.

4) A survey of mercury in eggs of west coast species in 1970.

5) Regular analysis of mercury in three east coast monitor species (Double-crested Cormorant, Atlantic Puffin and Leach's storm-petrel) from 1972 to 1980.

6) Occasional mercury analyses of specific species or of birds found dead from both coasts.

7) A small amount of lead and cadmium data for some east coast seabirds in 1970-71.

3.4.2 Mercury

East Coast:

Species Differences:

Mercury levels in eggs of east coast birds are summarized in Table 5 of Appendix 5. Highest mean egg levels (ppm, wet weight) in 1972 were in Leach's Storm-petrel (0.33), followed by Double-crested Cormorant (0.28), Atlantic Puffin (0.19), Black Guillemot (*Cepphus grylle*) (0.13), Common Tern (0.12), and Common Eider (0.06). Mercury levels in other tissues from east coast species are summarized in Table 6, Appendix 5. Levels in breast muscle from locations in Labrador in 1970 are similar in alcids and much lower in Common Eiders. Liver mercury levels in other species from Baie des Chaleurs, in New Brunswick were relatively high.

Spatial Differences:

Egg mercury levels for each species were similar among sampling sites except from the Baie des Chaleurs where concentrations were greater. Mercury levels in cormorant eggs from Heron Island, at the mouth of the Restigouche River contained comparable levels of mercury, 0.27 ppm, to colonies outside the bay; however, eggs from the colony at Riorden, PEI contained 0.497 ppm which is almost double the mean concentration elsewhere. Mercury levels in Common Tern eggs from Bathurst Harbour were also much higher in 1973 (0.18 ppm), than from a colony at Tabusintac (0.057 ppm), further south on the New Brunswick coast.

Mercury levels in livers of various species collected in 1969 and 1970 from the Baie des Chaleurs contained mean values (ppm, wet weight) of 2.50 in Common Terns to 11.3 in a Double-crested Cormorant.

Temporal Differences:

Mercury levels in Common Tern eggs at Bathurst Harbour were higher in 1969 than in subsequent sampling years, mainly due to one particularly high value (1.42 ppm) that year.

Mercury levels in eggs of the three monitoring species do not display any trends with time except in petrels from Kent Island. Mercury in eggs at this site increased over 1972 levels in 1976 and again in 1980. Fitting a linear regression line to the log-transformed data indicates a highly significant increase ($F = 25.2$, $p \leq 0.001$) with a slope of + 0.075.

West Coast:

Species Differences:

Mean egg mercury levels (ppm, wet weight), as summarized in Table 7, Appendix 5, are from highest to lowest: Pigeon Guillemot 0.42, Double-crested Cormorant 0.36, Leach's Storm-petrel 0.29, Pelagic Cormorant 0.26, Rhinoceros Auklet 0.23, Fork-tailed Storm-petrel (*Oceanodroma furcata*) 0.18, Glaucous-winged Gull 0.15, Tufted Puffin (*Lunda cirrhata*) 0.11 and Ancient Murrelet 0.05. Sample size and collection locations vary among species and the data are not strictly comparable; however, they do indicate the range of egg mercury levels in the early 1970's.

Highest liver levels were in Marbled Murrelets, 2.31 ppm from Horseshoe Bay in 1968 while lowest levels were in Glaucous-winged Gulls, 0.10 ppm at Nanaimo.(Table 7, Appendix 5).

Spatial Differences

Mercury levels in eggs of Glaucous-winged Gulls varied considerably between locations in 1970; levels were lower at Mandarte Island, 0.13 ppm, than at Mittlenatch Island, 0.21 ppm. Pelagic Cormorant eggs collected at the same time showed the reverse pattern, higher at Mandarte Island, 0.35 ppm, and lower at Mittlenatch Island, 0.16 ppm. Mercury in eggs of Pigeon Guillemots were highest at Mittlenatch Island, 0.47 ppm, similar at Cleland Island, 0.45 ppm, and lowest at Skedans Island, 0.33 ppm.

Liver mercury levels (ppm, wet weight) were highest in both Marbled Murrelets (2.21), and Glaucous-winged Gulls (0.45), at Horsehoe Bay in 1968. High levels were also recorded in Pelagic Cormorants from Nanaimo (1.91 ppm) and Leach's Storm-petrels from Graham Island (1.30 ppm).

3.4.3 Cadmium and Lead

Cadmium survey

Double-crested Cormorants were collected in 1970 from two locations in the Baie des Chaleurs area of New Brunswick, Heron Island and near Dalhousie, and from Boot Island in the Minas Basin of Nova Scotia (Table 4, Appendix 5). Cadmium analysis was performed on pools of liver and kidney taken from 6 individual birds. Cadmium levels were higher in kidney than liver in each case. Geographically, dry weight kidney cadmium levels were higher in the Baie des Chaleurs samples: 5.23 ppm at Heron Island and 3.0 ppm at Dalhousie than at Boot Island (0.13 ppm).

Lead and cadmium survey

In 1971, adult specimens of Black Guillemots, razorbills and Common Murres were collected from the Ste. Marie Islands while gannets were collected from Bonaventure Island. Breast muscle samples were analyzed for cadmium and lead (Table 4, Appendix 5).

Cadmium was detected in all samples. Differences between males and females were not significant and are therefore grouped to determine mean levels. Mean dry weight cadmium levels were highest in Common Murres, 0.26 ppm. Mean cadmium levels in Black Guillemots, 0.19 ppm, and gannets, 0.11 ppm, were lower but there was overlap in the range of values found among the three species. Cadmium levels in Razorbills, 0.06 ppm, were much lower and did not overlap with the cadmium range in murres.

Mean lead levels in birds from the 1971 survey were higher than cadmium; however, detectable levels were not found in all samples (limit of detection was 0.05 ppm, wet weight). Highest mean lead levels were 2.75 ppm dry weight in Black Guillemots. However, there was considerable variation in breast muscle lead content in this species, from non-detectable to 8.9 ppm. Mean levels in Razorbills, (2.01 ppm) and Common Murres (1.42 ppm) were lower, but highly variable. Mean levels in gannets, (0.24 ppm), were substantially lower than in the other 3 species and were also quite variable. There were no differences in lead levels between males and females with the exception of Common murres, based on a very small sample size.

DISCUSSION:

4. TOXICOLOGICAL EFFECTS ON SEABIRDS

4.1 Summary

The toxicological effects of organochlorines on seabirds have been extensively reviewed (Bourne,1976; Cooke,1973; Stickel,1975; Peakall, 1975a, Ohlendorf et al, 1978). Therefore we will present only a brief summary.

Toxicity studies examine the lethal, reproductive, physiological or behavioural effects of the toxin. Lethal (or acute toxicity) studies are typically lab oriented and are largely restricted to common laboratory species. Reproductive studies undertaken in the laboratory measure parameters such as egg production, hatching success or chick mortality as related to contaminant dosage in food and tissues. Investigations of reproductive effects in the field are more difficult to assess, since rates of uptake are seldom known and the cause of most egg mortality cannot be determined. There are few studies on physiological or behavioural aspects of toxicity, such as effects on hunting behaviour, salt-gland osmoregulation or hormone production. Where toxicity studies involved the Canadian seabird species included in this report, they are discussed under the individual species sections.

Acute toxicity

Organochlorine pesticides and PCBs differ in their toxicity to birds by several orders of magnitude. In studies of acute mortality, dieldrin and the other cyclodiene insecticides were discovered to be the most toxic; dieldrin at brain residue levels of 4 to 5 ppm (Stickel et al, 1969), oxychlordane at brain levels of 6 to 16 ppm, heptachlor at 9 to 27 ppm (Stickel et al, 1979a) and endrin, the most toxic, at brain levels of 0.8 ppm (Stickel et al, 1979b). DDT compounds were toxic at brain residue concentrations of 250 to 400 ppm DDE, 50 ppm DDD or 10 ppm DDT

(Stickel, 1973). Mirex caused mortality at brain concentrations close to 200 ppm (Heath and Spann, 1973). PCBs were the least toxic, with lethal brain residue levels of 500 to 3000 ppm in laboratory species (Heath et al, 1972). Seabirds are probably more sensitive, as implied by studies by Koeman et al (1973), who found PCB brain levels of 130 ppm associated with mortality in cormorants. Mortality occurs as the result of contaminant interference with hepatic and nerve tissue function. Many sublethal effects have also been documented.

Sublethal effects

DDE, the main metabolite of DDT, is well known for its effect on eggshell thickness. This contaminant apparently interferes with calcium metabolism in the shell gland (Peakall, 1975) thus reducing the thickness and often the strength of the shell. This effect has been documented for several species of fish-eating birds associated with drastically reduced productivity (Ratcliffe, 1970: Blus et al, 1971: Elliott et al, in prep).

Cyclodienes such as dieldrin, heptachlor and chlordane have been shown to be embryotoxic and teratogenic to a number of avain species.

Many polychlorinated compounds, including PCBs, dibenzo-dioxins, dibenzo-furans, polychlorinated naphthalenes and polychlorinated styrenes have been found to induce a suite of toxic responses in most species studied. These include: dermal lesions, weight loss, immunotoxicity, liver enlargement, porphyria, reproductive toxicity and induction of drug-metabolizing enzymes. The toxicity of specific PCB isomers vary considerably. The most toxic isomers are approximate stereo isomers of 2,3,7,8 TCDD (tetrachloro dibenzo-p-dioxin), and cause the same type of biochemical responses.

Mortality in seabird wrecks

The role of environmental contaminants in seabird wrecks is largely unknown. Wrecks of seabirds have been reported since the

1800's (Bourne, 1976: Tuck, 1961) and are not always associated with elevated contaminant levels. Most wrecks are apparently the result of continuously inclement weather decreasing food availability. Starvation results in metabolism of stored lipids, and mobilization of lipophilic toxins into the bloodstream and eventually the brain. It is therefore very difficult to separate the effects of the contaminant from the effects of starvation.

Wrecks have been reported for many seabirds including murres, razorbills (Lloyd et al, 1974), dovekies (Hudson, 1985) and gannets (Parslow et al, 1973). Wrecks usually occur in the winter during harsh weather conditions and the dead or sick birds are characteristically cachectic.

Murres and razorbills from the Irish Sea in 1969 contained PCB residues as high as 880 ppm wet weight and DDE at 25 ppm (Bourne, 1976), enough to have adverse effects apart from starvation. But in 1974, levels of organochlorines in seabirds from another wreck in the Irish Sea were too low to be associated with toxic effects (Lloyd et al, 1974).

In 1970, a mass die-off of 100,000 Common Murres in Alaska was associated with recent storms. Birds were starved but contaminant loads were very low, all less than 1.0 ppm.(Bailey and Davenport, 1972).

Wrecks have also occurred in the breeding season. Scott et al (1975) found elevated levels of organochlorines and PCBs in a die-off of murres in Oregon, in 1969. The absence of the usual fish prey was suspected to be the cause. Bodle (1969) reported a similar die-off of this species in California in 1968.

Interpretation of productivity data

Reproductive failure in a particular year is not in itself a reliable indication of contaminant effects. Food shortages, whether natural phenomenoms or the result of competition with humans for a food resource occur regularly, hence the large variation in breeding success between years for many seabirds. Vermeer et al (1979) noted that on Triangle I., B.C., Tufted Puffins showed reproductive failure in 3 out of 5 years, while

Rhinocerous Auklets, perhaps feeding on a different prey, failed only once in the same 5 years (Vermeer, 1980). During the El Nino year of 1982-83, reproductive failure was reported in a number of seabird species, including shearwaters, boobies, storm-petrels, frigate-birds, noddies and terns (Schreiber and Schreiber, 1984). It is therefore necessary that suspected contaminant-related reproductive effects be supported by determination of toxin residue levels in the tissues or eggs of affected birds.

4.2 Status of Canadian Seabird Populations and Significance of Contaminant Levels

4.2.1 Atlantic Coast Seabirds

Northern Fulmar

The world population of Northern Fulmars, particularly in eastern North Atlantic, has been increasing for 150 to 200 years (ICBP, 1984), most likely the result of modern fish disposal methods and the rise in whaling until recently. The Greenland population is considered stable but little is known about the status of fulmars in the Canadian arctic. Small numbers have recently colonized southeast Labrador and Newfoundland, suggesting population expansion.

Since fulmars from both sides of the Atlantic probably winter along the continental shelf of Newfoundland, birds collected in Canadian waters have varied origins.

Levels of organochlorines in the whole bodies of healthy (14% fat) fulmars from the Labrador sea in 1971 were higher than in other seabirds sampled from the same region. Mean values were 2.6 ppm DDE, 0.086 ppm HCB, 7.28 ppm PCB, all wet weights (Table 1, Appendix 6) .Although the toxicity of organochlorines has not been investigated in this species, these levels are below the critical levels associated with toxic effects in other species (Koeman et al, 1973; Miller et al, 1976). Livers of fulmars breeding in the Canadian arctic in 1975 and 1976, contained lower levels of most contaminants (Table 2, Appendix 6) but direct comparisons are not possible because of the differences in tissues and lipid content.

Investigations of temporal trends of contaminant levels in other arctic marine animals were inconclusive. Seals, which feed at a similar trophic level to seabirds, show evidence of decreases in PCBs and s-DDT, but not chlordane compounds (Muir et al, in prep.; Addison et al, 1984). In adipose tissue of polar bears, however, all organochlorines except DDT compounds increased 2 to 4 fold between 1969 and 1984 (Norstrom et al, in prep.), but this may have been an artefact of yearly differences in condition, and therefore fat content. Conversion of our data to lipid weights does not suggest any corresponding increase in fulmars.

Considering the evident population expansion, fulmars are not in any danger due to organochlorine contaminants but its propensity for fatty food like whale or seal carcasses which are often high in lipophilic chemicals (Addison et al, 1984; Massé et al, 1986) may expose some individuals to toxic levels.

Leach's Storm-petrel

The eastern North American population of Leach's Storm-petrel, which breeds mainly in Newfoundland, has been estimated at 4 million individuals (R.D. Eliott, unpublished). Some colonies have disappeared as a result of the introduction of ground predators to breeding colonies but without reliable censuses, population trends in this species are unknown. In the northern Pacific the populations are apparently stable, and in northern Europe its status is uncertain (ICBP, 1984).

Pearce et al (1979) calculated a critical level of 12 ppm DDE to cause 20 % eggshell thinning in this species (using data included in this report), and noted that several eggs from eastern Canada approached this value. Wurster and Wingate (1968) attributed egg residue levels of 4.0 ppm DDE to the 1960's decline of the Bermuda petrel (Pterodroma cahow) but further investigations reported improved reproduction with similar concentrations.

On the Farallon Islands of California, egg residues of 43 ppm DDE and 26 ppm PCB (wet weight) were associated with 9 % eggshell thinning in the Ashy Storm-petrel (Oceanodroma homochroa) in 1969 (Coulter and Risebrough,1973). No information was available on reproductive success during this period. These extremely high levels were most likely due to the proximity of a large pesticide manufacturing plant rather than background levels in the Pacific ocean, since residues in the Hawiaian Dark-rumped Petrel (King and Lincer, 1973) and in storm-petrels from British Columbia (Table 2, Appendix 5) at the same time were much lower.

Levels of DDE in eggs of the Leach's Storm-petrel collected on Atlantic coast colonies were all lower than the critical value of 12 ppm calculated by Pearce et al (1979). Residues were greatest in 1972 in eggs from Kent I. in the Bay of Fundy, with a mean of 6.8 ppm DDE and an upper range of 8.4 ppm, probably enough to cause some eggshell thinning. Since 1972, DDE levels decreased at both locations (Table 1, Appendix 5).

PCBs were the only other contaminant showing a significant decrease since 1972. Dieldrin, heptachlor epoxide, oxychlordane, HCB and HCH levels fluctuated but showed no consistent temporal changes. All residues of these contaminants were well below levels associated with toxic effects in other avian species.

With the exception of cormorants, petrel eggs usually contained more organochlorine residues than other seabird species sampled concurrently. The scant knowledge of their movements suggests that petrels disperse widely offshore in the winter to the mid Atlantic with subsequent mixing of populations. Therefore, the geographical differences evident in 1972 reflect differences in local contamination at the breeding colonies.

The relatively high organochlorine levels in this species reflect its diet of invertebrates and larval fish (Linton, 1978) obtained in the lipid-rich surface layer of the ocean where airborne organochlorines are deposited (Bidleman and Olney, 1974). Tanabe et al (1984) also found elevated amounts of many organochlorines in the surface layers of both oceans.

Since DDE is at present declining slowly to levels approaching 1.0 ppm in eggs in the Bay of Fundy and 0.5 ppm in Newfoundland, there is probably no current threat to storm-petrel populations due to pesticide contamination. More reliable censusing of local populations will provide information on the influence of other factors affecting the status of this species. The continuing presence of significant amounts of some contaminants, particularly the chlordane compounds, warrants future sampling, particularly where populations are declining.

Double-crested Cormorant

The Double-crested Cormorant, although apparently flourishing now in most parts of eastern Canada, has shown evidence of population declines in the past, particularly in the Great Lakes. Milton and Austin-Smith (1983) estimated the Nova Scotia population of Double-crested Cormorants to be over 12,000 breeding pairs in 1982, three times the population in 1971. In the St. Lawrence River estuary at Iles aux Pommes, Desgrange and Reed (1981) found a 1.7 fold increase in cormorants between 1963 and 1980, while in Maine where cormorant control measures had severely reduced the population, numbers rose 10 % from 1972 to 1977 (Buckley and Buckley, 1984). Only the relatively small population along the Quebec north shore of the Gulf of St. Lawrence declined, by 53 %, between 1972 and 1977 (Chapdelaine, 1980), but increased again by 1982 (Chapdelaine and Brousseau, 1984).

Pearce et al (1979) calculated a critical value of 10 ppm DDE in eggs of this species to cause 20 % eggshell thinning. This was confirmed by other studies. Significant eggshell thinning and population declines were reported in cormorant populations from the Great Lakes associated with DDE egg residues of 7 to 11 ppm (Postupalsky,1971). On Lake Huron in 1972, Weseloh et al (1983) found DDE residues of 14.5 ppm in eggs to be associated with 24 % shell thinning and near total reproductive failure. Another dramatic example of DDE toxicity occurred in California in the 1960's where Gress et al (1973) documented almost complete reproductive failure in Double-crested Cormorants (and pelicans) with egg residues in the order of 24 to 32 ppm DDE wet weight.

The toxicity of PCBs to the similar Cormorant (Phalacrocorax carbo) of Europe was studied by Koeman et al (1973) who induced mortality in experimental birds when liver PCB levels reached 250 ppm and brain levels 130 ppm, wet weights. These values corresponded to levels found in wild cormorants found dead in Holland during instances of suspected pesticide poisoning, but there was a strong possibility of synergistic effects from other contaminants. DDE in body tissues was close to 20 ppm, dieldrin levels in livers over 1.0 ppm and HCB residues over 10 ppm, wet weights.

Although the mean levels of DDE in eggs of Double-crested cormorants from the Atlantic coast (Table 1, Appendix 5) in 1970 to 1973 were in the 4 to 8 ppm range, 20 % of the eggs, particularly from the Bay of Fundy and Baie des Chaleurs contained DDE residues greater than 15 ppm, enough to have deleterious effects. Egg lipid levels varied considerably, presumably reflecting differences in the fat levels of females, from about 3% at most colonies to 9 % at Manawagonish I. and along the north shore of the Gulf of St. Lawrence. Conversion of DDE residues to a fat weight basis revealed that eggs with the most concentrated organochlorine levels were from Ile aux Pommes (in the St. Lawrence estuary), Baie des Chaleurs, the Magdellan Islands and some colonies on PEI.

In the early 1970's, egg levels of DDE and PCBs were not significantly different between cormorant colonies along the Atlantic coast and in the Great Lakes. Only mercury was significantly higher in the Great Lakes. Since the early 1970's, only DDE decreased (not significantly) at the Ile aux Pommes colony, while in the Bay of Fundy, DDE, PCBs and dieldrin decreased significantly. In the Great Lakes, levels of most organochlorines have decreased, and reproductive success is much higher than a decade ago (J.Struger, pers. comm.)

Cormorants from the Atlantic coast and the Great Lakes probably mix during the winter in coastal waters of southeast USA and the Gulf of Mexico. The rapid decline of DDE residues in eggs of cormorants from the Bay of Fundy is undoubtably related to the cessation of forest spraying of DDT in New Brunswick. The decline of this contaminant in other regions is probably more related to the ban on this compound throughout North America since 1971, although its persistent nature and previous high usage rate still make it the most prevalent pesticide-derived contaminant in wildlife tissue.

In the heavily contaminated Great Lakes, cormorant numbers have risen rapidly since DDE levels started to decline. In Atlantic Canada, it appears that while certain individuals were affected by organochlorines, the population was unaffected. Factors such as recruitment, food supply and high reproductive ability may have over-ridden any contaminant effects.

We therefore conclude that there is presently no threat to Double-crested Cormorant populations in Atlantic Canada due to pesticide contamination but that the stable or increasing levels of many contaminants, particularly in the Gulf of St. Lawrence should continue to be monitored.

Northern Gannet

Northern Gannet populations in North America and worldwide have declined since the late 1800's as a result of human persecution and habitat disturbance. Since protection in North America in 1917, the Canadian population, which breeds primarily on Bonaventure I.) increased slowly until the 1960's (Nettleship, 1975). In the late 1960's, very low hatching success and a high incidence of egg breakage and loss was noted at this colony. Fresh and addled eggs were collected for analysis, and an investigation of the reproductive failure and population decline, was initiated.

Detailed studies of the productivity of gannets on Bonaventure I. were undertaken in 1966, '67, '70 and '74, and further productivity measurements taken in 1976, '79 and '84. (Chapdelaine et al, in prep.). Net productivity rose from a low of 29.6 % in 1966 to 75.1 % in 1984, the earlier high failure rate apparently due to the failure of eggs to hatch.

Eggshell thickness from 1968 to 1970 was about 20 % thinner than in 1984 or pre-1947. Many eggs collected in 1969 had no outside shell cover.(Elliott et al, in prep.) DDE, the contaminant associated with eggshell thinning was significantly negatively correlated with eggshell thickness. Other contaminants were also correlated with eggshell thickness, as well as with DDE.

These studies provide evidence that elevated DDE levels in the eggs of gannets can reduce reproductive success and result in population declines. Since the banning of DDT and other organochlorine pesticides, the Bonaventure Island population of gannets has started to recover.

During the late 1960's, the carcasses of gannets found dead in the Gulf of St. Lawrence contained extremely high tissue levels of some organochlorines. The brain levels of up to 49 ppm DDE, 2.5 ppm DDD, and 81 ppm PCBs (Table 1, Appendix 6) are below the lethal ranges established by Stickel (1973) and others. It is possible, however, that the dieldrin concentrations of 1.44 ppm may have contributed to mortality, by triggering irreversible starvation, as noted in other birds (Heinz and Johnson, 1982).

Gannets at this colony were exposed to large amounts of DDT and related compounds from the N.B. forest spraying program until 1967, many contaminants (particularly PCBs) from the relatively polluted St. Lawrence River outflow, and to a variety of contaminants in their wintering areas along the southeastern coast of the U.S. This species appears relatively vulnerable to organochlorines due to its typical diet of large-bodied "fatty" fish and its habit of incubating the egg underneath its foot such that thin-shelled eggs are easily broken.

Although DDE was the major contaminant apart from PCBs, and the toxin associated with eggshell thinning, it should be noted that all other contaminants (except a-HCH) were also significantly negatively correlated with hatching success. Dieldrin levels in some eggs (up to 2.5 ppm in addled eggs) were high enough to have impaired reproduction in pelicans (Blus, 1982), shags (Potts, 1968) or ospreys (Wiemeyer et al, 1975). PCBs in some eggs were also at levels associated with embryotoxic effects in some species (Peakall, 1972). The effects of the relatively high levels of chlordane compounds are not known. Levels of all chlordane metabolites detected (cis and trans chlordane, oxychlordane and cis-nonachlor) were significantly higher in unhatched eggs than in randomly collected eggs during the early 1970's when productivity was very low.

The Northern Gannet population at Bonaventure Island is currently recovering, apparently associated with the decrease in DDE egg levels since the ban on DDT. However, there remains the possibility of synergistic effects of the other organochlorines which were also correlated with reproductive failure, and which are not necessarily decreasing in gannet eggs. A-HCH appears to be increasing and most chlordane compounds are stable.

Common Tern

The Common Tern, like several other tern species, has experienced recent declines in North America and Europe. In particular, many colonies in Atlantic Canada have either disappeared or been reduced (Brown and Nettleship, 1984). There is no doubt that threats due to habitat destruction, gulls and persecution on their wintering grounds are major factors in the decline; the role of pesticide contamination is less clear.

Reduced hatching success and eggshell thickness were associated with DDE residues in Common Tern eggs at levels greater than 5 ppm wet weight by Fox (1976), who also speculated on toxic effects related to shell structural abnormalities at even lower residue levels. Nisbet and Reynolds (1984), in an extensive study of organochlorine residues in tissues of Massachusetts Common Terns and their prey, recorded hatching failure associated with significantly higher DDE levels (2 ppm) at only one colony. Most sites showed no significant differences in residues between successful and failed nests.

PCB levels as high as 51 ppm (converted to wet weight) in tern eggs have been associated with some incidence of congenital abnormalities (Gilbertson et al, 1976) but whether this was due to the PCB or microcontaminants such as dioxins or dibenzofurans is not clear.

The levels of organochlorine residues in Common Tern eggs collected by CWS, 1970 to 1975, along the Atlantic coast (Table 1, Appendix 5), were lower than those found in the studies mentioned above, DDE usually less than 1.0 ppm and PCBs less than 2.0 ppm. These values are similar to levels measured by Custer et al (1983) in eggs of this species from several colonies along the eastern U.S. coast, in 1983. In contrast, DDE and PCB concentrations in Common Tern eggs from the industrialized Great Lakes in the early 1970's, were considerably higher than in coastal samples (Gilbertson, 1974).

Fox (1976), who found no contaminants in their prey at a colony in Alberta, speculated that Common Terns were exposed to contaminants in their wintering range in South and Central America. However, studies in Hamilton Harbour (Gilbertson, 1974) found significant increases in PCBs, DDE, HCB and dieldrin during the breeding season. The local contribution to the contaminant levels in eggs is dependent on the time present at the breeding grounds prior to egg-laying. In the Hamilton Harbour study, this was about 4 weeks, long enough for most contaminants to approach equilibrium between environmental and body residue levels, according to calculations by Clark et al (1986) for Herring gulls.

Ohlendorf et al (1985) documented 27.3 % hatching failure in a colony of Caspian Terns (Hydroprogne caspia) in California in the early 1980's, where DDE egg levels averaged 10 ppm wet weight. They were able to correlate eggshell density but not reproductive failure with DDE residue levels. The high incidence of broken and thin-shelled eggs observed over several years suggested that significant eggshell thinning was occurring.

Although the organochlorine levels in the eggs of the Common tern in Atlantic Canada appear to be below levels known to affect reproductive success, the current decline of this species warrants further investigation. Pesticide use in the wintering area continues unabated (Maltby, 1980); toxins such as HCH and chlordane are currently in use in North America, yet no tern eggs from Atlantic Canada have been analyzed since 1975. It is possible that the present decline of the Common Tern in many areas (although due to many factors) is being enhanced by continuing exposure to toxic substances on the wintering grounds and at certain breeding sites.

Razorbill

The Razorbill population of Canada was estimated by Brown (1985) to be in the order of 23,000 breeding pairs. The lack of census data for most locations (such as Labrador) does not allow the determination of trends. However, colonies in the St. Lawrence estuary and gulf, declined 50 % between 1969 and 1975. Razorbill populations along the north shore of the gulf decreased a further 22 % between 1977 and 1982 (Chapdelaine and Brousseau, 1984), but have probably increased during the past ten years in the St. Lawrence estuary (Chapdelaine, pers. comm.). Declines were also reported for populations in Europe (Evans, in ICBP, 1984).

Levels of organochlorines in razorbill eggs (Table 1, Appendix 5), were high, over 40 ppm DDE and over 80 ppm PCB wet weight in some addled eggs (dehydrated to 50 % water). All organochlorines and particularly PCBs were higher than residues found in any other alcid eggs from the Atlantic coast. Scanty banding recoveries suggest that razorbills, unlike other east coast alcids, winter south to George's Bank along the coast of New England (Brown, 1985), rather than along the Newfoundland continental shelf. The high levels of contaminants, particularly PCBs, in this species could be the result of exposure in the industrialized area from Massachusetts to Long Island. The significant differences in PCB levels between colonies in the estuary and those in the gulf suggest considerable local exposure.

Chapdelaine and Laporte (1982) examined the above CWS data with respect to hatching success, eggshell thickness and DDE residues in razorbill eggs from several colonies in the St. Lawrence gulf and estuary. They found no correlations although samples were admittably small, and concluded that human disturbance and oil pollution in the wintering areas were more likely causes for the decline.

The levels of organochlorines in fresh razorbill eggs from the gulf of St. Lawrence (2 - 4 ppm DDE, 8 - 22 ppm PCB) were lower than those found by Andersson et al (1974) in the Baltic Sea during the early 1970's, who also found no correlation between DDE residues and eggshell thickness. Barrett et al (1985) found that organochlorine residues in razorbill eggs were higher, but not significantly, than in murres or puffins sampled concurrently, although these eggs from Norway in 1983 were relatively clean (2.22 ppm PCB and 0.83 ppm DDE).

The temporal trends of organochlorine concentrations were similar to those of the Double-crested Cormorants breeding in the gulf of St. Lawrence. Only DDE levels decreased significantly between 1972 and 1978; PCBs and dieldrin remained stable, while HCB and heptachlor epoxide increased significantly.

High concentrations of DDT metabolites and PCB congeners have also been reported in the tissues of stranded Beluga whale (Delphinapterus leucas) in the St. Lawrence estuary (Masse et al, 1986). Considering the relatively high levels of some organochlorines, particularly PCBs and chlordane compounds, in Razorbill eggs and the population decline in the Gulf of St. Lawrence, further investigation seems warranted. Although there is no evidence yet of reproductive effects or eggshell thinning, PCBs or other environmental contaminants may be impairing survival or productivity in other ways.

Common Murre

The population of Common Murres in eastern Canada, estimated to be 568,000 pairs by Brown and Nettleship (1984), appears to be stable, even increasing in Newfoundland. In contrast, the colonies in the Gulf of St. Lawrence may be declining

(Chapdelaine,1980). Worldwide, its status is variable, stable or increasing along the Pacific coast and Alaska, but declining in the southern parts of its range in Europe and Iceland (ICBP,1984).

As for other alcids, this species suffers mortality due to hunting, oilspills and drowning in monofilament fishing nets (Brown and Nettleship, 1980). The role of pesticide contamination is unknown. Dyck and Kraul (1984) looking at murre colonies in the polluted Baltic Sea and the cleaner Faeros Islands found that DDE residues as high as 75 ppm wet weight were not correlated to eggshell thinning or population declines. They did discover that eggshell thinning was related to methylmercury levels and seawater salinity, and postulated that the shell and saltglands had similar regulatory mechanisms such that local salinities affected eggshell thickness. No population decline was observed in the Baltic colonies with high (>75 ppm) residues of DDE, but since no reproductive data was available, factors such as recruitment could mask any individual effects.

On the other hand, Gress et al (1971) found that DDE levels of 43 ppm wet weight were associated with 13 % eggshell thinning in murre eggs from the Farallon Is. in California. These conflicting conclusions about the association between eggshell thinning and DDE residues have been recorded in other seabird species. Jorgensen and Kraul (1974) found both positive and negative correlations in Herring Gull eggs collected from the same colony in different seasons. Fox (1976) found highly significant negative correlation between shell thinning and DDE residues of 5 ppm wet weight in Common Tern eggs from Alberta, while Switzer et al (1971) also in Alberta, found no correlation in eggs of the same species at DDE levels of 8 ppm. It was further suggested by Fox (1976) that DDE might influence shell quality and therefore hatching success in other ways than thickness, for example structural abnormalities.

Levels of organochlorines in eggs of Common Murres collected by CWS (Table 1, Appendix 5) were lower (1 - 2 ppm DDE, 2.2 ppm PCB) than any levels known to have adverse effects in other species. These values from 1968 and 1971 are similar to levels found in Norwegian Common Murres (Fimreite, 1977) and considerably higher than in eggs from Alaska (Ohlendorf et al, 1978) in the early 1970's.

DDE and PCBs were possible factors in a mass die-off of Common Murres off the coast of Oregon in 1969 (Scott et al, 1975), where levels of 8.7 ppm wet weight DDE were found in the brains of dead birds; contrasted with an average of 0.44 ppm DDE in the brains of healthy individuals the following summer. PCB levels were 4.0 and 1.1 ppm in dead and healthy birds, respectively.

Although food shortage appeared to be the primary cause for this mortality, as in other reports of seabird wrecks, it appears that mobilization of lipids during starvation may result in lethal brain residues even where body burdens are relatively low. Jefferies and Parslow (1976) dosed murres with PCBs at varying concentrations and found sub-lethal effects related to the thyroid glands. At higher dosages, the thyroid atrophied, thyrotrophin production was reduced, and the murres died with liver concentrations similar to liver concentrations in dead murres from wrecks.

Eastern Canadian murre populations are currently stable and contaminant levels are low. However, it appears that even low background contaminant levels with little effect on reproduction, may be lethal during periods of poor food availability, or to seabirds caught in oilspills.

Black Guillemot

Very little is known about the population size or status of the Black Guillemot in Canada but it appears to be stable elsewhere (ICBP, 1984). This species breeds along the Atlantic coast from New England to the arctic. There is a tendency (Brown, 1985) for guillemots from the arctic to disperse southward in the fall but most individuals winter close to the breeding sites.

There have been no reproductive studies related to contaminant levels. Miller et al (1976) found inconclusive evidence that DDE-dosed young guillemots lost weight and died at liver concentrations of 21 ppm wet weight DDE , comparable to the DDE levels found in livers of dead murres from wrecks along the English coast. These workers also demonstrated that DDE-induced osmoregulatory failure was not involved in these mortalities as suggested by work with mallards (Friend et al, 1973).

Organochlorine levels in eggs (1.0 ppm DDE and 2.14 ppm PCB) and breast muscle from the Gulf of St. Lawrence in 1973 (Table 1, Appendix 6) were lower than in puffins or razorbills, but similar to those in Common Murres. However, the small sample size and the lack of reliable population data precludes any conclusions about the present threat of pesticides to this species.

Perhaps the Black Guillemot would be most useful as an indicator of local contaminant conditions. This species is resident in the Gulf of St. Lawrence, and although adults are omnivorous, chicks are fed primarily on benthic fish (Table 1, Appendix 7). Data from other species (razorbills and cormorants) suggests that other than DDE, most organochlorines are not decreasing in the estuary. Future monitoring of levels in the tissues and eggs of the resident Black Guillemot might provide more appropriate data to assess contamination of the St. Lawrence system.

Dovekie

Dovekies, which have been recently reported breeding near Baffin Island (Finley and Evans, 1984), are a regular winter visitor to low arctic and boreal waters. Little is known about the status of Dovekie populations, even in Greenland where 80 % of the world population breeds, but there are no obvious declines anywhere (ICBP, 1984).

Breast muscles of Dovekies collected in Davis Strait in 1968 (Table 1, Appendix 6) had extremely low levels of organochlorines, compared to other arctic species. These low levels (0.015 to 0.030 ppm DDE) were partly due to the low lipid levels, but even converted to fat weight, organochlorine levels were well below levels known to cause toxic effects in any species. Norheim and Kjos-Hanssen (1984) analyzed livers and fat of Dovekies from Spitzbergen in 1980 and found DDE levels of 0.067 ppm in livers, 2.1 in fat, and PCBs at 0.20 in livers and 7.1 in fat. It appears that this planktivorous alcid does not readily accumulate organochlorines and populations are therefore at no risk from this source.

Atlantic Puffin

The Canadian population of Atlantic Puffins has apparently declined over the past several decades (Nettleship, 1977). Worldwide, they are showing declines in parts of their range, including the United Kingdom, Norway and Iceland (ICBP, 1984).

In a study by Ingebrigtsen et al (1984), DDE residues of 0.5 ppm wet weight in eggs were eliminated as a serious factor in impaired reproduction at certain colonies in Norway. They did note, however, that chicks with very little body fat contained significantly higher organochlorine residues (up to 150 ppm DDE in the liver) and that lipophilic contaminants might have lethal effects near starvation. Miller et al (1976) also noted that dietary DDE was toxic to young puffins particularly during the fasting stage prior to fledging. A daily dose of about 50 ppm DDE prior to fasting resulted in liver levels of 805 ppm, enough to cause mortality. Control puffins also undergoing this voluntary fast were not affected and contained tissue levels of DDE less than 5 ppm wet weight. Harris and Osborn (1981) found no reproductive effects in Atlantic Puffins dosed with PCB, although liver levels reached 45 ppm and fat levels reached 650 ppm three months later. They noted, however, that conditions for puffins on the Isle of May were very favourable.

The levels of organochlorines found in puffin eggs from the Atlantic coast (Table 1, Appendix 5) were highest in the Bay of Fundy, in 1972, when DDE levels reached 2.5 ppm wet weight and PCBs 8.12 ppm. Levels of DDE, dieldrin and PCBs, but not HCB or heptachlor epoxide in the Gulf of St. Lawrence and from eastern Newfoundland were lower than in the Bay of Fundy. By 1984, DDE and PCBs were decreasing, dieldrin and HCB were stable, but heptachlor and oxychlordane had increased. The 1984 values are comparable to those found by Barrett et al (1985) in puffin eggs from northern Norway where reproductive failure had occurred at some colonies.

Puffins, like other alcids, are sometimes found dead in seabird wrecks. Parslow et al (1972) reported elevated levels in carcasses of puffins found in England in the late 1960's with 200 times the DDE and 20 times the PCBs of healthy birds. As in the case of the chicks, lipid mobilization resulted in high contaminant levels (20 ppm PCB and 2 ppm DDE) but was not necessarily the cause of mortality.

Since puffins evidently undergo periodic food shortages as a result of a variety of environmental conditions, it is possible that pesticide contamination has enhanced the effects of starvation and thus contributed to the puffin decline. The fasting period in chicks prior to fledging may also result in elevated tissue levels high enough to cause mortality or have sublethal effects. If organochlorine levels continue to decrease as in the case of DDE and PCBs, their influence should become less important relative to other causes of mortality. The current increase in certain chlordane compounds however, may become a significant factor, and we therefore suggest that the monitoring of contaminants in this species continue.

Common Eider

Numbers of Common Eiders in eastern Canada are fairly stable (Reid, 1985). Populations along the coast of Nova Scotia, in the Gulf of Maine, the St. Lawrence estuary and in the low arctic are healthy; only the Hudson Bay and gulf of St. Lawrence populations appear to be declining. Eiders from the gulf of St. Lawrence and further north tend to winter off the coast of southern Nova Scotia with the more sedentary eiders from the boreal regions, resulting in mixing of populations outside the breeding season.

DDE at brain levels greater than 100 ppm caused mortality in Common Eiders breeding in Holland (Koeman et al, 1972), where the incubating females that had metabolized most of their body fat were the most severely affected.

Eider eggs collected in 1972 from several locations in eastern Canada were all low in organochlorines (Table 1, Appendix 5). DDE, dieldrin and PCB levels were significantly higher in eggs from the Bay of Fundy and the St. Lawrence estuary than in eggs from two colonies in the gulf of St. Lawrence. HCB and heptachlor epoxide were not significantly different between locations.

The low DDE values, generally less than 0.5 ppm, reflect the eider's diet of intertidal invertebrates, particularly molluscs, which are usually low in organochlorine contaminants. In eider eggs from two remote colonies in the gulf, PCB concentrations were low, less than 0.6 ppm, but in the relatively industrial Bay of Fundy, PCB levels were 4.37 ppm.

By 1977, in nearby Maine, both DDE and PCB levels had decreased to 0.23 and 1.6 ppm, respectively, which fits the general pattern of decreasing organochlorine residues in other seabirds (Szaro et al, 1979). One egg of this species from Greenland in 1972 contained barely detectable levels of DDE or PCBs (Braestrup et al, 1974) as expected in this remote location.

Since contaminant residues in eider eggs were not at all consistent with population declines, it appears that organochlorines can be eliminated as a factor in any declines of Canadian eider populations.

4.2.2 Pacific Coast Seabirds

Fork-tailed and Leach's Storm-petrels

Two species of storm-petrels, the Leach's and the Fork-tailed regularly breed in British Columbia. Censuses of these species have been too recent and incomplete to allow any conclusions about population size or status. In Alaska, both species are thought to have increased in recent decades (Lensink in ICBP, 1984) based mainly on re-establishments of colonies previously exterminated by foxes. To the south, in California, the much smaller populations of storm-petrels may be declining (Jehl in ICBP, 1984).

Eggshell thinning associated with elevated DDE residues has been reported for several petrel species. Pearce et al (1979) calculated a critical value of 12 ppm DDE (wet weight) to cause 20 % eggshell thinning in the Leach's Storm-petrel. On the Pacific coast, Coulter and Risebrough (1973) found DDE levels of 43 ppm in eggs of the Ashy storm-petrel associated with 9 % eggshell thinning, but did not report any effects on reproductive success. The toxic effects of PCBs or other organochlorines have not been studied in these species.

The small sample of Fork-tailed Storm-petrel eggs, all from the Queen Charlotte Islands, contained some of the highest residue levels of any western species sampled (Table 2, Appendix 5), with DDE close to 2 ppm and PCBs approaching 10 ppm in 1970. Leach's Storm-petrel eggs collected from the same sites as the Fork-tailed consistently contained significantly less DDE, and less than 20 % of the PCBs, HCB or oxychlordane.

These differences suggest that the two petrel species differ significantly in diet, foraging behaviour and/or wintering areas. Virtually nothing is known about movements outside the breeding season, although banding returns of Atlantic storm-petrels show wide dispersal over long distances. Both species have been described as strictly surface feeders with a diet of fish, squid, copepods and euphausiids (Palmer, 1962: Wataniki, 1985: Linton, 1978), mainly prey which rises to the surface at night. However, some feeding studies of Fork-tailed Storm-petrels included offal in the diet (Martin, 1942 : Gill, 1977). Whale carcasses or scraps of large commercial fish, because of their higher trophic level and size, might be expected to contain more organochlorine residues, as reported by analyses of seals (Addison et al, 1984) and dolphins (Tanabe et al, 1984).

Although the prevalence of carrion in the diet of the Fork-tailed storm-petrel is unknown, it is a possible explanation for the higher residue levels in this species. In addition, the typical storm-petrel diet of zooplankton and larval fish obtained from the oily surface layer of the ocean contains significant amounts of atmospherically borne lipophilic organochlorine compounds (Seba and Corcoran, 1969).

Eggs of Leach's Storm-petrels from western Vancouver I. and the Queen Charlottes, in 1970 and 1985, did not differ significantly in residues among locations, except for higher dieldrin levels in the south, in 1970. This implies that local exposure levels are similar in both of these remote locations. The levels of contaminants presented here are comparable to those found in eggs of Leach's Storm-petrel from Oregon in 1979 (Henny et al, 1982) . In eggs of Fork-tailed Storm-petrels from Oregon, DDE levels (but not PCBs) were considerably higher (12 ppm wet weight) than in B.C. A probable source of DDT compounds in Oregon (and southern B.C.) was the extensive tussock moth control program in the northwestern states (Henny, 1977). Organochlorine residues in eggs of both species from Alaska in the mid 1970's were lower than residues in British Columbia (Ohlendorf et al, 1982).

All organochlorine residues declined between 1970 and 1985, in both species, although none of the chlordanes could be included in this comparison.

Based on the decreasing organochlorine residues in eggs of storm-petrels from the Pacific coast, there appears to be no current threat due to contaminants.

Double-crested and Pelagic Cormorants

The western subspecies of Double-crested Cormorant, which breeds mainly in the Strait of Georgia, has increased from a low of 219 breeding pairs in 1960 to 1600 in 1983 (Vermeer and Sealy, 1984). Jehl (in ICBP, 1984) reported similar increases in California.

The Pelagic Cormorant, which breeds on both sides of Vancouver Island and has recently colonized the Queen Charlotte Islands, has also increased over the past several decades (Vermeer and Sealy, 1984).

Cormorants, like pelicans, have been found to be relatively susceptible to organochlorines. DDE egg levels greater than 10 ppm wet weight were found to cause greater than 20 % eggshell thinning in Double-crested Cormorants from the Atlantic coast (Pearce et al, 1979) and in the Great Lakes region (Weseloh et al, 1983). On the Pacific coast, cormorants in California suffered almost complete reproductive failure in the late 1960's where mean DDE egg residues were as high as 32 ppm wet weight (Gress et al, 1973). PCBs have also been associated with reproductive failure and mortality in cormorants from Holland (Koeman et al, 1973) at brain PCB levels of 130 ppm.

In 1970, a pool of eggs of Double-crested Cormorants from Mandarte I. contained DDE residues of 4.0 ppm and PCBs at 14 ppm, but by 1979 and 1985, levels of all contaminants were considerably lower (Table 2, Appendix 5). Where both cormorant species were sampled concurrently, DDE, PCBs and HCB were significantly lower in the Pelagic Cormorant eggs, in contrast to dieldrin and most chlordane metabolites, which were lower in the Double-crested. Neither species is migratory in British Columbia, but there may be differences in wintering areas. Studies of the diet of these species on the Pacific coast (Table 2, Appendix 7) suggest that the Pelagic Cormorant may include more zooplankton (decapods) and proportionally more pelagic fish in its diet than the Double-crested Cormorant, but otherwise their diets overlap considerably (Robertson, 1974; Palmer, 1962). It seems likely that the larger benthic fish preferred by the Double-crested cormorant contain higher levels of the more persistent organochlorines, but the pattern for dieldrin and chlordane does not fit this hypothesis.

Mercury concentrations of 2.1 ppm in livers of Pelagic cormorants from Nanaimo in 1968-69, presumably originated from a nearby pulp mill that had used mercury slimicides. Mercury at this level has not been associated with toxic effects.

In 1970, only HCB differed (by a factor of 15) in eggs of Pelagic Cormorants from two sites in the Strait of Georgia. By 1985, egg contaminants were similar between eggs from the strait and the west coast of Vancouver I., except for higher PCBs in the more industrialized strait. Organochlorine residues in this species were highest in the 1973 sample but had declined by 1985.

Considering the rapid population growth of both cormorant species in recent years, it is apparent that the contaminant related declines reported elsewhere did not occur in British Columbia. DDE, which was implicated in those reproductive failures, is currently at levels not associated with reproductive effects, and other contaminant levels are relatively low.

Glaucous-winged Gull

The breeding range of the Glaucous-winged Gull extends from Washington to Alaska, on marine islets. In winter, this species may move south along the coast as far as California or move offshore to the edges of the continental shelf (Vermeer et al, 1984). Coastal gulls feed opportunistically on refuse, littoral invertebrates and fish. Those wintering offshore feed on crustaceans and fish in upwelling zones, or follow fishing boats and whales for the same prey (Drury in Haley, 1984).

Based on data from some colonies, the Alaskan population may have increased significantly in the past few decades (Lensink in ICBP, 1984). The population in British Columbia has increased tremendously since the early 1900's, largely as a result of human enroachment (with its garbage dumps and fishing boats) and the cessation of commercial egging (Vermeer and Sealy, 1984). New colonies are still being established in the Strait of Georgia and the west coast of Vancouver Island.

Gulls are considered relatively insensitive to organochlorine contaminants. Keith and Gruchy (1972) estimated a DDE concentration of 162 ppm wet weight in eggs, to be the critical value causing serious (20%) eggshell thinning in the similar Herring gull. HCB levels up to 3.0 ppm and PCB levels over 100 ppm in Great Lakes Herring gull eggs may have contributed to poor reproduction during the early 1970's, but it appears that gulls of the genus *Larus* can tolerate higher contaminant levels than most other seabirds. However, because of their position on top of the food chain, gulls are capable of ingesting lethal doses of some toxins. A Glaucous gull found in convulsions in the arctic by Bogan and Bourne (1972) was found to contain 67 ppm DDE and 311 ppm PCBs.

Levels of organochlorines in eggs of Glaucous-winged Gulls from British Columbia were low, even lower than alcids from the same locations (Table 2, Appendix 5).

In 1970, DDE concentrations were highest (1.6 ppm) on Cleland I. on the west coast of Vancouver I., intermediate (0.50 to 1.4 ppm) in the Strait of Georgia, and very low (0.22 to 0.34 ppm) in Hecate Strait. HCB was also highest (0.046 ppm) on Cleland I. but very low (0.006 to 0.011) everywhere else. It is possible that DDE and HCB, which were extensively used to the south in California were carried north by the Davidson current to the west coast of Vancouver I. Levels of PCB, which are more indicative of local contamination, were equally high (about 2.6 ppm) in the industrial Strait of Georgia and Cleland I. PCB levels in Glaucous-winged Gull eggs from Hecate Strait in the north were significantly lower (0.50 ppm). Dieldrin levels showed no consistent geographic variation, but unlike the other contaminants, were higher than in other seabirds sampled concurrently.

By 1983, DDE levels in eggs from western Vancouver I. had declined to about 0.50 ppm, HCB levels to 0.013 ppm, dieldrin to 0.015 ppm, and PCBs to 0.96 ppm, wet weight. This represents a 2-3 fold decrease for all contaminants, at least in this region. In 1977, an analysis of eggs from Tsawwassen Bay revealed that between 1970 and 1977 in the Strait of Georgia, only dieldrin had declined significantly. DDE and PCB levels were about the same, and HCB concentrations had increased to 0.023 ppm.

Ohlendorf et al (1982) examined organochlorine contaminants in eggs of Glaucous-winged Gulls from many locations in Alaska during the mid 1970's. DDE, although generally similar to levels in our data, was occasionally much higher (over 5 ppm in some eggs from the Aleutian Isands). PCBs and other contaminants at these localities were also higher than elsewhere in Alaska. Since the Aleutians are the most remote Alaskan islands, this suggests that diet rather than location was the influencing factor. In the Alaskan gulls, HCB concentrations ranged from less than 0.01 ppm to 0.19 ppm. Dieldrin in the particularly contaminated eggs mentioned above was over 0.2 ppm.

Total chlordane residues in the eggs of Glaucous-winged gulls from western Vancouver I. in 1983 averaged 0.04 ppm, mainly in the form of oxychlordane. Chlordane residues in the Alaskan eggs ranged from 0.03 in most samples to over 0.2 ppm in the heavily contaminated eggs from the Aleutian Islands.

In 1979, the closely related Western gull (Larus occidentalis) showed little (5.4 %) eggshell thinning in Oregon, associated with DDE egg concentrations of 1.0 ppm. Therefore, levels of DDE in eggs of the Glaucous-winged Gulls from B.C. may have caused some eggshell thinning but not enough to seriously affect reproductive success.

Lipid levels in eggs of Glaucous-winged Gulls from B.C. were between 8 and 9 %, which should be considered when comparing organochlorine residue levels in these eggs to those in alcids and storm-petrels (with normally 15 % fat) or cormorants (with only 4 % fat).

Considering the obvious population growth of the Glaucous-winged gull in B.C., pesticide contamination has not had any effects on numbers. Levels of organochlorine residues in eggs from 1970 to 1983 were never high enough to have the toxic effects recorded in other locations for closely related species. This is due in part to the lower background levels on the British Columbian coast (of most contaminants) and possibly a less contaminated diet with more invertebrates than in other localities (Table 2, Appendix 7). The high contaminant levels found in two samples of the Alaskan gulls were probably due to a diet containing a large proportion of bird's eggs or chicks. On the Canadian west coast, it might be advisable to look at organochlorine levels in a population of Glaucous-winged or other gulls known to be feeding on birds or their eggs.

Common Murre

The breeding population of Common Murres in British Columbia, which numbers about 9,000 individuals, is considered stable. This species is increasing in California and Oregon to the south (Jehl in ICBP, 1984) and is probably stable in Alaska, despite local fluctuations (Lensink in ICBP, 1984). Common Murres collected outside the breeding season in British Columbian waters may originate from the large colonies in Oregon, or from southern Alaska.

DDE has been associated with eggshell thinning in this species. Gress et al (1971) found 13 % shell thinning in eggs from California with DDE levels of 40 ppm wet weight. In Oregon, DDE levels of 0.87 ppm (Henny et al, 1982), comparable to our data, were associated with 5 % eggshell thinning. Pesticide contamination has been suggested as the cause of murre wrecks in Oregon, where brains of dead birds contained 8.7 ppm DDE and 4.0 ppm PCBs (Scott et al, 1975).

Livers and whole bodies but no eggs, were analyzed for organochlorine contaminants in this species. Liver lipid levels vary more than egg lipids, but when converted to a fat weight basis, liver residues are considered analagous to egg residues (Vermeer and Reynolds, 1970). Organochlorine levels in whole bodies vary considerably, depending on the bird's condition, i.e. lipid content.

All murre samples were collected in Semiahmoo Bay, in the Strait of Georgia (Table 3, Appendix 6). The whole body sample, with 11.5 % lipid similar to that found in eggs, contained DDE residues of 1.21 ppm wet weight, PCBs at 1.04 ppm and HCB at 0.016 ppm. The high proportion of DDT (0.356 ppm), suggests recent exposure. In the liver sample, DDE was only 0.60 ppm but other contaminant residues were similar. Organochlorines found in murre eggs from Alaska in 1973-76 were slightly lower, except for HCB, which was as high as 0.11 ppm.

Contaminant levels found in Common Murre tissues appear to have had no effects on local populations and are below levels associated with adverse reproductive effects in this species. Murres disperse widely outside the breeding season and feed opportunistically primarily on fish, zooplankton and squid (Table 1, Appendix 7). Since they spend time in both "clean" and industrialized areas (such as the Strait of Georgia) and have a diet spanning several trophic levels, the sources of the contaminants cannot be ascribed.

Pigeon Guillemot

The resident Pigeon Guillemot breeds along the Pacific coast from southern California to Alaska. Census data for British Columbia is incomplete and therefore its population status is unknown. In Alaska, the estimated population of 200,000 is considered stable (Lensink in ICBP, 1984).

Miller et al (1976) apparently induced mortality in the physiologically similar Black Guillemot at liver DDE concentrations of 21 ppm, wet weight. However, due to mortality of the control birds for unknown reasons, this experiment was not conclusive.

Eggs of the Pigeon Guillemot were collected in 1970 from three locations in British Columbia. DDE residues were highest (1.26 ppm) in eggs from Cleland I. on the west coast of Vancouver I. than in the Strait of Georgia (0.6 ppm) and lowest in the Queen Charlotte Is. (0.16 ppm). PCBs, in contrast, were highest in the strait (3.54 ppm) than on Cleland I. (2.56 ppm) and very low in the Queen Charlottes (0.42 ppm). HCB concentrations showed a similar pattern as DDE, and dieldrin concentrations were low everywhere (less than 0.01 ppm).

The elevated PCB levels in the Strait of Georgia reflect its industrialization, and parallel the pattern found in cormorants. The higher levels of DDE and HCB found on Cleland I. imply long range transport by the Davidson current as hypothesized by Nelson and Myers (1976), from high use areas in California and Mexico. Levels of organochlorine contaminants in Alaskan guillemots in 1974 were considerably lower, 0.07 ppm DDE and 0.07 ppm PCB (Ohlendorf et al, 1982). In Oregon, in 1979, DDE levels of 0.26

ppm did not appear to have any effect on eggshell thickness (Henny et al, 1982) and PCBs were very low (0.33 ppm).

Mercury concentrations in eggs of Pigeon Guillemots collected from Mittlenatch I. in 1970 were at the low end of the range associated with reproductive effects in pheasants (Spann et al, 1972).

Although the current organochlorine levels found in eggs of the Pigeon Guillemot should not cause adverse effects, this species is particularly useful as an indicator of inshore contaminant levels. Unlike most alcids, this species apparently remains in the coastal zone throughout the year (Vermeer et al, 1983) which is reflected by its relatively high PCB/DDE ratio (2.0 to 6.0). Organochlorine concentrations in eggs were usually less than in other species sampled concurrently, perhaps because of its more omnivorous diet (than puffins or auklets), or due to a more efficient capacity to metabolize xenobiotics.

Marbled Murrelet

The status of the Marbled Murrelet in British Columbia is unknown although the population probably numbers in the tens of thousands. Alaskan populations are considered stable but there are some indications of a decline in California (ICBP, 1984). This species nests solitarily in forested habitat and very little is known about its breeding biology.

Murrelet tissue from Langara I. in the Queen Charlottes in 1969, contained low levels of organochlorines (Table 3, Appendix 6). The liver DDE concentration, which is most similar to levels in the egg, was 0.126 ppm, wet weight. Lipid level in these livers was 3 % which should be compared to the usual 10 to 15 % fat in eggs. Only the fat sample contained PCBs (at levels somewhat less than DDE), B-HCH and heptachlor epoxide.

Like the Ancient Murrelet, this species feeds mainly on small pelagic fish, and occasionally invertebrates. Organochlorine concentrations were low relative to other alcids, although its diet is intermediate in trophic level. In contrast, mercury levels in livers of this species from Horseshoe Bay in 1968-69 (2.23 ppm) were the highest recorded in any seabird from the west coast (Fimreite et al, 1971). However, the small sample size and lack of population data precludes any conclusions about the effects of organochlorines or heavy metals, if any, on this species.

Ancient Murrelet

About one half of the North American population of Ancient murrelets breeds in the Queen Charlotte Islands. In the early 1970's, Nelson and Myers (1976) investigated significant declines in the breeding population on Langara I. and Cox I. Sealy (1975) estimated a population of 80,000 pairs in 1968 to 1971, less than 20% of the original estimate in the 1940' and 1950's. By 1981, the population had further decreased to 22,500 pairs (Vermeer in ICBP, 1984). Ancient Murrelets and other alcids also disappeared from some smaller colonies near Langara Island.

In Alaska, Ancient Murrelets are increasing. Recovery is probably due to the elimination of introduced fox populations, which had previously wiped out many colonies of ground-nesting seabirds (Lensink in ICBP, 1984).

Analyses of both fresh and unhatched Ancient Murrelet eggs collected in 1968 revealed low levels of DDE (less than 1.0 ppm), DDT, DDD, endrin, dieldrin and heptachlor epoxide, and no differences in these residues between fresh and dead eggs (Table 3, Appendix 6). Organochlorine analyses of breast muscle, fat, liver and brain in 1968, 1971 and 1972 from adult birds revealed the presence of the contaminants mentioned above as well as HCH, HCB, PCBs and mercury. DDE levels were predictably highest in the fat but relatively low in the liver (0.13 ppm) and brain (0.07 ppm), tissues where toxic effects are usually manifested.

On Langara I., Ancient Murrelets are the primary summer prey of the resident Peregrine Falcons. Whole body DDE residues in murrelets from Langara I. in 1969 were 5.29 ppm wet weight (7 % fat) but only 1.03 ppm in whole bodies from elsewhere in the Queen Charlottes in 1970. Levels of DDE in prey in excess of 1.0

ppm are thought to contribute significantly to peregrine falcon adult burdens (Enderson et al, 1982). PCB levels in murrelet tissues were also low, less than 1.0 ppm, except in fat. The PCB/DDE ratio ranged from 0.15 in some whole bodies to 2.5 in livers.

Nelson and Myers (1976) speculated that the Ancient Murrelet decline at Langara I. was related to reduced food availability around the breeding colony. This was attributed to either changes in ocean currents and associated upwellings, or to poisoning of the food supply by contaminants brought north by the Davidson current.

There are no recent analyses of murrelet tissues from the Queen Charlottes to account for the further declines, since 1970. DDE in most other seabirds has declined over the past 15 years. Ancient Murrelet eggs from Alaska in 1974 contained DDE at 1.61 ppm and PCBs at 0.829 ppm (Ohlendorf et al, 1982), somewhat higher than on Langara in 1970.

HCH was not usually included in the analysis, but one sample of whole bodies in 1969 contained a very high concentration of B-HCH (0.968 ppm, wet weight). The toxicity of this contaminant has not been studied in seabirds, but levels as high as this may have significant effect. Tanabe et al (1984) found this compound to be very abundant in surface ocean water of the Pacific. Norstrom and Muir (1986) suspected Asian origin of this pesticide and suggested that long range atmospheric and oceanic transport was the main vector to the arctic. Ancient murrelets and other pelagic seabirds, particularly surface feeders, may be exposed to relatively high concentrations of HCH in the north Pacific.

Ancient Murrelets feed in the offshore zone on small pelagic fish and euphausiids (Sealy, 1975). Little is known about movements outside the breeding season, but like most alcids they probably disperse widely offshore.

Organochlorine contamination may have contributed to the murrelet decline at Langara Island in the Queen Charlottes, but considering the low residue levels, not by direct toxicity. Other possible reasons for declines of Ancient Murrelet populations include logging of forested habitat, mortality in fishing nets and current-associated zooplankton changes.

Cassin's Auklet

This abundant alcid breeds from southern California to Alaska. Its status in British Columbia is not known, except for population declines in the vicinity of Langara I. In Alaska, numbers are increasing as the introduced fox populations on the islands disappear (Lensink in ICBP, 1984). Cassin's Auklets also appear to be increasing in California (Jehl in ICBP, 1984).

The one sample of eggs from Moore I. in Hecate Strait in 1970, contained the highest DDE residues of any alcid; 2.92 ppm wet weight. PCBs were lower at 0.60 ppm, and HCB levels were 0.023 ppm (Table 3, Appendix 6). Analyses of whole bodies and tissues from the Queen Charlotte Islands in 1970 and 1971 revealed lower DDE concentrations in the order of 0.68 to 1.48 ppm, and PCBs from 0.38 to 1.04 ppm.

Eggs of this species in California in 1966 contained DDE concentrations as high as 10.4 ppm, and in whole bodies 2 to 15 ppm (Risebrough et al, 1967). Evidence of high levels of DDT contamination in coastal California, associated with reproductive failure, was found in some seabird species during the late 1960's (Blus et al, 1971: Risebrough et al, 1971), but no reproductive data was reported for the Cassin's Auklet during this period.

In the Queen Charlottes, the Cassin's Auklet feeds primarily on a copepod Calanus cristata (Vermeer, 1981) but other studies reported euphausiids, sand lance and other larval fish (Table 2, Appendix 7). This species is almost exclusively planktivorous, so the relatively high organochlorine levels in its eggs suggest that some species of zooplankton contain significant amounts of contaminants. The consistently low PCB/DDE ratio reflects the distance from industrial sources of the sampling locations, or possibly greater exposure to DDE than PCB in its diet.

Organochlorine levels in eggs and tissues of the Cassin's auklet do not appear to have caused any significant population declines. The toxicity of organochlorines to this species have not been studied, but the concentrations found in samples were considerably lower than levels known to have toxic effects in other alcids.

Rhinoceros Auklet

The North American population of the Rhinoceros Auklet numbers about 450,000, breeding mainly in Alaska and British Columbia. Its status in B.C. seems stable except at Langara Island where the colony disappeared between 1952 and 1970 (Vermeer and Sealy, 1984). In California, the small population is expanding, and in Alaska, numbers are apparently stable.(ICBP, 1984)

Tissue samples from Langara I. in 1969 contained low amounts of DDE, PCBs, dieldrin, heptachlor epoxide and B-HCH. Whole bodies from elsewhere in the Queen Charlottes in 1970 contained significantly more organochlorines: 5.88 ppm DDE, 0.14 ppm DDT and 2.76 ppm PCB (Table 3, Appendix 6).

Eggs of Rhinoceros Auklets from Lucy I. and Moore I. in Hecate Strait in 1970 were similar in organochlorine content. DDE levels were 2.1 to 2.8 ppm wet weight, and PCBs were 1.7 to 2.0 ppm. By 1985, both DDE and PCBs levels had declined to about 0.62 ppm, at Lucy Island. This is the only western alcid for which temporal data was available.

This species is almost entirely piscivorous (Table 2, Appendix 7). Main prey species include anchovies, herring, sand lance, capelin and surf smelt, all schooling pelagic fish (Manuwal in Haley, 1984). In winter, Rhinoceros Auklets disperse offshore. The relatively high organochlorine residue levels in this alcid probably reflect its preference for highly mobile "fatty" pelagic fish.

There have been no studies on the toxicity of organochlorines to this species but investigations of the similar Atlantic Puffin suggests that the concentrations found in eggs and tissues would not have significant effects on reproduction or populations. Like most of the west coast alcids, Rhinoceros

Auklets are probably in more danger from oil spills or mortality in fishing nets. Vermeer (1980) reported periodic reproductive failures in this species presumably due to food shortages, at Triangle I. As in puffins from the eastern Atlantic (Ingebrigtsen et al, 1984) it is possible that in years of low food availability, levels of organochlorine contaminants in the starving chicks may reach toxic concentrations.

Tufted Puffin

Close to 4 million Tufted Puffins breed in North America, most in Alaska where the population is increasing as the introduced fox populations on the islands decrease (Lensink in ICBP, 1984). In British Columbia, Tufted Puffins disappeared from several locations in the Queen Charlottes (near Langara I.) and have recently suffered almost complete reproductive failure at Triangle I. in three out of five years of studies (Vermeer et al, 1979). In California, the relatively small population of this species is also decreasing (ICBP, 1984).

Analyses of whole bodies (8% fat) from the Queen Charlottes in 1970 revealed low levels of DDE (0.35 ppm) and higher levels of PCB (1.00 ppm). HCB and dieldrin were also very low, 0.01 and 0.02 ppm, respectively. Puffin eggs (10 % fat) from Cleland I. on the west coast of Vancouver I. in 1970 were similar in DDE (0.42 ppm) and PCBs (0.67 ppm) but contained significantly more HCB at 0.13 ppm, wet weight (Table 3, Appendix 6).

Organochlorines in eggs of Tufted Puffins from Alaska in 1973 to 1976 were slightly lower than in B.C. (Ohlendorf et al, 1982). Henny et al (1982) found eggs of this species in Oregon in 1979 to contain somewhat more DDE (0.62 ppm) and less PCB (0.51 ppm) than on Vancouver I. in 1970.

Like the Rhinoceros Auklet, the Tufted Puffin is primarily piscivorous, feeding on herring, sardines, sand lance, anchovies, smelt, rockfish and occasionally squid in the offshore zone. Despite the similarities in diet, organochlorine levels in this species are significantly lower than in the Rhinocerous Auklet, and the PCB/DDE ratio is always in the order of 1.5 to 3. Since both of these alcids move offshore in winter and feed at similar trophic levels, we are unable to account for the differences in contaminant levels.

Tufted Puffins are obviously vulnerable to food shortages severe enough to cause reproductive failure for several years, and as discussed previously, this may result in elevated contaminant levels in food-deprived chicks. Ingebrigtsen et al (1984) reported organochlorine concentrations in cachectic chicks that were 300 times the concentrations in healthy chicks, easily high enough to have toxic effects. Considering the unstable status of this species in the southern parts of its range, it would be advisable to re-examine contaminant levels at colonies where reproductive failure are common.

4.2.3 Arctic Seabirds

Northern Fulmar

As discussed previously, Northern Fulmar populations are increasing worldwide, and there seems to be no threat due to pesticide contamination. Little is known about the status of the Canadian arctic population but there is evidence of range extension to the south, in Newfoundland and Labrador.

No studies exist relating contaminant levels in this species to toxic effects of any kind. Studies on other procellariformes (i.e. storm-petrels) documented eggshell thinning associated with elevated DDE residues (Pearce et al, 1979).

Organochlorine levels in livers of breeding fulmars from Prince Leopold I. in 1975 and 1976 (Table 3, Appendix 5), were lower than levels found in fulmars from the Labrador sea in 1971 (Table 1, Appendix 6). DDE in the livers ranged from 0.23 to 0.61 ppm wet weight, significantly higher than in livers of kittiwakes and murres collected at the same time. PCB in the fulmars were similar to concentrations in kittiwake livers (1 to 3 ppm) and considerably greater than levels in the murres.

Dieldrin, heptachlor epoxide and HCB concentrations in the fulmar livers were comparable to levels in the other species but oxychlordane was significantly higher (0.11 to 0.26 ppm).

Fulmars feed primarily on fish, squid and crustaceans (Shallenberger in Haley, 1984) but also obtain some food by scavenging from whale carcasses or fishing boats. Although scavenging does not appear to be important, at least during the breeding season in Lancaster Sound, it may be the source of the relatively high levels of some chlordane metabolites, particularly oxychlordane in fulmar livers. Muir et al (in prep.) found oxychlordane to be the major contaminant in adipose tissue of polar bears feeding mainly on Ringed seals. It is possible that closer examination of the isomer ratios of PCBs, HCH and chlordane metabolites would help to determine likely routes of contaminants to seabirds via the arctic food chain.

Organochlorine levels in livers of fulmars from Spitzbergen in 1980 (Norheim and Kjos-Hanssen, 1984) were comparable to concentrations in Canadian birds. Analyses of fulmar eggs from Alaska in 1975-1976 (Ohlendorf et al, 1982) revealed similar levels of DDE, dieldrin and HCB, but much lower levels of PCBs and particularly oxychlordane. These differences may be due to differences in background contaminant levels (between the Atlantic and Pacific oceans), differences in diet related to timing of the collection, or differential residue deposition in livers and eggs.

Fulmar populations are obviously in no danger. However, total chlordane residues in adipose tissue of polar bears at least doubled between 1969 and 1984 (Norstrom et al, in prep.) and may have increased in arctic seabirds as well, to potentially toxic levels. Oxychlordane, the most toxic, is already relatively high. Levels of other organochlorines appear to be well below effect levels found in studies of other seabirds.

Ivory Gull

Ivory Gulls, which number perhaps 1500 pairs in Canada, also occur in Greenland, Spitzbergen and the northwest USSR.

Population declines have been documented in Spitzbergen, and in Canada, this species has disappeared or moved from many of its former breeding sites (MacDonald, 1978). Ivory Gulls breed only in the high arctic (Ellesmere, Devon and Seymour Islands) and usually winter along the edge of the pack ice.

The organochlorine contaminant levels presented here are apparently the only data existing for this species. Being the only member of the genus Pagophila, its physiology and the significance of contaminant levels may differ from Larus gulls. However, most charadriiformes appear to be relatively tolerant of organochlorines.

Analysis of 10 eggs of Ivory Gulls from Seymour I. in the mid-arctic in 1976 revealed organochlorine residues similar to those in other arctic seabirds, with 0.46 ppm DDE, 0.024 ppm dieldrin, 0.061 ppm oxychlordane, 0.043 ppm HCB and 1.63 ppm PCB. All contaminants concentrations were much higher in the Ivory gull eggs than in an egg of the King Eider sampled concurrently (Table 3, Appendix 5).

Ivory Gulls feed primarily on fish, amphipods and euphausiids associated with ice edges, and to a lesser extent on the feces and carcasses of marine mammals (Divoky, 1976: Orr and Parsons, 1982). This species seldom moves south of the pack ice and therefore exposure to contaminants must occur in the arctic. None of the contaminants, including oxychlordane, were significantly higher than in more planktivorous species, suggesting that mammal carcasses were not important in the diet of these birds. Orr and Parsons (1982) noted seasonal changes in diet in that lantern fish were the principle prey prior to the breeding season, although Hooded seal remains were eaten in the winter.

Although we know nothing of population trends, the contaminant levels found in eggs of the Ivory Gull were lower than levels known to have toxic effects in other seabird species. There appears to be no immediate threat due to contaminants.

Black-legged Kittiwake

As in the case of some gulls and fulmars, the Black-legged Kittiwake population in Atlantic Canada (Gulf of St.Lawrence, Nova Scotia, Newfoundland and Labrador) has increased dramatically (ICBP, 1984). Nothing is known of the status of the kittiwakes in arctic Canada or Greenland, but numbers have also increased in northeast Europe, Norway and Iceland, and are at least stable in Alaska (ICBP, 1984).

The metabolism or toxic effects of organochlorine contaminants have not been studied in this species, but the high PCB/DDE ratio in tissues and eggs has been found over a wide geographical range (Bogan and Bourne,1972: Ohlendorf et al, 1982: Barrett et al, 1985). These workers suggested that the kittiwake had an enhanced ability to metabolize and excrete DDE.

Levels of DDE in kittiwake eggs collected from P.L.I. in 1976 were considerably higher (0.38 ppm) than in livers (0.01 ppm) from the same location. PCBs, HCB, oxychlordane and heptachlor epoxide residues were also greater in the eggs than in livers (Table 3, Appendix 5).

Although the DDE levels in livers of kittiwakes were considerably lower than in fulmar livers, they were similar to the levels in livers of Thick-billed Murres. Higher concentrations of DDE in kittiwake eggs also matched the DDE concentrations in eggs of murres and Ivory Gulls. In contrast, PCB levels in eggs or livers of kittiwakes (1.3 to 5.7 ppm) were higher than in any of the other seabirds sampled, particularly murres. This suggests that the high PCB/DDE ratio is the result of elevated PCB residues rather than low DDE concentrations, in contrast to the conclusion reached by Ohlendorf et al (1982) and others. Analyses identifying the specific PCB congeners (with respect to amount of chlorination) might be useful.

DDE and PCB levels in kittiwake eggs from P.L.I. were considerably higher than in eggs from Alaska (Ohlendorf et al,1982) but comparable to levels found in eggs from Norway (Fimreite et al, 1976 : Barrett et al, 1985).

Levels of HCB, dieldrin and heptachlor were similar in this species to those found in the other arctic seabirds. Oxychlordane was lower than in the fulmars and higher than in the murres.

The Black-legged Kittiwake feeds primarily on surface zooplankton and small fish. Like the storm-petrels, it forages only on the surface, and may therefore be exposed to the high concentration of contaminants present in the surface microlayer of the ocean (Seba and Corcoran, 1969). Nevertheless, there is considerable overlap in the diets of murres, kittiwakes and fulmars.

None of the organochlorines found in the tissues or eggs of Black-legged Kittiwakes were high enough to cause adverse effects in other seabirds. Considering the evident growth of kittiwake populations, we conclude that there is probably no effect on this species due to environmental contaminants.

Thick-billed Murre

Canadian Thick-billed Murre colonies have been only recently censused, making it difficult to determine population trends. Some colonies in Canada (at Cape Hay) and in Greenland and Iceland, are known to have declined in the past few decades, mainly attributed to hunting and mortality in fishing nets (Nettleship *in* ICBP, 1984).

Toxic effects of organochlorines have been documented in a number of studies in the related Common Murre. Gress *et al* (1971) reported 13 % eggshell thinning associated with 43 ppm DDE in eggs of the Common Murre in California. Parslow and Jefferies (1976) induced thyroid atrophy and eventually mortality in this species by dosing with PCBs. However, it appears that Thick-billed murres are less prone to mortality in the seabird "wrecks" described by Bailey and Davenport (1972) and others, for Common murres, even where both species co-exist.

Organochlorine contaminants found in eggs and livers of murres collected at Prince Leopold I. in 1975 to 1977, were at low levels, generally less than 0.5 ppm (Table 3, Appendix 5). DDE levels in the eggs averaged 0.34 ppm, compared to 0.12 ppm in adult livers and 0.08 ppm in livers of nestlings. This suggests that the murres arrive and start breeding at their breeding grounds relatively contaminated (from exposure in their wintering areas along the Newfoundland coast), but feed their chicks on the relatively uncontaminated fish of the arctic. Concentrations of PCB showed a similar pattern, but with more overlap between tissues. This species contained significantly less PCB than the other seabirds sampled at the same time, always under 0.5 ppm in livers and less than 1 ppm in eggs.

The diet of Thick-billed Murres is similar to that of the fulmars and kittiwakes, consisting of fish (mainly arctic cod), zooplankton and other invertebrates, but obtained by pursuit diving rather than surface feeding. The depth at which these murres feed may be the explanation for the relatively low DDE, PCB and chlordane compounds in this species. Only HCB was anomalous by being higher in murres than the other seabirds, perhaps related to levels in mid-strata or benthic fish also taken by murres during their dives.

Adult Thick-billed Murres at P.L.I., particularly early in the breeding season, feed on arctic cod and ice-associated amphipods (Gaston and Nettleship, 1983). Chicks are fed almost exclusively on fish, and may therefore be exposed to higher residues. Certainly, contaminant concentrations measured in fledglings represent local contamination. In a pooled sample of chick livers from 1976, all organochlorine concentrations were greater than in adult livers collected the same year. This may have been due to concentrations in the fish diet (cod, sculpins) of the chicks, or more likely, the less efficient detoxification mechanism in young birds.

Across the Atlantic, Norheim and Kjos-Hanssen (1984) found similar levels of DDE, HCB and PCBs in livers of Thick-billed murres from Spitzbergen, in 1980. In the northern Pacific, 1974 to 1976, Ohlendorf et al (1982) reported DDE and PCB levels in eggs of this species that were two to three fold lower than in eggs from P.L.I. Other contaminants such as oxychlordane and HCB were not significantly different. Muir et al (in prep.) ranked organochlorines in seals and marine fish as follows: Atlantic ocean, North Sea > north Pacific > arctic > antarctic. The relatively "high" levels in Thick-billed Murres from P.L.I. may be related to its more southern winter range, or more likely, to greater long-range input of pollutants via the Gulf Stream and Hudson Bay.

Ohlendorf et al (1982) was the only study to present contaminant data for Common and Thick-billed Murres from the same locations, and there was no consistent pattern of differences.

Organochlorine residues in Thick-billed Murres from the Canadian arctic were lower than concentrations known to cause eggshell thinning or induce other toxic effects in murres in other studies, and lower than levels in other alcids from further south along the east coast. Despite some colony declines in this species, organochlorine contaminant levels of this magnitude should have no significant effects.

King Eider

Very little is known about the status of King Eider populations in Canada. The breeding range of this species in Canada includes the arctic islands, the coast of N.W.T. and Hudson Bay. King Eiders from Seymour Island probably winter in the Bering Sea with the western arctic population. Eastern King eiders move as far south as Newfoundland, the nearest ice-free water.

One egg collected from Seymour Island, N.W.T. in 1976, contained very low concentrations of contaminants. DDE levels were 0.02 ppm, PCBs were 0.06 ppm, and other contaminants were less than 0.01 ppm. These are very close to the values found in three King Eider eggs from Greenland in 1972 (Braestrup et al, 1974) and are considerably below concentrations known to have toxic effects in eiders elsewhere (Koeman et al, 1972).

4.2.4 Other Seabird Species

The species discussed in this report are seabirds which breed in Canada for which we have egg or tissue contaminant residue data. The main focus is on marine pollution, so we have not discussed contaminants in populations breeding inland (ie. Common Terns on the Great Lakes), or species which are generally terrestrial foragers (ie. Ring-billed Gulls, Larus delewarensis). The following is a brief summary of what is known about contaminants in groups of seabirds not discussed elsewhere in this report, and status of these populations.

Among the procellariformes, the Black-footed Albatross (Diomeda nigripes) and two shearwaters, the Sooty (Puffinus griseus) and Greater (P. gravis), are regular common visitors to Canadian waters, although they do not breed here. Gaskin et al (1978) analyzed tissues of both shearwater species collected in August 1974, from the Bay of Fundy. Organochlorine and mercury concentrations were low. DDE in livers ranged from 0.03 - 0.65 ppm in the Sooty, and up to 3.0 ppm wet weight in the Greater. These workers speculated that the greater proportion of herring in the diet of the Greater was responsible for the higher residue concentrations. PCBs were as high as 4 ppm in some livers of female Greater Shearwaters, but all other compounds were less than 0.05 ppm. Another species, the Manx Shearwater (P. puffinus) has recently started to breed in southern Newfoundland in small numbers, but no samples have been analyzed. The only Black-footed Albatrosses analyzed were collected on Midway I. in the mid-Pacific in the early 1970's. Body fat was found to contain 22 ppm DDE, and 14 ppm PCBs (Fisher, 1973).

In the pelecaniformes, excluding White Pelicans (Pelecanus erythrorhychos) which breed on fresh water, there are two species of breeding cormorants not discussed in this report. The Brandt's Cormorant (Phalacrocorax penicillatus) breeds in small numbers in southern British Columbia, and the Great Cormorant (P. carbo) which breeds mainly in the Gulf of St. Lawrence. Neither species appears to be declining (Erskine, 1972; Vermeer and Sealy, 1984).

In this report, we discuss contaminant levels in only a few species of gulls or terns. The Glaucous (*Larus hyperboreas*), Iceland (L. *glaucoides*), Western, Great Black-backed (L. *marinus*) and Sabine's (*Xema sabini*) gulls are all primarily marine. Some of the larger species feed primarily on the eggs, young or adults of other seabirds during the breeding season. There have been few analyses for contaminants in most of these species, although their position at the top of the marine food chain warrants investigation. Szaro *et al* (1979) found high levels of organochlorines (8.7 ppm DDE, 0.22 ppm oxychlordane, 31 ppm PCBs, all wet weight) in eggs of Great Black-backed Gulls from Maine in 1977. They attributed these residue levels to the incidence of birds and mammals in the diet of this species, but noted that hatching success (76%) was similar to data reported elsewhere. Eggs of Western Gulls from Oregon in 1979 (Henny *et al*, 1982) contained levels of DDE of 1.0 ppm and PCBs at 0.47 ppm, considerably less than in storm-petrel eggs sampled concurrently. In contrast, tissues of Glaucous Gulls from Spitzbergen in 1980, where this species preys on seabirds and their eggs and also feeds on carrion, contained the highest levels of any species sampled there; 1.9 ppm DDE, 6.1 ppm PCBs, 0.14 ppm HCB and 1.6 ppm mercury in 6.2 % fat livers (Barrett *et al*, 1983). Glaucous Gulls have previously been reported dying apparently due to the toxic effects of DDE levels of 67 ppm and PCBs at 311 ppm in the liver (Bogan and Bourne, 1972). Little is known of the population status of these gulls in Canada, except for the Great Black-backed Gull, which like the Herring Gull, is increasing over much of its range (Nettleship, 1977).

Gulls such as the Ring-billed, Mew (L. *canus*), Bonapartes (L. *philadelphia*) and Franklins (L. *pipixcan*) are considered terrestrial, although some winter along the coast.

The Herring Gull has been extensively studied in terms of contaminants in Canada, particularly on the Great Lakes. The elevated contaminant levels in eggs of this species in the early 1970's and associated reproductive failure were well documented in a number of studies (Gilman *et al*, 1977: Weseloh *et al*, 1983).

Contaminant concentrations in eggs from colonies in Maine were much lower than on the Great Lakes, usually in the order of 2 ppm DDE and 8 ppm PCBs (Szaro et al, 1979). The population of Herring Gulls has increased dramatically in eastern Canada over the last few decades, in spite of past and present levels of organochlorine or heavy metal contaminants. Environmental contaminants in this species from the Atlantic coast and St. Lawrence River system will be discussed in another report (Noble, in preparation).

Of the tern species, only the Common Terns breeding along the Atlantic coast have been included. Residues in Caspian and Common terns breeding in the Great Lakes have been examined elsewhere (Gilbertson, 1974: Struger and Weseloh, 1985). The only data for the Arctic Tern (Sterna paradisaea) is from Alaska in 1971, where White et al (1973) found 1.8 ppm DDE in whole bodies. Many terns have suffered population declines recently, but these are mainly attributed to loss of habitat, and disturbance by humans and gulls.

One other group of seabirds, the jaegers and skuas, are also considered primarily terrestrial, although some certainly prey on seabirds or obtain fish by kleptoparasitism. Furness and Hutton (1979) found relatively high levels of environmental contaminants in the Great Skua (Catharacta skua) in the Shetlands, but no evidence of eggshell thinning or other reproductive effects. It is possible that where jaegers are feeding to a large extent on seabirds or their eggs, significant contaminant residues may be accumulated.

5. CONTAMINANT DYNAMICS

In the previous section, we discussed the possible toxic effects of organochlorine and heavy metal contaminants on Canadian seabird species, in terms of mortality, population declines and reproductive failure. In this section, we examine the fate of the various contaminants in the marine ecosystem from probable sources, routes of input to the environment and metabolism in avian systems.

The contaminant burden of relatively long-lived seabirds is the result of both recent and longterm exposure, through its diet, during and outside the breeding season. These concentrations are further influenced by the physiological capacity of the particular species to metabolize these compounds, its age, sex and seasonal changes in condition (amount of fat) and organ composition. Differences in residue levels between species must take into account the combined effects of these factors.

Walker and Knight (1981) measured the relative activity of some xenobiotic-metabolizing enzymes in several seabird species from Britain. They found that species such as the puffin had a greater capacity to metabolize foreign compounds than the shag. Hepatic detoxification by the mixed-function oxidase system in fledgling Herring Gulls was investigated by Peakall et al (1986) and Boersma et al (1985), who found no correlation between organochlorine residues and enzyme activity. The age of the nestling and the rate of growth of its tissues were found to be important influences on enzyme activity levels. In general, we will not consider hepatic detoxification as a variable influencing residue levels for the purpose of this report.

In this report, we attempt to attribute differences in residue levels among species to what is known about their diet and seasonal movements. Where relevant, factors such as age, condition or physiological aspects (incubation, migration stress) are discussed.

The majority of samples are eggs, which most closely represent contaminant levels in the female's liver at the time of egg-laying (Vermeer and Reynolds, 1970). In order to assess the relative influences of local and background sources of pollutants, it is necessary to know something of the time spent on the breeding grounds prior to egg-laying. Gilbertson (1974) showed that significant amounts of contaminants can be accumulated within a month, such that egg residues increase with respect to date of laying. Norstrom (pers. comm.) noted that in Herring Gulls, the main source of organochlorines in eggs was from exogenous fat (ie. in the diet) rather than from stored fat, although this may not be true for all species. Although the time for internal residue levels to reach equilibrium with environmental levels has been estimated to average one month, species which migrate long distances may clear organochlorines at a faster rate because of increased plasma lipid circulation (Norstrom et al, 1986).

Information on pesticide use in Canada and elsewhere, is limited and usually in the form of annual sales rather than use. However, for some classes of pesticides, we have fairly reliable information on the overall temporal patterns of use, in terms of introduction, peak usage and restrictions. In the case of forest spraying in New Brunswick and Maine, local use was significant and measurable, but more often, geographic details of use are not available. Timing of overall use patterns were usually similar between Canada and the USA, the area encompassing the range of most of our seabirds.

In the case of PCBs and heavy metals, which are not directly "applied", it is difficult to quantify input to the environment. Local sources are identified, and general patterns of industrial production considered.

5.1 Long Range Transport

Organochlorines are transported through the atmosphere and by run-off and ocean currents. Most of the contaminants discussed in this report are relatively volatile and may be present in the atmosphere for up to 200 days (Norstrom and Muir, 1986), long enough to be transported by air-masses to remote locations. The rates of input to oceans by precipitation and scavenging (or rates of re-vapourization from the oceans) are not known. Several papers (Tanabe et al, 1984: Ottar, 1981: Norstrom and Muir, 1986) discuss aspects of atmospheric transport, to which we refer where relevant.

Atmospherically borne organochlorines are most favourably deposited on large bodies of water (lakes and seas) via precipitation. This means that areas with the greatest precipitation receive the highest atmospheric contaminant input. Pollutants in riverine run-off near sources of pollution result in elevated local levels.

Although organochlorines are very insoluble in water, they are readily adsorbed to suspended particulate matter in the sea, and transported by ocean currents. Organochlorines also tend to be concentrated in the lipid-rich surface microlayer of the ocean where atmospherically transported contaminants are first deposited (Bidleman and Olney, 1974).

Excluding the surface microlayer, typical organochlorine concentrations in seawater range from 0.1 to 100 ng/kg. In Atlantic coastal waters, Wilson and Addison (1984) measured total DDT at 0.1 to 10 ng/kg and PCBs at 1.0 to 100 ng/kg, in the water column. On the Pacific coast, Tanabe et al (1984) found total DDT to average 0.14 ng/kg, PCBs to average 0.28 ng/kg and total HCH to be 2.1 ng/kg. These concentrations are many orders of magnitude less than typical residue levels in seabirds, and fluctuate too much due to such factors as season, time, weather conditions and turbidity, to reliably measure pollution.

Ocean currents are important long-range vectors of organochlorine contaminants, and may account for observed differences in residue levels in wildlife in remote locations.

On the east coast of Canada, the relatively warm Gulf Stream flows northward along the edge of the continental shelf, and has limited exchange with inshore areas (Hildebrand, 1984). The east coast of Newfoundland and the north shore of the Gulf of St.Lawrence are fed mainly by the inshore Labrador current, which consists of colder, less salty and presumably less contaminated water from Hudson Bay and the arctic. This means that colonies along the Quebec north shore as far east as Sept-Isles are influenced most by contaminant levels in arctic waters.

Gaspe, northern N.B. and to a lesser extent PEI. the Magdellan Islands and N.S. are affected most by the strong coastal Gaspe current, the outflow of the St. Lawrence river which carries contaminants from sources along the river and Great Lakes (Hildebrand, 1984). The Bay of Fundy is fed mainly by water flowing southward from the Gulf of St. Lawrence (including the Gaspe current), which picks up salinity and nutrients in exchange with the offshore Gulf Stream on the way.

The Pacific coast is influenced in the offshore zones by the relatively warm water of the North Pacific current, and in the north, cold water from the Bering Sea. However, during most of the year, coastal British Columbia is fed by the Davidson current, a warm inshore current originating south of California (Nelson and Myers, 1976). This means that contaminants from areas of heavy use could be transported northward to B.C., particularly in the inshore zone. In a review of pollution in the Strait of Georgia, Waldichuk (1983) noted that the main sources of "critical" pollutants in the strait were: inflowing seawater from industrial Puget Sound, Fraser River run-off and ocean dumping in the strait. Although the strait is flushed regularly, pockets of pollution were found in industrial estuaries.

Considering the high mobility of most seabirds and their prey, more detailed examination of ocean currents may be irrelevant. The transfer of contaminants to deeper water and the sediments is poorly understood. It is likely that areas with high turnover or continuous upwelling (and associated biological activity) would result in more rapid degradation of pollutants. This was suggested as the reason for relatively low contaminant levels in shallow Lake Erie during the early 1970's, despite its proximity to dense agricultural and industrial areas.

5.2 Sources of Organochlorines

Organochlorine use in Canada and the U.S.A. began in the late 1940's, peaked by the mid 1960's and then declined due to restrictions around 1970. In Latin America, however, use of these compounds has increased in most countries since the 1960's and is not expected to decrease significantly in the near future (Maltby, 1980). Nevertheless, use in Latin America even today is considerably less than in the heyday of organochlorine pesticide use in North America during the 1960's.

In eastern Canada, the most significant use of DDT was spraying of New Brunswick forests from the early 1950's to 1969. During this time, 5.7 million kg. of DDT per year were sprayed in New Brunswick, with lesser amounts in Quebec, Nova Scotia and PEI (Nigam, 1975) and Maine (Pearce et al, 1978). In addition, until the late 1960's, aldrin, endrin and DDT were used in New Brunswick and other Maritime provinces on root and fruit crops, particularly potatoes. Organochlorines currently in use are mainly chlordane (household uses), lindane, methoxychlor and endosulfan (vegetable crops). Organophosphate insecticides are now used in the forest spraying operations. The other main source of contaminants in the St. Lawrence system is the outflow from the Great Lakes, where both agricultural and industrial uses of pesticides and industrial chemicals were, and continue to be high (I.J.C., 1985).

In British Columbia, the only documented historical use of organochlorines was over 90,000 kg of DDT for forest insect control between 1946 and 1962 (Nigam, 1975). Endosulfan and lindane were also used for insect control during the 1960's. Agricultural and industrial uses have not been well documented in this province.

Pesticide use in the U.S.A. has been more than ten fold the amount in Canada, but with similar timing. Some of the major uses include forest spraying of DDT in the northwest states, on agricultural crops in California, Texas, Florida and other southern states, and heavy industrial and household use in urban areas. In addition, some pesticide manufacturing plants are situated in the USA, where leakage and waste disposal undoubtably caused very high local levels, prior to stricter regulations.

In Latin America, DDT, chlordanes, dieldrin and HCH are still extensively used, but the total amounts used are significantly less than in the U.S.A. during the 1960's (Maltby, 1980: Matsumura, 1972). Pesticides used in these locations may eventually be transported to Canadian waters via ocean currents or atmospheric transport, as discussed previously. In addition, seabirds which migrate to the southern U.S.A. or South America may pick up contaminants in their wintering areas, as has been documented in some non-seabird species such as Peregrine Falcons (Henny et al, 1982b). Recent studies of contaminants in Common Terns and Black-crowned Night-herons along the eastern US coast, however, suggest that contaminant exposure in the southern wintering areas is insignificant relative to conditions at the breeding sites (Ohlendorf et al, 1978; Custer et al, 1983).

5.3 DYNAMICS OF INDIVIDUAL ORGANOCHLORINE COMPOUNDS

POLYCHLORINATED BIPHENYLS

Sources:

Polychlorinated biphenyls (PCBs) are industrial chemicals with a wide range of uses, including pesticide extenders, hydraulic fluids and lubricants, plasticizers and primarily (60% of use) in closed circuit electrical and heat-transfer systems. PCBs are produced commercially in the USA (as Aroclors), France (Phenoclors), Germany (Clophen), Japan and the USSR. Since their introduction in 1930, production increased in the USA to 34,000 tons annually in 1970 but little is known about production on a global scale. (Nisbet and Sarofim, 1972: Peakall, 1972)

In 1970, Monsanto, the only US producer, voluntarily restricted production of PCBs for any uses but closed-cicuit electrical equipment. However, despite this reduction of North American uses, exports increased.

Commercial PCBs are mixtures of many congeners differing in the amount of chlorine present in the molecular structure. In this report, we present data on the basis of a 1:1 ratio mixture of Aroclor 1254 and Aroclor 1260, as our best estimate of environmental proportions.

Input to the Environment:

There are many routes by which PCBs enter the environment, from direct dumping and industrial disposal, vapourization by incineration of PCB-impregnated products, spills during transportation to leakage from transformers and leaching from dump sites. Its use as a pesticide extender has been banned in North America since 1970.

Nisbet and Sarofim (1972) estimated that annual input of PCBs to the environment was in the order of 2000 tons to the atmosphere, 4500 tons into fresh and coastal waters and 18,000 tons into dumps and landfills. Although not particularly volatile, PCBs are readily absorbed by airborne particulate matter and transported by prevailing air masses. Nisbet and Sarofim (1972) thought that most of this atmospheric PCB was deposited locally within two or three days resulting in the observed high concentrations close to urban centers. Much of this PCB mixture remains in the troposphere for as long as 45 to 70 days (Norstrom et al, in prep.), becoming an important vector to remote areas. Relatively high levels found in mid ocean areas also imply air transport although ocean dumping by ships is another possibility (Patin, 1982).

PCBs have a low water solubility but are readily absorbed by particulate matter and the sediments. Nisbet and Sarofim (1972) estimated the annual river runoff to oceans in North America to be relatively small, in the order of 200 tons, because of losses to the sediments and sludge. For this reason, dredging and dumping operations may have significant impact on local coastal PCB levels.

Many PCB products are disposed of in landfill sites where gradual decay and leaching of the contaminants provides a longterm diffuse route to the environment. This is also true of old transformers and other electrical equipment still in use.

PCBs are relatively inert chemically, and as in the case of DDE, their persistence causes bioaccumulation in food chains. A number of studies have shown that the lower chlorinated biphenyls are more easily metabolized in biological systems, particularly at the higher trophic levels. (Tanabe et al, 1984: Peakall, 1972). For this reason, PCBs in warm-blooded animals near the top of the food chain usually contain a high proportion of highly chlorinated PCBs relative to lower organisms. In the long food chains of the marine system, where biomagnification may be 100,000,000 times, this is particularly evident. Like organochlorines, PCBs are lipophilic and tend to be stored in the fat of seabird tissues, released during lipid mobilization.

Although the routes of input to the environment are different, DDE and PCBs behave very similarly, and therefore the PCB/DDE ratio tends to be characteristic of a locality at all trophic levels. Risebrough et al (1967) identified "bay" and "ocean" profiles of this ratio, which differed in that the PCB/DDE ratio close to urban centers where local discharge of PCBs occurred, was much higher than in the open ocean where long range ocean currents and air transport were the main vectors.

Toxicity:

PCBs are considered acutely toxic at levels in the 200 to 400 ppm range, well above the typical levels of 1.0 to 40.0 ppm reported here. Less is known about their sublethal effects, although embryotoxicity, microsomal enzyme induction and hormonal effects have been reported.

Dibenzodioxins and dibenzofurans, impurities in PCB mixtures, have been associated with toxic effects in wildlife at very low levels. Norstrom et al (1985) and Vos et al (1970), among others have suggested that these chemicals contributed to the toxic effects supposedly induced by PCBs in some toxicity experiments. Both dioxins and dibenzofurans have been detected in the Great Lakes and the Strait of Georgia since the advent of more sophisticated detection techniques, and future monitoring may discover these microcontaminants in other locations.

Geographic Differences:

Like DDE, PCBs have been found in biota from all over the world. Unlike DDE, PCB residues in penguins and seabirds from the Antarctic were generally at least a magnitude lower than in similar species from the northern hemisphere (Ballschmiter et al, 1981; Bennington et al, 1975). This is probably due to relatively less industrialization south of the equator, although there was (and continues to be) widespread use of DDT (Maltby, 1980).

The lack of geographical differences suggests that point sources of pollution were not influencing levels of PCBs in seabird eggs. Puffins from the Bay of Fundy laid eggs with significantly higher PCB levels than puffins from Newfoundland, as expected with respect to relative industrialization. PCB residues in eggs of Leach's Storm-petrel showed the same trend but not significantly since 1972, perhaps because this species forages greater distances during the breeding season. Razorbills eggs from the St. Lawrence estuary were higher in PCBs than those from the more remote Ste. Marie Is., but PCB levels in Double-crested Cormorant eggs were variable, and not significantly different between locations in the St. Lawrence estuary or gulf, Bay of Fundy or even Lake Ontario. This species is highly migratory, wintering off the southeast coast of the USA to the Gulf of Mexico. In contrast, the Common Tern, which migrates to central America, had much higher egg residues in Lake Ontario than in coastal colonies. Differences in the amount of lipids mobilized during migration, the length of time on the colony prior to egglaying and routes of migration might account for these trends. Gilbertson (1974) found that Common Terns arrived from the south with low tissue PCB levels which increased over the course of the breeding season in Hamilton Harbour. Double-crested Cormorants, on the other hand, probably migrate gradually via heavily industrialized areas along the northern US Atlantic coast, and may pick up most of their contaminants there.

PCBs in arctic seabirds in 1975-1977 were generally lower than further south. Eggs and livers of Black-legged Kittiwakes contained the highest levels (up to 5.7 ppm wet weight), while levels in livers of Ivory Gulls and Northern Fulmars ranged from 1.0 to 2.0 ppm. PCBs in the Thick-billed Murre were surprisingly low, less than 0.5 ppm in livers and less than 1.0 ppm in eggs. This species feeds largely on Arctic cod prior to egglaying at P.L.I., but less on the surface than the kittiwake. Elevated concentrations in the ocean surface layer might explain the relatively high residues in kittiwakes.

PCB levels in the eggs and tissues of west coast seabirds were never as high as on the east coast, which agrees with data for Polar Bears (Norstrom et al, in prep) who found low levels in areas influenced by the Beaufort Sea, and the highest levels associated with Hudson Bay. Double-crested and Pelagic Cormorants from the Strait of Georgia laid eggs with the highest residue levels, as expected in this fairly industrialized area. In the Queen Charlotte Islands, the Fork-tailed Storm-petrel eggs contained PCB residues approaching 10 ppm in 1970, but other planktivorous alcids and Leach's Storm-petrel were less contaminated. There was a pattern of declining PCB levels to the north in these species, in agreement with even lower levels from Alaska (Ohlendorf et al, 1982). Only Glaucous-winged Gulls differed, the large variation in concentrations probably due to local differences in diet (Table 2, Appendix 7).

The PCB/DDE ratios, although always higher (greater than three) in the Strait of Georgia, and usually less than three elsewhere, were not consistent. Ratios of less than one occurred in several planktivorous species in the early 1970's, and were only slightly higher in the same species in the 1980's. Ohlendorf et al (1982) also recorded PCB/DDE ratios of about one in murrelets, Leach's Storm-petrels, and some murres from Alaska.

Temporal Trends:

Very little temporal change in PCB levels was detected. Gannets of Bonaventure I. and three species (cormorants, puffins and petrels) from the Bay of Fundy were the only species to show significant decreases in PCB levels more than once between sampling periods (Table 1. Appendix 5.). In the Gulf of St. Lawrence, levels appeared to be stable in Double-crested Cormorants and Razorbills.

Differences Between Species:

Species ranking by contaminant levels were identical for PCBs and DDE, confirming their similar accumulation rates. The gannets and cormorants, which tend to feed on mid-sized fish from the inshore zone always contained the most PCB residues, followed by the storm-petrels, alcids, terns and finally eiders. Alcid diets include both fish and zooplankton in variable proportions, while terns feed primarily on small larval fish. Storm-petrels are mainly planktivorous but it is thought that the surface microlayer of the ocean where petrels forage contains the highest concentrations of volatile organochlorine residues (Bidleman and Olney, 1974). Eiders feed mainly on mussels and other sublittoral invertebrates which contain less PCB than fish (Patin, 1982), so this ranking seems consistent with diet.

Conclusions:

In offshore waters of the North Atlantic, re-analyses of eggs of Leach's Storm-petrel revealed declines of PCBs not originally considered significant (Table 1, Appendix 5). PCBs do not appear to be decreasing in the Gulf of St. Lawrence or along the Pacific coast and may be having as yet undetected effects, possibly synergistically with other organochlorines. The routes of input to the environment discussed above are likely to continue for a long time. Local contamination has been reduced in the Bay of Fundy and in some sites in the Gulf of St. Lawrence, the latter probably related to the decline of PCB levels in the Great Lakes (Norstrom et al, 1986).

Canadian seabirds are exposed to PCBs on their breeding grounds, and at their wintering areas elsewhere. Species which migrate to the southern USA or central and South America do not contain significantly more residues than species which winter in the mid-ocean zones, as noted by Ohlendorf et al (1978) and Custer et al (1983).

PCBs appear to be currently ubiquitous in the Canadian marine environment. Long range transport, whether in the atmosphere, or by ocean currents, is probably the main vector to the arctic and mid-ocean, although there remains the possibility of PCB disposal at sea. Although not considered toxic at the levels encountered in Canadian seabirds, PCBs have been implicated in mortality of seabirds elsewhere, particularly where lack of food or other stresses induced metabolism of endogenous lipids and subsequent release of PCBs into the bloodstream.

DDT AND RELATED COMPOUNDS

DDT was widely used in Canada and the USA since the 1950's as a broad-spectrum insecticide, but has been restricted since 1971 to minor uses. It is currently still in use in many tropical countries (Maltby, 1980) and also occurs as a contaminant of difocol (or Kelthane), an insecticide used mainly on fruit trees and ornamentals. Difocol is still in use in both Canada and the USA and may contain up to 15.7 % DDT related compounds. On the east coast, dicofol is used mainly in the southern states (US EPA 1984).

DDT is metabolized in most animals to a number of compounds, of which DDD and DDE are the most prevalent. Other metabolites include DDMU, DDCN, DDA and DBP (Menzies, 1980). DDE is the most persistent and therefore the major component of total DDT in species at the higher trophic levels. Seabirds, at the top of the marine food chain, generally contain over 90 % DDE, and sometimes no other detectable DDT compounds. The DDE / DDD+DDT ratio can be used to estimate the position in the food chain of the species sampled. Tanabe et al (1984), in a study of organochlorines at several trophic levels in the Pacific Ocean, clearly demonstated increasing proportions of DDE with trophic level.

DDT and its derivatives decreased in Canadian seabird tissues and eggs during the past decade. This trend is clearly demonstrated by the long term monitoring of the Leach's Storm-petrel, Double-crested Cormorant, Atlantic Puffin and the Northern Gannet in eastern Canada.(Pearce et al, in prep.; Elliott et al, in prep). Total DDT residues in these species declined most rapidly at colonies in the Bay of Fundy and parts of the Gulf of St. Lawrence, compared to colonies along the coast of Newfoundland. Residues in Razorbills from the Ste. Marie Is. and in Common Terns in the des Chaleurs also decreased during the 1970's. Only in eggs of Double-crested Cormorants from Ile aux Pommes in the St. Lawrence estuary, were there no significant declines of DDE.

On the Pacific coast, total DDT and DDE declined (not always significantly) at all localities where temporal data were available. Although no temporal data pertaining to contaminants in arctic seabirds are available, studies on seals (Muir et al, in prep.) suggest that DDT compounds are declining in the arctic.

In the early 1970's, when DDT was used extensively in eastern Canada for control of the spruce budworm, there were clear geographical differences in residue levels. DDE in the eggs of puffins and petrels was consistently higher in the Bay of Fundy samples than from the continental shelf of Newfoundland, even in 1984. The still elevated levels of this compound in areas where it has not been used for almost 15 years suggest continuing DDT input to the marine environment. Possible sources include mobilization from the sediments, use of dicofol on fruit crops in southern Canada and the USA, and continuing DDT use in Mexico and other Latin American countries.

Double-crested Cormorants differed from petrels and puffins in that levels in eggs showed no significant difference between locations in any year. Some of the highest levels occurred along the north shore of the Gulf of St. Lawrence, an area fed by the Labrador current. Even cormorants from industrial Lake Ontario, in 1971, laid eggs with residues similar to those in marine colonies. The lack of significance is partly due to the large individual variance in cormorant contaminant levels. It is also possible that this species is exposed to relatively high DDT levels during its slow migration along the industrial US coast.

Before the ban on DDT, Kury et al (1969) found DDT + DDD levels of 6.0 ppm and DDE at 7.6 ppm in eggs of cormorants from Muscongus Bay in Maine. This strongly suggests recent exposure as would be expected during the era of spraying budworm with DDT, in Maine and New Brunswick. Kury did not find any contamination in the prey of this species but in 1967, that could have been a problem of detection.

In contrast to cormorants, the levels of DDE in Ring-billed Gulls, Herring Gulls and Common Terns were much higher in colonies from the Great Lakes than in colonies from the Atlantic coast. Gilbertson (1974) hypothesized that Common Terns nesting in Hamilton Harbour obtained most of their contaminants locally after arriving fairly clean from their wintering grounds in South America. Concentrations of DDE in eggs of terns from several colonies in the Gulf of St. Lawrence were much lower than from the Great Lakes, and showed no geographic variation. Levels were less than in other seabirds. Terns may rid themselves of lipophilic contaminants because of faster plasma lipid clearance rates during their rapid migrations, and therefore reflect local conditions better than cormorants.

DDT compounds were generally lower on the west coast. Even in 1970, only one pool of eggs of Double-crested Cormorants contained residues greater than 4.0 ppm. The petrels, particularly Fork-tails, usually contained the highest DDE residues of any species sampled and were similar between locations, in the Queen Charlottes and western Vancouver I. The only species sampled at many locations, the Glaucous-winged Gull and Pigeon Guillemot, in 1970, were most contaminated on western Vancouver I. and "cleanest" in the north. DDE levels higher along the western coast of Vancouver Island than in the industrial Strait of Georgia, may be the result of ocean transport from areas of high pesticide use and manufacture, in California. By 1984, DDE levels in eggs of Rhinoceros auklets from Hecate Strait were higher than in Atlantic Puffin eggs from Newfoundland, but lower than in the Bay of Fundy.

Residues of DDE in alcids were usually higher than in gulls and extremely variable. The planktivorous Cassin's Auklet in the Queen Charlottes contained DDE residues of almost 3 ppm, similar to those found in petrels, although the auklet forages below the surface. It is possible that its copepod prey spend enough time at the surface (nocturnally) to accumulate atmospherically deposited organochlorines.

The relatively low levels in most species from the Strait of Georgia suggests that point source pollution was never significant here, unlike the situation for PCBs.

Examination of the DDE / DDD+DDT ratio in samples gives an indication of its trophic level. The only species on the west coast to contain significant amounts of DDD or DDT were the two storm-petrels, presumably because these species feed on the ocean surface where recently deposited unmetabolized DDT is deposited. On the east coast, eggs of the Leach's Storm-petrel from Great Island contained significant amounts of DDD and DDT, up to 50 % of total DDT compounds. On Kent Island in the Bay of Fundy, the proportion of DDD + DDT to DDE was less than in Newfoundland but DDE egg concentrations were much higher. By 1984, DDD and DDT at both locations were less than 0.03 ppm in all petrel eggs.

DDD and DDT residues in eggs of Black-legged Kittiwakes which also feed on the surface were very low, less than 0.05 ppm, and ranged from 10 to 40 % of the total DDT. As discussed previously, this species may be unusual in its capacity to metabolize DDT.

DDT and its derivatives have been found at several trophic levels in the north Atlantic and Pacific oceans. Ottar (1981) calculated that DDT is probably atmospherically transported northward and west by prevailing air masses and deposited primarily on the open ocean. It is readily absorbed by particulate matter and transported by ocean currents. The amount of revapourization is unknown but there is probably some loss down to the sediments and deeper water. This chemical is very persistent, with a half-life of over 200 days (Norstrom et al, 1986). Continued use in many parts of the world will add to the 'sink' in the oceans, although it is not known whether this would have much impact on marine life. It has certainly declined in seabird eggs from colonies in Canada but it seems likely to remain near current levels as the curve of the DDE decline approaches an asymptote.

CHLORDANE RELATED COMPOUNDS

Technical chlordane (which contains 10.6 % cis-chlordane, 9 % trans-chlordane, 7 % nonachlor and 8 % heptachlor) was used extensively in the USA and Canada as an insecticide. In the 1950's and 1960's it was largely replaced by DDT and other cyclodienes, but when these chemicals were banned, chlordane use increased again. In Canada, some uses of chlordane were cancelled in 1978, but it is still widely available as a household pesticide.

Technical heptachlor contains 74 % heptachlor, 15 % cis-chlordane and 2.5 % trans-chlordane. Use of this compound has been restricted in Canada since 1976, to nursery-bulb dips, but use for seed treatment in the USA continued until 1982. Because of the similarities between chlordane and heptachlor, the resulting metabolites could originate from either.

In most animals, cis- and trans-chlordane are readily metabolized to compounds of which oxychlordane is the most persistent. (Menzies,1980). In avian tissue, Stickel et al (1979) found that cis-chlordane disappeared most rapidly, followed by heptachlor epoxide and trans-chlordane. Nonachlor was almost as persistent as oxychlordane, but apparently much less toxic.

Oxychlordane was found to be the most toxic, followed by heptachlor epoxide. However, synergistic effects of these compounds and nonachlor were implicated by mortality at concentrations lower than lethal concentrations of the individual chemicals.

Since cis-chlordane is readily metabolized in biological systems, significant amounts of it suggest recent exposure. Oxychlordane should be the most persistent metabolite expected; however, there are interspecific differences in retention and metabolic capacity. Polar Bears, at the top of the arctic food chain, contained more oxychlordane than any other organochlorine, and a nonachlor isomer which was virtually undetectable in their seal prey (Norstrom et al, in prep).

Eggs of Fork-tailed Storm-petrels from the Queen Charlottes contained the highest residues on the west coast, 0.20 ppm wet weight total chlordane, most of it oxychlordane. Leach's storm-petrels sampled concurrently had much less oxychlordane but similar low amounts of the other chlordane metabolites. This difference could reflect the Fork-tailed's inclusion of offal in its diet (Gill, 1977) unlike the exclusively planktivorous Leach's. The only other species sampled for chlordane in northern B.C., the Rhinocerous Auklet, contained residues similar to those in the Leach's Storm-petrel.

All species sampled from western Vancouver Island (petrels, cormorants and gulls) in the mid 1980's contained similar total chlordane concentrations, about 0.03 ppm, mainly oxychlordane.

Chlordane residues in eggs of seabirds from the Strait of Georgia were characteristically low, except for a pool of Double-crested Cormorant eggs from Mandarte I. in 1979 which contained 0.06 ppm of cis-chlordane but only 0.01 ppm oxychlordane. By 1985, this cis-chlordane had disappeared in cormorant eggs, but oxychlordane levels remained the same. The lack of spatial differences in chlordane levels suggests no significant local sources.

In the arctic, chlordane compounds were more prevalent than further south, except in Thick-billed Murres and King eiders. The higher levels in Ivory Gulls (0.09 ppm) and Northern Fulmars (up to 0.26 ppm), almost exclusively oxychlordane, might be a reflection of their incidental scavenging behaviour. These species, although primarily omnivorous, have been observed to feed on carcasses and feces of marine mammals, or in the case of fulmars, scraps from fishing boats.

Ottar (1981) noted that chlordane levels were higher at northern latitudes in Europe although use was greatest in the south and suggested that volatile chlordane was readily transported northward by atmospheric processes.

On the east coast, total chlordane residues were undetectable in eiders, less than 0.05 ppm in terns, up to 0.10 ppm in cormorants, puffins and petrels, and up to 0.50 ppm in Gannets and Razorbills. In all but the latter two species, oxychlordane was the major component.

The extremely high levels in Northern Gannets, decreasing but still 0.25 ppm in 1984, may originate in their southern (Gulf of Mexico) wintering grounds, a particularly contaminated prey species or an inefficient metabolic capacity. Interestingly, the major chlordane component in gannet eggs was cis-chlordane not oxychlordane, except in 1984 when it was cis-nonachlor. In the Double-crested Cormorant which also winters in the Gulf of Mexico, chlordane residues were much lower and predominantly oxychlordane. The elevated levels of cis-chlordane in gannet eggs suggests recent exposure.

Of the alcids, only Razorbills contained significantly high chlordane levels, like the Gannets, predominantly in the form of cis-chlordane. Unlike in gannets, no trans-chlordane or nonachlor were detected. There were no differences between locations. Razorbills are presumed to disperse widely from the breeding areas after the breeding season, but winter off the coast of New England, a relatively industrialized area of the US coast.

Considering the apparent stability of chlordanes in seabirds, further investigation of possible biological effects seems warranted.

HEPTACHLOR EPOXIDE

As mentioned previously, heptachlor is both a component of technical chlordane and of technical heptachlor, used mainly as an agricultural insecticide. Many of its applications were cancelled in 1970, but it was still used for nursery bulbs in Canada and for seed treatment until 1982 in the USA. It is readily metabolized to heptachlor epoxide, the most persistent metabolite of heptachlor in biological tissue.

Levels of heptachlor epoxide were generally low in all seabirds. The highest residues (0.18 ppm) occurred in the eggs of cormorants from the St. Lawrence estuary.

Temporally, residue levels of heptachlor epoxide rose in almost all species to a peak in 1980, and then declined. This reflects patterns of chlordane rather than heptachlor use, which has been restricted since 1970. There was little difference in residue levels between species: highest in the more inshore feeding cormorants and razorbills than the offshore feeding puffins and petrels and lowest in eiders and terns. The uniformly low levels and lack of spatial differences suggest no local sources.

Levels of heptachlor epoxide in the tissues of arctic seabirds were very low, usually not detectable, but its presence in the eggs of the Ivory Gull, an arctic resident, proves that this contaminant is transported to the arctic. Ivory Gulls, as discussed previously may also be exposed to heptachlor (and other chlordane compounds) from carrion in its diet. The relative roles of atmospheric or, more likely in the case of this water soluble compound, ocean current transport are not known. It was virtually undetectable in the livers of Fulmars and muscle of Dovekies from the Labrador Sea and Davis Strait in 1971.

Most west coast seabird samples were not analyzed for heptachlor epoxide. The highest levels recorded were 0.04 ppm in the eggs of Double-crested Cormorants in 1979. It did reach as far north as the Queen Charlottes, in Ancient Murrelet tissue in 1968 and eggs of Leach's Storm-petrel in 1985. As on the east coast, the source of this compound may have been technical chlordane rather than heptachlor, although heptachlor was used in Oregon until 1982.

HEXACHLOROBENZENE

HCB (hexachlorobenzene) was originally used as a fungicide in Canada (and the USA) but use has been restricted since the 1960's and was revoked in 1973. It also occurs, along with other chlorinated benzenes, as a byproduct of industrial processes such as pulp-bleaching (Hallet et al, 1982) and as a contaminant in certain pest control products. Ottar (1981) estimated annual world production to be 5000 tons, half that of PCBs.

This contaminant is particularly persistent in birds. Kan (1978) found HCB to be among the most accumulative of many organochlorines examined, in tissues and eggs of poultry. Excretion of the unchanged parent compound in egg lipids seemed to be the main removal mode rather than metabolism, although some mammals apparently metabolize it readily (Menzies, 1980).

Although other chlorinated benzenes are detected in routine analyses, hexachlorobenzene (HCB) is the major component and will be the only one discussed in this report.

Residues of HCB in seabirds were generally lower than 0.30 ppm, wet weight. In the early 1970's, levels of HCB were higher in Pacific coast birds than in Atlantic seabirds but by the early 1980's this situation was reversed. On the west coast, residue levels declined slightly in all species, particularly cormorants, between 1970 and 1984; levels in all east coast species except gannets increased or remained stable.

Arctic samples (Prince Leopold Island), 1975 to 1977 contained levels of HCB comparable to those in seabirds further south, highest in the Thick-billed Murre eggs (0.13 ppm). These levels are higher than those found in Polar Bears (Norstrom and

Muir, 1986) but similar to those found in seabirds from Spitzbergen in 1980 (Norheim and Kjos-Hanssen, 1984).

There was some indication of elevated residues in the open-ocean habitats, since Leach's Storm-petrels and Atlantic Puffins from Newfoundland consistently contained higher levels of HCB than those species in the Bay of Fundy. The inshore-feeding cormorants, which contained the highest levels of other organochlorine contaminants, were unusually low in HCB. Ohlendorf et al (1982) also reported higher HCB residues in samples from the more remote Aleutian Islands relative to levels in the gulf of Alaska. They found murres and puffins to contain the highest concentrations, murrelets and Leach's Storm-petrels the least.

Since levels of HCB were relatively low in cormorants from the St. Lawrence estuary and Bay of Fundy, there appeares to be no association with industrialization. Nisbet and Reynolds (1984) found no differences in HCB residues in Common Terns between urban and remote areas of Massachusetts, 1971 to 1981, and considered all HCB values to represent background contamination. Significantly higher local levels in cormorants from the Baie des Chaleurs and PEI, terns from Cape Breton and Razorbills from the north shore of the gulf of St. Lawrence may indicate minor local sources such as pulp mills.

This extremely volatile chemical probably quickly enters the atmosphere and is transported east and north with the prevailing air masses. This may account for the elevated levels east of Newfoundland and in the arctic. Ottar (1981) noted that HCB was readily transported to northern latitudes from sources further south. The lack of geographic variation of HCB levels in polar bears from the Canadian arctic (Norstrom et al, in prep.) also suggests that atmospheric rather than ocean transport was the main vector.

There appeared to be some point source contamination on the west coast, in 1970. Eggs of Double-crested Cormorants from Mandarte I. averaged 0.30 ppm HCB, the highest levels recorded for any Canadian seabird. Surprisingly, Pelagic Cormorant eggs from the same location contained almost no HCB (<0.01 ppm) due perhaps to differences in prey. Unfortunately, statistical analysis for differences was not possible because of pooled data.

On the west coast, the Strait of Georgia and western Vancouver Island were most contaminated with HCB, except for residues in Fork-tailed Storm-petrels from the Queen Charlottes. Converted to a lipid weight basis, the highest residues were found in cormorants, Pigeon Guillemots and Fork-tailed Storm-petrels, and were lowest in the planktivorous small alcids and Glaucous-winged Gulls for all sampling years. The consistently higher HCB levels in the Fork-tailed Storm-petrels compared to the Leach's was also noted by Ohlendorf et al (1982) in Alaska , and may reflect the Fork-tailed's propensity for offal (Gill, 1977).

The extremely low HCB levels in eggs of Glaucous-winged Gulls at all locations were probably related to diet of mainly shellfish and refuse (Vermeer, 1982), because in Alaska, Ohlendorf et al (1982) reported much higher HCB concentrations at two sites where Glaucous-winged Gulls were known to be feeding on bird eggs. Retrospective analysis of Herring Gull eggs from Lake Ontario in 1971, revealed HCB concentrations of 4.5 ppm, wet weight (Elliott and Norstrom, 1985), high enough to have significant embryotoxic effects. HCB concentrations of 4.3 ppm caused 50 % mortality of Herring Gull embryos in a study by Boersma et al (1985).

Since levels in eggs of Double-crested Cormorants from the Strait of Georgia showed a significant decrease since 1970, that source of HCB may be gone. Levels of HCB in eggs of the more pelagic species were stable or declined only slightly. The almost universal increase of HCB residues in east coast seabird eggs did not occur in the Great Lakes, where concentrations in gull eggs declined from 4.5 ppm in 1972 to less than 0.5 ppm in 1984 (Elliott and Norstrom, 1985). However, concentrations of HCB in marine birds are still considerably lower than in birds from the Great Lakes.

DIELDRIN

Dieldrin is less volatile and more water-soluble than most organochlorines and therefore tends to be removed from the atmosphere by precipitation and dissolution at the air:water interface of large water bodies. Because of its shorter time in the atmosphere, it is a more local contaminant usually associated with riverine/land runoff or ocean currents. (Norstrom et al, in prep). It is quite persistent in avian tissues. Kan (1978) estimated its half-life in poultry tissue to be 42 days. Clark et al (in prep) calculated a half-life of 75 to 129 days in plasma of Herring gulls, which was considerably shorter than the values for DDE, oxychlordane or mirex.

On the east coast, dieldrin and its relative aldrin were used extensively in North America with peak use in the early 1960's (U.S. E.P.A.,1979). In Canada, use was reduced during the 1960's and restricted to soil and seed treatments in 1971. In the U.S.A. most uses have been severely restricted since 1975. This compound was apparently not used in British Columbia, but may have been used in the northeastern states against gypsy moth.

Dieldrin residues of any significance are generally an east coast phenomenon, where it ranked third among contaminants. The highest dieldrin residues occurred in Gannet eggs in 1969 (1.04 ppm wet weight in fresh eggs and 2.53 ppm in addled eggs) from Bonaventure Island. Dieldrin levels in eggs of Double-crested Cormorants breeding in the nearby St. Lawrence estuary were much lower (0.12 to 0.21 ppm). By 1984, dieldrin levels had declined in both of these species to 0.15 ppm in gannets and 0.06 ppm in the cormorants. Both of these species winter along the southern US coast; the differences in residues may reflect differences in diet. Gannets feed on large-bodied surface schooling fish while cormorants feed on a wide variety of benthic and pelagic fish. Among the alcids, Razorbills from the Gulf of St. Lawrence contained the highest residues, ten-fold the levels in murres and guillemots, probably related to over-wintering along the industrial New England coast.

Eggs of Atlantic Puffins and the Leach's Storm-petrel contained dieldrin in the order of 0.05 to 0.09 ppm in 1972. Levels declined at all locations by 1984. Levels in puffins from the Bay of Fundy were consistently higher than those from Newfoundland, in contrast to petrels where the levels in Newfoundland eggs were highest. Since wintering areas of these populations must overlap considerably, we have no explanation for this pattern.

Dieldrin residues in tissues of arctic seabirds were very low, ranking fifth among organochlorines behind oxychlordane and HCB (Table 3, Appendix 4). Dieldrin concentrations in eggs of Thick-billed Murres and kittiwakes were 0.02 to 0.06 ppm wet weight, which is higher than levels found by Ohlendorf et al (1982) in the same species in Alaska. This fits the overall pattern of more dieldrin in Atlantic waters.

On the British Columbian coast, dieldrin levels were also low, usually less than 0.02 ppm. The greatest amount occurred in the eggs of the two non-migratory cormorant species in 1970, in the Strait of Georgia, up to 0.08 ppm wet weight.

Of the dieldrin concentrations encountered in Canadian seabirds, only the values over 1.0 ppm (over 2.5 ppm in some addled eggs) in eggs of gannets in 1970, have been associated with embryotoxic effects elsewhere (Potts, 1968; Blus et al, 1982). Current dieldrin levels probably have no effect.

HEXACHLOROCYCLOHEXANE

The insecticide BHC, which was widely used in Canada and the USA until 1970, contains a mixture of 65 % alpha- and 35 % beta-hexachlorocyclohexane (HCH) isomers. BHC has since been replaced by lindane, which contains more than 99 % gamma-HCH.

HCH isomers are less lipophilic than DDT or PCBs and are bioaccumulated much less efficiently (Tanabe et al, 1984). These volatile isomers were found to be the dominant organochlorine in surface seawater of the Pacific, but the least prevalent in biological tissues, particularly at the higher trophic levels. Kan (1978) calculated a very low accumulation ratio for alpha-HCH (1.9) in the fat and eggs of poultry, but a much higher ratio (18) for the beta- isomer (comparable to DDT). He considered biodegradation to be the major factor in disappearence of this residue, as did Tanabe et al (1984) in studies on dolphins.

The most striking result in our seabird data was the difference in the isomer ratios between the Atlantic and Pacific samples. In all Pacific seabird eggs, the beta- isomer was dominant, accounting for 62 to 89% of the total HCH. In contrast, the supposedly less persistent alpha- isomer was dominant in almost all eggs from the east coast, from 50 to 89% of total HCH. Since technical BHC contains more alpha- than beta-, this may indicate recent exposure. According to Maltby (1980), about 5000 tons of "BHC 16%" is used annually in Latin America, mainly in Brazil and Mexico. This is a possible source of the elevated levels found in gannets and cormorants, which winter in the Gulf of Mexico.

Tanabe et al (1984) predicted a greater beta- isomer proportion in the higher trophic levels. This was not apparent in samples from either coast: since the mainly planktivorous Leach's Storm-petrel consistently contained a greater proportion of the beta-isomer than the piscivorous cormorants and gannets. Total HCH residues (on a lipid weight basis for comparison) were highest in eggs of the entirely piscivorous species, unlike the situation in Striped dolphins (Stenella coeruleoalba) which apparently metabolize HCH compounds. It appears that seabirds differ from dolphins in their capacity to metabolize HCH, particularly the alpha-isomer.

Another explanation may lie in the relatively high water solubility of HCH, resulting in elevated levels in areas where run-off and precipitation are the major vectors. Gannets and cormorants tend to feed in the inshore zone where run-off is an important vector.

Norstrom and Muir (1986) considered HCH residues in arctic wildlife to be largely of Asian origin, where this pesticide is still in use. This may also explain the tendency for Pacific seabird samples to have greater total HCH residue levels than from Atlantic species, in contrast to the situation for all other organochlorines.

Since HCH was not included in analyses prior to 1976, except for some re-analyses, few temporal trends could be determined. There was no consistency, since total HCH decreased in Double-crested Cormorants, increased in Leach's Storm-petrels and was stable in gannets and puffins.

In conclusion, it seems that the source and time of most recent exposure are more relevant to the total HCH and the isomer ratio than the trophic level of the seabird's diet. The isomer ratios within the same species were highly variable (35% to 90% beta-HCH) which suggests that any inherent specific capacity to metabolize the two HCH isomers is masked by differences in exposure. This contaminant is not particularly persistent in biological systems (Kan, 1978; Norstrom, pers. comm.) and at the present low levels is unlikely to have any adverse effects.

MIREX / PHOTOMIREX

Mirex was used industrially as a flame retardant and in the southern USA in the control of fire ants. It has never been registered as a pesticide in Canada. Photolysis of mirex yields several byproducts, of which 8-monohydromirex (photomirex) was the most prevalent in tissues of fish, oysters and Herring gulls (Menzies, 1980). It is very slowly degraded in soil.

Mirex was found in seabird tissues and eggs from both coasts and the arctic (Tables 1,2 & 3, Appendix 6). The highest mirex levels occurred in eggs of Double-crested Cormorants breeding on Iles Razades in the St. Lawrence estuary, at 0.070 ppm, wet weight. Mirex in the order of 0.01 to 0.05 ppm was found in eggs of cormorants, gannets, Leach's Storm-petrels and Atlantic Puffins, along the east coast during the early 1980's. On the west coast, similar mirex concentrations were found in eggs of both storm-petrel species but were less than 0.01 ppm in cormorants and auklets. We have no explanation for the anomalous high level in one of the Glaucous-winged Gull eggs from Thornton I. in 1983.

Mirex residues in arctic seabirds were highest (0.01 to 0.02 ppm) in the livers of Fulmars and the livers and eggs of Black-legged Kittiwakes. Tissues and eggs of Thick-billed Murres, King Eiders and Ivory Gulls contained mirex at concentrations less than 0.01 ppm.

With so few samples, trends were not evident. However, all regions of both coasts were represented by mirex in at least some eggs. This chemical has been reported in Herring Gull eggs from all Great Lakes, with particularly high concentrations (2.5 ppm) occurring in Lake Ontario (Mineau et al, 1984). It was considered to have originated from manufacturing sources around the lake.

Mirex levels declined significantly in three seabird species from the Bay of Fundy, and in puffins and petrels from the east coast of Newfoundland, between 1980 and 1984. The levels in the eggs of cormorants from the St. Lawrence estuary remained stable during this time, but levels in gannet eggs decreased between 1968 and 1984. No temporal trends could be determined for the west coast species. These declines agree with significant decreases of mirex in Herring Gull eggs from the Great Lakes between 1973 and 1979 (Mineau et al, 1984).

The source of mirex in seabirds is unknown. Cormorants and gannets could be exposed to this chemical in their wintering areas along the southeast coast of USA, but its occurrence in almost all storm-petrel samples suggests that this contaminant is present in mid ocean regions, presumably in the surface layer. Its occurrence in nearly all arctic seabird samples also implies long range transport by ocean currents or in the atmosphere. Contamination of the outflow of the St. Lawrence River from sources in the Great Lakes is a likely vector to areas in the Gulf of St. Lawrence.

ENDRIN

Endrin is an organochlorine pesticide used mainly in the control of cutworms, potato beetles and grasshoppers. Its use in the U.S.A. began in 1951, but it has been banned by the U.S. E.P.A. in all states east of the Mississippi since 1979 (Schladweiler and Weigand, 1983). It is still registered for use in grainfields in the western states. In Canada, its use is restricted to control of cutworms, aphids and potatao beetles in grainfields and potato crops (E.P.S. 1980).

Endrin is very toxic. Its acute toxicity to several avian species ranged from 0.75 to 5.64 ppm (Tucker and Crabtree, 1970). Levels of 0.3 ppm in the eggs of Screech Owls and 0.5 ppm in Brown Pelicans were found to seriously impair reproduction (Schladweiler and Weigand, 1983).

Endrin was found in tissues and eggs of most seabird species from both coasts in the early 1970's, but not in the arctic (Tables 1,2 & 3, Appendix 6). The highest levels (0.167 ppm) occurred in the eggs of gannets from Bonaventure I. in 1974, and levels between 0.05 and 0.10 ppm were reported in eggs of cormorants and Leach's Storm-petrels in 1972 to 1974. In 1972, puffin eggs from five different colonies all contained endrin at concentrations of about 0.03 ppm, wet weight. Levels in some tern and eider eggs from the Gulf of St. Lawrence were less than 0.02 ppm at the same time.

On the west coast, endrin residues in eggs (where detected) were usually less than 0.02 ppm, wet weight. The highest concentrations occurred in the fat of adult birds (0.089 ppm in the fat of Leach's Storm-petrels in 1971, 0.24 ppm in the fat of Ancient Murrelets, also from the Queen Charlottes, in 1972.

Endrin has not been detected in tissues of seabirds from the Atlantic coast since 1974, but apparently occurred in some pooled egg samples from the Pacific coast in 1983. This chemical does not appear to be particularly persistent in the marine environment; nor was it widely used. Re-analysis of seabird eggs on the Atlantic coast did not detect endrin, which suggests that it was mistakenly identified in the first place, possibly for some of the nonachlors discovered later. Endrin was detected in only one egg (of a kittiwake) in Alaska in the mid-1970's (Ohlendorf et al, 1982).

The recent endrin "scare" in Montana suggests that this contaminant does occasionally reach toxic levels in wildlife, but the unreliability of data in seabirds precludes any conclusions about its dynamics in marine systems. It appears that most seabirds are not usually exposed to this contaminant.

5.4 DISCUSSION OF HEAVY METALS

MERCURY:

Biomagnification of mercury in aquatic food chains has been widely reported (Miller, 1977). Fimreite et al (1971) reported accumulation of mercury in fish-eating birds in areas of industrial mercury contamination in Canada, including some of the data in this report. They discussed the possibility of reproductive effects on fish-eating birds in the Bathurst Harbour area, based on evidence of reduced hatchability in pheasants with mercury egg levels of 0.5 to 1.5 ppm (Fimreite, 1971; Spann et al, 1972). Since Fimreite's work, there has been limited effort to determine mercury and other metal levels in wildlife from mercury contaminated locations in Canada.

Liver mercury levels in Double-crested Cormorants, Common Terns and Northern Gannets from the Baie des Chaleurs area and in Pelagic Cormorants and Marbled Murrelets from the Strait of Georgia in the early 1970's ranged from 2.0 to 11.0 ppm, wet weight. These are probably higher than "background" levels, but lower than lethal values reported elsewhere; 20 ppm w.w. in livers of Red-tailed Hawks (Fimreite and Karstad, 1971), and about 50 ppm w.w. in livers of Grey Herons (Van Der Molen et al, 1982).

Recent data (Nicholson and Osborn, 1984) demonstrated nephrotoxic lesions in Starlings with kidney mercury levels of 36 ppm and liver levels of 6 ppm. A single Bathurst Harbour cormorant collected in 1969 contained 11.3 ppm mercury in liver. However, Nicholoson and Osborn point out that metabolism and toxicity of mercury varies with the elemental form in the diet. Therefore, biological effects observed in Starlings from ingestion of inorganic mercury may not be strictly applicable to interpretation of levels in seabirds, which are exposed mainly to methyl-mercury in fish.

Industrial and agricultural sources of mercury in Canada were placed under stricter regulation during the 1970's by federal government legislation (Sherbin, 1979). Lacking data, we are unable to determine whether this legislation has resulted in declining mercury levels in wildlife from areas such as Bathurst Harbour and Horseshoe Bay. Some recent data on Common Mergansers collected in 1983 from the Restigouche River, N.B. (Pearce, unpublished) shows that these birds contain high levels of mercury (13.1 ppm, wet weight, pool of 5 adult mergansers) when they leave the Baie des Chaleurs area in the early spring and move up the Restigouche River to breed. A study of mercury levels and possible effects in wildlife from the areas investigated by Fimreite seems advisable.

Mercury levels in eggs of Leach's Storm-petrel from Kent I. in the Bay of Fundy in 1980 were 0.55 ppm. This is the highest mean egg mercury level recorded in a sample of seabirds from Canada, including Common Terns and cormorants from Bathurst Harbour in 1968. Although this is in the range of mercury levels associated with reduced hatchability in pheasants (Fimreite, 1971), the effects on reproduction in storm-petrels are not known. In 1979, mercury in Pigeon Guillemot eggs from western Vancouver Island also approached the 0.50 ppm level.

No overall long-term trends in mercury levels were discernible. In all east coast seabirds except Leach's Storm-petrels from the Bay of Fundy, mercury levels were stable between 1972 and 1980. Leach's Storm-petrel eggs collected from Kent Island in 1984 for organochlorine monitoring, and stored in the CWS specimen bank, should be re-analyzed for mercury to determine if the mercury levels continued to increase.

CADMIUM:

Although not considered an essential element, cadmium levels much higher than those in ambient water and sediments have been reported for plankton (Price and Knight, 1978) invertebrates (Pringle et al, 1968) and aquatic macrophytes (McIntosh et al, 1978). High levels of cadmium have been found in tissues of pelagic surface-feeding procellariiform seabirds and also in puffins, which are reported to feed largely on plankton during the winter season (Bull et al, 1977; Osborne et al 1979). Bull et al reported high cadmium concentrations in seaskaters and other zooplankton seabird prey. High metal levels in seawater were thought to be associated with upwelling of nutrients and bottom sediments at sites in the open ocean. Low cadmium levels in Razorbills were ascribed to the coastal range and fish diet of this species.

Cadmium tends to accumulate in the kidney cortex while muscle levels are generally low (Nicholson, 1981). However, some limited interspecific comparisons should be possible using levels in breast muscle. Lowest cadmium levels were reported in a sample of two Razorbills, which is similar to the findings of Bull et al. However, cadmium levels in Black Guillemots, based on a larger sample size of six, were much higher. Guillemots probably feed more opportunistically on zooplankton than razorbills, and tend to remain within site of land year round (Brown et al, 1975). Cadmium levels in Common Murres were highest and may also relate to a more planktivorous diet, particularly outside the breeding season (Bradstreet, 1985). Levels in gannets, which feed on large-bodied schooling fish, were generally lower and varied considerably.

Tolerance to high Cadmium levels by seabirds is thought to be due to binding of the element to low molecular weight proteins such as metallothionein (Hutton, 1981). However, Nicholoson and Osborn (1983) have reported kidney lesions in seabirds with high tissue levels of cadmium and mercury. No data is available on kidney cadmium levels in pelagic seabirds breeding in Canadian waters. In light of these findings, a comparitive study of cadmium and other trace element levels in selected species from both the east and west coasts of Canada seems warranted.

Higher levels of cadmium were found in 1970 in Double-crested Cormorant liver and kidney samples from the Baie des Chaleurs than in samples from the Bay of Fundy. These cadmium levels are not associated with toxic effects in other avian species (Cain et al, 1983; Di Guilio and Scanlon, 1984a). The elevated levels from the Baie des Chaleurs area may, however, indicate local contamination from human activities. There are two large metal mines operating within the watershed of the bay. Cadmium levels in Common Mergansers collected in June 1973, from the Restigouche river had 0.26 ppm (wet weight) cadmium in liver and 0.77 ppm in kidney. These birds were probably in the bay area for some time prior to collection and did not show tissue cadmium levels indicative of recent exposure.

LEAD:

The large variance in lead residues in seabird breast muscle samples points to lead contamination during sampling or analysis. Although no data is available on toxicity of lead to the species collected, mallard ducks that died after being fed lead shot had average dry weight breast muscle lead content of 2.3 to 10.6 ppm with a mean of 4.6 ppm (Longcore et al, 1974). Therefore, 8.9 ppm of lead in breast muscle of guillemots would indicate much higher, probably toxic exposure. The possibility that guillemots, although frequently benthic foragers, are regularly ingesting spent lead shot, seems unlikely. Three of the guillemots or 50 % of the samples had high lead levels. Guilio and Scanlon (1984b) found no ingested lead shot in the gizzards of 89 marine ducks as opposed to 27 out of 184 freshwater mallards. There is a possibility of residual lead in birds which had been wounded by lead shot; however, this should be more prevalent in murres, large numbers of which are regularly harvested in Newfoundland (Wendt and Cooch, 1984).

The most probable source of high lead levels in these breast muscle samples is from contamination by lead shot at time of collection. This suggests that breast muscle should not be analyzed for lead if specimens are collected by shooting. Analysis of other organs is possible unless impacted directly by shot and provided that the animal is killed instantly (Kendall and Scanlon, 1981). The seabird samples in Table 4, Appendix 5, with non-detectable lead levels were probably not hit in the breast by lead shot. These samples probably indicate that background lead levels in seabird breast muscles are low, i.e. less than 0.05 ppm.

Human Consumption

Approximately half a million murres are harvested for human consumption in Newfoundland and Labrador every year (Wendt and Cooch, 1984). The effect on the consumer of eating murres with the higher breast muscle lead levels is not known but should be considered. Children are the most sensitive consumers due to the possibility of central nervous system damage. The maximum permissable daily intake of lead for children is estimated at 25 ug/kg per day (King, 1971). Consumption of a 100 gram portion of murre breast muscle would include 3.23 ug of lead, as in the one male sample. For a 20 kg child, this would be approximately 0.16 ug/kg per unit of breast muscle which is an order of magnitude below the tolerance level even if consumed on a daily basis. However, higher levels could be obtained from shot samples judging by levels in razorbills. Also, lead in wild game is only one of many dietary and other environmental sources of lead to the consumer.

6. USE OF SEABIRDS AS INDICATORS OF MARINE POLLUTION

6.1 Introduction:

The need for marine pollution monitoring and the utility of seabirds as indicators has been discussed elsewhere (Gilbertson et al, 1986). The main advantages of seabirds can be summarized as follows:

1. As long-lived, wide-ranging marine organisms, the load of persistent contaminants in seabirds provides a general picture of pollutant levels in the marine environment. Although organisms at lower trophic levels can be used to obtain specific pollutant information, levels are often too variable and temporary to allow much interpretation.

2. Seabirds are generally near the top of marine food chains, tend to bioaccumulate lipophilic contaminants, and are therefore relatively sensitive to changes in environmental levels of pollutants. Some pathological responses observed in seabirds (dermal lesions, hepatic disfunction) may also be applicable to human health.

3. Our knowledge of the seasonal movements, feeding ecology, population size and dynamics of seabirds compare well to our knowledge of other components of the marine ecosystem.

4. Most seabirds breed in large permanent (although seasonal) colonies, making collection of tissues or eggs feasible, and with less impact on populations.

6.2 Existing Monitoring Programs:

The Canadian Wildlife Service has a monitoring program for seabirds on the Atlantic coast. Residue levels of organochlorines, PCBs and mercury in the eggs of three species (Double-crested Cormorants, Atlantic Puffins and Leach's Storm-petrels), each from two sites, were monitored at four year intervals from 1968 to 1984. A detailed evaluation of the contaminant levels in these species and the long-term trends observed are discussed in Pearce et al (in prep). Eggs of the Northern Gannet on Bonaventure Island have also been sampled for contaminants over the same time period. Trends in concentrations of environmental contaminants in the eggs of these gannets were statistically compared to such quality of life parameters as eggshell thickness (Elliott et al, in prep), breeding success and population size (Chapdelaine et al, in prep).

6.3 Selection of Monitoring Species:

The selection of seabird species to use as indicators of marine pollution is dependent on the ecology of the seabird, characteristics of the pollutants to be monitored and the physical and chemical oceanography of the region to be monitored.

Ashmole (1971) divided the ocean into zones based on such criteria as ocean currents, temperature and salinity. In Canadian waters, this results in three zones: high arctic, low arctic and boreal. These regions can be further divided to discrete bodies of water, such as the Bay of Fundy. Strait of Georgia or Gulf of St. Lawrence. Pollutants enter the ocean mainly by two routes, riverine run-off and atmospheric transport, although ocean dumping, mining and industrial discharges and shipping also contribute. Coastal areas are most influenced by run-off from local or riverine sources. The open-ocean areas are most influenced by long-range transport atmospherically or by ocean currents. In order to monitor pollutant levels in the widest range of niches possible, the selection of species should take into account the seasonal movements between the different zones, and the foraging habitat, whether coastal or pelagic, surface-feeding or diving.

To monitor marine pollution in Canadian waters, a non-migratory species feeding on non-migratory prey would be ideal for determining local conditions, but these criteria are seldom met. The seasonal movements, foraging habitat and diet of the seabirds discussed in this report are summarized in Appendix 7 (Tables 1 and 2). The trophic level of the principal and minor prey as well as their habitat and depth found (surface, mid-strata or in the sediments) are important considerations in the interpretation of residue levels in the seabirds sampled.

Finally, there are numerous practical aspects to consider such as the size of the population to be sampled, accessibility of colonies, reliability of collecting samples, and the existence of residue data with which to compare. For example, Herring Gulls have been used to monitor contaminants in the Great Lakes, so there is now an extensive data base on residue levels, physiological parameters, seasonal movements and feeding strategies for this species. Since the aim of the monitoring program is to be able to detect changes in levels of environmental contaminants in the marine system, the most pollutant sensitive species are preferred. The sensitivity of a species is related to its physiology, longevity and reproductive strategy, as well as the aspects discussed earlier. Obvious population declines or reproductive failure in certain species may be indications of sensitivity to pollutants.

6.4 Selection of Tissues:

Avian eggs have been widely used in the detection of lipophilic contaminants in birds. During yolk formation, lipids containing organochlorines are deposited in the egg. Organochlorine concentrations in eggs appear to be most similar to the concentrations in the female's liver at the time of egg-laying, a relationship which has been demonstrated for a number of species including the California Gull (Vermeer and Reynolds, 1970), the Ring Dove (Lincer and Peakall, 1973) and the Herring Gull (Norstrom et al, 1986). Egg removal is less destructive than collection of adults as eggs are often replaced during the same breeding season. They are usually easily collected, provide a standard unit for sampling and do not rapidly decompose.

Other than mercury, heavy metals are not usually detectable in eggs. To monitor cadmium, lead and other possibly toxic metals, collection of whole bodies (or at least certain tissues) is necessary. Feathers can be used to monitor mercury levels. Fledglings might provide a means of determining local metal contaminant levels, and would also be relatively easy to collect. There has been some research on the feasibility of using blood samples, particularly for the detection of lead in species where collection of specimens is undesirable.

6.5 Suggested Atlantic Region Monitoring Strategy:

The criteria for selection of seabird species for monitoring have been discussed in section 6.3. In the case of the Atlantic coast program, the main consideration is the already existing monitoring scheme, initiated in 1968. The three species were originally selected to represent seabirds from each of two marine habitats (coastal and pelagic) and one to represent overall pollution, and to represent different seabird phyla, as follows:

1. Inshore feeder - to detect contaminants in run-off. The Double crested Cormorant was selected because of its inshore foraging preferences and evidence of eggshell thinning in other studies.

2. Pelagic feeder - to detect aerial fall-out. The Leach's Storm-petrel was selected because of its surface-feeding behaviour. The Black-legged Kittiwake is less pelagic and may be abnormal in its ability to excrete DDE.

3. Offshore sub-surface feeder - to detect overall pollution levels. The Atlantic Puffin was chosen over other alcids mainly on the basis of its more extensive breeding range, accessibility and abundance. The Northern Gannet is also being monitored in response to observations of reproductive failure, and like the puffin, may be regarded as an indicator of overall pollution in the region.

These species are not ideal monitors. Very little is known of the wintering areas or winter diet of petrels or puffins, which precludes conclusions about the source of contaminants. Cormorants winter along the U.S. coast as far south as Florida, so the pollutant load must be regarded as a summation of exposure in the wintering areas as well as at the breeding sites. In spite of these problems, we feel that monitoring of these species should continue, justified mainly by the existing long term contaminant data, and partly for the original criteria discussed above.

In order to investigate spatial distribution of contaminants in the estuary and Gulf of St. Lawrence, we suggest collections of pre-fledged young of Double-crested Cormorants or Black Guillemots. Collection of chicks to eliminate the influence of contaminants acquired outside the breeding area has been used successfully elsewhere (Fimreite and Bjerke, 1979: Niethammer _et al_, 1984). It is also easier to study the diet of fledglings, and thus determine routes of exposure. The feasibility of such a study would depend on a number of factors. In order to look at the contaminant flux from the St. Lawrence river outflow to other regions in the Gulf, appropriate collection sites must be available. This requires a preliminary survey of the distribution of colonies of Double-crested Cormorants and Black Guillemots in the Gulf. Investigations of the length of time for contaminant levels in the tissues of fledglings to reach equilibrium with levels in the diet would also be required to determine the optimum collection dates.

Detection of most heavy metals requires collection of tissues (livers and kidneys) or whole bodies. The Black Guillemot is an abundant omnivorous coastal resident, which feeds primarily in the inshore zone, often on benthic fish during the breeding season. It therefore provides a means of detecting exposure of marine birds to sediment-associated heavy metals and organochlorines. Chicks are fed entirely on fish, usually benthic, which could be verified by observations. One problem might be that, although abundant, this species does not always nest in accessible sites. It would therefore be advisable to initiate preliminary investigations of suitable sampling locations, in terms of both nest site and colony location, as suggested above. If appropriate collection sites were found, it might be possible to use the Black Guillemot to monitor both heavy metal and organochlorine contaminants. Sampling of seaducks from different intertidal zones would be a valuable addition to the seabird monitoring program, particularly in the detection of trace metals in estuarine sediments.

One final suggestion is to examine organochlorine residues in eggs or tissues of a seabird at the top of the food chain, such as a Great Black-backed Gull or Herring Gull known to be preying on other seabirds or their eggs. These species have the potential at certain sites (depending on diet) to be exposed to the highest levels of contaminants of any seabirds. The Herring Gull, in particular, has the advantage of being extensively monitored elsewhere (in the Great Lakes) and the internal contaminant dynamics have been extensively studied (Norstrom et al, 1986; Clark et al, in prep.).

6.6 Suggested Pacific Coast Monitoring Strategy:

On the west coast, the monitoring scheme has been less structured than on the east coast, so little long term contaminant data is available for any species. Most species were sampled in 1970 at one or more locations and again in the early 1980's.

Selection of species to use in this monitoring scheme should take into account the species being used elsewhere in Canada, in order to minimize differences in physiology and metabolism. Practical aspects such as abundance, colony accessibility and evidence of pollutant related problems should also be considered. We suggest the following monitoring program:

1. In order to monitor inshore pollution, particularly in the industrialized Strait of Georgia, we recommend sampling of eggs of Double-crested Cormorants. This species is resident in the strait, feeds mainly on benthic and mid-strata fish, is

relatively abundant and has been sampled here in the past and on the east coast.

2. In order to monitor contamination in remote locations where long-range transport (by ocean currents or in the atmosphere) is most important, we recommend the Leach's Storm-petrel. Although residues in this species were not as high as in the Fork-tailed Storm-petrel, it has a more extensive breeding range and could therefore be sampled at sites in the Queen Charlottes and on Vancouver Island. It has been monitored in B.C. in the past, is presently monitored on the east coast, and is known to feed exclusively at the ocean surface.

3. Using similar criteria to select a species to represent overall exposure as on the east coast, an alcid feeding on mid-strata fish would be the best choice. The Rhinocerous Auklet fits these criteria, is physiologically similar to the Atlantic Puffin, and has been sampled in the past. Furthermore, both this species and the Tufted Puffin have undergone periodic reproductive failures at some colonies, where contaminant concentrations in almost starved chicks may have contributed to mortality.

4. In order to monitor concentrations of heavy metals in Pacific coast seabirds, we recommend the Pigeon Guillemot. This species is physiologically similar to the Black Guillemot (suggested as an indicator on the east coast), is abundant along the B.C. coast, feeds primarily in the coastal zone, often on benthic fish near the sediments, and has been investigated previously. As on the Atlantic coast, sampling of seaducks in estuaries would help to identify local sources of trace metals.

5. Most organochlorine residues are lower in seabirds from the west coast than in species from the east coast. It seems unlikely from reported contaminant concentrations that Glaucous-winged Gulls are being significantly exposed through their diet. It

might be interesting to investigate residues in this species where they are known to be feeding on other seabirds or their eggs, or at locations where human refuse constitutes a significant proportion of their diet.

6.7 Suggested Arctic Seabird Monitoring Program:

Sampling of residues in arctic seabirds has so far been limited to a series of samples in the mid-1970's from two sites. Levels of most contaminants were much lower than in more southern seabirds, which does little to justify an extensive monitoring program. Of all arctic species, the Ivory Gull, was most indicative of levels in the arctic marine system, since it seldom ventures further south than the edge of pack ice. However, collection of pre-fledged young of such abundant species as the Thick-billed Murre might be a more feasible method of monitoring local arctic contamination. Murres feed their young almost exclusively on fish, are relatively abundant, and collection trips might be combined with ongoing investigations of this species in the Canadian arctic.

Species exposed to the highest levels of contaminants would be the predators of marine seabirds and their eggs, ie. Glaucous and Iceland Gulls. Acute mortality has been recorded in the Glaucous Gull associated with elevated contamiant levels (Bogan and Bourne, 1972), and its occasional scavenging behaviour to supplement a diet of seabirds could result in very high exposure. We recommend a preliminary investigation of toxic residues in this species, which is relatively abundant and widespread.

6.8 Statistical Sampling Design:

In order to detect temporal and spatial trends in levels of environmental contaminants in seabirds, the statistical design must be tailored to take into account the high degree of variance within samples.

The main considerations in this design are as follows:

- -the desired detectable difference between samples
- -the variation within the sample, ie. between eggs
- -analytical variation
- -the maximum number of units (eggs) which could be collected
- -the analytical costs per egg
- -required reliability of estimate

Tests of the relative efficiencies (R.E.) of various sampling models employing pooling of samples, were examined by Struger (1984) in looking at ways to reduce the cost of the Great Lakes Herring Gull Monitoring Program without jeopardizing statistical interpretations. Due to the high individual variation in contaminant concentrations in eggs, the number of individual analyses required to detect minor changes (10%) is prohibitively high, both biologically and financially. On the other hand, the current design of 10 individual analyses means that we are only 80 % confident of detecting a change of 54% of residues between years at the .05 level of significance. Struger therefore proposed the use of pooled samples and calculated the relative efficiency and cost efficiency of a number of models, for Great Lakes Herring Gulls.

Gilbertson et al (1986) modified the model above using the coefficients of variation (C.V.) for DDE, dieldrin, HCB and PCBs from C.W.S. data collected on the east coast. The model was designed to detect changes in levels of the most variable compound, in this case, HCB. Using the Sokal and Rohlf (1969) formula, the number of individual samples required to detect a 20% change in HCB residue levels of Atlantic Puffins from Great Island was calculated to be 34. The analytical costs of analyzing 34 egg samples (at about $300 per sample) are prohibitively high. In order to test the "pooling" model, it is necessary to know the analytical variance. Although no analytical variances of HCB were available for Atlantic Puffins, they were available for Herring Gulls. It was assumed that this variance is mainly a function of the analyst (in both cases the Ontario Research Foundation) if the residue levels are similar (which they are). These workers tested alternative designs with various numbers of pools of various numbers of eggs. The model with 10 pools of 3 eggs each, was found to be most efficient, with an R.E. of 164 % compared to 10 individual analyses. Moreover, although the collecting and preparation costs would be somewhat higher, the major expense of analyses at over $300.00 per sample would be no higher than 10 individual analyses.

The above is true only for the desired detection ability of HCB in Atlantic Puffins, and would have to be modified for each seabird species to be monitored. It seems clear, however, that the usual 5 to 10 randomly collected samples may not be sufficient to detect the types of changes really occurring. We recommend that various sampling models using pools of eggs be tested for the seabird species selected above, in order to obtain the maximum useful data for the given allocation of funds and effort.

It should be noted that although analyses would be done on pooled samples, all samples would be processed and stored in the CWS National Specimen Bank individually. This would allow the option of individual analyses where health effects were suspected, if funds became available.

7. CONCLUSIONS:

7.1 Occurrence:

All routinely-measured organochlorine contaminants (PCBs, DDE, DDT, DDD, HCB, dieldrin, heptachlor epoxide, mirex, oxychlordane, cis-chlordane and HCH) and mercury were detected in seabirds from all regions of Canada, between 1968 and 1985, fifteen years after severe restrictions on the use of most of these chemicals in North America.

7.2 Contaminant Levels:

Levels of organochlorine contaminants in seabird samples ranged from nondetectable to almost 100 ppm, wet weight. PCBs were the most prevalent, typically in the 1.0 to 10.0 ppm range with an upper limit of 81.4 ppm. DDE, the primary DDT metabolite in birds was present in all samples, usually in the 0.50 to 5.0 ppm range. Dieldrin, HCB and oxychlordane generally occurred at levels less than 1.0 ppm, but greater than 0.10 ppm, except in remote locations. The remaining compounds, the HCH isomers, cis and trans chlordane, cis and trans nonachlor, heptachlor epoxide, mirex, DDD and DDT, were usually at concentrations less than 0.10 ppm. Mercury levels in eggs were generally less than 0.50 ppm, but levels in livers were as high as 10 ppm.

7.3 Comparison with other regions:

Levels of most organochlorines and mercury were lower in seabird species from marine locations in Canada than in similar species from the Great Lakes. Contaminant related effects such as serious eggshell thinning, congenital abnormalities and low productivity documented for several fish-eating species in the Great Lakes, were not observed in any Atlantic coast seabirds except Northern Gannets.

Contaminants, particularly PCBs and mercury, in Common Tern eggs from colonies in the Gulf of St. Lawrence in the early 1970's were almost an order of magnitude lower than in eggs from the Great Lakes. In contrast, residues of DDE and PCB's in

Double-crested Cormorants were not significantly higher in eggs from the Great Lakes than in eggs from the east coast. DDE in tern eggs collected along the U.S. Atlantic coast in 1980, was comparable to our samples, but PCBs near some industrial sites in the northern states were much higher.

Levels of most organochlorines in eggs and tissues of alcids, gannets and cormorants collected along the east coast of Canada, were lower than residue levels in those species from northern European locations. However, gannet eggs from the early 1970's contained organochlorine residues considerably higher than levels in the United Kingdom, where toxic effects on reproduction had been reported.

Most arctic seabirds are considerably less contaminated than similar species sampled further south. The contaminant burden in arctic seabirds is similar to levels in seabirds and their eggs collected from Norway and Spitzbergen, but higher than in seabird eggs from Alaska.

Concentrations of contaminants in Pacific coast seabirds were intermediate between higher levels to the south in Oregon and California, and lower levels to the north in Alaska. Organochlorines, except for HCH, were lower overall in seabirds from the west coast than from the east coast. By 1984, however, DDE in storm-petrels and Rhinoceros Auklets from Vancouver Island and the Queen Charlottes was higher than in storm-petrels and puffins from Newfoundland.

7.4 Effects:

Levels of organochlorines and heavy metals found in tissues or eggs of Canadian seabirds from 1968 to 1985, were not high enough to cause direct mortality. However, some of the levels were high enough to have sublethal effects.

Levels of contaminants in the brains of dead Northern Gannets (up to 49 ppm DDE, 1.44 pmm dieldrin and 81 ppm PCB's) were below diagnostic lethal levels. However, it is possible that mortality was induced at these sublethal levels by triggering fasting and subsequent mobilization of lipophilic compounds to the brain, or by affecting the bird's ability to forage efficiently.

DDE has been associated with eggshell thinning in several species of seabirds. Eggshell thinning greater than 20 % is generally considered to affect egg hatchability. Canadian seabird populations thought to have suffered reproductive effects due to DDE include the following:

i) During the late 1960's, eggs of Northern Gannets from Bonaventure Island, Quebec, contained DDE levels of 30 ppm, wet weight, associated with significant eggshell thinning, extremely low productivity (29 %) and a population decline. In 1969, many unhatched eggs were devoid of the normal chalky outside cover. Levels of PCBs, dieldrin and HCB may also have contributed to reduced hatching success. By 1984, DDE levels had decreased, eggshell thickness had increased and productivity rose to 75 %.

ii) In the early 1970's, 20% of the Double-crested Cormorant eggs from the Atlantic coast contained DDE residues in excess of 15 ppm, enough to cause significant eggshell thinning in this species. No information is available on hatching success during this period, and localized population declines were not associated with elevated residue levels.

iii) DDE residues greater than 8 ppm in some eggs of Leach's Storm-petrel from Kent I. in 1972, probably caused some eggshell thinning, but there was no evidence of reproductive or population effects.

iv) Mercury levels in livers of some fish-eating birds, including cormorants, collected from the Baie des Chaleurs in 1969, were high enough to be associated with adverse reproductive effects according to studies on other species. Mercury in eggs of Leach's Storm-petrel from the Bay of Fundy, and Pigeon Guillemot from Vancouver I. around 1980, are close to levels found to reduce hatchability in eggs of pheasants.

v) Dieldrin concentrations greater than 1.0 ppm in some Northern Gannet eggs in the early 1970's may have contributed to the reproductive failure documented at that time.

7.5 Temporal trends:

Sufficient data were available to establish long term trends in five Atlantic coast seabirds. The overall picture was of declining residues everywhere, except in the St. Lawrence estuary and parts of the gulf. PCBs, DDE and dieldrin showed the most significant declines: HCB, oxychlordane, HCH, mirex and heptachlor epoxide levels revealed no consistent trend. Less complete data from the Pacific coast also show decreases of most contaminants.

The decreases of contaminant levels correspond roughly with patterns of use. In North America and Europe, restrictions on the use of DDT, PCBs, dieldrin, HCB and HCH, started around 1970. Most compounds were further restricted in the mid-1970's. The restrictions on chlordane use in North America date from 1978.

The pattern of changes in contaminant levels, by geographic region, are described below.

i) In the Bay of Fundy, residues of PCBs, DDE, and dieldrin declined significantly in eggs of Leach's Storm-petrel, Atlantic Puffin and Double-crested Cormorant between 1968 and 1984. Oxychlordane, heptachlor and HCB did not show consistent or statistically significant changes.

ii) In eggs of Leach's Storm-petrel and Atlantic Puffin from Great I., Newfoundland, PCBs, DDE and dieldrin declined between 1972 and 1984. HCB and oxychlordane did not change significantly, and heptachlor epoxide increased.

iii) At Ile aux Pommes in the St. Lawrence estuary, no contaminants declined significantly in eggs of Double-crested Cormorant between 1972 and 1984, although DDE and dieldrin were initially higher in 1972.

In the Gulf of St. Lawrence, the situation was somewhat better. Only DDE declined in Razorbill eggs from the Ste. Marie Islands (between 1972 and 1978). Dieldrin, oxychlordane and PCB levels were stable, while HCB and heptachlor increased significantly. Organochlorine concentrations in eggs of Northern Gannet from Bonaventure Island show similar temporal trends.

Dieldrin and the DDT compounds declined between 1968 and 1984, but most other contaminants did not change significantly. Therefore, although contaminant levels in the St. Lawrence estuary have changed little since the late 1960's, some contaminants (particularly DDT compounds and dieldrin) had declined in the gulf by 1976. The main continuing sources of these contaminants include the Great Lakes outflow, St. Lawrence River basin run-off and mobilization from the sediments.

iv) In the Strait of Georgia, DDE, PCBs, dieldrin, and heptachlor declined in eggs of Double-crested Cormorant, Pelagic Cormorant and Glaucous-winged Gull between 1970 and 1985. Other compounds did not show consistent patterns. Oxychlordane increased slightly only in Double-crested Cormorant, and HCB increased in eggs of Glaucous-winged Gull. DDE and PCB's, but not HCB declined in eggs of Rhinocerous Auklet from Lucy Island between 1970 and 1985. Data on longterm trends of contaminants in west coast samples is limited and little can be concluded other than an overall picture of declining residues of most contaminants.

7.6 Potential Contaminant Effects:

7.6.1 Seabird Wrecks and Oilspills:

Environmental contaminants have previously been implicated in large scale mortality at sea, usually associated with inclement weather. Under the stress of food shortage, birds mobilize internally stored lipids, increasing plasma and target organ concentrations, which can contribute to mortality. Seabirds caught in oilspills, and therefore unable to forage efficiently also cannibalize stored lipids, and become vulnerable to otherwise low "background" contaminant burdens.

7.6.2 Nestling Mortality:

Years of low food availability and reduced productivity are not uncommon in many alcid species, particularly puffins and Rhinocerous Auklets. Studies in Europe showed that emaciated puffin chicks contained over 100 times the contaminant levels of healthy chicks, enough to contribute significantly to mortality. It is possible that contaminants affected nestling survival in seabirds on Triangle Island (north of Vancouver Island), where Tufted Puffins recently failed in three out of five years.

7.6.3 **Population Effects:**

Environmental contaminants have been implicated in the declines of some seabird populations over the past 20 years, in the southern U.S.A. and parts of Europe. In Canada, several species of seabirds have declined in parts of their range since the late 1960's, but the role of contaminants is not known. For most seabirds, particularly storm-petrels and alcids, censusing is incomplete and the status of populations can only be estimated. The following species have experienced population declines:

i) Razorbills have apparently declined along the north shore of the Gulf of St. Lawrence, although the population in the estuary is now probably stable. Double-crested Cormorant populations from the north shore of the gulf also declined in the early 1970's, but had recovered considerably by 1982.

ii) Common Tern populations have declined at some locations in eastern Canada over the past several decades. Although habitat destruction, hunting on the wintering areas and harassment by large gulls have all been implicated, the role of contaminants is unclear.

iii) Several species of west coast alcids (particularly Ancient Murrelets and Tufted Puffins) have apparently suffered declines recently in the Queen Charlotte Islands. Most of these species have not been analyzed for contaminants since 1970.

7.7 Significance to Predators of Seabirds:

Organochlorine contaminants in seabird tissues constitute a possible toxic risk to the predators which prey on them. Enderson et al (1982) reported eggshell thinning and associated reproductive failure in Peregrine Falcons, where prey contained

DDE residues in excess of 1.0 ppm.

In British Columbia, storm-petrels and small alcids are the primary summer prey of some Peregrine Falcons and Bald Eagles. Although populations of the western peregrine subspecies are currently stable, reproductive failures have been documented in the past (Nelson and Myers, 1976).

Many gull species (Glaucous, Iceland, Glaucous-winged, Herring, Western and Great Black-backed) often prey on seabirds, particularly the eggs and chicks. Although most populations of these species appear to be flourishing, there may be localized effects where these species are specializing on seabird prey, and where the winter food is largely obtained at garbage dumps. Other predators of seabirds potentially at risk from contaminated prey include jaegers, Great Horned Owls, Gyrfalcons, ravens, otters and foxes.

7.8 Human Health Implications:

Seabirds or their eggs constitute a significant proportion of the diet of a small number of Canadians. The major species consumed are Common and Thick-billed Murres from Newfoundland, the Gulf of St. Lawrence and the arctic, eiders along the Atlantic coast, and the eggs of murres, cormorants, eiders, gulls and terns at their breeding colonies in the arctic, the Gulf of St. Lawrence and Newfoundland. Egging, however, has been greatly reduced in recent years.

The maximum organochlorine and heavy metal residue limits in meat, fish and poultry, in Canada, have been established by the Food Directorate of the Department of Health and Welfare (Anon.,1980) and by Fisheries and Oceans (Anon.,1977). Wong (1985) noted that these limits are based on estimates of the average amount of fish, meat and poultry consumed on a weekly basis, and may not be relevant where people are consuming significant quantities of wild game.

On several occasions, public health authorities curtailed hunting in response to unacceptable contaminant levels in wild game. These included suspected heptachlor in New Brunswick woodcock (Pearce and Baird, 1971), mercury in Albertan game-birds (Wishart, 1970) and the endrin "scare" in Montana (Schladweiler and Weigand, 1983). Similar closures have occurred where sport fish were found to be highly contaminated (Wilson and Addison, 1984).

Organochlorine and mercury levels in some seabird tissues and eggs were higher than the maximum residue limits in poultry established by Health and Welfare. Therefore, regular ingestion of seabird game over a long period of time, may be harmful.

8. RECOMMENDATIONS:

8.1 Identification of contaminated areas

Although levels of many contaminants appear to have declined, levels are still elevated in seabirds from some regions of Canada. We recommend further investigation of contaminant levels and biological effects in the following areas:

i) St. Lawrence estuary and gulf:

Look at pattern of residue levels in different parts of the gulf and estuary by measuring residue levels in a local indicator, such as eggs or fledglings of the resident Black Guillemot, prefledged cormorants or other fish-eating birds.

Determine influence of the outflow from the Great Lakes via the St. Lawrence river by sampling of eggs of a particular seabird or other fish-eating species, from locations in the freshwater section of the St. Lawrence River, along the estuary to localities along the north shore (Ste. Marie Islands) and in the middle of the gulf (Magdalen Islands).

These investigations would be most valuable as part of a comprehensive study of contaminants in the St. Lawrence system biota. An integrated monitoring scheme would include surveillance of contaminants in water, sediments, plankton, fish and wildlife. Seabirds included in this monitoring program would be Double-crested Cormorants and Northern Gannets, but considering the high levels in some Razorbill eggs in the mid 1970's, this species should also be investigated.

ii) Strait of Georgia:

Certain sites in the Strait of Georgia, near pulp and paper mills, waste treatment plants or other industries should be re-examined to evaluate the impact of PCBs, mercury and such microcontaminants as dioxins and dibenzofurans on local wildlife, particularly fish-eating seabirds. As mentioned above, a comprehensive survey of contaminants in water, sediments, plankton and fish (particularly species which are important seabird prey) would be most useful.

iii) Baie des Chaleurs:

Seabirds in this region should be investigated to determine contaminant (particularly mercury) levels, and the status of local seabird populations. Recent evidence of elevated mercury levels in fish-eating waterfowl suggests that exposure to mercury may still be high.

8.2 Assessment of contaminant effects on seabirds:

Where residue levels in eggs or tissues of seabirds approach potentially toxic levels, or in locations where local pollutant sources are suspected, there should be a comprehensive reproductive assessment. Sites that should be investigated are listed above. The manifestations of toxic effects to look for include:

a) eggshell thinning and egg breakage rates
b) embryotoxicity
c) incidence of congenital abnormalities in chicks
d) pathological examination of dead nestlings or adults
e) any unusual behaviour, such as deliberate egg breakage
f) biochemical responses, including porphyria and hepatic enzyme induction.

Much of this type of information may be obtained during ongoing ecological studies on seabirds. Greater coordination of contaminant monitoring and other seabird research would yield valuable biological data (on productivity, diets, behaviour) associated with the measured contaminant levels.

8.3 Investigations of potentially vulnerable species:

Considering the levels in eggs of many alcids and storm-petrels, we would encourage investigation of contaminant levels in species which prey on these species or their eggs. These would include:

a) Great Black-backed Gulls on the east coast
b) Glaucous Gulls, Iceland Gulls and jaegers in the arctic
c) Glaucous-winged Gulls on the west coast

Most of the *Larus* gulls are physiologically and behaviourally very similar, and could be used to monitor levels at the top of the food chain all over Canada. Some species may also be exposed to significant amounts of toxins by scavenging in garbage dumps, and indirectly, by feeding in areas close to garbage incinerators. Herring Gulls are presently successfully used to monitor pollution in the Great Lakes. A review of contaminant levels in this species in marine colonies is in preparation.

8.4 Temporal trends:

Seabird Monitoring Program:

The current seabird monitoring program is discussed in detail in Section 6. The species to be monitored are Double-crested Cormorants and Leach's Storm-petrel on both coasts Atlantic Puffins and Northern Gannets on the Atlantic coast, Rhinoceros Auklets on the Pacific coast, and Thick-billed Murres in the arctic. Sampling on the west coast and in the arctic should be done every four years, as on the east coast. Potential improvements and additions include the following:

a) monitoring of levels of heavy metals and radionuclides in seabird species from both coasts and the arctic, to determine "background" levels and to identify local sources.

b) use of resident species such as Black and Pigeon Guillemots, which could be used as local indicators, and are found in all coastal regions of Canada.

c) further sampling of arctic seabirds, from Prince Leopold Island to determine temporal trends, and from elsewhere to investigate geographical variation in the arctic.

d) use of serial blood or feather sampling techniques, which are nonlethal, and could potentially be performed on the same bird in different years.

e) re-assessment of the present sampling design used in the seabird monitoring program to ensure that it is adequate to detect the differences in measured contaminant levels required.

As mentioned previously, there should be greater coordination with current seabird research and censusing, to maximize the relevant biological data and minimize logistics.

Use of National Specimen Bank:

The National Specimen Bank contains most of the seabird samples discussed in this report. There are also many specimens from Canada (including Sooty Shearwater, Glaucous Gull, Great Cormorant, Great Black-backed Gull) which have not been analyzed. To process all of these samples would be prohibitively expensive, but if investigations of such species are undertaken, analyses of banked samples could show past levels. Since all samples are stored in the specimen bank, older specimens could be re-analyzed using new techniques, if funds became available.

8.5 Sources and routes of environmental contaminants:

8.5.1 Use data:

Knowledge of past and current industrial, agricultural and household uses of the chemicals and pesticides discussed in this report would help to evaluate their present significance. In Canada, pesticides are regulated by Agriculture Canada, and in the USA, by the Environmental Protection Agency. Access to information on amounts of pesticides produced, sold and used would be very valuable to all agencies involved with monitoring environmental levels.

There are still some organochlorines in use in Canada and the USA, including dicofol (which contains up to 15 % DDT), technical chlordane and lindane. Although these chemicals probably have little impact on seabirds, they are potential continuing sources of input to the environment.

In addition to pesticides, industrial chemicals (including PCBs, HCB and other chlorinated benzenes, dibenzodioxins, dibenzofurans, polychlorinated naphthalenes, polychlorinated styrenes, polychlorinated terphenyls, polybrominated compounds and perchloric acid), heavy metals and radionuclides are also present in the marine ecosystem. Knowledge of the chemicals used and treatment of discharge at manufacturing plants, power generators and mines will be essential if local effects on wildlife or other marine biota are suspected, or where "leaks" occur.

Use data in other countries, particularly Latin America, would also help to determine sources of contaminants in Canadian seabirds. Long range transport from such sources may account for much of the pollution in remote areas (Norstrom and Muir, 1986). It is also possible that Canadian seabirds overwintering in Central and South America may accumulate a considerable contaminant burden before returning north.

8.5.2 Influence of long-range transport:

In order to better assess the health of the marine ecosystem, we would encourage investigations of the routes taken by contaminants in the marine environment. This would involve determination of the input from riverine run-off, ocean currents and direct atmospheric deposition.

i) Riverine input:

Riverine input of contaminants via the St. Lawrence river and the Fraser river are important vectors to the Gulf of St. Lawrence and the Strait of Georgia, respectively. Investigations of contaminant levels in fish-eating birds at different points along the river, and attempts to relate these to currents, the effects of mobilization from the sediments and the chemical/physical properties of the water are suggested.

ii) Oceanic zone:

Higher residues in some remote locations suggest mid-ocean "sinks". We suggest investigation of contaminants in seabirds in oceanic habitat, ie. offshore islands or by collection of strictly pelagic seabirds. Examples of oceanic islands include Sable Island on the east coast, and the western Queen Charlottes on the west coast. Sooty and Greater Shearwaters are regular abundant visitors to our coasts during summer, and could provide baseline data for a species which ranges widely over the ocean outside its breeding season in the southern hemisphere.

iii) Arctic:

We recommend looking at contaminants in arctic seabirds at more locations, preferably a species with a range including most of the arctic (Black Guillemot, Thick-billed Murre, Black-legged Kittiwake) to duplicate the more comprehensive geographical data for fish, seals and polar bears.

8.5.3 Influence of wintering / migration areas of seabirds:

Where possible, it would be useful to examine levels of environmental contaminants in the same species during their overwintering along the coast of the USA, Gulf of Mexico and Latin America. Although exposure during overwintering has been suggested as the reason for elevated residues in some migratory species, most recent studies, at least in the eastern USA, found that local conditions were much more important. The main drawback is that eggs could not be used.

Another technique to determine the influence of non-locally acquired contaminants would be to survey residues in eggs in relation to laying date. The changes in proportion and amounts of the contaminants could be ascribed to the growing influence of local environmental levels. However, females may also reduce their organochlorine burden during the breeding season by excretion via egg lipids.

Some research has been done on "fingerprinting" the chemical profile of a particular region. This could simply be the prevalence of a particular chemical, such as mirex. Contaminant analyses can be presented as chromatographs with individual peaks identified. The types of PCB congeners detected, in some cases, might help to identify the original PCB mixture, and hence, its likely origin. Other useful indicators are the presence of microcontaminants such as dibenzodioxins and dibenzofurans, although detection of most of these requires more sophisticated (and expensive) analyses.

8.5.4 Influence of local conditions:

In order to determine the influence of local environmental levels, contaminant levels in the diet should be studied where possible. These could be obtained by collection of the known prey species or by collection of regurgitations. Since species higher in the food chain tend to preferentially metabolize less chlorinated organochlorines, the proportion of higher to lower chlorinated metabolites of a particular compound might be an indication of the trophic level. However, the molecular structure of a particular isomer may be more important than total chlorine content to its resistance to degradation. By examination of the proportions in the prey as well as the seabird predator, the primary vector of contaminants to the seabird could be studied.

Comparison of the contaminant levels in the sediments near seabird breeding colonies, may help to account for differences between locations. Type of substrate, local currents, depth and salinity all affect the availability of the contaminant.

8.6 Physiological aspects:

The physiological state of a seabird varies over the year, depending on timing of breeding, associated hormonal changes, migration stress, moult and changes in diet. This affects uptake, metabolism and excretion of contaminants, independent of ambient environmental levels. Further research on seasonal and inter-year variation in physiology and tissue composition are required in order to better interpret observed changes in contaminant levels. This could be accomplished by simulation modelling to consider the influence of such variables as age, sex, breeding status and condition.

Certain species may have evolved mechanisms to metabolize, excrete or exclude certain xenobiotics, depending on previous exposure, as suggested by Walker and Knight (1981). Research on possible detoxification mechanisms, on the individual or specific level may help to explain the wide range of effects caused by these chemicals. Research on the feasibility of using biochemical indicators of exposure to pollutants (such as porphyria or induction of hepatic enzymes) is presently underway.

8.7 Coordination of monitoring agencies:

Many non-wildlife agencies also monitor environmental contaminants. Water quality in Canada is the responsibility of a number of agencies including federal (Inland Water Directorate of Environment Canada) and provincial governments, municipalities and through international agreements. Contaminants in commercial fish and shellfish are monitored by Fisheries and Oceans Canada (Anon., 1977). Further coordination, at least in terms of data exchange, between these agencies, the Canadian Wildlife Service and universities undertaking research on environmental contaminants, should be encouraged.

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Appendix 1.

COMMON AND SCIENTIFIC NAMES OF CANADIAN SEABIRDS SAMPLED

Northern Fulmar	Fulmaris glacialis
Leach's Storm-petrel	Oceanodroma leucorhoa
Fork-tailed Storm-petrel	Oceanodroma furcata
Northern Gannet	Sula bassana
Double-crested Cormorant	Phalacrocorax auritus
Pelagic Cormorant	Phalacrocorax pelagicus
Ivory Gull	Pagophila eburnea
Glaucous-winged Gull	Larus glaucescens
Black-legged Kittiwake	Rissa tridactyla
Common Tern	Sterna hirundo
Dovekie	Alle alle
Razorbill	Alca torda
Thick-billed Murre	Uria lomvia
Common Murre	Uria aalge
Black Guillemot	Cepphus grylle
Pigeon Guillemot	Cepphus columba
Marbled Murrelet	Brachyramphus marmoratus
Ancient Murrelet	Synthliboramphus antiquus
Cassin's Auklet	Ptychoramphus aleuticus
Rhinoceros Auklet	Cerorhinca monocerata
Atlantic Puffin	Fratercula arctica
Tufted Puffin	Lunda cirrhata
Common Eider	Somateria mollissima
King Eider	Somateria spectabili

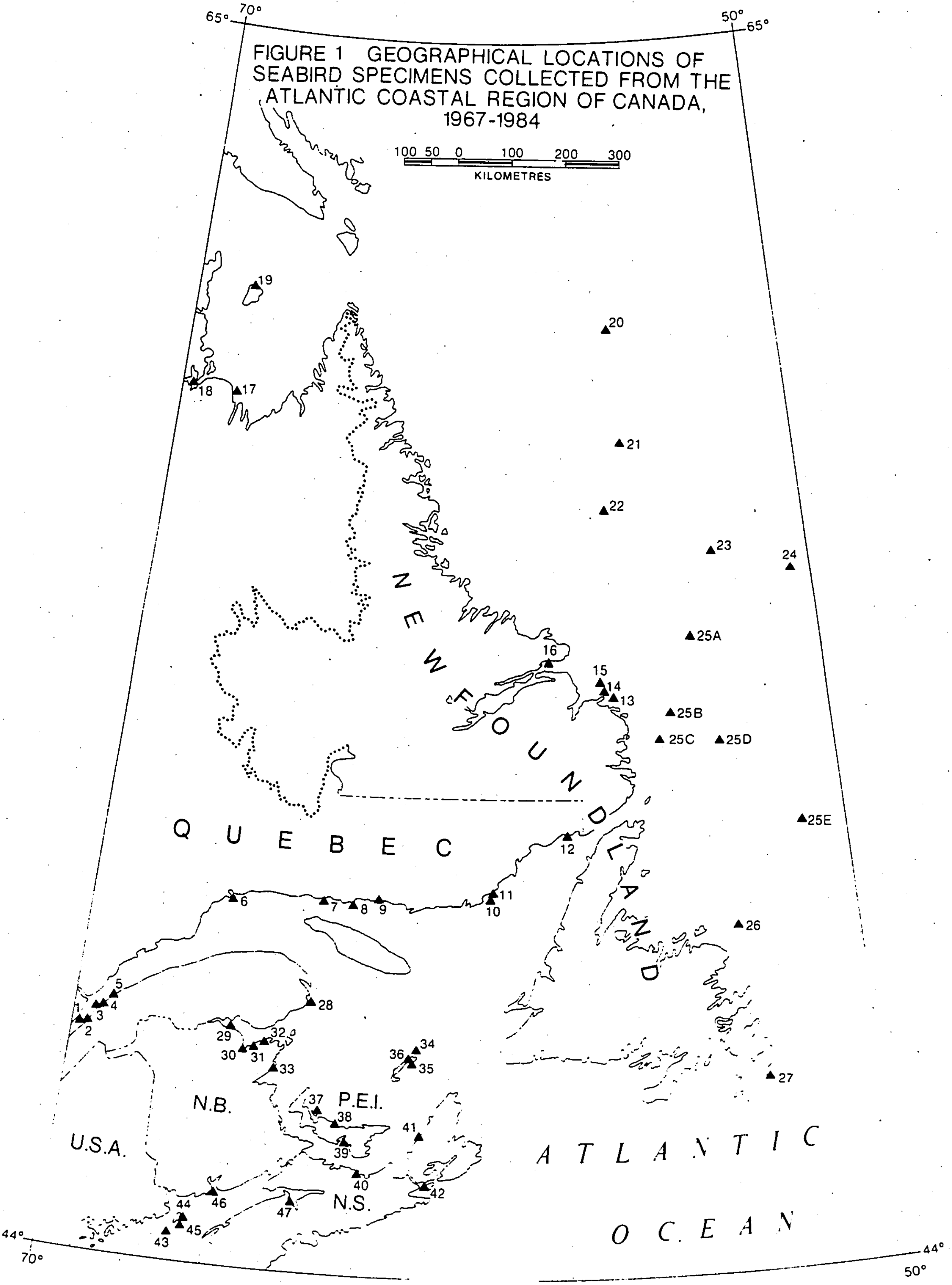

FIGURE 1 GEOGRAPHICAL LOCATIONS OF SEABIRD SPECIMENS COLLECTED FROM THE ATLANTIC COASTAL REGION OF CANADA, 1967-1984

Appendix 2a.

Geographical Locations of Seabird Specimens Collected from the Atlantic Coastal Region of Canada, 1968-1984

Map No.	Location Name	Latitude	Longitude
1.	Pèlerin Islands, Quebec	47°45'N	69°42'W
2.	Ile Blanche, Quebec	47°45'N	69°41'W
3.	Ile Verte, Quebec	48°04'N	69°25'W
4.	Ile aux pommes, Quebec	48°06'N	69°19'W
5.	Iles Razades	48°09'N	69°15'W
6.	Carrousel Island, Quebec	50°05'N	66°23'W
7.	Inner Birch Island, Quebec	50°13'N	64° 0'W
8.	Betchouane, Quebec	50°12'N	63°13'W
9.	Watschishu, Quebec	50°16'N	62°38'W
10.	Ste-Marie Islands, Quebec	50°19'N	59°39'W
11.	Harrington Harbour, Quebec	50°25'N	59°35'W
12.	Parroquet Island, Quebec	51°26'N	57°14'W
13.	Bird Island, Newfoundland	53°44'N	56°15'W
14.	Grady Harbour, Newfoundland	53°48'N	56°28'W
15.	Gannet Islands, Newfoundland	53°56'N	56°31'W
16.	Tinker Harbour, Newfoundland	54°20'N	58° 0'W
17.	Pauktorvic Island, Quebec	58°42'N	68°16'W
18.	Leaf Bay, Quebec	58°48'N	69°16'W
19.	Akpotak Island	60°25'N	68°08'W
20.	Davis Strait A	60° 0'N	55°55'W
21.	Davis Strait B	58°05'N	55°36'W
22.	Davis Strait C	56°58'N	56°08'W
23.	Davis Strait D	56°08'N	52°59'W
24.	Davis Strait E	55°42'N	50°35'W
25.	Labrador Sea A	54°40'N	53°49'W
	Labrador Sea B	53°26'N	54°34'W
	Labrador Sea C	53° 0'N	54°55'W
	Labrador Sea D	52°51'N	53°13'W
	Labrador Sea E	51°24'N	51°17'W
26.	Funk Island, Newfoundland	49°45'N	53°11'W
27.	Great Island, Newfoundland	47°11'N	52°49'W
28.	Bonaventure Island, Quebec	48°30'N	64°09'W
29.	Heron Island, New Brunswick	48° 0'	66°09'W
30.	Bathurst, New Brunswick	47°37'	65°39'W
31.	Janeville, New Brunswick	47°48'	65°25'W
32.	Riorden, New Brunswick	47°48'	65°15'W
33.	Tabusintac, New Brunswick	47°20'N	64°56'W
34.	Brion Island, Quebec	47°48'N	61°28'W
35.	Magdalen Islands, Quebec	47°33'N	61°30'W
36.	Magdalen Islands (Ile Rouge), Quebec	47°36'N	61°33'W

Map No.	Location Name	Latitude	Longitude
37.	Little Courtin Island	46°30'	63°46'
38.	Cape Tryon, Prince Edward Island	46°32'N	63°30'W
39.	Charlottetown, Prince Edward Island	46°13'N	63°08'W
40.	Pictou, Nova Scotia	45°40'N	62°43'W
41.	Margaree Island, Nova Scotia	46°21'N	61°16'W
42.	Campbell Island, Nova Scotia	45°33'N	61°09'W
43.	Machias Seal Island, New Brunswick	44°30'N	67°06'W
44.	Low Duck Island, New Brunswick	44°42'N	66°43'W
45.	Kent Island, New Brunswick	44°35'N	66°45'W
46.	Manawagonish Island, New Brunswick	45°12'N	66°06'W
47.	Boot Island, Nova Scotia	45°08'N	65°16'W

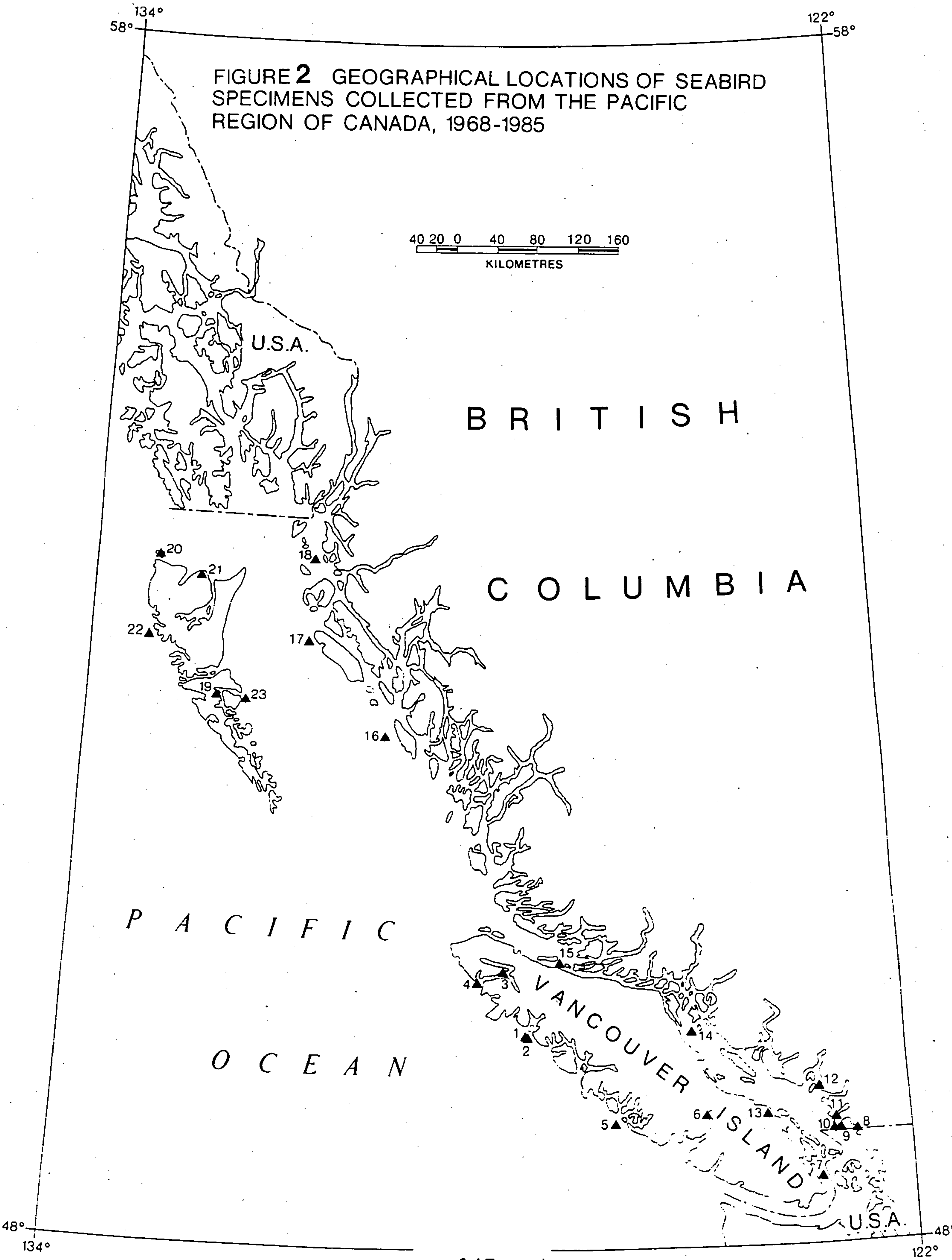

FIGURE 2 GEOGRAPHICAL LOCATIONS OF SEABIRD SPECIMENS COLLECTED FROM THE PACIFIC REGION OF CANADA, 1968-1985

Appendix 2b.

GEOGRAPHICAL LOCATIONS OF SEABIRD SPECIMENS COLLECTED FROM THE PACIFIC COASTAL REGION OF CANADA, 1968 - 1985.

Map No.	Location Name	Latitude	Longitude
1.	Nipple Rocks, Kuyguot	49° 06'N	127° 10'W
2.	Thornton Island	49° 57'N	127° 20'W
3.	Thomas Island	50° 30'N	127° 28'W
4.	Guillam's Island	50° 26'N	127° 57'W
5.	Cleland Island	49° 10'N	126° 05'W
6.	Port Alberni	49° 15'N	124° 48'W
7.	Mandarte Island	48° 38'N	123° 17'W
8.	Semiahmoo Bay	49° 00'N	122° 46'W
9.	Boundary Bay	49° 03'N	123° 00'W
10.	Tsawwassen	49° 03'N	123° 00'W
11.	Fraser River Estuary	49° 06'N	123° 10'W
12.	Horseshoe Bay	49° 22'N	123° 17'W
13.	Nanaimo, B.C.	49° 10'N	123° 57'W
14.	Mittlenatch Island	49° 57'N	125° 00'W
15.	Stephenson Inlet	50° 35'N	126° 49'W
16.	Moore Islands	52° 41'N	129° 25'W
17.	Northwest Rocks	53° 33'N	130° 38'W
18.	Lucy Island	54° 18'N	130° 36'W
19.	Queen Charlotte Islands	53° N	132° W
20.	Langara Island	54° 15'N	132° 58'W
21.	Graham Island	54° 10'N	133° 02'W
22.	Hippa Island	53° 33'N	133° 02'W
23.	Skedans Island	52° 57'N	131° 34'W

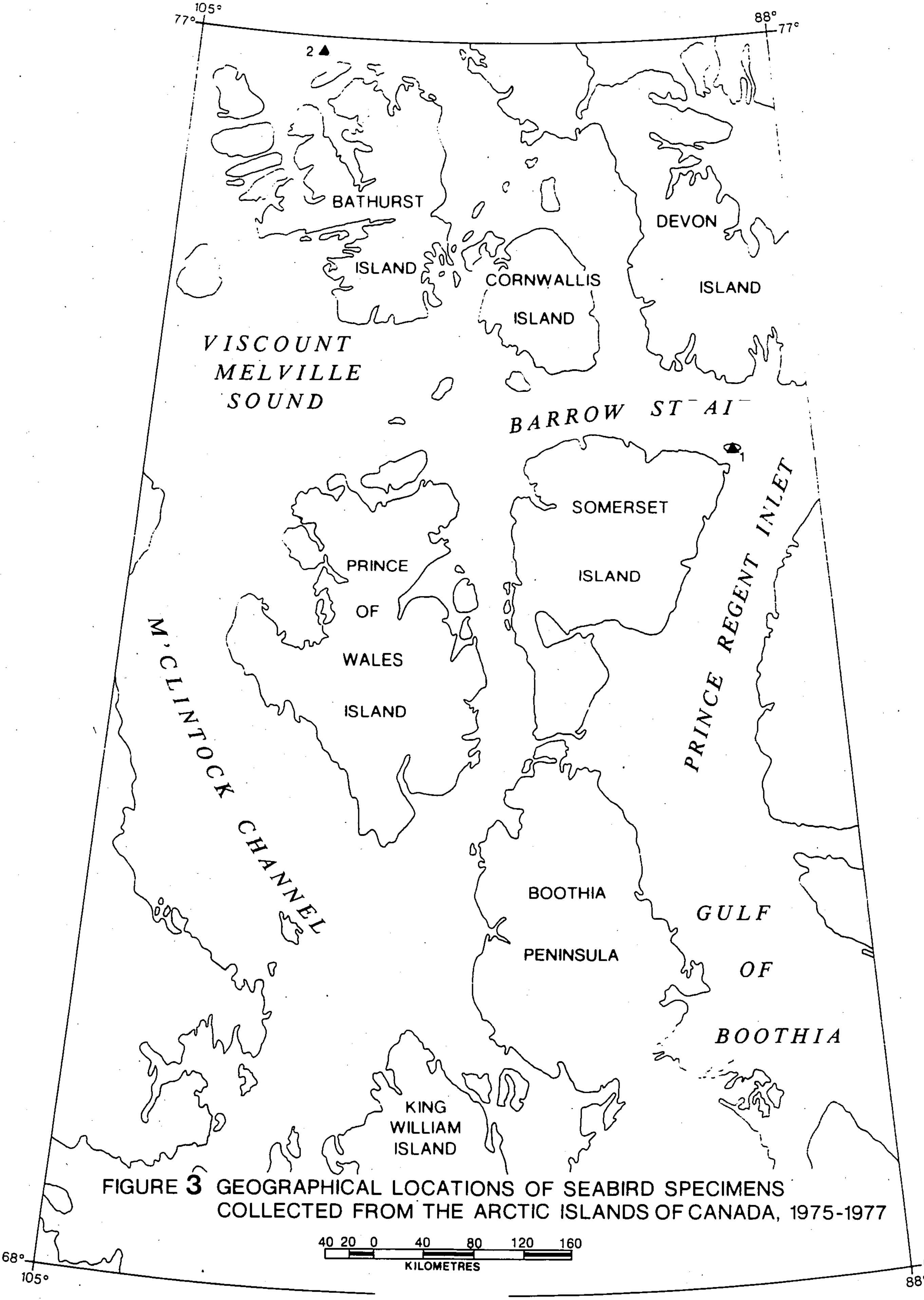

FIGURE 3 GEOGRAPHICAL LOCATIONS OF SEABIRD SPECIMENS COLLECTED FROM THE ARCTIC ISLANDS OF CANADA, 1975-1977

Appendix 2c.

Geographical Locations of Seabird Specimens Collected from the Arctic Islands of Canada, 1975-1977.

Map No.	Location Name	Latitude	Longitude
1.	Prince Leopold Island	74° 2'N	90° 0' W
2.	Seymour Island	76° 48'N	101° 20'W

Appendix 3.

COLLECTORS OF CANADIAN SEABIRDS, 1967 to 1985

1. D.D. Berger
2. A.W.A. Brown
3. R. Drent
4. N. Fimreite
5. G.A. Fox
6. R.W. Fyfe
7. J.A. Keith
8. P. Laporte
9. W.A. Morris
10. W. Nelson
11. D.N. Nettleship
12. R.J. Norstrom
13. D.B. Peakall
14. P.A. Pearce
15. I.M. Price
16. L.M. Tuck
17. P. Whitehead
18. K. Vermeer
19. D. Blood
20. S.M. Teeple

APPENDIX 4

CHEMICAL NAMES OF ORGANOCHLORINES DISCUSSED IN THIS REPORT:

DDT	1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane
DDD	1,1-dichloro-2,2-bis(p-chlorophenyl)ethane
DDE	1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene
Heptachlor epoxide	1,4,5,6,7,8,8a-hexachloro-2,3-epoxy-3a,4,7,7a-tetrahydro-4,7-methanoindane
Mirex	Dodecachlorooctahydro-1,3,4-metheno-1H-cyclo-buta [cd]pentalene
Oxychlordane	1-exo-2-endo-4,5,6,7,8,8a-octachloro-2,3-exo-epoxy-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene
Chlordane	1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane (cis and trans isomers)
Nonachlor	1,2,3,4,5,6,7,8,8-nonachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane (cis and trans isomers)
HCB	Hexachlorobenzene
HCH	1,2,3,4,5,6-hexachlorocyclohexane (alpha, beta and gamma isomers)
Endrin	1,2,3,4,10,10-hexachlorocyclohexane-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethananaphthalene
PCBs	Mixtures of polychlorinated biphenyls differing in the amount of chlorine present

Appendix 5.

Table 1

Levels of organochlorines (geometric mean, ppm, wet wt.) in fresh eggs of east coast Seabirds 1968-1984 compared by chemical, collection site and date of collection.

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
Leach's Storm Petrel											
DDE											
Great Island	$^{xy}1.46$			$^{x}2.91^{a}$			$^{yz}0.74^{a}$			$^{yz}0.460^{a}$	$^{z}0.396^{a}$
Kent Island				$^{x}6.81^{a}$			$^{y}1.75^{b}$			$^{y}1.13^{a}$	$^{y}1.05^{b}$
Dieldrin											
Great Island	$^{xy}0.051$			$^{y}0.083^{a}$			$^{xy}0.044^{a}$			$^{x}0.038^{a}$	$^{xy}0.045^{a}$
Kent Island				$^{x}0.053^{a}$			$^{x}0.041^{a}$			$^{x}0.033^{a}$	$^{x}0.037^{a}$
Heptachlor epoxide											
Great Island	$^{x}0.007$			$^{xy}0.012^{a}$			$^{x}0.010^{a}$			$^{y}0.020^{a}$	$^{x}0.01^{a}$
Kent Island				$^{x}0.010^{a}$			$^{x}0.007^{a}$			$^{x}0.011^{b}$	$^{x}0.01^{a}$
Oxychlordane											
Great Island	$^{xy}0.03$						$^{x}0.051^{a}$			$^{y}0.025^{a}$	$^{xy}0.045^{a}$
Kent Island							$^{x}0.058^{a}$			$^{x}0.034^{a}$	$^{x}0.066^{a}$
HCB											
Great Island	$^{x}0.059$			$^{x}0.057^{a}$			$^{x}0.079^{a}$			$^{x}0.062^{a}$	$^{x}0.057^{a}$
Kent Island				$^{x}0.031^{a}$			$^{x}0.053^{a}$			$^{x}0.038^{a}$	$^{x}0.038^{a}$
B-HCH											
Great Island	$^{x}0.001$									$^{xy}0.003$	$^{y}0.004$
Kent Island										$^{x}0.001$	$^{x}0.002$
PCB 1254:1260											
Great Island	$^{x}2.28$			$^{y}3.65^{a}$			$^{xy}2.61^{a}$			$^{xy}1.55^{a}$	$^{xy}1.16^{a}$
Kent Island				$^{x}11.5^{b}$			$^{y}4.11^{a}$			$^{y}4.38^{a}$	$^{y}3.44^{b}$

[a] For each separate compound, means that do not share the same letter are significantly different:
- lower case a,b,c indicate differences between sites
- lower case x,y,z indicate difference between years

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
Double-crested Cormorant											
DDE											
Gros Pèlerin Island						3.25					
Ile aux Pommes				[x]2.85[a]			[x]2.18[a]			[x]1.34[a]	[x]1.88[a]
Razades									2.83		
Watshishu Sanctuary				7.56[a]							
Ste. Marie Islands				4.99[a]							
Heron Island		[x]5.93[a]			[x]7.37[a]						
Riorden		8.57[a]									
Magdalen Island					7.44[a]						
Cape Tryon					5.93[a]						
Pictou Island				4.27[a]							
Campbell Island							1.62[a]				
Manawagonish Island				[x]6.51[a]			[y]1.49[a]		1.98	[y]1.91[a]	[y]1.0724[b]
Boot Island				[x]4.41[a]			[y]1.66[a]				
Dieldrin											
Gros Pèlerin Island						0.113					
Ile aux Pommes				[x]0.125[a]			[x]0.069[a]			[x]0.050[a]	[x]0.0643[b]
Razades									0.090		
Watshishu Sanctuary				0.186[a]							
Ste. Marie Islands				0.123[a]							
Heron Island		[x]0.147[a]			[x]0.210[a]						
Riorden		0.123[a]									
Magdalen Island					0.161[a]						
Cape Tryon					0.201[a]						
Pictou Island				0.155[a]							
Campbell Island							0.095[a]				
Manawagonish Island				[x]0.153[a]			[xy]0.057[a]		0.120	[y]0.047[a]	[y]0.017[b]
Boot Island				[x]0.144[a]			[x]0.073[a]				
Heptachlor epoxide											
Gros Pèlerin Island						0.015					
Ile aux Pommes				[x]0.013[a]			[x]0.010[a]			[y]0.086[a]	[z]0.028[a]
Razades									0.020		
Watshishu Sanctuary				0.017[a]							

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
Ste. Marie Islands				0.011^{a}							
Heron Island					0.035^{a}						
Riorden		0.001									
Magdalen Island					0.047^{a}						
Cape Tryon					0.037^{a}						
Pictou Island				0.020^{a}							
Campbell Island							0.025^{b}				
Manawagonish Island				^{x}0.015^{a}			^{x}0.014^{ab}		0.030	^{y}0.064^{a}	^{x}0.010^{b}
Boot Island				^{x}0.025^{a}			^{x}0.016^{ab}				
Oxychlordane											
Ile aux Pommes							^{x}0.046^{a}			^{x}0.028^{a}	^{x}0.037^{a}
Razades									0.050		
Campbell Island							0.067^{a}				
Manawagonish Island							^{x}0.044^{a}		0.050	^{x}0.028^{a}	^{x}0.018^{b}
Boot Island							0.056^{a}				
HCB											
Gros Pèlerin Island						0.035					
Ile aux Pommes				^{x}0.010^{ab}			^{y}0.038^{a}			^{y}0.023^{a}	^{y}0.037^{a}
Razades									0.070		
Watshishu Sanctuary				0.016^{b}							
Ste. Marie Islands				0.008^{a}							
Heron Island		^{x}0.014^{a}			^{y}0.053^{b}						
Riorden		0.008^{a}									
Magdalen Island					0.022^{a}						
Cape Tryon					0.076^{b}						
Pictou Island				0.010^{ab}							
Campbell Island							0.022^{a}				
Manawagonish Island				^{x}0.014^{ab}			^{xy}0.022^{a}		0.030	^{y}0.025^{a}	^{x}0.012^{b}
Boot Island				^{x}0.010^{ab}			^{y}0.025^{a}				
B-HCH											
Ile aux Pommes										^{x}0.024	^{y}0.005
Manawagonish Island										^{x}0.013	^{y}0.001

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
PCB 1254:1260											
Gros Pèlerin Island						22.1					
Ile aux Pommes				[x]14.0[a]			[x]17.1[b]			[x]10.2[a]	[x]11.5[a]
Razades									23.4		
Watshishu Sanctuary				17.0[a]							
Ste. Marie Islands				11.5[a]							
Heron Island		[x]10.5[a]			[x]17.2[a]						
Riorden		9.97[a]									
Magdalen Island					22.4[a]						
Cape Tryon					13.7[a]						
Pictou Island				13.9[a]							
Campbell Island							11.9[ab]				
Manawagonish Island				[x]17.8[a]			[yz]7.78[a]		19.6	[xy]12.4[a]	[z]3.55[b]
Boot Island				[x]10.3[a]			[x]7.62[a]				
Common Eider											
DDE											
Inner Birch Island				0.380[ab]							
Watshishu				0.283[a]							
Ste. Marie Islands				0.288[a]							
Low Duck Island				0.588[b]							
Dieldrin											
Inner Birch Island				0.022[b]							
Watshishu				0.010[a]							
Ste. Marie Islands				0.011[a]							
Low Duck Island				0.020[ab]							
Heptachlor epoxide											
Inner Birch Island				0.010[a]							
Watshishu				0.012[a]							
Ste. Marie Islands				0.017[a]							
Low Duck Island				0.013[a]							

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
HCB											
Inner Birch Island				0.016^{a}							
Watshishu				0.017^{a}							
Ste. Marie Islands				0.015^{a}							
Low Duck Island				0.021^{a}							
PCB 1260											
Inner Birch Island				1.83^{b}							
Watshishu				0.575^{a}							
Ste. Marie Islands				0.572^{a}							
Low Duck Island				4.37^{b}							
Common Tern											
DDE											
Harrington Harbour			0.568								
Bathurst Harbour		$^{x}0.877$		$^{y}0.615$	$^{y}0.463^{a}$						
Tabusintac					0.516^{a}						
Magdalen Island					0.536^{a}						
Little Courtin Island						0.400					
Charlottetown					1.11^{a}						
Margaree Island					0.953^{a}						
Dieldrin											
Harrington Harbour			0.029								
Bathurst Harbour		$^{x}0.037$		$^{x}0.023$	$^{x}0.022^{a}$						
Tabusintac					0.028^{a}						
Magdalen Island					0.080^{b}						
Little Courtin Island						0.030					
Charlottetown					0.054^{ab}						
Margaree Island					0.039^{ab}						
Heptachlor epoxide											
Harrington Harbour			0.006								
Bathurst Harbour				0.010	0.010^{a}						
Tabusintac					0.010^{a}						
Magdalen Island					0.010^{a}						

Species, Chemical, Location	Collection Year, Geometric Mean^{a}										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
Little Courtin Island						0.010					
Charlottetown					0.011^{a}						
Margaree Island					0.011^{a}						
Oxychlordane											
Bathurst Harbour					0.018						
Tabusintac					0.018						
Little Courtin Island						0.010					
HCB											
Harrington Harbour			0.018								
Bathurst Harbour		^{x}0.028		^{x}0.035	^{x}0.042^{a}						
Tabusintac					0.049^{a}						
Magdalen Island					0.071^{ab}						
Little Courtin Island						0.020					
Charlottetown					0.051^{a}						
Margaree Island					0.101^{b}						
PCB 1254:1260											
Harrington Harbour			1.25								
Bathurst Harbour		^{x}1.99		^{x}1.96	^{x}1.61^{a}						
Tabusintac					1.37^{a}						
Magdalen Island					1.95^{a}						
Little Courtin Island						1.09					
Charlottetown					1.95^{a}						
Margaree Island					1.86^{a}						
Puffin											
DDE											
Great Island	^{x}0.898			^{x}0.641^{abc}			^{x}0.588^{a}			^{x}0.544^{a}	^{y}0.303^{a}
Gannet Island				0.570^{a}							
Bird Island				0.579^{ab}							
Betchouane				1.24^{cd}							
Ste. Marie Island				0.994^{bcd}							
Perroquet Island				1.49^{de}							
Brion Island					1.46						
Machias Seal Island				^{x}2.57^{e}			^{y}1.27^{b}			^{yz}1.03^{b}	^{z}0.735^{b}

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
Dieldrin											
Great Island	[x]0.050			[x]0.049[a]			[x]0.044[a]			[x]0.040[a]	[x]0.041[a]
Gannet Island				0.047[a]							
Bird Island				0.041[a]							
Betchouane				0.065[ab]							
Ste. Marie Island				0.055[a]							
Perroquet Island				0.065[ab]							
Brion Island					0.060						
Machias Seal Island				[x]0.089[b]			[x]0.080[b]			[y]0.036[a]	[xy]0.049[a]
Heptachlor epoxide											
Great Island	[x]0.010			[xy]0.016[ab]			[xy]0.015[a]			[y]0.022[a]	[y]0.019[a]
Gannet Island				0.020[b]							
Bird Island				0.023[b]							
Betchouane				0.012[ab]							
Ste. Marie Island				0.009[a]							
Perroquet Island				0.010[a]							
Brion Island					0.020						
Machias Seal Island				[x]0.015[ab]			[y]0.029[b]			[y]0.027[a]	[xy]0.020[a]
Oxychlordane											
Great Island	[x]0.031						[z]0.082[a]			[xy]0.038[a]	[y]0.049[a]
Machias Seal Island							[x]0.128[b]			[y]0.059[b]	[y]0.070[b]
HCB											
Great Island	[x]0.076			[x]0.058[a]			[x]0.091[a]			[x]0.092[a]	[x]0.086[a]
Gannet Island				0.027[a]							
Bird Island				0.030[a]							
Betchouane				0.091[b]							
Ste. Marie Island				0.049[a]							
Perroquet Island				0.067[a]							
Brion Island					0.060						
Machias Seal Island				[x]0.058[a]			[y]0.188[b]			[x]0.082[a]	[x]0.065[a]

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
B-HCH											
Great Island	$^{x}0.001$									$^{y}0.003^{a}$	$^{y}0.004^{a}$
Machias Seal Island										$^{x}0.003^{a}$	$^{x}0.003^{a}$
PCB 1254:1260											
Great Island	$^{x}2.33$			$^{x}1.91^{a}$			$^{x}2.41^{a}$			$^{x}2.50^{a}$	$^{y}0.991^{a}$
Gannet Island				2.32^{ab}							
Bird Island				1.90^{a}							
Betchouane				4.39^{bc}							
Ste. Marie Island				2.89^{ab}							
Perroquet Island				3.99^{bc}							
Brion Island					4.19						
Machias Seal Island				$^{x}8.12^{c}$			$^{x}7.25^{b}$			$^{x}5.52^{b}$	$^{y}3.20^{b}$
Razorbills											
DDE											
Pèlerin Island								2.27^{a}			
Carrousel Island				4.54^{a}							
Ste. Marie Island				$^{x}2.68^{a}$				$^{y}1.70^{a}$			
Brion Island					2.55						
Dieldrin											
Pèlerin Island								0.139^{a}			
Carrousel Island				0.154^{a}							
Ste. Marie Island				$^{x}0.105^{a}$				$^{x}0.158^{a}$			
Brion Island					0.125						
Heptachlor epoxide											
Pèlerin Island								0.062^{a}			
Carrousel Island				0.025^{a}							
Ste. Marie Island				$^{x}0.025^{a}$				$^{y}0.065^{a}$			
Brion Island					0.042						
Oxychlordane											
Pèlerin Island								0.108^{a}			
Ste. Marie Island								0.100^{a}			

Species, Chemical, Location	Collection Year, Geometric Mean[a]										
	1968	1970	1971	1972	1973	1975	1976	1978	1979	1980	1984
HCB											
Pèlerin Island								0.162[a]			
Carrousel Island				0.059[a]							
Ste. Marie Island				[x]0.095[b]				[y]0.195[a]			
Brion Island					0.127						
B-HCH											
Pèlerin Island								0.017[b]			
Ste. Marie Island								0.010[a]			
PCB 1254:1260											
Pèlerin Island								19.7[b]			
Carrousel Island				21.7[b]							
Ste. Marie Island				[x]9.34[a]				[x]10.3[a]			
Brion Island					8.37						

Appendix 5

Table 2

Organochlorine Concentrations in West Coast Seabird Eggs, 1968-1985. Samples from 1970 and some from 1983 are a single analysis of a pool of N samples as indicated. Samples for other years marked with an * are geometric means.

Collection Site and Species	N	Year	Fat %	Chemical Residues in ppm (wet weight)									
				DDE	DDD+DDT	Dieldrin	Hept. ep.	Oxychlor	Mirex	HCB	HCH	PCB 1:1[a]	PCB/DDE
Strait of Georgia													
Mandarte Island													
Double-crested Cormorant	3	1970	6.9	4.07	0.045	0.040				0.304		14.00[a]	3.44
Double-crested Cormorant	10	1979	5.6	0.640	0.020	0.050	0.040	0.010		0.030	0.030	5.34[a]	8.86
Double-crested Cormorant	5*	1985	4.4	0.501	0.001	0.006	0.004	0.014		0.030	0.012	3.79	7.56
Pelagic Cormorant	10	1970	5.3	0.819	0.107	0.061				0.009		2.64[a]	3.22
Pelagic Cormorant	6*	1973	-	1.52	0.07	0.08	0.02	0.04	0.01	0.031	0.02	8.01	5.27
Pelagic Cormorant	5*	1985	4.0	0.274	0.015	0.027	0.008			0.014	0.027	1.839	6.71
Glaucous-winged Gull	10	1970	6.0	0.750	0.073	0.046	0.021			0.009		2.49[a]	3.32
Tsawwassen													
Glaucous-winged Gull	10*	1977	9.4	0.483	0.029	0.009	0.014	0.001		0.023	0.007	1.78[a]	3.69
Fraser Estuary													
Double-crested Cormorant	5*	1985	3.9	0.464	0.005	0.004	0.003	0.012	0.008	0.014	0.010	2.92	6.29
Mitlenatch Island													
Pelagic Cormorant	10	1970	4.4	0.547	0.196	0.082				0.131		5.36[a]	9.80
Glaucous-winged Gull	10	1970	8.0	0.456	0.129	0.045				0.006		1.53[a]	3.36
Pigeon Guillemot	10	1970	10.5	0.604		0.008				0.072		3.54[a]	5.86
Western Vancouver Island													
Cleland Island													
Leach's Storm Petrel	10	1970	12.7	2.16	0.228	0.045						1.09[a]	0.505
Glaucous-winged Gull	10	1970	8.6	1.59	0.014	0.037				0.046		2.58[a]	1.62
Pigeon Guillemot	1	1970	10.8	1.29	0.003	0.008				0.131		2.56[a]	2.03
Tufted Puffin	1	1970	10.0	0.424	0.019	0.015				0.129		0.660[a]	1.56

Collection Site and Species	N	Year	Fat %	Chemical Residues in ppm (wet weight)									
				DDE	DDD+DDT	Dieldrin	Hept. ep.	Oxychlor	Mirex	HCB	HCH	PCB 1:1[a]	PCB/DDE
Thornton Island													
Leach's Storm Petrel	6*	1985	10.9	0.725	0.112	0.008	0.004	0.015	0.014	0.026	0.020	0.739	1.02
Glaucous-winged Gull	8*	1983	-	0.63	0.02	0.02	0.04	0.03	0.76	0.011	0.01	1.07	1.70
Glaucous-winged Gull	10	1983	9.15	0.535	0.01	0.02	0.045	0.03	-	0.011	0.025	0.835	1.56
Thomas Island													
Leach's Storm Petrel	3*	1985	10.7	0.601	0.122	0.019	0.004	0.019	0.018	0.029	0.019	0.860	1.43
Guillam's Island													
Glaucous-winged Gull	8*	1983	-	0.52	0.06	0.01	0.01	0.02		0.015	0.01	0.78	1.50
Glaucous-winged Gull	9	1983	9.1	0.35		0.01	0.01	0.02	0.005	0.014	0.015	1.13	3.23
Nipple Rocks													
Pelagic Cormorant	6	1985	4.2	0.270	0.006	0.023	0.023	0.014		0.018	0.030	0.605	2.24
Queen Charlotte Strait													
Stevenson Islets													
Glaucous-winged Gull	10	1970	8.6	1.43	0.027	0.027	0.027			0.018		2.83[a]	1.98
Hecate Strait													
Cassin's Auklet	4	1970	12.0	2.92		0.007				0.023		0.600[a]	0.205
Rhinoceros Auklet	1	1970	14.0	2.09		0.019				0.018		1.73[a]	0.828
North-west Rocks													
Glaucous-winged Gull	3	1970	8.7	0.224		0.008	0.015			0.007		0.364[a]	1.63
Lucy Island													
Glaucous-winged Gull	10	1970	9.7	0.282		0.038				0.009		0.567[a]	2.01
Rhinoceros Auklet	10	1970	15.0	2.84						0.029		2.01[a]	0.708
Rhinoceros Auklet	6*	1985	14.0	0.631	0.005	0.012	0.009	0.023	0.003	0.034	0.018	0.607	0.962

Collection Site and Species	N	Year	Fat %	Chemical Residues in ppm (wet weight)									
				DDE	DDD+DDT	Dieldrin	Hept. ep.	Oxychlor	Mirex	HCB	HCH	PCB 1:1[a]	PCB/DDE
Queen Charlotte Islands													
Hippa Island													
Fork-tailed Storm Petrel	3	1983	11.3	1.68	0.12	0.04	0.03	0.150		0.064	0.05	3.89	2.32
Leach's Storm Petrel	6*	1983	-	0.78	0.06	0.01	0.03	0.02	0.01	0.019	0.04	0.83	1.06
Langara Island													
Ancient Murrelet	3*	1968	15.3	0.871		0.008	0.031						
Ancient Murrelet (addled)	2*	1968	17.3	0.883		0.001	0.015						
Graham Island													
Leach's Storm Petrel	5*	1971	14.1	1.89	0.300	0.013	0.010			0.053		1.71[a]	0.905
Skedans Island													
Fork-tailed Storm Petrel	2	1970	29.6	2.62	0.721	0.009				0.174		9.78[a]	3.73
Glaucous-winged Gull	10	1970	8.3	0.342		0.012				0.011		0.487[a]	1.42
Pigeon Guillemot	2	1970	11.7	0.164		0.009				0.015		0.421[a]	2.57

Appendix 5.

Table 3

Organochlorine Concentrations in Livers and Eggs of Arctic Seabirds, 1975-1977. Samples marked with an * are geometric means. All other samples are a single analysis of N samples, as indicated.

Collection Site and Species	N	Year	Tissue	Fat %	Chemical Residues in ppm (wet weight)										
					DDE	DDD+DDT	Dieldrin	Hept. ep.	Oxychlor	Cis-chlor	Mirex	HCB	B-HCH	PCB 1:1[a]	PCB/DDE
Prince Leopold Island															
Northern Fulmar	3*	75	Liver-Ad.	5.6	0.228	0.017	0.01		0.114			0.023		0.888	3.89
Northern Fulmar	7	75	Liver-Ad.	4.2	0.25	0.025	0.02	0.01	0.17	0.005	0.01	0.026		1.08	4.32
Northern Fulmar	2*	76	Liver-Ad.	8.0	0.605	0.245	0.01		0.26			0.073		2.113	3.49
Northern Fulmar	7	76	Liver-Ad.	8.1	0.50	0.03	0.02	0.01	0.22		0.02	0.058	0.005	1.97	3.94
Black-legged Kittiwake	10	75	Liver-Ad.	5.4	0.05	0.02	0.02	0.01	0.04	0.01	0.01	0.03	0.005	1.31	26.2
Black-legged Kittiwake	5	76	Liver-Ad.	6.9	0.05	0.015	0.02	0.01	0.04	0.005	0.02	0.05	0.01	2.37	47.4
Black-legged Kittiwake	5*	76	Liver-Ad.	9.2	0.11			0.013	0.05	0.006		0.07	0.005	3.30	30.0
Black-legged Kittiwake	6	76	Egg	9.7	0.38	0.035	0.02	0.04	0.08	0.005	0.02	0.091	0.01	5.73	15.1
Thick-billed Murre	10*	75	Liver-Ad.	4.5	0.059	0.004	0.008	0.001	0.005	0.001		0.027	0.001	0.203	3.44
Thick-billed Murre	10*	76	Liver-Ad.		0.191	0.002	0.002	0.001	0.013	-		0.071	0.002	0.404[a]	2.12
Thick-billed Murre	8*	77	Liver-Ad.		0.115		0.005	0.001	0.009	-		0.035	0.001	0.260[a]	2.26
Thick-billed Murre	10	76	Liver-Yg.	10.5	0.17	0.01	0.02	0.01	0.03	0.005	0.005	0.130	0.01	0.48	2.82
Thick-billed Murre	2*	76	Liver-Yg.		0.035		0.002	0.003	0.002	0.003		0.024		0.144[a]	4.11
Thick-billed Murre	12*	77	Liver-Yg.		0.037	0.001	0.002	0.001	0.004	0.003		0.019	0.001	0.095[a]	2.57
Thick-billed Murre	12*	75	Egg	12.6	0.297		0.019	0.002	0.018	0.001		0.097	0.004	0.708	2.38
Thick-billed Murre	10	76	Egg	14.3	0.34	0.01	0.06	0.01	0.03	0.005	0.005	0.127	0.01	0.23	0.68
Thick-billed Murre	10*	77	Egg	12.6	0.377		0.016	0.004	0.024	0.001		0.109	0.011	0.854	2.27
Seymour Island															
Ivory Gull	10	76	Egg	5.8	0.464	0.035	0.024	0.012	0.061	0.011	0.004	0.043	0.005	1.63	3.51
King Eider	1	76	Egg	8.9	0.02	0.005	0.005	0.005	0.005	0.005		0.01	0.005	0.06	3.0

PCB values marked (a) are PCB 1260.

Appendix 5
Table 4

Lead and Cadmium Levels (arithmetic mean, range) in Canadian Seabirds

Species	Location	Date	Time	N	$\%H_2O$	Levels in ppm (dry weight[x]) Cd	Pb
Double-crested Cormorant	Dalhousie, N.B.	1970	Kidney	3 *	75.5	3.00 (1.87-4.53)	
			Liver	3 *	70.3	0.390 (0.250-0.520)	
	Heron Island, N.B.	1970	Kidney	3 *	75.7	5.23 (4.95-5.79)	
			Liver	3 *	69.4	2.28 (1.54-2.67)	
	Boot Island, Nova Scotia	1970	Kidney	1 *	74.9	0.13	
			Liver	1 *	69.7	0.09	
Black Guillemot	St. Mary's Islands Quebec	1971	Breast Muscle	6		0.194 (0.053-0.310)	2.75 (0-8.9)
Razorbill	"	"	"	2		0.056 (0.053-0.059)	2.01 (1.55-2.54)
Common Murre	"	"	"	3		0.263 (0.220-0.307)	1.42 (0-3.23)
Gannet	Bonaventure Island	"	"	11		0.114 (0.033-0.257)	0.24 (0-1.62)

* each analysis from a pool of 5 individuals.
[x] calculated for breast muscle from wet weight values x 3.3.

Appendix 5: Table 5

Total Mercury in Eggs of East Coast Seabirds, 1969-1980

Levels in ppm, wet weight

Species	Location	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Leach's Storm-petrel	Great Island					0.354				0.394				0.383
	Kent Island					0.296				0.378				0.545
Common Eider	Inner Birch Is.					0.078								
	Watshishu					0.083								
	Ste. Marie Islands					0.025								
	Low Duck Island					0.053								
Common Tern	Harrington Harbour				0.137									
	Bathurst Habour		0.429	0.120		0.124	0.180							
	Tabusintac						0.057							
	Little Courtin Is.									0.150				
Atlantic Puffin	Great Island					0.255				0.231				0.324
	Gannet Island					0.179								
	Bird Island					0.183								
	Betchouane					0.172								
	Ste. Marie Islands					0.162								
	Perroquet Island					0.156								
	Machias Seal Is.					0.204				0.090				0.179
Double-crested Cormorant	Ile aux Pommes					0.324				0.355				0.296
	Watshishu					0.344								
	Ste. Marie Islands					0.251								
	Heron Island			0.270										
	Riorden			0.497										
	Pictou Island					0.261								
	Campbell Island									0.210				
	Manawagonish Is.						0.221			0.243				0.189
	Boot Island						0.271			0.254				
Common Murre	Ste. Marie Islands				0.117									
Black Guillemot	Magdalen Island						0.130							

Appendix 5
Table 6

Total Mercury in Tissues of Adult East Coast Seabirds

Species	Location	Tissue[1]	Date	N	Level (ppm, wet weight)
Gannet	Janesville, New Brunswick	Liver	1970	1	3.20
Double-Crested Cormorant	Heron Island, New Brunswick	Liver	1969	3	3.49[2]
	Bathurst Harbour, New Brunswick	Liver	1969	1	11.3
Common Eider	Tinker Harbour, Newfoundland	BM	1970	1	0.05
Common Tern	Bathurst Harbour, New Brunswick	Liver	1969	4	2.50
Atlantic Puffin	Grady Harbour, Lab.	BM	1970	2	0.160
Razorbill	" " "	BM	1970	2	0.325
Common Murre	" " "	BM	1970	2	0.171
Black Guillemot	" " "	BM	1970	1	0.290

[1] BM - Breast Muscle

[2] Immature birds

Appendix 5
Table 7

Total Mercury in Eggs and Tissues of West Coast Seabirds

Species	Location	Tissue[1]	Date	N[2]	Level (ppm, wet weight)
Leach's Storm-petrel	Graham Island	Egg	1971	5/5	0.286
		Liver	1971	2/2	1.30
		BM	1971	2/2	0.219
Fork-tailed Storm-petrel	Skedans Island	Egg	1970	2/2	0.18
Double-crested Cormorant	Mandarte Island	Egg	1970	1/3	0.360
Pelagic Cormorant	Nanaimo	Liver	1968	5/5	1.91
	Mandarte Island	Egg	1970	1	0.350
	Mittlenatch Island	Egg	1970	1	0.160
Glaucous-winged Gull	Port Alberni	Liver	1968	3/3	0.295
	Nanaimo	Liver	1968	1	0.100
	Horseshoe Bay	Liver	1968	4/4	0.451
	Mandarte Island	Egg	1970	1/10	0.130
	Mittlenatch Island	Egg	1970	1/10	0.210
	Cleland Island	Egg	1970	1/10	0.130
	Skedans Island	Egg	1970	1/10	0.080
	Lucy Island	Egg	1970	1/10	0.282
	Northwest Rocks	Egg	1970	1/10	0.050
	Stevenson Islets	Egg	1970	1/10	0.170
Common Murre	Semiahmoo Bay	Liver	1970	4/4	0.370
	Queen Charlotte Islands	WB	1970	1	1.21
Pigeon Guillemot	Mittlenatch Island	Egg	1970	1/10	0.470
	Cleland Island	Egg	1979	1	0.450
	Skedans Island	Egg	1970	1/2	0.330
Marbled Murrelet	Port Alberni	Liver	1968	3/3	0.37
	Horseshoe Bay	Liver	1968	3/3	2.21
Ancient Murrelet	Langara Island	BM	1972	9/9	0.149
		Liver	1972	9/9	0.732
		Brain	1972	9/9	0.128
	Queen Charlotte Islands	WB	1970	2/2	0.229

2 – Number analyzed/number collected.

Table 7 (continued)

Total Mercury in Eggs and Tissues of West Coast Seabirds

Species	Location	Tissue[1]	Date	N[2]	Level (ppm, wet weight)
Cassin's Auklet	Moore Islands	Egg	1970	1/4	0.050
	Langara Islands	BM	1971	1	0.060
		Liver	1971	1	0.440
Rhinoceros Auklet	Queen Charlotte Islands	WB	1970	2/2	0.365
	Lucy Island	Egg	1970	1/10	0.320
	Moore Island	Egg	1970	1/10	0.130
Tufted Puffin	Cleland Island	Egg	1970	1	0.110
	Queen Charlotte Islands	WB	1970	2/2	0.297

2 - Number analyzed/number collected.

Appendix 6
Organochlorine and Mercury Residues in Canadian Seabirds
Table 1: Atlantic Seabirds

Organochlorine and Mercury Residue Concentrations (Geometric Mean, 95% Confidence Interval (CI)) in Tissues of Canadian Seabirds collected from Atlantic coastal areas of Canada, 1967-1984, by species.

Lipid and moisture content of tissues are presented as arithmetic means and standard deviation. Chemicals are included only if detected in the samples, although not all samples were analyzed for all chemicals. This is especially true for pre 1971 samples (see Methods for details).

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Fulmar					
Labrador Sea (25) All locations					14
Whole Body					
1971 (19/19)					
% Fat = 14.4 ± 1.61					
[illegible] ater = [illegible] ± [illegible]					
DDE	19	2.60	2.18-3.08	1.10-4.55	
DDT	19	0.182	0.133-0.249	0.060-0.750	
DDD	19	0.119	0.089-0.158	0.030-0.300	
Dieldrin	19	0.019	0.013-0.027	0.005-0.080	
Heptachlor epoxide	19	0.005	-	0.005-0.005	
HCB	19	0.086	0.072-0.102	0.050-0.170	
PCB 1260	19	6.19	5.06-7.57	2.83-15.0	
PCB 1254:1260	19	7.28	5.91-8.96	3.05-19.2	
PCB/DDE = 2.81					
Labrador Sea A (25A)					14
Whole Body					
1971 (1/1)					
% Fat = 12.9					
% Water = 63.5					
DDE	1	3.02	-	-	
DDT	1	0.220	-	-	
DDD	1	0.110	-	-	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Dieldrin	1	0.020	-	-	
Heptachlor epoxide	1	0.005	-	-	
HCB	1	0.100	-	-	
PCB 1260	1	4.59	-	-	
PCB 1254:1260	1	5.57	-	-	
PCB/DDE = 1.84					
Labrador Sea B (25B)					14
Whole Body					
1971 (9/9)					
% Fat = 11.0 ± 1.46					
% Water = 62.0 ± 1.06					
DDE	9	2.78	2.25-3.44	1.49-4.12	
DDT	9	0.143	0.080-0.256	0.060-0.710	
DDD	9	0.108	0.068-0.172	0.030-0.210	
Dieldrin	9	0.014	0.007-0.025	0.005-0.080	
Heptachlor epoxide	9	0.005	-	0.005-0.005	
HCB	9	0.081	0.061-0.108	0.050-0.170	
PCB 1260	9	6.41	5.29-7.76	4.38-9.49	
PCB 1254:1260	9	7.41	6.20-8.85	5.20-10.3	
PCB/DDE = 2.66					
Labrador Sea C (25C)					14
Whole Body					
1971 (2/2)					
% Fat = 18.3 ± 2.75					
% Water = 57.6 ± 2.30					
DDE	2	2.73	0.055-136.	2.01-3.72	
DDT	2	0.160	-	0.160-0.160	
DDD	2	0.193	0.038-0.995	0.170-0.220	
Dieldrin	2	0.025	0.002-0.322	0.020-0.030	
Heptachlor epoxide	2	0.005	-	0.005-0.005	
HCB	2	0.070	-	0.070-0.070	
PCB 1260	2	5.15	0.003-10300.	2.83-9.36	
PCB 1254:1260	2	5.55	0.003-11200.	3.05-10.1	
PCB/DDE = 2.03					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Labrador Sea D (25D)					14
Whole Body					
1971 (4/4)					
% Fat = 20.1 ± 5.30					
% Water = 56.7 ± 3.84					
DDE	4	2.47	1.16-5.27	1.48-4.55	
DDT	4	0.262	0.078-0.881	0.130-0.750	
DDD	4	0.178	0.075-0.423	0.090-0.300	
Dieldrin	4	0.040	0.016-0.102	0.020-0.070	
Heptachlor epoxide	4	0.005	-	0.005-0.005	
HCB	4	0.113	0.052-0.244	0.060-0.170	
PCB 1260	4	5.31	2.54-11.1	3.13-9.66	
PCB 1254:1260	4	6.32	2.96-13.5	3.83-11.9	
PCB/DDE = 2.56					
Labrador Sea E (25E)					14
Whole Body					
1971 (3/3)					
% Fat = 14.7 ± 4.42					
% Water = 59.8 ± 3.64					
DDE	3	2.06	0.534-7.95	1.10-2.83	
DDT	3	0.235	0.176-0.316	0.220-0.270	
DDD	3	0.067	0.027-0.163	0.050-0.100	
Dieldrin	3	0.016	0.006-0.043	0.010-0.020	
Heptachlor epoxide	3	0.005	-	0.005-0.005	
HCB	3	0.077	0.063-0.093	0.070-0.080	
PCB 1260	3	8.55	1.92-38.2	4.53-15.0	
PCB 1254:1260	3	10.9	2.41-49.4	5.74-19.2	
PCB/DDE = 5.30					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Leach's Storm-petrel (27)					
Great Island, Newfoundland					
Eggs (Fresh)					
1968 (19/19)					11
% Fat = 10.3 ± 0.737					
% Water = 72.2 ± 0.753					
DDE	19	1.64	1.28-2.11	0.798-4.65	
Dieldrin	19	0.061	0.035-0.104	0.019-1.77	
Heptachlor epoxide	4	0.016	0.005-0.045	0.006-0.025	
1968 (5/5) (re-analyzed 1984)					11
% Fat = 8.88 ± 1.88					
% Water = 69.5 ± 3.68					
DDE	5	1.46	0.813-2.61	1.03-3.10	
DDT	5	0.135	0.044-0.414	0.058-0.448	
DDD	5	0.630	0.369-1.07	0.398-1.05	
Dieldrin	5	0.051	0.028-0.090	0.033-0.091	
Heptachlor epoxide	5	0.007	0.003-0.013	0.004-0.014	
Oxychlordane	5	0.030	0.017-0.052	0.020-0.056	
Cis-chlordane	5	0.023	0.014-0.036	0.012-0.030	
Mirex	5	0.013	0.007-0.023	0.009-0.027	
HCB	5	0.059	0.041-0.084	0.045-0.090	
A-HCH	5	0.004	0.002-0.011	0.002-0.011	
B-HCH	5	0.001	0.000-0.003	0.001-0.005	
G-HCH	5	0.001	-	0.001-0.001	
PCB 1254:1260	5	2.28	1.26-4.14	1.57-5.00	
PCB/DDE = 1.56					
1972 (5/5)					16
% Fat = 19.8 ± 2.74					
% Water = 63.7 ± 4.57					
DDE	5	2.91	1.04-8.09	1.19-8.35	
DDT	4	0.170	0.092-0.313	ND-0.280	
DDD	2	0.373	0.114-1.23	ND-0.410	
Dieldrin	5	0.083	0.048-0.144	0.050-0.130	
Heptachlor epoxide	4	0.012	0.007-0.021	ND-0.020	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Endrin	5	0.080	0.028-0.231	0.030-0.250	
HCB	5	0.057	0.031-0.103	0.030-0.110	
PCB 1260	5	3.41	1.51-7.69	1.81-8.90	
PCB/DDE = 1.17					
Mercury (Hg)	5	0.354	0.247-0.506	0.260-0.510	
1976 (5/5)					14
% Fat = 7.26 ± 1.07					
% Water = 73.7 ± 1.17					
DDE	5	0.747	0.394-1.417	0.470-1.69	
DDT	5	0.147	0.105-0.207	0.110-0.210	
DDD	5	0.005	-	0.005-0.005	
Dieldrin	5	0.044	0.030-0.065	0.030-0.070	
Heptachlor epoxide	5	0.01	-	0.01-0.01	
Oxychlordane	5	0.051	0.032-0.081	0.036-0.090	
HCB	5	0.079	0.043-0.148	0.038-0.152	
PCB 1260	5	1.92	0.963-3.82	1.37-5.06	
PCB 1254:1260	5	2.61	1.29-5.27	1.79-7.04	
PCB/DDE = 3.49					
Mercury (Hg)	5	0.394	0.312-0.498	0.310-0.480	
1980 (5/5)					14
% Fat = 13.3 ± 1.96					
% Water = 71.3 ± 1.93					
DDE	5	0.460	0.145-1.46	0.190-0.950	
DDT	5	0.010	0.000-0.311	0.001-0.120	
DDD	5	0.060	0.031-0.114	0.030-0.100	
Dieldrin	5	0.038	0.020-0.071	0.020-0.080	
Heptachlor epoxide	5	0.020	-	0.020-0.020	
Oxychlordane	5	0.025	0.017-0.037	0.020-0.040	
HCB	4	0.062	0.029-0.131	ND-0.120	
Mirex	4	0.026	0.015-0.045	ND-0.040	
A-HCH	5	0.003	0.000-0.018	0.001-0.010	
B-HCH	5	0.003	0.000-0.023	0.001-0.010	
PCB 1260	4	2.18	1.16-4.11	1.55-3.88	
PCB 1254:1260	4	1.55	0.614-3.90	0.810-3.22	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
PCB/DDE = 3.37					
Mercury (Hg)	5	0.383	0.228-0.641	0.190-0.510	
1984 (5/5)					14
% Fat = 10.6 ± 0.532					
% Water = 74.3 ± 0.941					
DDE	5	0.396	0.265-0.591	0.250-0.590	
DDT	5	0.100	0.085-0.117	0.080-0.110	
DDD	5	0.032	0.020-0.053	0.023-0.063	
Dieldrin	5	0.045	0.036-0.056	0.038-0.058	
Heptachlor epoxide	5	0.010	0.008-0.013	0.009-0.014	
Oxychlordane	5	0.045	0.034-0.059	0.033-0.059	
Cis-chlordane	5	0.007	0.005-0.010	0.005-0.010	
Mirex	5	0.014	0.010-0.019	0.010-0.020	
HCB	5	0.057	0.043-0.076	0.043-0.073	
A-HCH	5	0.005	0.004-0.007	0.004-0.008	
B-HCH	5	0.004	0.003-0.005	0.003-0.005	
G-HCH	5	0.001	-	0.001-0.001	
Cis-nonachlor	5	0.016	0.012-0.021	0.011-0.021	
PCB 1254:1260	5	1.16	0.822-1.63	0.790-1.66	
PCB/DDE = 2.93					
Whole Body					
1976 (5/5)					11
% Fat = 29.8 ± 4.97					
% Water = 51.8 ± 4.05					
DDE	5	1.49	0.847-2.60	1.06-3.20	
Dieldrin	5	0.099	0.069-0.142	0.075-0.160	
Heptachlor epoxide	5	0.021	0.013-0.035	0.012-0.034	
PCB 1260	5	0.839	0.461-1.53	0.525-1.82	
PCB/DDE = 0.565					
Kent Island, New Brunswick					
Eggs, (Fresh)					
1972 (5/5)					14
% Fat = 16.8 ± 1.53					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
% Water = 69.2 ± 2.08					
DDE	5	6.81	5.13-9.04	4.61-8.38	
DDT	5	0.330	0.152-0.713	0.130-0.650	
DDD	1	0.230	-	-	
Dieldrin	5	0.053	0.044-0.064	0.050-0.070	
Heptachlor epoxide	4	0.010	-	ND-0.010	
Endrin	5	0.052	0.031-0.086	0.040-0.100	
HCB	5	0.031	0.013-0.072	0.010-0.060	
PCB 1260	5	11.1	8.08-15.2	7.51-15.4	
PCB/DDE = 1.63					
Mercury	5	0.296	0.250-0.350	0.260-0.350	
1976 (5/5)					14
% Fat = 10.3 ± 0.0440					
% Water = 74.1 ± 0.936					
DDE	5	1.75	1.35-2.28	1.37-2.35	
DDT	5	0.391	0.251-0.611	0.220-0.560	
DDD	5	0.040	0.004-0.377	0.007-0.490	
Dieldrin	5	0.041	0.032-0.054	0.030-0.050	
Heptachlor epoxide	5	0.007	0.003-0.016	0.005-0.020	
Oxychlordane	5	0.058	0.038-0.090	0.036-0.090	
HCB	5	0.053	0.042-0.066	0.038-0.057	
PCB 1260	5	3.45	2.63-4.53	2.80-4.66	
PCB 1254:1260	5	4.11	3.12-5.40	3.33-5.55	
PCB/DDE = 2.34	5				
Mercury	5	0.378	0.271-0.526	0.250-0.510	
1980 (5/5)					14
% Fat = 14.5 ± 0.295					
% Water = 71.9 ± 0.287					
DDE	5	1.13	0.365-3.49	0.340-3.74	
DDT	5	0.187	0.066-0.535	0.100-0.690	
DDD	5	0.064	0.037-0.109	0.030-0.090	
Dieldrin	5	0.033	0.016-0.067	0.020-0.080	
Heptachlor epoxide	5	0.011	0.008-0.017	0.010-0.020	
Oxychlordane	5	0.034	0.012-0.091	0.010-0.070	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	5	0.038	0.020-0.071	0.020-0.080	
Mirex	5	0.047	0.029-0.075	0.030-0.070	
A-HCH	5	0.001	0.000-0.006	0.001-0.005	
B-HCH	5	0.001	0.000-0.005	0.001-0.010	
PCB 1260	5	4.83	2.36-9.88	2.25-8.81	
PCB 1254:1260	5	4.38	2.02-9.47	1.79-8.70	
PCB/DDE = 3.88					
Mercury	5	0.545	0.505-0.589	0.051-0.580	
1984 (5/5)					14
% Fat = 11.2 ± 0.439					
% Water = 73.1 ± 0.492					
DDE	5	1.05	0.572-1.93	0.620-1.67	
DDT	5	0.238	0.159-0.357	0.159-0.372	
DDD	5	0.021	0.011-0.041	0.009-0.035	
Dieldrin	5	0.037	0.023-0.060	0.022-0.052	
Heptachlor epoxide	5	0.009	0.006-0.015	0.006-0.013	
Oxychlordane	5	0.066	0.034-0.128	0.034-0.107	
Cis-chlordane	5	0.015	0.007-0.030	0.006-0.028	
Mirex	5	0.030	0.022-0.042	0.022-0.042	
HCB	5	0.038	0.024-0.059	0.024-0.054	
A-HCH	5	0.004	0.002-0.008	0.002-0.008	
B-HCH	5	0.002	0.001-0.003	0.001-0.003	
G-HCH	5	0.001	-	0.001-0.001	
Cis-nonachlor	5	0.037	0.019-0.073	0.017-0.062	
PCB 1254:1260	5	3.44	1.93-6.12	2.00-5.07	
PCB/DDE = 3.28					
Whole Body					
1972 (9/9)					14
% Fat = 20.5 ± 1.41					
% Water = 56.0 ± 0.948					
DDE	9	3.99	3.43-4.63	2.73-5.14	
DDT	9	1.58	0.963-2.60	0.480-4.49	
DDD	9	0.841	0.436-1.62	0.150-1.75	
Dieldrin	9	0.070	0.050-0.098	0.040-0.150	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Heptachlor epoxide	9	0.046	0.023-0.093	0.010-0.130	
HCB	9	0.036	0.026-0.050	0.020-0.070	
PCB 1260	9	12.5	9.64-16.2	6.79-20.0	
PCB 1254:1260	9	14.6	11.5-18.6	8.22-23.0	
PCB/DDE = 3.66					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Gannet (28)					
Bonaventure Is., Quebec					
Eggs (Fresh)					
1969 (10/10)					7
% Fat = 4.54 ± 0.309					
% Water = 84.2 ± 0.368					
DDE	10	14.5	12.3-17.1	10.0-20.6	
Dieldrin	10	0.500	0.415-0.603	0.365-0.818	
Heptachlor epoxide	10	0.058	0.044-0.076	0.029-0.099	
PCB 1260	10	5.11	3.81-6.87	1.81-8.57	
PCB/DDE = 0.352					
1969 (6/6) (re-analyzed 1984)					7
% Fat = 4.4 ± 0.679					
% Water = 83.0 ± 0.649					
DDE	6	18.5	10.6-32.3	9.5-35.8	
DDT	6	1.67	0.703-3.95	0.687-3.93	
DDD	6	0.811	0.524-1.26	0.416-1.48	
Dieldrin	6	0.641	0.452-0.911	0.467-1.04	
Heptachlor epoxide	6	0.029	0.019-0.043	0.019-0.050	
Mirex	6	0.030	-	0.030-0.030	
A-HCH	6	0.021	0.013-0.035	0.013-0.037	
B-HCH	6	0.006	0.003-0.010	0.004-0.013	
G-HCH	6	0.003	0.002-0.005	0.002-0.005	
Oxychlordane	6	0.093	0.061-0.143	0.052-0.154	
Transchlordane	6	0.021	0.014-0.031	0.015-0.039	
Cis-chlordane	6	0.240	0.163-0.353	0.158-0.385	
Cis-nonachlor	6	0.173	0.130-0.230	0.125-0.250	
HCB	6	0.075	0.045-0.125	0.044-0.128	
PCB 1254:1260	6	23.9	14.3-39.9	13.1-43.4	
PCB/DDE = 1.29					
1973 (10/10)					7
% Fat = 3.94 ± 0.211					
% Water = 84.2 ± 0.159					
DDE	10	8.93	7.87-10.1	6.60-10.8	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDT	10	0.234	0.165-0.334	0.150-0.910	
DDD	10	0.152	0.091-0.253	0.080-0.900	
Dieldrin	10	0.296	0.212-0.413	0.170-0.830	
Heptachlor epoxide	4	0.022	0.009-0.058	ND-0.040	
Endrin	10	0.066	0.047-0.092	0.030-0.120	
HCB	10	0.035	0.031-0.039	0.030-0.040	
PCB 1260	10	14.2	11.7-17.2	10.1-26.5	
PCB/DDE = 1.59					
1973 (6/6) (re-analyzed 1984)					7
% Fat = 3.9 ± 0.235					
% Water = 84.4 ± 0.214					
DDE	6	11.1	9.68-12.8	9.70-13.0	
DDD	6	0.377	0.293-0.485	0.249-0.456	
DDT	6	0.598	0.543-0.659	0.509-0.663	
Dieldrin	6	0.381	0.293-0.495	0.282-0.588	
HE	6	0.032	0.026-0.039	0.027-0.045	
Mirex	6	0.010	-	0.010-0.010	
A-HCH	6	0.029	0.020-0.042	0.016-0.043	
B-HCH	6	0.007	0.006-0.008	0.006-0.009	
G-HCH	6	0.004	0.003-0.005	0.003-0.006	
Oxychlordane	6	0.090	0.074-0.109	0.072-0.117	
Transchlordane	6	0.019	0.014-0.024	0.013-0.028	
Cis-chlordane	6	0.216	0.179-0.261	0.179-0.297	
Cis-nonachlor	6	0.176	0.150-0.206	0.154-0.230	
HCB	6	0.046	0.037-0.056	0.035-0.057	
PCB 1254:1260	6	18.8	14.9-23.8	15.5-28.6	
PCB/DDE = 1.69					
1974 (20/20)					7
% Fat = 3.76 ± 0.129					
% Water = 83.4 ± 0.193					
DDE	20	8.07	7.05-9.23	4.19-14.8	
DDT	20	0.362	0.002-0.433	0.190-0.874	
DDD	20	0.358	0.307-0.417	0.168-0.616	
Dieldrin	20	0.259	0.225-0.299	0.160-0.550	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Heptachlor epoxide	20	0.028	0.023-0.034	0.010-0.060	
Endrin	20	0.167	0.135-0.205	0.060-0.360	
HCB	20	0.023	0.019-0.026	0.019-0.038	
PCB 1260	20	14.8	12.3-17.7	7.94-30.4	
PCB 1254:1260	20	18.2	15.3-21.7	10.3-37.4	
PCB/DDE = 2.26					
1974 (6/6) (re-analyzed 1984)					7
% Fat = 4.1 ± 0.279					
% Water = 84.0 ± 0.401					
DDE	6	7.96	5.78-11.0	5.50-11.5	
DDD	6	0.318	0.239-0.422	0.227-0.470	
DDT	6	0.545	0.409-0.726	0.342-0.752	
Dieldrin	6	0.330	0.294-0.371	0.291-0.396	
HE	6	0.031	0.026-0.037	0.025-0.039	
Mirex	6	0.014	0.008-0.026	0.010-0.030	
A-HCH	6	0.034	0.028-0.042	0.026-0.047	
B-HCH	6	0.006	0.004-0.009	0.003-0.009	
G-HCH	6	0.004	0.003-0.005	0.003-0.006	
Oxychlordane	6	0.095	0.074-0.121	0.070-0.129	
Transchlordane	6	0.021	0.017-0.026	0.017-0.027	
Cis-chlordane	6	0.243	0.207-0.285	0.182-0.281	
Cis-nonachlor	6	0.199	0.173-0.229	0.168-0.250	
HCB	6	0.057	0.046-0.072	0.042-0.073	
PCB 1254:1260	6	17.7	14.2-22.1	13.5-22.3	
PCB/DDE = 2.22					
1976 (6/6)					7
% Fat = 4.58 ± 0.156					
% Water = 83.4 ± 0.129					
DDE	6	2.08	1.39-3.10	1.37-3.79	
DDT	6	0.059	0.030-0.116	0.020-0.130	
DDD	6	0.228	0.106-0.491	0.056-0.378	
Dieldrin	6	0.277	0.140-0.548	0.080-0.500	
Heptachlor epoxide	6	0.024	0.015-0.041	0.010-0.040	
Oxychlordane	6	0.178	0.105-0.301	0.072-0.324	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Cis-Chlordane	6	0.453	0.062-3.33	0.010-1.40	
HCB	6	0.078	0.064-0.095	0.057-0.095	
PCB 1260	6	15.2	11.9-19.5	12.0-19.8	
PCB 1254:1260	6	18.5	14.4-23.7	14.6-24.0	
PCB/DDE = 8.87					
1976 (6/6) (re-analyzed 1984)					7
% Fat = 4.3 ± 0.172					
% Water = 84.6 ± 0.164					
DDE	6	4.35	2.78-6.80	3.10-9.30	
DDD	6	0.237	0.187-0.301	0.169-0.303	
DDT	6	0.240	0.183-0.315	0.180-0.354	
Dieldrin	6	0.324	0.248-0.423	0.229-0.454	
HE	6	0.040	0.031-0.052	0.030-0.055	
Mirex	6	0.020	0.009-0.044	0.010-0.050	
A-HCH	6	0.036	0.029-0.045	0.029-0.052	
B-HCH	6	0.005	0.003-0.008	0.002-0.008	
G-HCH	6	0.004	0.003-0.005	0.003-0.005	
Oxychlordane	6	0.097	0.075-0.126	0.074-0.131	
Transchlordane	6	0.018	0.012-0.026	0.013-0.029	
Cis-chlordane	6	0.245	0.182-0.330	0.165-0.321	
Cis-nonachlor	6	0.199	0.147-0.270	0.139-0.273	
HCB	6	0.063	0.049-0.081	0.048-0.094	
PCB 1254:1260	6	15.4	12.3-19.3	11.7-19.6	
PCB/DDE = 3.54					
1984 (6/6)					
% Fat = 3.9 ± 0.189					
% Water = 83.6 ± 0.100					
DDE	6	1.12	0.894-1.41	0.810-1.53	
DDD	6	0.050	0.021-0.116	0.012-0.125	
DDT	6	0.065	0.052-0.081	0.050-0.084	
Dieldrin	6	0.148	0.125-0.175	0.130-0.194	
HE	6	0.030	0.025-0.037	0.026-0.042	
Mirex	6	0.014	0.010-0.018	0.010-0.021	
A-HCH	6	0.033	0.025-0.043	0.023-0.047	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
B-HCH	6	0.002	-	0.002-0.002	
G-HCH	6	0.002	0.001-0.004	0.001-0.004	
Oxychlordane	6	0.070	0.059-0.084	0.059-0.093	
Transchlordane	6	0.003	0.001-0.010	0.001-0.012	
Cis-chlordane	6	0.099	0.072-0.134	0.072-0.166	
Cis-nonachlor	6	0.106	0.084-0.135	0.075-0.140	
HCB	6	0.025	0.018-0.036	0.014-0.040	
PCB	6	9.54	7.64-11.9	7.50-13.2	
PCB/DDE = 8.52					
Eggs (addled)					
1968 (9/9)					7
% Fat = 5.14 ± 0.375					
% Water = 80.0 ± 0.852					
DDE	9	24.2	15.3-38.4	10.5-96.5	
Dieldrin	9	0.746	0.497-1.12	0.296-1.62	
1968 (6/6) (re-analyzed 1984)					7
% Fat = 4.7 ± 0.426					
% Water = 83.1 ± 0.688					
DDE	6	27.6	18.4-41.4	16.5-50.0	
DDD	6	1.82	1.19-2.80	0.916-2.93	
DDT	6	1.17	0.324-4.21	0.116-3.65	
Dieldrin	6	0.806	0.555-1.17	0.515-1.49	
HE	6	0.037	0.024-0.055	0.021-0.063	
Mirex	6	0.030	-	0.030-0.030	
A-HCH	6	0.022	0.014-0.034	0.013-0.042	
B-HCH	6	0.010	0.009-0.011	0.008-0.012	
G-HCH	6	0.003	0.001-0.005	0.002-0.008	
Oxychlordane	6	0.096	0.069-0.134	0.069-0.168	
Transchlordane	6	0.023	0.016-0.033	0.015-0.037	
Cis-chlordane	6	0.213	0.162-0.279	0.160-0.309	
Cis-nonachlor	6	0.183	0.121-0.277	0.132-0.385	
HCB	6	0.088	0.061-0.127	0.054-0.127	
PCB 1254:1260	6	30.7	20.2-46.7	19.2-59.0	
PCB/DDE = 1.11					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Eggs (Addled)					
1969 (10/10)					7
% Fat = 7.66 ± 1.46					
% Water = 72.6 ± 5.40					
DDE	10	30.0	21.6-41.7	18.3-68.6	
Dieldrin	10	1.16	0.864-1.56	0.738-2.53	
Heptachlor epoxide	9	0.19	0.109-0.339	ND-0.781	
PCB 1260	10	16.9	10.9-26.1	9.57-56.8	
PCB/DDE = 0.562					
1969 (6/6) (re-analyzed 1984)					
% Fat = 5.6 ± 0.460					
% Water = 79.7 ± 1.45					
DDE	6	30.6	21.7-43.3	18.9-49.7	
DDD	6	3.57	2.32-5.49	1.79-5.51	
DDT	6	0.826	0.184-3.72	0.074-4.31	
Dieldrin	6	1.17	0.851-1.60	0.728-1.55	
HE	6	0.053	0.038-0.072	0.035-0.073	
Mirex	6	0.035	0.024-0.050	0.030-0.070	
A-HCH	6	0.029	0.020-0.042	0.018-0.047	
B-HCH	6	0.012	0.006-0.022	0.004-0.020	
G-HCH	6	0.005	0.002-0.009	0.002-0.008	
Oxychlordane	6	0.155	0.116-0.208	0.115-0.243	
Transchlordane	6	0.044	0.034-0.058	0.029-0.056	
Cis-chlordane	6	0.441	0.352-0.553	0.333-0.534	
Cis-nonachlor	6	0.304	0.243-0.381	0.229-0.428	
HCB	6	0.098	0.075-0.128	0.071-0.136	
PCB 1254:1260	6	40.6	29.5-55.8	27.8-66.0	
PCB/DDE = 1.33					
1970 (6/6) (re-analyzed 1984)					7
% Fat = 4.8 ± 0.731					
% Water = 80.9 ± 0.883					
DDE	6	33.7	23.9-47.6	21.9-57.4	
DDD	6	1.87	1.26-2.78	1.34-3.69	
DDT	6	0.359	0.070-1.83	0.068-2.80	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Dieldrin	6	0.955	0.670-1.36	0.637-1.44	
HE	6	0.052	0.037-0.072	0.033-0.077	
Mirex	6	0.060	-	0.060-0.060	
A-HCH	6	0.028	0.020-0.039	0.017-0.044	
B-HCH	6	0.014	0.011-0.017	0.011-0.017	
G-HCH	6	0.002	0.002-0.004	0.002-0.006	
Oxychlordane	6	0.142	0.100-0.202	0.096-0.235	
Transchlordane	6	0.031	0.023-0.042	0.022-0.051	
Cis-chlordane	6	0.367	0.257-0.524	0.216-0.558	
Cis-nonachlor	6	0.276	0.201-0.379	0.205-0.479	
HCB	6	0.090	0.061-0.133	0.065-0.146	
PCB 1254:1260	6	36.6	26.5-50.5	24.0-55.2	
PCB/DDE = 1.09					
1974 (10/10)					7
% Fat = 6.82 ± 0.596					
% Water = 76.8 ± 2.20					
DDE	10	13.0	9.03-18.8	6.01-27.7	
DDT	10	0.287	0.155-0.529	0.076-1.82	
DDD	10	0.573	0.329-0.998	0.140-1.97	
Dieldrin	10	0.359	0.232-0.557	0.140-1.25	
Heptachlor epoxide	10	0.034	0.022-0.051	0.020-0.090	
Endrin	10	0.231	0.160-0.335	0.090-0.580	
HCB	10	0.101	0.067-0.151	0.038-0.228	
PCB 1260	10	21.1	15.1-29.5	10.6-50.0	
PCB 1254:1260	10	25.4	18.1-35.4	12.7-60.0	
PCB/DDE = 1.95					
1974 (6/6) (re-analyzed 1984)					7
% Fat = 5.2 ± 0.842					
% Water = 80.7 ± 1.21					
DDE	6	10.1	6.17-16.6	5.30-20.8	
DDD	6	0.682	0.348-1.34	0.259-1.40	
DDT	6	0.329	0.237-0.456	0.260-0.508	
Dieldrin	6	0.435	0.282-0.673	0.203-0.683	
HE	6	0.040	0.023-0.070	0.014-0.066	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Mirex	6	0.024	0.012-0.049	0.010-0.040	
A-HCH	6	0.019	0.011-0.033	0.008-0.031	
B-HCH	6	0.006	0.002-0.014	0.002-0.013	
G-HCH	6	0.004	0.002-0.008	0.001-0.008	
Oxychlordane	6	0.090	0.043-0.187	0.024-0.186	
Transchlordane	6	0.027	0.017-0.043	0.014-0.041	
Cis-chlordane	6	0.266	0.174-0.409	0.128-0.426	
Cis-nonachlor	6	0.208	0.127-0.340	0.087-0.357	
HCB	6	0.078	0.054-0.112	0.043-0.116	
PCB 1254:1260	6	20.2	13.2-30.9	10.0-33.5	
PCB/DDE = 2.00					
Brain					
1968 (10/10)					7
% Fat = 7.63 ± 0.239					
% Water = 80.1 ± 0.106					
DDE	10	3.20	2.55-4.01	1.52-4.62	
Dieldrin	10	0.097	0.062-0.150	0.044-0.205	
Fat					
1968 (10/10)					7
% Fat = 95.8 ± 0.368					
% Water = 4.19 ± 0.386					
DDE	10	10.9	9.56-12.3	7.71-13.6	
Dieldrin	10	0.358	0.292-0.439	0.212-0.557	
Funk Is., Newfoundland (26)					
Brain					
1968 (10/10)					7
% Fat = 7.63 ± 0.239					
% Water = 79.8 ± 0.206					
DDE	10	1.14	0.714-1.83	0.660-5.43	
Dieldrin	10	0.060	0.037-0.097	0.021-0.183	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Fat					
1968 (10/10)					7
% Fat = 96.5 ± 0.599					
% Water = 3.44 ± 0.610					
DDE	10	3.58	2.61-4.91	1.87-5.95	
Dieldrin	10	0.270	0.204-0.359	0.114-0.412	
Bathurst, New Brunswick (30)					
Brain					
1972 (1/1)					14
% Fat = 11.5					
% Water = 80.6					
DDE	1	1.76	-	-	
DDD	1	0.10	-	-	
Dieldrin	1	0.34	-	-	
Heptachlor epoxide	1	0.23	-	-	
HCB	1	0.01	-	-	
PCB 1260	1	4.92	-	-	
PCB/DDE = 2.80					
Janeville, New Brunswick (31)					
Brain					
1970 (1/1)					14
% Fat = 8.0					
% Water = 80.0					
DDE	1	49.5	-	-	
DDT	1	0.06	-	-	
DDD	1	2.48	-	-	
Dieldrin	1	1.44	-	-	
Heptachlor epoxide	1	0.02	-	-	
HCB	1	0.26	-	-	
PCB 1260	1	81.4	-	-	
PCB/DDE = 1.64					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Liver					
1970 (1/1)					
Mercury	1	3.20	-	-	
Magdellan Islands (35)					
Brain					
1972 (1/1)					14
% Fat = 7.0					
% Water = 79.8					
DDE	1	19.1	-	-	
DDD	1	0.79	-	-	
Dieldrin	1	0.68	-	-	
Heptachlor epoxide	1	0.05	-	-	
HCB	1	0.02	-	-	
PCB 1260	1	35.1	-	-	
PCB/DDE = 1.84					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Double Crested Cormorant					
Gros Pèlerin Island, Québec (1)					
Eggs (Fresh)					
1975 (14/14)					15
% Fat = 3.76 ± 0.165					
% Water = 83.8 ± 0.231					
DDE	14	3.253	2.90-3.64	2.25-4.35	
DDT	14	0.023	0.016-0.033	0.010-0.070	
DDD	14	0.029	0.021-0.039	0.014-0.056	
Dieldrin	14	0.113	0.081-0.157	0.050-0.240	
Heptachlor epoxide	14	0.015	0.011-0.019	0.010-0.030	
HCB	14	0.035	0.025-0.047	0.019-0.095	
PCB 1260	14	16.8	15.6-18.2	13.3-22.3	
PCB 1254:1260	14	22.1	20.5-24.0	17.6-29.6	
PCB/DDE = 6.82					
Liver					
1975 (1/1)					15
% Fat = 4.07					
% Water = 71.5					
DDE	1	0.220	-	-	
DDT	1	0.001	-	-	
DDD	1	0.001	-	-	
Dieldrin	1	0.030	-	-	
Heptachlor epoxide	1	0.001	-	-	
HCB	1	0.020	-	-	
Oxychlordane	1	0.001	-	-	
A-Chlordane	1	0.001	-	-	
PCB 1260	1	2.49	-	-	
PCB 1254:1260		2.95	-	-	
PCB/DDE = 13.4					

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Ile Blanche, Québec (2)					
Liver					
1975 (1/1)					13
% Fat = 3.10					
% Water = 73.9					
DDE	1	1.76	-	-	
DDT		0.030	-	-	
DDD		0.120	-	-	
Dieldrin		0.090	-	-	
Heptachlor epoxide		0.020	-	-	
Oxychlordane		0.001	-	-	
Cis-Chlordane		0.001	-	-	
HCB		0.080	-	-	
PCB 1260		11.4	-	-	
PCB 1254:1260		13.5	-	-	
PCB/DDE = 7.67					
Ile aux Pommes, Québec (4)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 1.96 ± 0.291					
% Water = 85.3 ± 0.347					
DDE	5	2.85	0.358-22.7	0.180-12.8	
DDT	3	0.014	0.003-0.070	ND-0.030	
DDD	5	0.103	0.025-0.432	0.040-0.760	
Dieldrin	5	0.125	0.055-0.283	0.080-0.390	
Heptachlor epoxide	5	0.013	0.008-0.021	0.010-0.020	
Endrin	5	0.045	0.021-0.095	0.020-0.110	
HCB	3	0.010	-	ND-0.010	
PCB 1260	5	11.5	5.35-24.6	4.62-22.7	
PCB/DDE = 2.66					
Mercury	5	0.324	0.262-0.401	0.260-0.400	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1976 (5/5)					14
% Fat = 3.12 ± 0.263					
% Water = 83.6 ± 0.257					
DDE	5	2.18	1.36-3.51	1.16-3.25	
DDT	5	0.051	0.026-0.010	0.020-0.070	
DDD	5	0.071	0.044-0.115	0.042-0.112	
Dieldrin	5	0.069	0.025-0.187	0.020-0.170	
Heptachlor epoxide	5	0.010	-	0.010-0.010	
Oxychlordane	5	0.046	0.023-0.090	0.018-0.072	
Cis-Chlordane	5	0.013	0.006-0.029	0.010-0.040	
HCB	5	0.038	0.021-0.070	0.019-0.076	
PCB 1260	5	14.3	9.58-21.2	9.13-18.7	
PCB 1254:1260	5	17.1	11.5-25.4	10.9-22.4	
PCB/DDE = 7.81					
Mercury	5	0.355	0.194-0.652	0.160-0.540	
1980 (5/5)					14
% Fat = 4.92 ± 0.296					
% Water = 83.8 ± 0.315					
DDE	5	1.34	0.661-2.71	0.840-3.53	
DDT	5	0.023	0.018-0.031	0.020-0.030	
DDD	5	0.045	0.017-0.118	0.020-0.100	
Dieldrin	5	0.050	0.019-0.131	0.020-0.150	
Heptachlor epoxide	5	0.086	0.039-0.189	0.040-0.180	
Oxychlordane	2	0.028	0.000-2.31	ND-0.040	
Cis-Chlordane	5	0.003	0.000-0.032	0.000-0.020	
Mirex	5	0.047	0.030-0.075	0.030-0.070	
HCB	5	0.023	0.018-0.031	0.020-0.030	
A-HCH	5	0.013	0.007-0.023	0.010-0.030	
B-HCH	5	0.024	0.013-0.044	0.010-0.030	
PCB 1260	5	10.1	4.74-21.4	5.69-26.5	
PCB 1254:1260	5	10.2	4.55-22.6	5.48-28.1	
PCB/DDE = 7.57					
Mercury	5	0.296	0.170-0.518	0.180-0.460	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1984 (5/5)					14
% Fat = 4.44 ± 0.194					
% Water = 84.2 ± 0.332					
DDE	5	1.88	1.27-2.78	1.44-2.78	
DDT	5	0.032	0.022-0.047	0.024-0.046	
DDD	5	0.003	0.001-0.008	0.001-0.007	
Dieldrin	5	0.064	0.043-0.097	0.040-0.091	
Heptachlor epoxide	5	0.028	0.020-0.040	0.018-0.038	
Oxychlordane	5	0.054	0.042-0.071	0.044-0.077	
Cis-chlordane	5	0.003	0.002-0.005	0.002-0.005	
Mirex	5	0.046	0.025-0.084	0.023-0.090	
HCB	5	0.037	0.023-0.059	0.022-0.053	
A-HCH	5	0.016	0.011-0.022	0.010-0.019	
B-HCH	5	0.005	0.003-0.010	0.003-0.010	
G-HCH	5	0.002	0.002-0.003	0.002-0.003	
Cis-nonachlor	5	0.028	0.020-0.040	0.021-0.039	
PCB 1254:1260	5	11.5	6.82-19.3	7.86-22.2	
PCB/DDE = 6.12					
Razades, Québec (5)					
Eggs (Fresh) pool					
1979 (1/10)					14
% Fat = 5.40					
% Water = 83.0					
DDE	1	2.83	-	-	
DDT	1	0.010	-	-	
DDD	1	0.080	-	-	
Dieldrin	1	0.090	-	-	
Heptachlor epoxide	1	0.020	-	-	
Oxychlordane	1	0.050	-	-	
Cis-Chlordane	1	0.010	-	-	
Mirex	1	0.070	-	-	
Photomirex	1	0.030	-	-	
HCB	1	0.070	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCH	1	0.020	-	-	
PCB 1260	1	14.1	-	-	
PCB 1254:1260	1	23.4	-	-	
PCB/DDE = 8.27					
Watshishu Sanctuary, Québec (9)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 9.62 ± 3.30					
% Water = 81.1 ± 3.89					
DDE	5	7.56	2.74-20.9	2.15-14.8	
DDT	2	0.079	0.016-0.392	ND-0.090	
Dieldrin	5	0.186	0.071-0.485	0.050-0.310	
Heptachlor epoxide	4	0.017	0.010-0.029	ND-0.020	
Endrin	5	0.054	0.032-0.092	0.030-0.080	
HCB	5	0.016	0.009-0.030	0.010-0.030	
PCB 1260	5	13.9	5.61-34.2	5.44-24.3	
PCB/DDE = 1.83					
Mercury	5	0.344	0.257-0.461	0.270-0.480	
Ste. Marie Islands, Québec (10)					
Eggs (Fresh)					
1972 (10/10)					14
% Fat = 7.68 ± 0.696					
% Water = 83.8 ± 0.346					
DDE	10	4.99	3.35-7.45	2.50-10.6	
DDT	10	0.011	0.005-0.023	0.001-0.020	
DDD	1	0.030	-	-	
Dieldrin	10	0.123	0.071-0.213	0.040-0.340	
Heptachlor epoxide	7	0.011	0.009-0.014	ND-0.020	
Endrin	10	0.021	0.013-0.035	0.010-0.050	
HCB	4	0.008	0.005-0.015	ND-0.010	
PCB 1260	10	9.45	6.07-14.7	3.00-20.2	
PCB/DDE = 1.89			-	-	
Mercury	10	0.251	0.213-0.294	0.150-0.360	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Heron Island, New Brunswick (29)					
Eggs (Fresh)					
1970 (10/10)					14
% Fat = 3.64 ± 0.294					
% Water = 84.7 ± 0.344					
DDE	10	5.93	3.21-11.0	1.11-18.8	
Dieldrin	10	0.147	0.042-0.509	0.010-0.680	
HCB	2	0.014	0.000-1.16	ND-0.020	
PCB 1260	10	8.63	3.95-18.8	1.34-30.2	
PCB/DDE = 1.46					
Mercury	10	0.270	0.173-0.420	0.100-0.510	
1973 (5/5)					14
% Fat = 4.36 ± 0.317					
% Water = 83.9 ± 0.127					
DDE	5	7.37	3.74-14.5	4.03-17.9	
DDT	5	0.285	0.129-0.628	0.152-0.798	
Dieldrin	5	0.210	0.149-0.295	0.140-0.270	
Heptachlor epoxide	5	0.035	0.023-0.051	0.030-0.060	
HCB	5	0.053	0.042-0.066	0.038-0.057	
PCB 1260	5	14.3	8.98-22.7	9.86-26.1	
PCB 1254:1260	5	17.2	10.9-27.4	11.9-31.5	
PCB/DDE = 2.34					
Methyl Mercury	5	0.325	0.233-0.453	0.240-0.440	
Liver					
1969 (3/3)					14
% Fat = 0.000					
% Water = 66.0 ± 0.577					
Mercury	3	3.49	2.51-4.85	3.08-4.01	
Bathurst Harbour, New Brunswick (30)					
Liver					
1969 (1/1)					14
Mercury	1	11.3	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Riorden, New Brunswick (32)					
Eggs (Fresh)					
1970 (5/5)					14
% Fat = 4.26 ± 0.353					
% Water = 84.3 ± 0.657					
DDE	5	8.57	4.60-16.0	4.82-17.7	
DDT	5	0.092	0.048-0.175	0.050-0.180	
DDD	5	0.077	0.047-0.125	0.050-0.140	
Dieldrin	5	0.123	0.035-0.429	0.050-0.590	
Heptachlor epoxide	5	0.001	-	0.001-0.001	
HCB	3	0.008	0.003-0.021	ND-0.010	
PCB 1260	5	8.17	3.57-18.7	4.57-19.7	
PCB/DDE = 0.953					
Mercury	5	0.497	0.413-0.600	0.400-0.600	
Magdalen Island, Québec (35)					
Eggs (Fresh)					
1973 (5/5)					14
% Fat = 4.60 ± 0.179					
% Water = 84.0 ± 0.278					
DDE	5	7.44	3.88-14.3	3.76-13.6	
DDT	5	0.340	0.162-0.713	0.190-0.798	
Dieldrin	5	0.161	0.093-0.276	0.080-0.260	
Heptachlor epoxide	5	0.047	0.021-0.108	0.020-0.110	
HCB	5	0.022	0.015-0.032	0.019-0.038	
PCB 1260	5	19.3	6.90-53.9	7.13-59.5	
PCB 1254:1260	5	22.4	8.01-62.6	8.27-69.0	
PCB/DDE = 3.01					
Methyl Mercury	5	0.295	0.188-0.463	0.200-0.520	
Cape Tryon, Prince Edward Island (38)					
Eggs (Fresh)					
1973 (5/5)					14
% Fat = 4.70 ± 0.363					
% Water = 83.8 ± 0.345					
DDE	5	5.93	2.65-13.3	2.56-11.0	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDT	5	0.200	0.145-0.275	0.152-0.266	
Dieldrin	5	0.201	0.085-0.475	0.060-0.300	
Heptachlor epoxide	5	0.037	0.010-0.142	0.010-0.200	
HCB	5	0.076	0.040-0.143	0.038-0.133	
PCB 1260	5	11.8	5.01-27.7	3.67-21.0	
PCB 1254:1260	5	13.7	5.83-32.2	4.27-24.4	
PCB/DDE = 2.31					
Methyl Mercury	5	0.157	0.046-0.529	0.028-0.310	
Pictou Island, Nova Scotia (40)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 3.60 ± 0.358					
% Water = 83.1 ± 0.395					
DDE	5	4.27	2.51-7.08	2.52-7.84	
DDT	5	0.053	0.038-0.073	0.040-0.070	
DDD	5	0.036	0.022-0.058	0.020-0.050	
Dieldrin	5	0.155	0.083-0.287	0.090-0.330	
Heptachlor epoxide	5	0.020	0.011-0.037	0.010-0.040	
Endrin	5	0.056	0.032-0.098	0.030-0.090	
HCB	5	0.010	-	0.010-0.010	
PCB 1260	5	11.4	5.26-24.7	4.56-22.7	
PCB/DDE = 2.71					
Mercury	5	0.261	0.203-0.337	0.200-0.350	
Campbell Island, Nova Scotia (42)					
Eggs (Fresh)					
1976 (5/5)					14
% Fat = 3.96 ± 0.269					
% Water = 83.6 ± 0.252					
DDE	5	1.62	1.11-2.35	1.23-2.68	
DDT	5	0.027	0.019-0.039	0.020-0.040	
DDD	5	0.007	-	0.007-0.007	
Dieldrin	5	0.095	0.065-0.137	0.070-0.140	
Heptachlor epoxide	5	0.025	0.019-0.034	0.020-0.030	
Oxychlordane	5	0.067	0.051-0.088	0.054-0.090	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Cis-Chlordane	5	0.013	0.008-0.021	0.010-0.020	
HCB	5	0.022	0.015-0.032	0.019-0.038	
PCB 1260	5	9.71	7.88-12.0	7.79-11.5	
PCB 1254:1260	5	12.2	9.92-15.1	9.82-14.5	
PCB/DDE = 7.57					
Mercury	5	0.210	0.162-0.273	0.150-0.260	
Manawagonish Island, New Brunswick (46)					
Eggs (Fresh)					
1972 (10/10)					14
% Fat = 9.95 ± 0.352					
% Water = 83.2 ± 0.200					
DDE	10	6.51	4.53-9.34	3.46-20.0	
DDT	2	0.025	0.002-0.322	ND-0.030	
DDD	2	0.025	0.002-0.322	ND-0.030	
Dieldrin	10	0.153	0.095-0.247	0.050-0.360	
Heptachlor epoxide	10	0.015	0.011-0.021	0.010-0.030	
HCB	10	0.014	0.010-0.019	0.010-0.030	
PCB 1260	10	14.6	12.2-17.4	9.88-22.3	
PCB/DDE = 2.24					
Mercury	10	0.221	0.177-0.275	0.140-0.390	
1976 (5/5)					14
% Fat = 3.84 ± 0.238					
% Water = 83.1 ± 0.195					
DDE	5	1.49	0.592-3.75	0.480-3.15	
DDT	5	0.031	0.015-0.065	0.020-0.060	
DDD	5	0.008	0.005-0.012	0.007-0.014	
Dieldrin	5	0.057	0.014-0.232	0.010-0.170	
Heptachlor epoxide	5	0.014	0.006-0.035	0.005-0.030	
Oxychlordane	5	0.044	0.018-0.106	0.018-0.126	
Cis-Chlordane	5	0.015	0.005-0.047	0.005-0.050	
HCB	5	0.022	0.015-0.032	0.019-0.038	
PCB 1260	5	6.31	3.10-12.8	2.73-11.9	
PCB 1254:1260	5	7.78	3.66-16.6	3.12-15.0	
PCB/DDE = 5.22					
Mercury	5	0.243	0.106-0.556	0.100-0.500	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1979 (1/1)					14
% Fat = 5.10					
% Water = 84.1					
DDE	1	1.98	-	-	
DDT	1	0.030	-	-	
DDD	1	0.100	-	-	
Dieldrin	1	0.120	-	-	
Heptachlor epoxide	1	0.030	-	-	
Oxychlordane	1	0.050	-	-	
Cis-Chlordane	1	0.040	-	-	
Mirex	1	0.040	-	-	
Photomirex	1	0.001	-	-	
HCB	1	0.030	-	-	
HCH	1	0.020	-	-	
PCB 1260	1	11.8	-	-	
PCB 1254:1260	1	19.6	-	-	
PCB/DDE = 9.90					
1980 (5/5)					14
% Fat = 5.58 ± 0.244					
% Water = 83.6 ± 0.311					
DDE	5	1.91	0.977-3.75	1.00-4.35	
DDT	5	0.039	0.031-0.049	0.030-0.050	
DDD	5	0.034	0.022-0.053	0.020-0.050	
Dieldrin	5	0.047	0.025-0.087	0.030-0.090	
Heptachlor epoxide	5	0.064	0.016-0.249	0.020-0.220	
Oxychlordane	2	0.028	0.000-2.31	ND-0.040	
Cis-Chlordane	5	0.001	0.000-0.006	0.001-0.005	
Mirex	5	0.032	0.014-0.071	0.010-0.050	
HCB	5	0.025	0.017-0.037	0.020-0.040	
A-HCH	5	0.014	0.008-0.027	0.010-0.030	
B-HCH	5	0.013	0.005-0.036	0.005-0.030	
PCB 1260	5	12.2	7.58-19.8	8.60-22.2	
PCB 1254:1260	5	12.4	7.71-20.0	8.86-22.9	
PCB/DDE = 6.50					
Mercury	5	0.189	0.139-0.258	0.140-0.270	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1984 (5/5)					14
% Fat = 4.62 ± 0.166					
% Water = 83.42 ± 0.10					
DDE	5	1.07	0.677-1.70	0.640-1.59	
DDT	5	0.016	0.011-0.021	0.012-0.022	
DDD	5	0.004	0.003-0.007	0.003-0.007	
Dieldrin	5	0.017	0.010-0.028	0.010-0.030	
Heptachlor epoxide	5	0.010	0.007-0.013	0.007-0.012	
Oxychlordane	5	0.018	0.011-0.028	0.010-0.026	
Cis-chlordane	5	0.002	0.002-0.003	0.002-0.003	
Mirex	5	0.011	0.005-0.025	0.005-0.024	
HCB	5	0.012	0.008-0.018	0.007-0.016	
A-HCH	5	0.012	0.010-0.014	0.010-0.014	
B-HCH	5	0.001	0.000-0.002	0.001-0.003	
G-HCH	5	0.001	0.001-0.002	0.001-0.002	
Cis-nonachlor	5	0.009	0.007-0.013	0.006-0.013	
PCB 1254:1260	5	3.56	2.02-6.26	1.81-6.50	
PCB/DDE = 3.33					
Boot Island, Nova Scotia (47)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 3.96 ± 0.964					
% Water = 83.7 ± 0.291					
DDE	5	4.41	1.93-10.1	2.16-13.1	
DDT	5	0.042	0.021-0.087	0.020-0.080	
DDD	5	0.019	0.011-0.031	0.010-0.030	
Dieldrin	5	0.144	0.063-0.332	0.080-0.440	
Heptachlor epoxide	5	0.025	0.002-0.322	0.020-0.030	
Endrin	5	0.049	0.029-0.080	0.030-0.090	
HCB	2	0.010	-	ND-0.010	
PCB 1260	5	8.46	4.267-16.755	6.13-22.3	
PCB/DDE = 1.92					
Mercury	5	0.271	0.162-0.455	0.170-0.520	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1976 (5/5)					14
% Fat = 3.48 ± 0.171					
% Water = 83.0 ± 0.499					
DDE	5	1.66	1.01-2.72	1.08-2.44	
DDT	5	0.030	0.012-0.075	0.010-0.060	
DDD	5	0.007	-	0.007-0.007	
Dieldrin	5	0.073	0.031-0.172	0.030-0.130	
Heptachlor epoxide	5	0.016	0.009-0.030	0.010-0.030	
Oxychlordane	5	0.056	0.027-0.118	0.036-0.108	
Cis-Chlordane	5	0.014	0.006-0.034	0.010-0.050	
HCB	5	0.025	0.016-0.040	0.019-0.038	
PCB 1260	5	5.66	2.85-11.24	3.10-9.65	
PCB 1254:1260	5	7.62	3.88-15.0	4.13-12.7	
PCB/DDE = 4.58					
Mercury	5	0.254	0.163-0.396	0.180-0.440	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Common Eider					
Inner Birch Is., Quebec (7)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 17.6 ± 0.428					
% Water = 66.7 ± 0.474					
DDE	5	0.380	0.214-0.675	0.170-0.540	
DDT	5	0.038	0.014-0.102	0.010-0.080	
Dieldrin	5	0.022	0.012-0.040	0.010-0.030	
Heptachlor epoxide	3	0.010	-	ND-0.010	
Endrin	1	0.010	-	-	
HCB	5	0.016	0.006-0.047	0.005-0.040	
PCB 1260	5	1.83	0.667-5.03	0.450-3.17	
PCB/DDE = 4.82					
Mercury	5	0.078	0.029-0.211	0.030-0.210	
Watshishu, Quebec (9)					
Eggs (Fresh)					
1972 (4/4)					14
% Fat = 20.7 ± 1.09					
% Water = 67.0 ± 0.302					
DDE	4	0.283	0.225-0.356	0.250-0.330	
Dieldrin	4	0.010	-	0.010-0.010	
Heptachlor epoxide	4	0.012	0.007-0.021	0.010-0.020	
HCB	4	0.017	0.010-0.029	0.010-0.020	
PCB 1260	4	0.575	0.480-0.688	0.510-0.670	
PCB/DDE = 2.03					
Mercury	4	0.083	0.046-0.152	0.050-0.120	
Ste.-Marie Is., Quebec (10)					
Eggs (Fresh)					
1972 (10/10)					14
% Fat = 21.4 ± 0.789					
% Water = 66.0 ± 0.337					
DDE	10	0.288	0.227-0.365	0.210-0.690	
DDT	4	0.016	0.007-0.037	ND-0.030	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Dieldrin	8	0.011	0.009-0.013	ND-0.020	
Heptachlor epoxide	5	0.017	0.012-0.026	ND-0.020	
HCB	10	0.015	0.011-0.020	0.010-0.030	
PCB 1260	10	0.572	0.404-0.810	0.350-2.03	
PCB/DDE = 1.99					
Mercury	10	0.025	0.013-0.048	0.005-0.060	
Tinker Harbour, Newfoundland (16)					
Breast Muscle					
1970 (1/1)					14
Mercury	1	0.050	-	-	
Low Duck Is., (New Brunswick (49)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 16.6 ± 0.378					
% Water = 66.4 ± 0.463					
DDE	5	0.588	0.375-0.923	0.360-0.960	
DDT	5	0.031	0.018-0.055	0.020-0.050	
Dieldrin	5	0.020	0.011-0.037	0.010-0.040	
Heptachlor epoxide	5	0.013	0.005-0.034	0.010-0.020	
HCB	5	0.021	0.012-0.036	0.010-0.030	
PCB 1260	5	4.37	1.11-17.2	1.94-30.0	
PCB/DDE = 7.42					
Mercury	5	0.053	0.035-0.081	0.040-0.090	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Common Tern					
Harrington Harbour, Quebec (11)					
Eggs (Fresh)					
1971 (3/3)					14
% Fat = 14.6 ± 2.11					
% Water = 70.5 ± 3.84					
DDE	3	0.568	0.190-1.70	0.380-0.910	
DDT	2	0.045	0.011-0.185	ND-0.050	
Dieldrin	3	0.029	0.012-0.069	0.020-0.040	
Heptachlor epoxide	3	0.006	0.001-0.043	0.002-0.010	
Endrin	3	0.016	0.006-0.043	0.010-0.020	
HCB	3	0.018	0.005-0.072	0.010-0.030	
PCB 1260	3	1.25	0.910-0.072	1.10-1.42	
PCB/DDE = 2.20					
Mercury	3	0.137	0.022-0.847	0.090-0.320	
Bathurst Harbour, New Brunswick (30)					
Eggs (Fresh)					
1969 (4/4)					14
% Fat = N/A					
% Water = 75.5 ± 0.867					
Mercury	4	0.429	0.109-1.69	0.182-1.42	
1970 (10/10)					14
% Fat = 9.60 ± 0.535					
% Water = 77.1 ± 0.259					
DDE	10	0.877	0.713-1.08	0.640-1.61	
DDT	10	0.067	0.048-0.092	0.030-0.140	
DDD	3	0.052	0.026-0.105	ND-0.070	
Dieldrin	10	0.037	0.028-0.050	0.030-0.110	
HCB	10	0.028	0.025-0.031	0.020-0.030	
PCB 1260	10	1.99	1.33-2.98	1.12-6.93	
PCB/DDE = 2.27					
Mercury	10	0.120	0.099-0.145	0.080-0.190	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1972 (10/10)					14
% Fat = 13.3 ± 0.523					
% Water = 76.0 ± 0.275					
DDE	10	0.615	0.505-0.751	0.450-1.19	
DDT					
DDD	1	0.030	-	-	
Dieldrin	10	0.023	0.015-0.034	0.010-0.050	
Heptachlor epoxide	1	0.010	-	-	
HCB	10	0.035	0.024-0.052	0.010-0.060	
PCB 1260	10	1.96	1.34-2.87	1.17-4.79	
PCB/DDE = 3.19					
Mercury	10	0.124	0.104-0.149	0.080-0.200	
1973 (5/5)					14
% Fat = 7.28 ± 0.668					
% Water = 77.6 ± 0.952					
DDE	5	0.463	0.308-0.694	0.260-0.570	
DDT	5	0.022	0.011-0.041	0.010-0.040	
DDD	5	0.007	-	0.007-0.007	
Dieldrin	5	0.022	0.012-0.040	0.010-0.030	
Heptachlor epoxide	5	0.010	-	0.010-0.010	
Oxychlordane	5	0.018	-	0.018-0.018	
Cis-Chlordane	5	0.010	0.005-0.018	0.005-0.020	
HCB	5	0.042	0.023-0.077	0.019-0.057	
PCB 1260	5	1.61	1.06-2.43	0.900-2.09	
PCB 1254:1260	5	2.02	1.33-3.06	1.13-2.63	
PCB/DDE = 4.37					
Mercury	5	0.180	0.081-0.143	0.080-0.140	
Liver					
1969 (4/4)					14
% Fat = N/A					
% Water = 66.5 ± 0.288					
Mercury	4	2.50	2.24-2.79	2.28-2.70	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Tabusintac, New Brunswick (33)					
Eggs (Fresh)					
1973 (5/5)					14
% Fat = 8.56 ± 0.482					
% Water = 76.1 ± 0.541					
DDE	5	0.516	0.404-0.660	0.370-0.610	
DDT	5	0.029	0.022-0.040	0.020-0.040	
DDD	5	0.007	-	0.007-0.007	
Dieldrin	5	0.028	0.013-0.061	0.010-0.050	
Heptachlor epoxide	5	0.010	-	0.010-0.010	
Oxychlordane	5	0.018	-	0.018-0.018	
Cis-Chlordane	5	0.014	0.006-0.035	0.005-0.030	
HCB	5	0.049	0.037-0.064	0.038-0.057	
PCB 1260	5	1.37	1.20-1.56	1.22-1.61	
PCB 1254:1260	5	1.73	1.52-1.97	1.54-2.02	
PCB/DDE = 3.35					
Mercury	5	0.057	0.037-0.087	0.040-0.100	
Magdalen Is., Quebec (35)					
Eggs (Fresh)					
1973 (5/5)					
% Fat = 9.08 ± 0.449					
% Water = 76.76 ± 0.469					
DDE	5	0.536	0.138-2.08	0.150-1.52	
DDT	5	0.106	0.043-0.263	0.038-0.266	
Dieldrin	5	0.080	0.047-0.137	0.040-0.130	
Heptachlor epoxide	5	0.010	-	0.010-0.010	
HCB	5	0.071	0.054-0.093	0.057-0.095	
PCB 1260	5	1.95	1.26-3.03	1.33-3.23	
PCB 1254:1260	5	2.26	1.46-3.51	1.54-3.74	
PCB/DDE = 4.22					
Methyl Mercury	5	0.105	0.068-0.162	0.070-0.170	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Little Courtin Is., Prince Edward Island (37)					
Eggs (Fresh) pool					
1975 (1/10)					5
% Fat = 9.30					
% Water = 75.10					
DDE	1	0.400	-	-	
DDT	1	0.010	-	-	
DDD	1	0.001	-	-	
Dieldrin	1	0.030	-	-	
Heptachlor epoxide	1	0.010	-	-	
Oxychlordane	1	0.010	-	-	
Cis-Chlordane	1	0.010	-	-	
Mirex	1	0.005	-	-	
Photomirex	1	0.005	-	-	
HCB	1	0.020	-	-	
B-HCH	1	0.005	-	-	
PCB 1260	1	1.09	-	-	
PCB 1254-1260	1	1.23	-	-	
PCB/DDE = 3.08					
Mercury	1	0.150	-	-	
Charlottetown, Prince Edward Island (39)					
Eggs (Fresh)					
1973 (5/5)					14
% Fat = 8.48 ± 0.177					
% Water = 76.2 ± 0.200					
DDE	5	1.11	0.470-2.60	0.550-3.36	
DDT	5	0.029	0.013-0.062	0.019-0.076	
Dieldrin	5	0.054	0.027-0.110	0.030-0.110	
Heptachlor epoxide	5	0.011	0.008-0.017	0.010-0.020	
HCB	5	0.051	0.035-0.074	0.038-0.076	
PCB 1260	5	1.95	0.761-5.00	0.770-4.55	
PCB 1254:1260	5	2.35	0.917-6.02	0.930-5.49	
PCB/DDE = 2.13					
Methyl Mercury	5	0.160	0.079-0.321	0.080-0.310	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Margaree Is., Prince Edward Island (41)					
Eggs (Fresh)					
1973 (5/5)					14
% Fat = 9.64 ± 0.206					
% Water = 76.3 ± 0.385					
DDE	5	0.953	0.533-1.71	0.440-1.440	
DDT	5	0.025	0.016-0.040	0.019-0.038	
Dieldrin	5	0.039	0.027-0.055	0.030-0.060	
Heptachlor epoxide	5	0.011	0.008-0.017	0.010-0.020	
HCB	5	0.101	0.077-0.131	0.076-0.133	
PCB 1260	5	1.86	1.23-2.81	1.15-2.59	
PCB 1254:1260	5	2.25	1.49-3.40	1.39-3.13	
PCB/DDE = 2.36					
Methyl Mercury	5	0.092	0.062-0.136	0.070-0.150	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Common Puffin					
Great Island, Newfoundland (27)					
Eggs (Fresh)					
1968 (20/20)					11
% Fat = 9.97 ± 0.423					
% Water = 73.2 ± 0.572					
DDE	20	0.563	0.384-0.824	0.024-1.42	
Dieldrin	20	0.038	0.031-0.048	0.007-0.067	
Endrin	2	0.028	0.000-1150.	ND-0.064	
1968 (5/5) (re-analyzed 1984)					11
% Fat = 11.1 ± 0.301					
% Water = 69.8 ± 1.12					
DDE	5	0.898	0.704-1.15	0.747-1.16	
DDT	5	0.082	0.062-0.107	0.057-0.101	
DDD	5	0.009	0.005-0.015	0.006-0.014	
Dieldrin	5	0.050	0.038-0.066	0.039-0.064	
Heptachlor epoxide	5	0.010	0.007-0.012	0.008-0.013	
Oxychlordane	5	0.031	0.024-0.041	0.022-0.040	
Cis-chlordane	5	0.005	0.001-0.023	0.001-0.012	
Mirex	5	0.010	0.008-0.013	0.008-0.013	
HCB	5	0.076	0.043-0.135	0.044-0.130	
A-HCH	5	0.004	0.002-0.006	0.002-0.005	
B-HCH	5	0.001	-	0.001-0.001	
G-HCH	5	0.001	-	0.001-0.001	
Cis-nonachlor	5	0.012	0.008-0.017	0.009-0.017	
PCB 1254:1260	5	2.33	1.53-3.53	1.76-4.06	
PCB/DDE = 2.59					
1972 (3/3)					14
% Fat = 15.8 ± 0.529					
% Water = 68.7 ± 1.07					
DDE	3	0.641	0.314-1.31	0.520-0.890	
Dieldrin	3	0.049	0.030-0.082	0.040-0.060	
Heptachlor epoxide	3	0.016	0.006-0.043	0.010-0.020	
Endrin	3	0.031	0.010-0.097	0.020-0.050	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	3	0.058	0.026-0.130	0.040-0.070	
PCB 1260	3	1.66	1.13-2.46	1.49-1.99	
PCB/DDE = 2.59					
Mercury	3	0.255	0.143-0.455	0.210-0.330	
1976 (5/5)					14
% Fat = 10.2 ± 0.314					
% Water = 71.5 ± 0.491					
DDE	5	0.588	0.428-0.808	0.430-0.870	
DDT	5	0.013	0.008-0.021	0.010-0.020	
DDD	5	0.007	-	0.005-0.005	
Dieldrin	5	0.044	0.038-0.051	0.040-0.050	
Heptachlor epoxide	5	0.015	0.009-0.024	0.010-0.020	
Oxychlordane	5	0.082	0.071-0.096	0.072-0.090	
Cis-Chlordane	5	0.025	0.019-0.034	0.020-0.030	
HCB	5	0.091	0.080-0.103	0.076-0.095	
PCB 1260	5	1.86	1.69-2.05	1.63-2.00	
PCB 1254:1260	5	2.41	2.18-2.68	2.11-2.64	
PCB/DDE = 4.10					
Mercury	5	0.231	0.162-0.330	0.140-0.280	
1980 (5/5)					14
% Fat = 10.7 ± 1.76					
% Water = 71.4 ± 1.33					
DDE	5	0.554	0.365-0.840	0.350-0.780	
DDT	5	0.001	0.000-0.005	0.001-0.010	
DDD	5	0.046	0.030-0.070	0.030-0.070	
Dieldrin	5	0.040	0.022-0.074	0.020-0.060	
Heptachlor epoxide	5	0.022	0.017-0.027	0.020-0.030	
Oxychlordane	5	0.038	0.025-0.058	0.030-0.060	
Cis-Chlordane	5	0.013	0.008-0.021	0.010-0.020	
Mirex	5	0.015	0.009-0.024	0.010-0.020	
HCB	5	0.092	0.087-0.097	0.090-0.100	
A-HCH	5	0.007	0.004-0.011	0.005-0.010	
B-HCH	5	0.003	0.000-0.018	0.001-0.010	
PCB 1260	5	2.49	1.84-3.39	1.90-3.41	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
PCB 1254:1260	5	2.50	1.85-3.38	1.91-3.37	
PCB/DDE = 4.51					
Mercury	5	0.324	0.197-0.531	0.180-0.540	
1984 (5/5)					7
% Fat = 8.96 ± 0.849					
% Water = 73.5 ± 1.25					
DDE	5	0.303	0.233-0.392	0.230-0.410	
DDT	5	0.047	0.041-0.056	0.043-0.059	
DDD	5	0.001	-	0.001-0.001	
Dieldrin	5	0.041	0.034-0.050	0.036-0.052	
Heptachlor epoxide	5	0.019	0.016-0.022	0.016-0.023	
Oxychlordane	5	0.049	0.037-0.065	0.039-0.069	
Cis-chlordane	5	0.008	0.006-0.010	0.006-0.010	
Mirex	5	0.005	0.004-0.007	0.004-0.007	
HCB	5	0.086	0.062-0.121	0.060-0.125	
A-HCH	5	0.005	0.003-0.008	0.003-0.008	
B-HCH	5	0.004	0.003-0.005	0.003-0.005	
G-HCH	5	0.001	-	0.001-0.001	
Cis-nonachlor	5	0.021	0.017-0.025	0.018-0.026	
PCB 1254:1260	5	0.991	0.838-1.17	0.820-1.11	
PCB/DDE = 3.27					
Whole Body					
1968 (5/5)					11
% Fat = 8.36 ± 1.02					
% Water = 66.3 ± 1.00					
DDE	5	0.245	0.193-0.310	0.195-0.328	
Dieldrin	5	0.024	0.021-0.029	0.021-0.028	
Heptachlor epoxide	5	0.009	0.006-0.015	0.006-0.018	
PCB 1260	5	0.384	0.331-0.446	0.352-0.462	
PCB/DDE = 1.57					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Gannet Island, Newfoundland (15)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 13.7 ± 0.589					
% Water = 70.7 ± 0.307					
DDE	5	0.570	0.426-0.761	0.430-0.730	
Dieldrin	5	0.047	0.038-0.059	0.040-0.060	
Heptachlor epoxide	3	0.020	-	ND-0.020	
Endrin	3	0.033	0.022-0.050	ND-0.040	
HCB	5	0.027	0.012-0.063	0.010-0.050	
PCB 1260	5	2.32	1.71-3.15	1.69-2.90	
PCB/DDE = 4.07					
Mercury	5	0.179	0.153-0.210	0.160-0.210	
Bird Island, Newfoundland (13)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 17.5 ± 0.655					
% Water = 72.0 ± 0.280					
DDE	5	0.579	0.421-0.796	0.480-0.900	
Dieldrin	5	0.041	0.032-0.054	0.030-0.050	
Heptachlor epoxide	3	0.023	0.013-0.041	ND-0.030	
Endrin	2	0.030	-	ND-0.030	
HCB	5	0.030	0.015-0.060	0.020-0.060	
PCB 1260	5	1.90	1.29-2.81	1.48-3.06	
PCB/DDE = 1.57					
Mercury	5	0.183	0.095-0.350	0.100-0.340	
Grady Harbour, Labrador (14)					
Breast Muscle					
1970 (2/2)					7
% Fat = 1.80 ± 0.200					
% Water = 72.6 ± 0.600					
DDE	2	0.284	0.041-1.97	0.244-0.331	
PCB 1260	2	0.403	0.056-2.91	0.345-0.471	
PCB/DDE = 1.42					
Mercury	2	0.160	-	0.160-0.160	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Betchouane, Quebec (8)					
Eggs (Fresh)					
1972 (4/4)					14
% Fat = 15.5 ± 0.680					
% Water = 71.4 ± 0.751					
DDE	4	1.24	0.517-2.97	0.750-2.280	
DDT	2	0.010	-	ND-0.010	
DDD	1	0.070	-	-	
Dieldrin	4	0.065	0.038-0.109	0.050-0.100	
Heptachlor epoxide	4	0.012	0.007-0.021	0.010-0.020	
Endrin	4	0.036	0.016-0.083	0.020-0.070	
HCB	4	0.091	0.044-0.187	0.050-0.150	
PCB 1260	4	4.39	1.97-9.80	2.76-7.40	
PCB/DDE = 3.55					
Mercury	4	0.172	0.122-0.243	0.130-0.220	
Ste. Marie Island, Quebec (10)					
Eggs (Fresh)					
1972 (9/9)					14
% Fat = 16.7 ± 0.905					
% Water = 71.1 ± 0.660					
DDE	9	0.994	0.789-1.25	0.620-1.72	
DDT	3	0.013	0.005-0.034	ND-0.020	
Dieldrin	9	0.055	0.044-0.070	0.040-0.100	
Heptachlor epoxide	9	0.009	0.008-0.011	0.005-0.010	
Endrin	9	0.032	0.022-0.047	0.020-0.070	
HCB	9	0.049	0.022-0.108	0.005-0.140	
PCB 1260	9	2.89	2.14-3.91	1.20-5.11	
PCB/DDE = 2.91					
Mercury	9	0.162	0.119-0.220	0.070-0.240	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Perroquet Island, Quebec (12)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 14.8 ± 0.755					
% Water = 69.9 ± 0.731					
DDE	5	1.49	1.26-1.75	1.22-1.70	
DDT	5	0.011	0.008-0.017	0.010-0.020	
Dieldrin	5	0.065	0.049-0.085	0.050-0.090	
Heptachlor epoxide	4	0.010	-	ND-0.010	
Endrin	5	0.042	0.027-0.065	0.030-0.070	
HCB	5	0.067	0.041-0.111	0.040-0.110	
PCB 1260	5	3.99	3.11-5.11	3.08-5.04	
PCB/DDE = 2.68					
Mercury	5	0.156	0.097-0.251	0.080-0.200	
Brion Island, Quebec (34)					
Eggs (Fresh)					
1973 (1/1)					14
% Fat = 10.2					
% Water = 73.2					
DDE	1	1.46	-	-	
DDT	1	0.019	-	-	
DDD	1	0.056	-	-	
Dieldrin	1	0.060	-	-	
Heptachlor epoxide	1	0.020	-	-	
HCB	1	0.060	-	-	
PCB 1260	1	4.19	-	-	
PCB 1254:1260	1	4.85	-	-	
PCB/DDE = 3.32					
Machias Seal Island, New Brunswick (43)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 13.0 ± 0.665					
% Water = 71.5 ± 0.753					
DDE	5	2.57	1.74-3.80	1.97-3.89	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDT	1	0.020	-	-	
Dieldrin	5	0.089	0.069-0.114	0.070-0.110	
Heptachlor epoxide	5	0.015	0.009-0.024	0.010-0.020	
Endrin	5	0.087	0.036-0.211	0.040-0.170	
HCB	5	0.058	0.031-0.110	0.030-0.100	
PCB 1260	5	7.20	6.13-8.46	5.80-8.19	
PCB/DDE = 2.80					
Mercury	5	0.204	0.167-0.248	0.180-0.260	
1976 (5/5)					14
% Fat = 11.3 ± 0.440					
% Water = 70.7 ± 0.483					
DDE	5	1.27	0.832-1.93	0.750-1.76	
DDT	5	0.020	-	0.020-0.020	
DDD	5	0.007	-	0.007-0.007	
Dieldrin	5	0.080	0.043-0.150	0.040-0.130	
Heptachlor epoxide	5	0.029	0.022-0.040	0.020-0.040	
Oxychlordane	5	0.128	0.099-0.164	0.090-0.144	
Cis-Chlordane	5	0.037	0.022-0.064	0.020-0.060	
HCB	5	0.188	0.154-0.229	0.152-0.228	
PCB 1260	5	6.10	5.11-7.27	4.73-6.59	
PCB 1254:1260	5	7.25	6.07-8.66	5.62-7.83	
PCB/DDE = 5.72					
Mercury	5	0.090	0.061-0.134	0.060-0.120	
1980 (5/5)					14
% Fat = 12.9 ± 0.387					
% Water = 70.5 ± 0.453					
DDE	5	1.03	0.849-1.24	0.850-1.17	
DDT	5	0.010	-	0.010-0.010	
DDT	5	0.065	0.039-0.109	0.040-0.120	
Dieldrin	5	0.036	0.022-0.058	0.020-0.050	
Heptachlor epoxide	5	0.027	0.019-0.039	0.020-0.040	
Oxychlordane	5	0.059	0.044-0.078	0.050-0.080	
Cis-Chlordane	5	0.017	0.012-0.026	0.010-0.020	
Mirex	5	0.025	0.019-0.034	0.020-0.030	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	5	0.082	0.061-0.110	0.060-0.110	
A-HCH	5	0.008	0.005-0.012	0.005-0.010	
B-HCH	5	0.003	0.000-0.018	0.001-0.010	
PCB 1260	5	5.31	4.22-6.67	4.28-6.34	
PCB 1254:1260	5	5.52	4.33-7.04	4.38-6.64	
PCB/DDE = 5.38					
Mercury	5	0.179	0.143-0.226	0.150-0.230	
1984 (5/5)					14
% Fat = 11.3 ± 0.422					
% Water = 73.4 ± 1.47					
DDE	5	0.735	0.541-0.999	0.550-1.09	
DDT	5	0.044	0.029-0.067	0.031-0.075	
DDD	5	0.001	-	0.001-0.001	
Dieldrin	5	0.049	0.032-0.073	0.036-0.080	
Heptachlor epoxide	5	0.020	0.015-0.025	0.017-0.027	
Oxychlordane	5	0.070	0.051-0.096	0.052-0.104	
Cis-chlordane	5	0.006	0.005-0.008	0.005-0.008	
Mirex	5	0.010	0.008-0.014	0.008-0.015	
HCB	5	0.065	0.046-0.092	0.048-0.099	
A-HCH	5	0.004	0.003-0.004	0.003-0.004	
B-HCH	5	0.003	0.002-0.004	0.002-0.004	
G-HCH	5	0.001	-	0.001-0.001	
Cis-nonachlor	5	0.033	0.023-0.047	0.024-0.051	
PCB 1254:1260	5	3.20	2.39-4.30	2.26-4.20	
PCB/DDE = 4.35					
Whole Body					
1972 (5/5)					14
% Fat = 11.1 ± 0.989					
% Water = 62.1 ± 0.574					
DDE	5	1.65	1.27-2.15	1.32-2.15	
DDT	5	0.009	0.001-0.068	0.001-0.030	
DDD	5	0.006	0.001-0.051	0.001-0.040	
Dieldrin	5	0.062	0.044-0.088	0.040-0.080	
Heptachlor epoxide	5	0.016	0.006-0.047	0.005-0.040	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	5	0.043	0.035-0.054	0.040-0.060	
PCB 1260	5	4.77	3.61-6.28	3.68-6.55	
PCB 1254:1260	5	5.13	3.90-6.76	3.97-7.05	
PCB/DDE = 3.12					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Razorbills					
Pèlerin Island, Québec (1)					
Eggs (Fresh)					
1978 (4/4)					8
% Fat = 7.60 ± 1.37					
% Water = 72.0 ± 0.880					
DDE	4	2.27	1.04-4.95	1.09-3.04	
DDT	4	0.056	0.019-0.171	0.020-0.090	
DDD	4	0.298	0.130-0.682	0.140-0.430	
Dieldrin	4	0.139	0.036-0.536	0.040-0.250	
Heptachlor epoxide	4	0.062	0.028-0.138	0.030-0.090	
Oxychlordane	4	0.108	0.037-0.309	0.040-0.160	
Cis-Chlordane	4	0.315	0.136-0.729	0.150-0.520	
HCB	4	0.162	0.075-0.351	0.080-0.240	
B-HCH	4	0.017	0.010-0.029	0.010-0.020	
PCB 1260	4	19.7	8.69-4.44	9.20-28.3	
PCB 1254:1260	4	21.3	9.10-49.9	9.65-31.0	
PCB/DDE = 9.11					
Eggs (Addled)					
1978 (3/3)					8
% Fat = 9.70 ± 0.900					
% Water = 46.8 ± 5.76					
DDE	3	14.2	1.17-173.	7.38-45.3	
DDT	3	0.181	0.052-0.630	0.110-0.300	
DDD	3	0.936	0.310-2.82	0.670-1.55	
Dieldrin	3	0.561	0.182-1.73	0.400-0.940	
Heptachlor epoxide	3	0.204	0.098-0.425	0.150-0.270	
Oxychlordane	3	0.471	0.205-1.08	0.370-0.690	
Cis-Chlordane	3	0.688	0.206-2.30	0.460-1.18	
HCB	3	0.632	0.434-0.920	0.540-0.730	
B-HCH	3	0.048	0.018-0.129	0.030-0.060	
PCB 1260	3	39.8	3.67-430.	13.2-75.4	
PCB 1254:1260	3	43.9	4.07-472.	14.6-83.1	
PCB/DDE = 3.09					

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Eggs (Dead)					
1978 (3/3)					8
% Fat = 5.73 ± 2.50					
% Water = 73.2 ± 3.17					
DDE	3	0.757	0.033-17.1	0.230-2.81	
DDT	3	0.010	0.001-0.197	0.005-0.040	
DDD	3	0.049	0.000-10.7	0.005-0.380	
Dieldrin	3	0.054	0.008-0.371	0.030-0.130	
Heptachlor epoxide	3	0.023	0.002-0.216	0.010-0.060	
Oxychlordane	3	0.042	0.001-1.65	0.010-0.190	
Cis-Chlordane	3	0.072	0.003-1.70	0.030-0.310	
HCB	3	0.072	0.006-0.838	0.030-0.210	
B-HCH	3	0.008	0.001-0.058	0.005-0.020	
PCB 1260	3	6.87	0.267-176.	1.97-26.7	
PCB 1254:1260	3	8.08	0.409-159.	2.56-28.0	
PCB/DDE = 10.7					
Carrousel Island, Québec (6)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 14.4 ± 0.523					
% Water = 71.4 ± 0.311					
DDE	5	4.54	1.87-11.0	2.30-14.9	
DDT	3	0.023	0.013-0.041	ND-0.030	
Dieldrin	5	0.154	0.062-0.381	0.080-0.520	
Heptachlor epoxide	5	0.025	0.019-0.034	0.020-0.030	
Endrin	5	0.119	0.087-0.163	0.080-0.150	
HCB	5	0.059	0.038-0.092	0.040-0.080	
PCB 1260	5	21.7	13.0-36.0	12.8-37.3	
PCB/DDE = 4.78					
Mercury	5	0.085	0.018-0.388	0.010-0.190	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Ste. Marie Island, Québec (10)					
Eggs (Fresh)					
1972 (5/5)					14
% Fat = 17.2 ± 0.978					
% Water = 72.4 ± 0.415					
DDE	5	2.68	1.81-3.98	1.82-4.11	
DDT	1	0.010	-	-	
Dieldrin	5	0.105	0.067-0.164	0.060-0.150	
Heptachlor epoxide	5	0.025	0.019-0.034	0.020-0.030	
Endrin	5	0.142	0.102-0.198	0.100-0.210	
HCB	5	0.095	0.070-0.130	0.070-0.140	
PCB 1260	5	9.34	6.30-13.9	6.29-15.0	
PCB/DDE = 3.48					
Mercury	5	0.121	0.090-0.164	0.080-0.150	
1978 (5/5)					8
% Fat = 11.2 ± 0.133					
% Water = 70.2 ± 1.62					
DDE	5	1.70	1.45-1.99	1.45-1.96	
DDT	5	0.064	0.013-0.134	0.040-0.180	
DDD	5	0.223	0.171-0.292	0.190-0.320	
Dieldrin	5	0.158	0.107-0.234	0.100-0.210	
Heptachlor epoxide	5	0.065	0.048-0.087	0.050-0.080	
Oxychlordane	5	0.100	0.077-0.130	0.080-0.140	
Cis-Chlordane	5	0.147	0.111-0.194	0.120-0.200	
HCB	5	0.195	0.165-0.229	0.160-0.230	
B-HCH	5	0.010	-	0.010-0.010	
PCB 1260	5	10.3	8.31-12.7	7.70-11.9	
PCB 1254:1260	5	11.5	9.28-14.1	8.63-13.4	
PCB/DDE = 6.74					
Eggs (Addled)					
1978 (5/5)					8
% Fat = 12.9 ± 0.473					
% Water = 66.9 ± 1.37					
DDE	5	2.93	1.52-5.66	1.47-6.45	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDT	5	0.046	0.039-0.053	0.040-0.050	
DDD	5	0.330	0.253-0.431	0.230-0.400	
Dieldrin	5	0.170	0.139-0.209	0.140-0.220	
Heptachlor epoxide	5	0.081	0.067-0.099	0.070-0.100	
Oxychlordane	5	0.125	0.092-0.170	0.090-0.180	
Cis-Chlordane	5	0.199	0.105-0.376	0.080-0.270	
HCB	5	0.229	0.182-0.287	0.190-0.310	
B-HCH	5	0.011	0.008-0.017	0.010-0.020	
PCB 1260	5	16.1	9.67-26.7	8.40-26.1	
PCB 1254:1260	5	17.7	10.6-29.4	9.28-28.9	
PCB/DDE = 6.03					
Grady Harbour, Newfoundland (14)					
Breast Muscle (pool)					
1970 (2/2)					7
% Fat = 2.95 ± 0.150					
% Water = 71.2 ± 0.750					
DDE	2	0.356	0.143-0.884	0.331-0.382	
PCB 1260	2	1.35	0.093-19.5	1.09-1.66	
PCB/DDE = 3.78					
Mercury	2	0.325	0.181-0.584	0.310-0.340	
Brion Island, Québec (34)					
Eggs (Fresh)					
1973 (3/3)					14
% Fat = 12.5 ± 1.13					
% Water = 72.0 ± 1.25					
DDE	3	2.55	1.61-4.05	2.14-3.10	
DDT	3	0.030	0.004-0.220	0.019-0.076	
Dieldrin	3	0.125	0.073-0.213	0.110-0.160	
Heptachlor epoxide	3	0.042	0.017-0.099	0.030-0.060	
HCB	3	0.127	0.052-0.311	0.095-0.190	
PCB 1260	3	8.37	4.77-14.7	6.68-10.5	
PCB 1254:1260	3	9.67	5.53-16.9	7.72-12.1	
PCB/DDE = 3.79					
Methyl Mercury	3	0.106	0.011-1.05	0.040-0.250	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Common Murre					
Ste. Marie Is., Québec (10)					
Eggs (Fresh)					
1971 (4/4)					14
% Fat = 17.0 ± 2.011					
% Water = 67.6 ± 2.90					
DDE	4	2.03	0.963-4.28	1.28-3.81	
DDT	2	0.002	-	ND-0.010	
Dieldrin	4	0.025	0.017-0.035	0.020-0.030	
Heptachlor epoxide	4	0.017	0.010-0.029	0.010-0.020	
Endrin	4	0.023	0.008-0.069	0.010-0.050	
HCB	4	0.066	0.015-0.295	0.020-0.160	
PCB 1260	4	2.21	0.583-8.38	0.940-7.00	
PCB/DDE = 1.088					
Mercury	4	0.117	0.069-0.201	0.080-0.170	
Grady Harbour, Newfoundland (14)					
Breast Muscle (pools)					
1970 (2/2)					14
% Fat = 3.60 ± 0.400					
% Water = 71.8 ± 0.195					
DDE	2	0.307	0.119-0.795	0.285-0.331	
PCB 1260	2	0.302	0.106-0.864	0.278-0.328	
PCB/DDE = 0.984					
Mercury	2	0.171	0.013-2.25	0.140-0.210	
Funk Is., Newfoundland (26)					
Eggs (dead)					
1968 (10/10)					7
% Fat = 13.8 ± 0.960					
% Water = 69.8 ± 1.21					
DDE	10	0.965	0.783-1.19	0.613-1.53	
DDT	9	0.021	0.007-0.058	ND-0.112	
DDD	4	0.025	0.006-0.100	ND-0.044	
Dieldrin	10	0.025	0.018-0.034	0.008-0.039	
Heptachlor epoxide	4	0.013	0.007-0.021	ND-0.017	
Endrin	5	0.032	0.015-0.067	ND-0.056	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Black Guillemot					
Grady Harbour, Newfoundland (14)					
Breast Muscle (pool)					
1970 (1/1)					7
% Fat = 1.60					
% Water = 73.2					
DDE	1	0.268	-	-	
PCB 1260	1	0.852	-	-	
PCB/DDE = 3.18					
Mercury	1	0.290	-	-	
Magdalen Is., Quebec (35)					
Eggs (Fresh)					
1973 (3/3)					14
% Fat = 9.90 ± 0.611					
% Water = 73.8 ± 0.352					
DDE	3	1.04	0.512-2.11	0.750-1.27	
DDT	3	0.026	0.015-0.047	0.020-0.030	
DDD	3	0.007	-	0.007-0.007	
Dieldrin	3	0.017	0.002-0.172	0.010-0.050	
Heptachlor epoxide	3	0.018	0.005-0.072	0.010-0.030	
Oxychlordane	3	0.065	0.043-0.099	0.054-0.072	
Cis-Chlordane	3	0.013	0.005-0.034	0.010-0.020	
HCB	3	0.050	0.028-0.089	0.038-0.057	
PCB 1260	3	2.14	0.986-4.62	1.62-2.99	
PCB 1254:1260	3	2.71	1.24-5.92	2.06-3.82	
PCB/DDE = 2.60					
Mercury	3	0.130	0.067-0.252	0.100-0.170	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Dovekie					
Davis Strait A (20)					
Breast Muscle					
1968 (2/2)					16
% Fat = 1.20 ± 0.500					
% Water = 72.5 ± 0.206					
DDE	2	0.025	0.003-0.242	0.021-0.030	
DDT	2	0.006	-	0.006-0.006	
DDD	2	0.006	0.000-0.125	0.005-0.008	
Dieldrin	2	0.009	0.005-0.019	0.009-0.010	
Davis Strait B (21)					
Breast Muscle					
1968 (1/1)					16
% Fat = 1.00					
% Water = 69.7					
DDE	1	0.016	-	-	
DDT	1	0.005	-	-	
DDD	1	0.004	-	-	
Dieldrin	1	0.005	-	-	
Heptachlor epoxide	1	0.007	-	-	
Davis Strait C (22)					
Breast Muscle					
1968 (3/3)					16
% Fat = 1.67 ± 0.203					
% Water = 70.8 ± 0.099					
DDE	3	0.014	0.010-0.019	0.013-0.016	
DDT	3	0.004	0.001-0.017	0.002-0.006	
DDD	3	0.002	0.000-0.014	0.001-0.004	
Dieldrin	3	0.006	0.005-0.008	0.006-0.007	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Davis Strait D (23)					
Breast Muscle					
1968 (1/1)					16
% Fat = 2.00					
% Water = 71.0					
DDE	1	0.021	-	-	
DDT	1	0.008	-	-	
DDD	1	0.004	-	-	
Dieldrin	1	0.004	-	-	
Davis Strait E (24)					
Breast Muscle					
1968 (2/2)					16
% Fat = 1.20 ± 0.500					
% Water = 70.9 ± 0.158					
DDE	2	0.028	0.018-0.044	0.027-0.029	
DDT	2	0.009	-	0.009-0.009	
DDD	2	0.006	0.001-0.050	0.005-0.007	
Dieldrin	2	0.003	0.001-0.021	0.003-0.004	

Appendix 6:
Table 2: Arctic Seabirds

Organochlorine and Mercury Residue Concentrations (Geometric Mean, 95% Confidence Interval (CI) and Range) in Tissues of Canadian Seabirds collected from the Canadian arctic, 1975-1977, by species.

Lipid and moisture content of tissues are presented as arithmetic means and standard deviation. Chemicals are included only if detected in the samples, although not all samples were analyzed for all chemicals (see Methods for details).

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Fulmar					
Prince Leopold Island, N.W.T.					
Livers (Adult)					
1975 (3/3)					11
% Fat = 5.63 ± 1.11					
% Water = 71.00 ± 1.34					
DDE	3	0.228	0.055-0.954	0.15-0.44	
DDD	3	0.017	0.001-0.305	0.005-0.050	
Dieldrin	3	0.01	---	0.01-0.01	
Oxychlordane	3	0.114	0.060-0.216	0.09-0.15	
HCB	3	0.023	0.013-0.041	0.02-0.03	
PCB 1260	3	0.679	0.348-1.326	0.55-0.92	
PCB 1254:1260	3	0.888	0.457-1.726	0.72-1.20	
PCB/DDE = 3.89					
Prince Leopold Island, N.W.T.					
Livers (Adult)*					
1975 (1/7)					11
% Fat = 4.2					
% Water = 68.9					
DDE	-	0.25			
DDT	-	0.005			
DDD	-	0.02			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.17			
Cis-chlordane	-	0.005			

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Trans-chlordane	-	0.005			
Mirex	-	0.01			
HCB	-	0.026			
PCB 1254:1260	-	1.08			
PCB/DDE = 4.32					
1976 (1/7)					11
% Fat = 8.1					
% Water = 68.9					
DDE	-	0.50			
DDD	-	0.03			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.22			
Mirex	-	0.02			
HCB	-	0.058			
HCH	-	0.005			
PCB 1254:1260	-	1.97			
PCB/DDE = 3.94					
Prince Leopold Island, N.W.T.					
Livers (Adult)					
1976 (2/2)					11
% Fat = 8.0					
% Water = 66.8					
DDE	2	0.605		0.39-0.94	
DDD	2	0.245		0.02-0.03	
Dieldrin	2	0.01		0.01-0.01	
Oxychlordane	2	0.260		0.25-0.27	
HCB	2	0.073		0.06-0.09	
PCB 1260	2	1.686		1.16-2.45	
PCB 1254:1260	2	2.113		1.45-3.08	
PCB/DDE = 3.49					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
King Eider					
Seymour Island, N.W.T.					
Eggs					
1976 (1/1)					20
% Fat = 8.9					
% Water = 79.8					
DDE	1	0.02			
DDD	1	0.0005			
DDT	1	0.005			
Dieldrin	1	0.005			
Heptachlor epoxide	1	0.005			
Oxychlordane	1	0.005			
Cis-chlordane	1	0.005			
Mirex	1	0.0005			
HCB	1	0.01			
B-HCH	1	0.005			
PCB 1260	1	0.05			
PCB 1254:1260	1	0.06			
PCB/DDE = 3.0					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Ivory Gull					
Seymour Island, N.W.T.					
Eggs (Fresh)					
1976 (10/10)					20
% Fat = 5.84 ± 0.387					
% Water = 83.3 ± 1.00					
DDE	10	0.464	0.348-0.618	0.260-0.910	
DDT	10	0.034	0.015-0.076	0.002-0.114	
DDD	10	0.001	---	0.001-0.001	
Dieldrin	10	0.024	0.016-0.035	0.010-0.050	
Heptachlor epoxide	10	0.012	0.010-0.016	0.010-0.020	
Oxychlordane	10	0.061	0.046-0.080	0.036-0.090	
Cis-chlordane	10	0.011	0.009-0.014	0.010-0.020	
Mirex	10	0.004	0.001-0.011	0.001-0.020	
Photomirex	10	0.014	0.008-0.023	0.005-0.030	
HCB	10	0.043	0.027-0.069	0.019-0.095	
B-HCH	9	0.005	---	ND-0.005	
PCB 1260	10	1.30	0.984-1.73	0.740-2.94	
PCB 1254:1260	10	1.63	1.20-2.21	0.840-3.69	
PCB/DDE = 3.51					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Black-legged Kittiwake					
Prince Leopold Island, N.W.T.					
Livers (Adult)*					
1975 (1/10)					11
% Fat = 5.4					
% Water = 65.9					
DDE	-	0.05			
DDD	-	0.01			
DDT	-	0.01			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.04			
Cis-chlordane	-	0.01			
Mirex	-	0.01			
HCB	-	0.03			
B-HCH	-	0.005			
PCB 1260	-	0.99			
PCB 1254:1260	-	1.31			
PCB/DDE = 26.2					
Prince Leopold Island, N.W.T.					
Eggs*					
1976 (1/6)					11
% Fat = 9.7					
% Water = 76.0					
DDE	-	0.38			
DDD	-	0.03			
DDT	-	0.005			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.04			
Oxychlordane	-	0.08			
Cis-chlordane	-	0.005			
Mirex	-	0.02			
HCB	-	0.091			
B-HCH	-	0.01			

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
PCB 1260	-	4.49			
PCB 1254:1260	-	5.73			
PCB/DDE = 15.1					
Prince Leopold Island, N.W.T.					
Livers (Adult)*					
1976 (1/5)					11
% Fat = 6.9					
% Water = 65.8					
DDE	-	0.05			
DDD	-	0.01			
DDT	-	0.005			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.04			
Cis-chlordane	-	0.005			
Mirex	-	0.02			
HCB	-	0.05			
B-HCH	-	0.01			
PCB 1260	-	1.87			
PCB 1254:1260	-	2.37			
PCB/DDE = 47.4					
Prince Leopold Island, N.W.T.					
Livers (Adult)					
1976 (5/5)					11
% Fat = 9.2%					
% Water =					
DDE	5	0.11			
Heptachlor epoxide	5	0.013			
Oxychlordane	5	0.05			
Cis-chlordane	5	0.006			
HCB	5	0.07			
B-HCH	4	0.005			
PCB 1254:1260	5	3.30			
PCB/DDE = 30.0					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Thick-billed Murre					
Prince Leopold Island, N.W.T.					
Eggs					
1975 (12/12)					11
% Fat = 12.6 ± 0.65					
% Water = 71.4 ± 2.68					
DDE	12	0.297	0.229-0.383	0.2-0.6	
Dieldrin	12	0.019	0.014-0.024	0.01-0.03	
Heptachlor epoxide	8	0.0025	0.001-0.005	ND-0.010	
Oxychlordane	12	0.0184	0.015-0.022	0.01-0.03	
Cis-chlordane	5	0.0013	0.001-0.003	ND-0.005	
HCB	12	0.097	0.078-0.119	0.06-0.15	
B-HCH	8	0.0035	0.001-0.009	ND-0.01	
PCB 1260	12	0.529	0.436-0.644	0.37-1.16	
PCB 1254:1260	12	0.708	0.582-0.859	0.49-1.55	
PCB/DDE = 2.38					
Prince Leopold Island, N.W.T.					
Livers					
1975 (10/10)					11
% Fat = 4.48 ± 1.26					
% Water = 69.5 ± 1.42					
DDE	10	0.059	0.044-0.080	0.03-0.13	
DDD	10	0.004	0.0005-0.0044	0.005-0.010	
Dieldrin	10	0.008	0.006-0.010	0.005-0.01	
Heptachlor epoxide	2	0.001	0.000-0.002	ND-0.01	
Oxychlordane	9	0.005	0.003-0.009	ND-0.01	
Cis-chlordane	3	0.001	0.000-0.002	ND-0.005	
HCB	10	0.027	0.017-0.042	0.01-0.08	
B-HCH	1	0.001	0-0.001	ND-0.0013	
PCB 1260	10	0.157	0.119-0.208	0.09-0.29	
PCB 1254:1260	10	0.203	0.151-0.273	0.11-0.39	
PCB/DDE = 3.44					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Prince Leopold Island, N.W.T.					
Eggs*					
1976 (1/10)					11
% Fat = 14.3					
% Water = 71.2					
DDE	-	0.34			
DDD	-	0.005			
DDT	-	0.005			
Dieldrin	-	0.06			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.03			
Cis-chlordane	-	0.005			
Mirex	-	0.005			
HCB	-	0.127			
B-HCH	-	0.01			
PCB 1260	-	0.20			
PCB 1254:1260	-	0.23			
PCB/DDE = 0.68					
Prince Leopold Island					
Livers (Nestling)*					
1976 (1/10)					11
% Fat = 10.5					
% Water = 69.0					
DDE	-	0.17			
DDD	-	0.01			
Dieldrin	-	0.02			
Heptachlor epoxide	-	0.01			
Oxychlordane	-	0.03			
Cis-chlordane	-	0.005			
Mirex	-	0.005			
HCB	-	0.130			
B-HCH	-	0.01			
PCB 1260	-	0.37			
PCB 1254:1260	-	0.48			
PCB/DDE = 2.82					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Prince Leopold Island, N.W.T.					
Livers (Nestling)					
1976 (2/2)					11
% Fat =					
% Water =					
DDE	2	0.035	---	0.03-0.04	
Dieldrin	1	0.002	---	ND-0.01	
Heptachlor epoxide	1	0.003	---	ND-0.02	
Oxychlordane	1	0.002	---	ND-0.01	
HCB	2	0.024	---	0.02-0.03	
Cis-chlordane	1	0.003	---	ND-0.005	
PCB 1260	2	0.144	---	0.13-0.16	
PCB/DDE = 4.11					
Prince Leopold Island, N.W.T.					
Livers (Adult)					
1976 (10/10)					11
% Fat =					
% Water =					
DDE	10	0.191	0.124-0.294	0.03-0.46	
DDD	3	0.002	---	ND-0.005	
Dieldrin	4	0.002	0-0.004	ND-0.01	
Heptachlor epoxide	3	0.001	0-0.003	ND-0.01	
Oxychlordane	10	0.013	0.010-0.017	0.01-0.03	
Cis-chlordane	1	0.0005	---	ND-0.005	
HCB	10	0.071	0.044-0.116	0.03-0.25	
B-HCH	5	0.002	0.001-0.003	ND-0.01	
PCB 1260	10	0.404	0.283-0.557	0.19-0.92	
PCB/DDE = 2.12					
Prince Leopold Island, N.W.T.					
Eggs					
1977 (10/10)					11
% Fat = 12.64 ± 1.43					
% Water = 71.01 ± 3.47					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDE	10	0.377	0.303-0.471	0.24-0.62	
Dieldrin	9	0.016	0.009-0.027	0.005-0.07	
Heptachlor epoxide	10	0.004	0.002-0.008	ND-0.01	
Oxychlordane	2	0.024	0.020-0.029	0.02-0.04	
Cis-chlordane	10	0.001	0.000-0.002	ND-0.005	
HCB	10	0.109	0.091-0.131	0.07-0.16	
B-HCH	10	0.011	0.009-0.013	0.01-0.02	
PCB 1260	10	0.649	0.494-0.851	0.39-1.26	
PCB 1254:1260	10	0.854	0.649-1.123	0.51-1.68	
PCB/DDE = 3.44					
Prince Leopold Island, B.C.					
Livers (Nestling)					
1977 (12/12)					11
% Fat =					
% Water =					
DDE	12	0.037	0.020-0.68	0.01-0.17	
DDD	2	0.001	---	ND-0.01	
Dieldrin	7	0.002	0.001-0.005	ND-0.01	
Heptachlor epoxide	1	0.001	0-0.001	ND-0.005	
Oxychlordane	10	0.004	0.002-0.009	ND-0.01	
Cis-chlordane	7	0.003	---	ND-0.05	
HCB	12	0.019	0.012-0.028	0.01-0.05	
B-HCH	3	0.001	0-0.001	ND-0.005	
PCB 1260	12	0.095	0.057-0.159	0.03-0.27	
PCB/DDE = 2.57					
Prince Leopold Island, B.C.					
Livers (Adult)					
1977 (8/8)					11
% Fat =					
% Water =					
DDE	8	0.115	0.075-0.177	0.06-0.23	
DDD	1	---	---	0.005	
Dieldrin	6	0.005	0.001-0.017	ND-0.02	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Heptachlor epoxide	3	0.001	0-0.005	ND-0.01	
Oxychlordane	8	0.009	0.006-0.013	0.005-0.02	
Cis-chlordane	1	---	---	0.005	
HCB	8	0.035	0.023-0.052	0.02-0.09	
B-HCH	4	0.001	0-0.002	ND-0.005	
PCB 1260	8	0.260	0.173-0.393	0.14-0.56	
PCB/DDE = 2.26					

Appendix 6:
Table 3: Pacific Seabirds

Organochlorine and Mercury Residue Concentrations (Geometric Mean, 95% Confidence Interval (CI) and Range) in Tissues of Canadian Seabirds collected from Pacific coastal areas of Canada, 1967-1980, by species.

Lipid and moisture content of tissues are presented as arithmetic means and standard deviation. Chemicals are included only if detected in the samples, although not all samples were analyzed for all chemicals. This is especially true for pre-1971 samples (see Methods for details).

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Leach's Storm-petrel					
Cleland Island (5)					
Eggs (pool)					
1970 (1/1)					18, 3
% Fat = 12.7					
% Water = 73.4					
DDE	1	2.16	-	-	
DDT	1	0.024	-	-	
DDD	1	0.204	-	-	
Dieldrin	1	0.045	-	-	
PCB 1260	1	1.09	-	-	
PCB/DDE = 0.505					
Graham Island (21)					
Eggs					
1971 (5/5)					6, 10
% Fat = 14.1 ± 0.810					
% Water = 64.8 ± 2.07					
DDE	5	1.89	0.186-19.2	0.48-49.7	
DDT	5	0.180	0.026-1.25	0.060-2.80	
DDD	1	0.120	-	-	
Dieldrin	4	0.013	0.006-0.032	0.010-0.03	
Heptachlor epoxide	1	0.010	-	-	
Endrin	4	0.022	0.009-0.058	0.010-0.040	
HCB	5	0.053	0.022-0.128	0.020-0.130	
PCB 1260	5	1.71	0.334-8.78	0.670-16.9	
PCB/DDE = 0.905					
Mercury	5	0.286	0.238-0.343	0.250-0.340	

* Indicates whether samples have been pooled.

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Fat					
1971 (2/2)					6, 10
% Fat = 81.4 ± 2.30					
% Water = 16.6 ± 4.35					
DDE	2	3.05	0.020-476.6	2.05-4.54	
DDT	2	0.360	0.009-13.9	0.270-0.480	
Dieldrin	2	0.042	0.001-3.47	0.030-0.060	
Endrin	2	0.089	0.022-0.369	0.080-0.100	
HCB	2	0.198	0.006-6.50	0.150-0.260	
PCB 1260	2	4.12	0.542-31.3	3.51-4.83	
PCB/DDE = 1.35					
Brain					
1971 (2/2)					6, 10
% Fat = 11.2 ± 0.150					
% Water = 78.5 ± 1.00					
DDE	2	0.053	0.002-1.85	0.040-0.070	
PCB 1260	1	0.040	-	-	
PCB/DDE = 0.755					
Liver					
1971 (2/2)					6, 10
% Fat = 13.3 ± 6.10					
% Water = 69.4 ± 0.300					
DDE	2	0.125	0.075-0.208	0.120-0.130	
HCB	1	0.01	-	-	
PCB 1260	2	0.213	0.000-115.	0.130-0.350	
PCB/DDE = 1.70					
Mercury	2	1.30	0.160-10.6	1.10-1.53	
Breast Muscle					
1971 (2/2)					6, 10
% Fat = 8.25 ± 0.050					
% Water = 68.9 ± 1.65					
DDE	2	0.166	0.001-30.5	0.110-0.250	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	2	0.010	-	0.010-0.010	
PCB 1260	2	0.260	0.159-0.424	0.250-0.270	
PCB/DDE = 1.57					
Mercury	2	0.219	0.004-11.9	0.160-0.300	
Hippa I., B.C. (22)					
Eggs					
1983 (6/6)					17

DDE	6	0.78	-	0.28-1.62	
DDT	6	0.05	-	0.02-0.08	
DDD	6	0.01	-	0.005-0.02	
Dieldrin	6	0.01	-	0.01-0.02	
Heptachlor epoxide	6	0.03	-	0.01-0.08	
Endrin	6	0.013	-	0.01-0.02	
Oxychlordane	6	0.02	-	-	
Cis-chlordane	6	0.01	-	0.005-0.01	
Trans-chlordane	6	0.01	-	0.005-0.01	
Nonachlor	6	0.01	-	0.01-0.02	
HCB	6	0.019	-	0.018-0.022	
A-HCH	6	0.02	-	0.01-0.03	
B-HCH	6	0.02	-	0.01-0.04	
Mirex	6	0.01	-	0.01-0.02	
PCB 1254:1260	6	0.83	-	0.50-1.11	
PCB/DDE = 1.06					
Thorton I., B.C. (2)					
Eggs					
1985 (6/6)					17
% Fat = 10.9					
% Water = 82.6					
DDE	6	0.725	0.372-1.412	0.450-2.42	
DDD	6	0.006	0.005-0.008	0.005-0.010	
DDT	6	0.106	0.089-0.126	0.084-0.131	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Dieldrin	6	0.008	0.006-0.012	0.004-0.011	
Heptachlor epoxide	6	0.004	0.004-0.005	0.004-0.005	
Oxychlordane	6	0.015	0.011-0.019	0.011-0.023	
Cis-chlordane	6	0.004	0.004-0.005	0.004-0.006	
Trans-chlordane	6	0.001	-	0.001-0.001	
Cis-Nonachlor	6	0.005	0.004-0.006	0.004-0.006	
Mirex	6	0.014	0.011-0.018	0.010-0.018	
HCB	6	0.026	0.024-0.029	0.023-0.029	
A-HCH	6	0.006	0.004-0.008	0.003-0.008	
B-HCH	6	0.014	0.012-0.017	0.012-0.019	
G-HCH	6	0.001	0.001-0.001	ND-0.001	
PCB 1254:1260	6	0.739	0.558-0.980	0.604-1.21	
PCB/DDE = 1.02					
Thomas I., B.C. (3)					
Eggs					
1985 (3/3)					17
% Fat = 10.7					
% Water = 73.1					
DDE	3	0.601	0.313-1.54	0.494-0.810	
DDD	3	0.006	0.003-0.014	0.006-0.009	
DDT	3	0.116	0.081-0.166	0.105-0.137	
Dieldrin	3	0.019	0.001-0.563	0.007-0.090	
Heptachlor epoxide	3	0.004	0.002-0.007	0.003-0.005	
Oxychlordane	3	0.019	0.013-0.027	0.016-0.021	
Cis-chlordane	3	0.005	0.003-0.008	0.004-0.006	
Trans-chlordane	3	0.001	-	0.001-0.001	
Cis-Nonachlor	3	0.004	0.002-0.013	0.003-0.007	
Mirex	3	0.018	0.007-0.046	0.014-0.028	
HCB	3	0.029	0.021-0.040	0.025-0.032	
A-HCH	3	0.005	0.002-0.015	0.003-0.007	
B-HCH	3	0.014	0.007-0.028	0.013-0.019	
G-HCH	3	0.001	-	0.001-0.001	
PCB 1254:1260	3	0.860	0.446-1.657	0.688-1.151	
PCB/DDE = 1.43					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Fork-tailed Storm-petrel					
Skedans Island (23)					
Eggs*					
1970 (1/2)					18, 3
% Fat = 29.6					
% Water = 47.6					
DDE	1	4.08	-	-	
DDT	1	0.030	-	-	
DDD	1	1.09	-	-	
Dieldrin	1	0.140	-	-	
HCB	1	0.271	-	-	
PCB 1260	1	15.2	-	-	
PCB/DDE = 3.73					
Mercury	1	0.280	-	-	
Data adjusted to 74% H_2O					
DDE		2.62	-	-	
DDT		0.02	-	-	
DDD		0.701	-	-	
Dieldrin		0.009	-	-	
HCB		0.174	-	-	
PCB 1260		9.78	-	-	
PCB/DDE = 3.73		0.180	-	-	
Mercury					
Hippa I., B.C. (22)					
Eggs*					
1983 (1/3)					17
% Fat = 11.3					
% Water = 70.6					
DDE	1.68		-	-	
DDT	0.10		-	-	
DDD	0.02		-	-	
Dieldrin	0.04		-	-	
Heptachlor epoxide	0.03		-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Endrin	0.01	-	-	-	
Oxychlordane	0.15	-	-	-	
Cis-chlordane	0.01	-	-	-	
Trans-chlordane	0.01	-	-	-	
Trans-Nonachlor	0.03	-	-	-	
HCB	0.064	-	-	-	
A-HCH	0.01	-	-	-	
B-HCH	0.04	-	-	-	
PCB 1254:1260	3.89	-	-	-	
PCB/DDE = 2.32					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Double-Crested Cormorant					
Mandarte Island (7)					
Eggs*					
1970 (1/3)					18, 3
% Fat = 6.9					
% Water = 81.4					
DDE	1	4.07	-	-	
DDD	1	0.045	-	-	
Dieldrin	1	0.040	-	-	
HCB	1	0.304	-	-	
PCB 1260	1	14.0	-	-	
PCB/DDE = 3.44					
Mercury	1	0.360	-	-	
1979 (1/10)					17
% Fat = 5.6					
% Water = 82.7					
DDE	1	0.640	-	-	
DDT	1	0.010	-	-	
DDD	1	0.010	-	-	
Dieldrin	1	0.050	-	-	
Heptachlor epoxide	1	0.040	-	-	
Oxychlordane	1	0.010	-	-	
A-Chlordane	1	0.060	-	-	
HCB	1	0.030	-	-	
HCH	1	0.030	-	-	
PCB 1260	1	5.34	-	-	
PCB 1:1	1	8.86	-	-	
PCB/DDE = 13.8					
Mandarte I., B.C.					
Eggs					
1985 (5/5)					17
% Fat = 4.40					
% Water = 83.4					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDE	5	0.501	0.252-0.998	0.338-1.31	
DDT	1	0.001	0-0.002	ND-0.008	
Dieldrin	5	0.006	0.003-0.013	0.004-0.017	
Heptachlor epoxide	5	0.004	0.003-0.008	0.003-0.008	
Oxychlordane	5	0.014	0.005-0.037	0.004-0.032	
Cis-Nonachlor	4	0.001	0-0.005	ND-0.004	
Mirex	1	-	-	ND-0.011	
HCB	5	0.030	0.020-0.045	0.020-0.042	
A-HCH	5	0.004	0.002-0.008	0.002-0.008	
B-HCH	5	0.008	0.004-0.016	0.003-0.014	
PCB 1254:1260	5	3.79	1.19-12.05	1.65-16.38	
PCB/DDE = 7.56					
Fraser Estuary, B.C. (11)					
Eggs					
1985 (5/5)					17
% Fat = 3.90					
% Water = 83.7					
DDE	5	0.464	0.362-0.595	0.382-0.634	
DDT	5	0.005	0.002-0.011	0.002-0.009	
Dieldrin	5	0.004	0.003-0.006	0.003-0.006	
Heptachlor epoxide	5	0.003	0.002-0.003	0.002-0.003	
Oxychlordane	5	0.012	0.009-0.016	0.009-0.017	
Cis-Nonachlor	5	0.002	0.001-0.003	0.001-0.003	
Mirex	5	0.008	0.005-0.014	0.005-0.013	
HCB	5	0.014	0.011-0.018	0.012-0.019	
A-HCH	5	0.004	0.003-0.006	0.003-0.007	
B-HCH	5	0.006	0.005-0.009	0.005-0.008	
PCB 1254:1260	5	2.92	1.86-4.59	1.90-4.60	
PCB/DDE = 6.29					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Pelagic Cormorant					
Nanaimo (13)					
Liver					
1968 (5/5)					4
% Water = 70.0 ± 0.447					
Mercury	5	1.91	1.15-3.19	1.22-3.68	
Mandarte Island (7)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 5.3					
% Water = 83.7					
DDE	1	0.819	-	-	
DDT	1	0.107	-	-	
Dieldrin	1	0.061	-	-	
HCB	1	0.009	-	-	
PCB 1260	1	2.64	-	-	
PCB/DDE = 3.22					
Mercury	1	0.350	-	-	
Mandarte I., B.C. (7)					
Eggs					
1973 (6/6)					6, 10

DDE	6	1.52	-	1.12-2.00	
DDT	6	0.06	-	0.03-0.09	
DDD	6	0.01	-	0.005-0.01	
Dieldrin	6	0.08	-	0.06-0.12	
Heptachlor epoxide	6	0.02	-	0.01-0.03	
Endrin	---	0.01	-	ND-0.01	
Oxychlordane	6	0.04	-	0.03-0.06	
Cis-chlordane	6	0.01	-	0.005-0.01	
Trans-chlordane	6	0.01	-	0.005-0.01	
HCB	6	0.031	-	0.022-0.038	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
A-HCH	6	0.01	-	0.005-0.01	
B-HCH	6	0.01	-	0.01-0.02	
Mirex	6	0.01	-	0.01-0.01	
PCB 1254:1260	6	8.01	-	4.87-10.0	
PCB/DDE = 5.27					
Mandarte I., B.C. (7)					
Eggs					
1985 (5/5)					17
% Fat = 4.03					
% Water = 83.7					
DDE	5	0.274	0.192-0.393	0.199-0.398	
DDT	5	0.015	0.005-0.043	0.006-0.042	
Dieldrin	5	0.027	0.022-0.033	0.023-0.032	
Heptachlor epoxide	5	0.008	0.007-0.010	0.007-0.010	
Oxychlordane	5	0.018	0.014-0.023	0.014-0.023	
Cis-chlordane	5	0.003	0.002-0.004	0.002-0.004	
Cis-Nonachlor	5	0.008	0.006-0.012	0.006-0.012	
HCB	5	0.014	0.010-0.020	0.010-0.018	
A-HCH	5	0.006	0.004-0.008	0.004-0.007	
B-HCH	5	0.021	0.016-0.027	0.016-0.026	
G-HCH	5	0.001	-	0.001-0.001	
PCB 1254:1260	5	1.839	1.248-2.708	1.18-2.57	
PCB/DDE = 6.71					
Mittlenatch Island (14)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 4.4					
% Water = 83.6					
DDE	1	0.547	-	-	
DDD	1	0.196	-	-	
Dieldrin	1	0.082	-	-	
HCB	1	0.131	-	-	
PCB 1260	1	5.36	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
PCB/DDE = 9.80					
Mercury	1	0.160	-	-	
Kynguot, B.C. (1)					
Eggs					
1985 (6/6)					17
% Fat = 4.23					
% Water = 83.9					
DDE	6	0.270	0.145-0.501	0.14-0.479	
DDD	2	0.001	0-0.001	ND-0.002	
DDT	5	0.005	0-0.053	ND-0.026	
Dieldrin	6	0.023	0.013-0.040	0.012-0.044	
Heptachlor epoxide	6	0.009	0.006-0.015	0.005-0.016	
Oxychlordane	6	0.014	0.009-0.023	0.008-0.023	
Cis-chlordane	6	0.003	0.002-0.006	0.002-0.006	
Cis-Nonachlor	6	0.007	0.004-0.012	0.004-0.012	
HCB	6	0.018	0.010-0.033	0.009-0.034	
A-HCH	6	0.010	0.009-0.011	0.008-0.011	
B-HCH	6	0.020	0.012-0.032	0.011-0.032	
G-HCH	6	0.001	-	0.001-0.001	
PCB 1254:1260	6	0.605	0.428-0.854	0.364-0.843	
PCB/DDE = 2.52					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Glaucous-winged Gull					
Boundary Bay (9)					
Breast Muscle					
1968 (6/6)					6
% Fat = 3.42 ± 0.138					
% Water = 69.4 ± 0.473					
DDE	6	0.111	0.068-0.180	0.060-0.173	
DDT	6	0.061	0.039-0.096	0.030-0.084	
DDD	6	0.024	0.013-0.041	0.010-0.038	
Dieldrin	6	0.019	0.006-0.058	0.003-0.046	
Brain					
1968 (6/6)					6
% Fat = 5.88 ± 0.275					
% Water = 76.6 ± 0.511					
DDE	6	0.029	0.013-0.063	0.012-0.106	
DDT	6	0.020	0.009-0.047	0.008-0.065	
DDD	6	0.010	0.006-0.019	0.006-0.025	
Dieldrin	6	0.006	0.002-0.020	0.002-0.024	
Port Alberni (6)					
Liver					
1968 (3/3)					4
% Water = 71.3 ± 1.17					
Mercury	3	0.295	0.022-3.98	0.090-0.650	
Nanaimo (13)					
Liver					
1968 (1/1)					4
% Water = 71.4					
Mercury	1	0.100	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Horseshoe Bay (12)					
Liver					
1968 (4/4)					4
% Water = 70.0 ± 0.856					
Mercury	4	0.451	0.183-1.107	0.240-0.800	
Mandarte Island (7)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 6.0					
% Water = 83.7					
DDE	1	0.750	-	-	
DDT	1	0.007	-	-	
DDD	1	0.066	-	-	
Dieldrin	1	0.046	-	-	
Heptachlor epoxide	1	0.021	-	-	
HCB	1	0.009	-	-	
PCB 1260	1	2.49	-	-	
PCB/DDE = 3.32					
Mercury	1	0.130	-	-	
Mittlenatch Island (14)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 8.0					
% Water = 77.6					
DDE	1	0.456	-	-	
DDT	1	0.084	-	-	
DDD	1	0.045	-	-	
Dieldrin	1	0.045	-	-	
HCB	1	0.006	-	-	
PCB 1260	1	1.53	-	-	
PCB/DDE = 3.36					
Mercury	1	0.210	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Cleland Island (5)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 8.6					
% Water = 77.0					
DDE	1	1.59	-	-	
DDT	1	0.014	-	-	
Dieldrin	1	0.037	-	-	
HCB	1	0.046	-	-	
PCB 1260	1	2.58	-	-	
PCB/DDE = 1.62					
Mercury	1	0.130	-	-	
Thorton I., B.C. (2)					
Eggs*					
1983 (8/8)					17

DDE	8	0.63	-	0.32-1.19	
DDT	-	0.01	-	ND-0.01	
DDD	-	0.01	-	ND-0.04	
Dieldrin	8	0.02	-	0.01-0.02	
Heptachlor epoxide	8	0.04	-	0.01-0.05	
Endrin	-	0.01	-	ND-0.01	
Oxychlordane	8	0.03	-	0.02-0.04	
Cis-chlordane	8	0.01	-	0.005-0.01	
HCB	8	0.011	-	0.006-0.017	
B-HCH	8	0.01	-	0.01-0.01	
Mirex	-	0.76*	-	ND-6.01	
PCB 1254:1260	8	1.07	-	0.57-2.09	
PCB/DDE = 1.70					

* probably analytical error

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Thorton I., B.C. (2)					
Eggs*					
1983 (1/10)					17
% Fat = 9.15					
% Water = 76.5					
DDE		0.535	-	-	
DDT		0.005	-	-	
DDD		0.005	-	-	
Dieldrin		0.02	-	-	
Heptachlor epoxide		0.045	-	-	
Endrin		0.005	-	-	
Oxychlordane		0.03	-	-	
Cis-chlordane		0.01	-	-	
Trans-nonachlor		0.005	-	-	
HCB		0.011	-	-	
A-HCH		0.005	-	-	
B-HCH		0.02	-	-	
PCB 1254:1260		0.835	-	-	
PCB/DDE = 1.56					
Guillam's I., B.C. (4)					
Eggs					
1983 (8/8)					17

DDE	8	0.52	-	0.28-0.88	
DDT		0.01	-	0-0.02	
DDD	8	0.05	-	0.005-0.06	
Dieldrin	8	0.01	-	0.005-0.01	
Heptachlor epoxide	8	0.03	-	0.01-0.04	
Oxychlordane	8	0.02	-	0.01-0.02	
HCB	8	0.015	-	0.007-0.020	
B-HCH	8	0.01	-	0.005-0.01	
PCB 1254:1260	8	0.78	-	0.34-1.50	
PCB/DDE = 1.50					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Guillam's I., B.C. (4)					
Eggs*					
1983 (1/9)					17
% Fat = 9.1					
% Water = 76.4					
DDE		0.35	-	-	
Dieldrin		0.01	-	-	
Heptachlor epoxide		0.03	-	-	
Oxychlordane		0.02	-	-	
Cis-chlordane		0.005	-	-	
Trans-nonachlor		0.005	-	-	
HCB		0.014	-	-	
A-HCH		0.005	-	-	
B-HCH		0.01	-	-	
Mirex		0.005	-	-	
PCB 1254:1260		1.13	-	-	
PCB/DDE = 3.23					
Skedans Island (23)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 8.3					
% Water = 76.0					
DDE	1	0.342	-	-	
Dieldrin	1	0.012	-	-	
HCB	1	0.011	-	-	
PCB 1260	1	0.487	-	-	
PCB/DDE = 1.42					
Mercury	1	0.080	-	-	
Lucy Island (18)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 9.7					
% Water = 76.3					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
DDE	1	0.282	-	-	
Dieldrin	1	0.038	-	-	
HCB	1	0.009	-	-	
PCB 1260	1	0.567	-	-	
PCB/DDE = 2.01					
Mercury	1	0.160	-	-	
Northwest Rocks (17)					
Eggs*					
1970 (1/3)					18, 3
% Fat = 8.7					
% Water = 77.3					
DDE	1	0.224	-	-	
Dieldrin	1	0.008	-	-	
Heptachlor epoxide	1	0.015	-	-	
HCB	1	0.007	-	-	
PCB 1260	1	0.364	-	-	
PCB/DDE = 1.63					
Mercury	1	0.050	-	-	
Stevenson Islets (15)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 8.6					
% Water = 77.0					
DDE	1	1.43	-	-	
DDT	1	0.027	-	-	
Dieldrin	1	0.027	-	-	
HCB	1	0.018	-	-	
PCB 1260	1	2.83	-	-	
PCB/DDE = 1.98					
Mercury	1	0.170	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Tsawwassen (10)					
Eggs					
1977 (10/10)					17
% Fat = 9.42 ± 0.396					
% Water = 75.6 ± 0.346					
DDE	10	0.483	0.367-0.635	0.210-0.780	
DDT	10	0.019	-	0.019-0.019	
DDD	10	0.010	0.008-0.013	0.007-0.014	
Dieldrin	10	0.009	0.007-0.011	0.005-0.010	
Heptachlor epoxide	10	0.014	0.011-0.018	0.010-0.020	
Oxychlordane	10	0.001	-	0.001-0.001	
A-Chlordane	10	0.001	-	0.001-0.001	
HCB	10	0.023	0.018-0.030	0.019-0.038	
B-HCH	10	0.007	0.005-0.009	0.005-0.010	
PCB 1260	10	1.64	1.22-2.20	0.820-3.17	
PCB 1:1	10	1.78	1.32-2.41	0.890-3.52	
PCB/DDE = 3.69					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Common Murre					
Semiahmoo Bay (8)					
Liver*					
1970 (4/4)					9
DDE	2	0.605	0.358-1.02	0.580-0.630	
Dieldrin	2	0.010	-	0.010-0.010	
HCB	2	0.010	-	0.010-0.010	
PCB 1260	2	1.18	1.06-1.31	1.17-1.19	
PCB/DDE					
Mercury	2	0.307	0.008-12.1	0.230-0.410	
Queen Charlotte Islands (19)					
Whole Body					
1970 (1/1)					9
% Fat = 11.5					
% Water = 62.8					
DDE	1	1.21	-	-	
DDT	1	0.356	-	-	
DDD	1	0.041	-	-	
Dieldrin	1	0.025	-	-	
HCB	1	0.016	-	-	
PCB 1260	1	1.04	-	-	
PCB/DDE = 0.860					
Mercury	1	0.100	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Pigeon Guillemot					
Mittlenatch Island (14)					
Eggs*					
1970 (1/10)					18, 3
% Fat = 10.5					
% Water = 73.5					
DDE	1	0.604	-	-	
Dieldrin	1	0.008	-	-	
HCB	1	0.072	-	-	
PCB 1260	1	3.54	-	-	
PCB/DDE = 5.86					
Mercury	1	0.470	-	-	
Cleland Island (5)					
Egg					
1970 (1/1)					18, 3
% Fat = 10.8					
% Water = 74.4					
DDE	1	1.26	-	-	
DDT	1	0.003	-	-	
Dieldrin	1	0.008	-	-	
HCB	1	0.131	-	-	
PCB 1260	1	2.56	-	-	
PCB/DDE = 2.03					
Mercury	1	0.450	-	-	
Skedans Island (23)					
Eggs*					
1970 (1/2)					18, 3
% Fat = 11.7					
% Water = 73.0					
DDE	1	0.164	-	-	
Dieldrin	1	0.009	-	-	
HCB	1	0.015	-	-	
PCB 1260	1	0.421	-	-	
PCB/DDE = 2.57					
Mercury	1	0.330	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Marbled Murrelet					
Port Alberni (6)					
Liver					
1968 (3/3)					4
% Water = 73.4 ± 1.27					
Mercury	3	0.37	-	0.33-0.46	
Horseshoe Bay (12)					
Liver					
1968 (3/3)					4
% Water =					
Mercury	3	2.21	-	0.19-4.90	
Langara Island (20)					
Breast Muscle					
1969 (3/3)					10
% Fat = 0.800 ± 0.100					
% Water = 73.1 ± 2.27					
DDE	3	0.076	0.012-0.498	0.036-0.164	
DDT	3	0.007	0.003-0.018	0.006-0.011	
DDD	3	0.008	0.002-0.047	0.004-0.016	
Dieldrin	3	0.004	0.002-0.010	0.003-0.006	
Fat					
1969 (3/3)					10
% Fat = 69.6 ± 2.89					
% Water = 23.5 ± 3.56					
DDE	3	1.73	0.559-5.35	1.30-2.92	
DDT	3	0.083	0.004-1.58	0.028-0.294	
DDD	3	0.075	0.010-0.559	0.030-0.139	
Dieldrin	3	0.080	0.035-0.183	0.059-0.114	
Heptachlor epoxide	2	0.098	0.001-17.4	0.065-0.147	
B-HCH	2	0.020	0.008-0.052	0.019-0.022	
PCB 1260	3	1.32	0.419-4.14	0.775-1.77	
PCB/DDE = 0.763					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Brain					
1969 (3/3)					10
% Fat = 4.50 ± 1.10					
% Water = 79.4 ± 0.236					
DDE	3	0.043	0.011-0.172	0.028-0.081	
DDT	3	0.005	0.001-0.040	0.003-0.013	
DDD	3	0.005	0.001-0.038	0.002-0.010	
Dieldrin	2	0.002	0.000-1.86	0.001-0.003	
Liver					
1969 (3/3)					10
% Fat = 3.07 ± 1.43					
% Water = 66.8 ± 1.33					
DDE	3	0.126	0.023-0.681	0.068-0.261	
DDT	3	0.007	0.003-0.015	0.006-0.010	
DDD	3	0.015	0.004-0.053	0.009-0.025	
Dieldrin	3	0.002	0.000-0.014	0.001-0.004	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Ancient Murrelet					
Langara Island (20)					
Eggs (Fresh)					
1968 (3/3)					10
% Fat = 15.3 ± 1.19					
% Water = 65.2 ± 1.53					
DDE	3	0.871	0.377-2.01	0.641-1.25	
Dieldrin	3	0.008	0.004-0.014	0.006-0.010	
Heptachlor epoxide	2	0.031	0.003-0.350	0.026-0.038	
Eggs (Dead)					
1968 (2/2)					10
% Fat = 17.2 ± 0.800					
% Water = 61.6 ± 2.35					
DDE	2	0.883	0.025-31.4	0.667-1.17	
Dieldrin	1	0.001	-	-	
Heptachlor epoxide	1	0.015	-	-	
Breast Muscle					
1968 (7/7)					10
% Fat = 1.94 ± 0.284					
% Water = 67.9 ± 0.876					
DDE	7	0.082	0.025-0.269	0.015-0.466	
Dieldrin	1	0.002	-	-	
1971 (1/1)					6, 10
% Fat = 8.5					
% Water = 68.5					
DDE	1	0.180	-	-	
Endrin	1	0.020	-	-	
PCB 1260	1	0.370	-	-	
PCB/DDE = 0.486					

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
1972 (9/9)					6, 10
% Fat = 10.1 ± 1.75					
% Water = 70.5 ± 1.30					
DDE	9	0.117	0.068-0.201	0.050-0.480	
Dieldrin	1	0.010	-	-	
Endrin	7	0.016	0.012-0.022	0.010-0.020	
B-HCH	5	0.027	0.013-0.056	0.010-0.050	
PCB 1260	9	0.117	0.076-0.182	0.070-0.280	
PCB/DDE = 1.00					
Mercury	9	0.149	0.113-0.196	0.080-0.210	
Fat					
1968 (7/7)					10
% Fat = 78.4 ± 3.19					
% Water = 14.2 ± 2.50					
DDE	7	3.79	1.69-8.48	1.10-13.9	
Dieldrin	5	0.015	0.010-0.024	0.009-0.022	
Heptachlor epoxide	4	0.095	0.036-0.256	0.044-0.179	
1971 (1/1)					6, 10
% Fat = 66.7					
% Water = 19.6					
DDE	1	10.1	-	-	
Endrin	1	0.240	-	-	
HCB	1	0.170	-	-	
PCB 1260	1	16.4	-	-	
PCB/DDE = 1.62					
1972 (9/9)					6, 10
% Fat = 74.8 ± 4.64					
% Water = 19.5 ± 3.55					
DDE	9	4.86	2.83-8.34	1.62-14.8	
Dieldrin	7	0.024	0.020-0.029	0.020-0.030	
Heptachlor epoxide	7	0.038	0.019-0.076	0.010-0.110	
Endrin	9	0.151	0.120-0.191	0.110-0.270	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
HCB	9	0.179	0.124-0.258	0.070-0.320	
B-HCH	9	0.420	0.198-0.889	0.080-1.14	
PCB 1260	9	4.16	2.58-6.70	2.34-11.1	
PCB/DDE = 0.856					
Liver					
1968 (7/7)					10
% Fat = 2.79 ± 0.848					
% Water = 66.6 ± 0.815					
DDE	7	0.106	0.056-0.200	0.047-0.267	
Dieldrin	1	0.001	-	-	
Heptachlor epoxide	2	0.030	-	0.030-0.030	
1971 (1/1)					6, 10
% Fat = 3.90					
% Water = 66.5					
DDE	1	0.120	-	-	
Endrin	1	0.010	-	-	
HCB	1	0.010	-	-	
PCB 1260	1	0.300	-	-	
PCB/DDE = 2.50					
1972 (9/9)					6, 10
% Fat = 11.7 ± 1.32					
% Water = 66.4 ± 0.877					
DDE	9	0.164	0.082-0.331	0.050-0.840	
Dieldrin	1	0.010	-	-	
Heptachlor epoxide	1	0.050	-	-	
Endrin	5	0.031	0.015-0.063	0.020-0.080	
HCB	8	0.013	0.009-0.018	0.010-0.030	
B-HCH	4	0.044	0.027-0.070	0.030-0.060	
PCB 1260	9	0.129	0.069-0.241	0.030-0.410	
PCB/DDE = 0.787					
Mercury	9	0.732	0.504-1.06	0.240-1.19	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Brain					
1968 (7/6)					10
% Fat = 4.85 ± 0.394					
% Water = 77.1 ± 0.744					
DDE	6	0.033	0.011-0.098	0.006-0.080	
DDT	2	0.005	0.000-5.58	0.003-0.009	
DDD	1	0.002	-	-	
Dieldrin	1	0.001	-	-	
Heptachlor epoxide	2	0.021	0.000-1.08	0.015-0.028	
1971 (1/1)					6, 10
% Fat = 11.4					
% Water = 75.9					
DDE	1	0.130	-	-	
PCB 1260	1	0.210	-	-	
PCB/DDE = 1.62					
1972 (9/9)					6, 10
% Fat = 12.3 ± 0.984					
% Water = 78.0 ± 0.877					
DDE	9	0.055	0.035-0.086	0.020-0.140	
B-HCH	1	0.020	-	-	
PCB 1260	7	0.078	0.056-0.109	0.050-0.150	
PCB/DDE = 1.42					
Mercury	9	0.128	0.099-0.165	0.080-0.210	
Whole Body					
1969 (2/2)					10
% Fat = 7.35 ± 1.75					
% Water = 68.5 ± 0.450					
DDE	2	5.29	0.029-960.	3.51-7.96	
DDT	2	0.096	0.000-00	0.021-0.435	
DDD	1	0.764	-	-	
Dieldrin	2	0.042	0.000-2280.	0.018-0.100	
Heptachlor epoxide	2	0.042	0.000-5.30	0.029-0.062	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
B-HCH	2	0.968	0.170-5.52	0.844-1.11	
PCB 1260	2	0.851	0.002-477.	0.517-1.40	
PCB/DDE = 0.161					
Queen Charlotte Islands (19)					
Whole Body					
1970 (2/2)					6, 19
% Fat = 9.30 ± 0.800					
% Water = 62.7 ± 2.20					
DDE	2	1.03	0.000-11200.	0.498-2.15	
DDT	1	0.115	-	-	
Dieldrin	2	0.021	0.005-0.094	0.019-0.024	
Heptachlor epoxide	2	0.036	0.036-0.323	0.028-0.040	
HCB	2	0.004	0.000-26.7	0.002-0.008	
PCB 1260	2	1.03	0.370-2.88	0.953-1.12	
PCB/DDE = 1.00					
Mercury	2	0.229	0.076-0.694	0.210-0.250	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Cassin's Auklet					
Moore Island (16)					
Eggs*					
1970 (1/4)					10, 18
% Fat = 12.0					
% Water = 70.0					
DDE	1	2.92	-	-	
Dieldrin	1	0.007	-	-	
HCB	1	0.023	-	-	
PCB 1260	1	0.600	-	-	
PCB/DDE = 0.205					
Mercury	1	0.050	-	-	
Queen Charlotte Islands (19)					
Whole Body					
1970 (2/2)					6, 19
% Fat = 7.3 ± 0.700					
% Water = 64.1 ± 1.45					
DDE	2	1.48	0.191-11.5	1.26-1.74	
Dieldrin	1	0.015	-	-	
HCB	2	0.002	-	0.002-0.002	
PCB 1260	2	0.380	0.008-19.4	0.279-0.518	
PCB/DDE = 0.257					
Langara Island (20)					
Breast Muscle					
1971 (1/1)					6, 10
% Fat = 6.0					
% Water = 74.2					
DDE	1	0.680	-	-	
Endrin	1	0.010	-	-	
HCB	1	0.010	-	-	
PCB 1260	1	0.38	-	-	
PCB/DDE = 0.559					
Mercury	1	0.060	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Liver					
1971 (1/1)					6, 10
% Fat = 6.3					
% Water = 64.3					
DDE	1	1.18	-	-	
Endrin	1	0.020	-	-	
HCB	1	0.030	-	-	
PCB 1260	1	1.04	-	-	
PCB/DDE = 0.881					
Mercury	1	0.440	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Rhinoceros Auklet					
Langara Island (20)					
Breast Muscle					
1969 (2/2)					10
% Fat = 2.35 ± 0.550					
% Water = 70.4 ± 0.800					
DDE	2	0.163	0.002-14.1	0.115-0.232	
DDT	2	0.006	-	0.006-0.006	
DDD	2	0.006	0.002-0.017	0.005-0.006	
Dieldrin	2	0.006	-	0.006-0.006	
Fat					
1969 (2/2)					10
% Fat = 79.4 ± 16.2					
% Water = 23.6 ± 10.0					
DDE	2	10.7	0.017-6700.	6.42-17.7	
DDT	2	0.002	0.00-00	0.000-0.009	
Dieldrin	2	0.062	0.009-0.433	0.053-0.072	
Heptachlor epoxide	2	0.023	0.017-0.030	0.022-0.023	
B-HCH	1	0.019	-	-	
PCB 1260	2	2.78	0.000-51900.	1.28-6.02	
PCB/DDE = 0.260					
Liver					
1969 (2/2)					10
% Fat = 5.05 ± 0.850					
% Water = 67.2 ± 0.453					
DDE	2	0.458	0.044-4.77	0.381-0.551	
DDT	2	0.017	0.000-1.835	0.012-0.025	
DDD	2	0.022	0.000-9.06	0.014-0.036	
Dieldrin	2	0.004	0.000-43000.	0.001-0.013	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Brain					
1969 (2/2)					10
% Fat = 6.35 ± 0.250					
% Water = 78.8 ± 0.211					
DDE	2	0.098	0.001-12.1	0.067-0.143	
DDT	2	0.005	0.000-5.58	0.003-0.009	
DDD	2	0.009	0.000-1.20	0.006-0.013	
Dieldrin	1	0.033	-	-	
Queen Charlotte Islands (19)					
Whole Body					
1970 (2/2)					18
% Fat = 7.30 ± 0.700					
% Water = 64.1 ± 1.45					
DDE	2	5.88	0.008-4110.	3.51-9.84	
DDT	1	0.140	-	-	
Dieldrin	2	0.022	0.000-1.49	0.016-0.031	
Heptachlor epoxide	1	0.023	-	-	
HCB	2	0.008	0.000-81.0	0.004-0.017	
PCB 1260	2	2.76	0.091-83.7	2.11-3.61	
PCB/DDE = 0.469			-	-	
Mercury	2	0.365	0.046-2.92	0.310-0.430	
Lucy Island (18)					
Eggs*					
1970 (1/10)					18
% Fat = 15.0					
% Water = 71.7					
DDE	1	2.84	-	-	
HCB	1	0.029	-	-	
PCB 1260	1	2.01	-	-	
PCB/DDE = 0.708					
Mercury	1	0.320	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Lucy Island, B.C.					
Eggs					
1985 (6/6)					17
% Fat = 14.0					
% Water = 67.1					
DDE	6	0.631	0.281-1.419	0.252-1.85	
DDT	6	0.005	0.004-0.006	0.004-0.006	
Dieldrin	6	0.012	0.008-0.017	0.009-0.021	
Heptachlor epoxide	6	0.009	0.007-0.011	0.006-0.011	
Oxychlordane	6	0.023	0.016-0.033	0.014-0.033	
Cis-chlordane	6	0.001	-	0.001-0.001	
Cis-Nonachlor	6	0.006	0.004-0.009	0.004-0.010	
Mirex	6	0.003	0.002-0.004	0.002-0.005	
HCB	6	0.034	0.026-0.046	0.023-0.049	
A-HCH	6	0.002	0.002-0.003	0.002-0.003	
B-HCH	6	0.016	0.013-0.022	0.013-0.024	
PCB 1254:1260	6	0.607	0.373-0.986	0.320-1.03	
PCB/DDE = 0.96					
Moore Island (16)					
Eggs					
1970 (1/1)					18
% Fat = 14.0					
% Water = 70.0					
DDE	1	2.09	-	-	
Dieldrin	1	0.019	-	-	
HCB	1	0.018	-	-	
PCB 1260	1	1.73	-	-	
PCB/DDE = 0.828					
Mercury	1	0.130	-	-	

Species; location (map no.); tissue; year (No. analyzed/No. collected*) % Fat; % H_2O); Chemical	No. with residues	Residues (wet weight)			Collector
		Mean	95% CI	Range	
Tufted Puffin					
Cleland Island (5)					
Egg					
1970 (1/1)					18, 3
% Fat = 10.0					
% Water = 73.2					
DDE	1	0.424	-	-	
DDT	1	0.004	-	-	
DDD	1	0.015	-	-	
Dieldrin	1	0.015	-	-	
HCB	1	0.129	-	-	
PCB 1260	1	0.660	-	-	
PCB/DDE = 1.56					
Mercury	1	0.110	-	-	
Queen Charlotte Islands (19)					
Whole Body					
1970 (2/2)					18, 3
% Fat = 8.15 ± 1.35					
% Water = 62.6 ± 1.90					
DDE	2	0.353	0.007-17.8	0.259-0.480	
DDT	2	0.163	0.000-8860.	0.069-0.384	
DDD	1	0.060	-	-	
Dieldrin	1	0.021	-	-	
Heptachlor epoxide	1	0.012	-	-	
HCB	2	0.009	0.000-0.281	0.007-0.012	
PCB 1260	2	0.997	0.038-26.2	0.771-1.29	
PCB/DDE = 2.82					
Mercury	2	0.297	0.054-1.64	0.260-0.340	

Appendix 7: Table 1.

DIET AND SEASONAL MOVEMENT OF ATLANTIC COAST SEABIRDS

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
N. Fulmar	- offshore and oceanic - surface-feeder and scavenger	- disperses widely after breeding - most winter off Newfoundland	- omnivorous (fish, crustaceae, squid, carrion)	- amphipods and copepods, arctic cod	- Prince Leopold Island	- spring	Nettleship, 1977
				- arctic cod, pelagic amphipods and copepods	- Lancaster Sound	- summer	Bradstreet, 1976
Leach's Storm Petrel	- offshore/oceanic - surface-feeder	- Atlantic birds probably winter somewhere in mid-ocean (some cross Atlantic)	- omnivorous, mainly zooplankton and small fish	- myctophid fish, euphausids	- Nova Scotia	- summer	Linton, 1978
				- myctophid fish, amphipods	- Newfoundland	- summer	Linton, 1978
N. Gannet	- offshore - plunge diver	- winters south to Gulf of Mexico	- piscivorous (large-bodied schooling fish) often associated with warmer water	- mackerel, herring, capelin and squid	- Funk Island	- summer	Kirkham et al, 1985
Double-crested Cormorant	- coastal - underwater pursuit	- winters south to Florida and Gulf of Mexico	- piscivorous (opportunistically) on wide variety of benthic or pelagic fish	- gunnels, sculpin, sandlance, capelin, herring, flounder	- Gulf of St. Lawrence	- summer	Palmer, 1962
				- flounders, sandlance, herring, also squid, spawning capelin	- Magdalen Islands	- summer	Pilon et al, 1983

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Ivory Gull	- offshore, ice-associated - surface-feeder and scavenger	- winters along edge of arctic pack ice	- omnivorous on fish, euphausids, amphipods and carrion	- myctophid fish, seal carrion	- Davis Strait	- spring	Orr and Parsons, 1982
				- arctic cod, amphipods	- Chukchi Sea	- fall	Divoky, 1976
Black-legged Kittiwake	- offshore - surface feeder	- disperses widely outside breeding season	- omnivorous on fish, pelagic amphipods	- arctic cod, copepods, pteropods	- Lancaster Sound	- summer/ fall	Bradstreet, 1976
				- capelin, sandlance, molluscs and fish offal	- Newfoundland	- summer	Maunder and Threlfall, 1972
				- sandlance and euphausids	- B.C.	- summer	Sealy, 1973
Common Tern	- coastal or freshwater - aerial surface dives	- migrates to Central and South America	- piscivorous on wide variety of small fish	- silversides, cunner, pollock, eel, sandlance, herring, mackerel	- Massachusetts	- summer	Nisbet, 1983
				- juvenile herring, euphausids	- Bay of Fundy	- fall	Braune and Gaskin, 1982
Dovekie	- arctic waters - dive pursuit to 20 m	- winters offshore in low arctic waters occ. south to Scotian shelf	- planktivorous (mainly zooplankton)	- copepods (Calanus)	- Baffin Bay	- spring	Bradstreet, 1982
				- young arctic cod, amphipods	- Baffin Bay	- summer	Bradstreet, 1982

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Razorbill	- coastal - dive pursuit to 5 m	- winters offshore south to George's Bank	- mainly piscivorous with some zooplankton	- sandlance, capelin - capelin, sculpins, euphausids - crustaceans	- Ste. Marie Island - Labrador - Newfoundland	- ---- - winter	Bedard, 1969 Bradstreet, 1983 Tuck, 1961
Thick-billed Murre	- coastal and offshore - dive pursuit to 100 m	- winters off Newfoundland	- omnivorous - major prey are fish (arctic cod) and amphipods	- arctic cod, amphipods - amphipods, mysids, arctic cod, sculpins	- Lancaster Sound - Hudson Strait	- spring - summer	Bradstreet, 1976 Gaston <u>et al</u>, 1983
Common Murre	- coastal and offshore - dive pursuit to 80 m	- winters off Newfoundland	- mainly piscivorous (usually pelagic fish)	- capelin, invertebrates - capelin, some sandlance, squid - capelin, some cod, haddock	- Labrador - Newfoundland - Newfoundland	- summer - summer - winter	Bradstreet, 1983 Mahoney, 1979 Tuck, 1961
Black Guillemot	- sublittoral, ice edges - dive pursuit to 20 m	- relatively sedentary - winters at edge of winter pack ice	- omnivorous, includes benthic and pelagic fish, amphipods, mysids, polycheates	- blennies, gobies, sculpins, arctic cod - pricklebacks, cod, mackerel - amphipods, mysids, arctic cod	- ---- - Gulf of St. Lawrence - Lancaster Sound	- chick diet - chick diet - spring	Bradstreet and Brown, 1985 Cairns, 1981 Bradstreet, 1976

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Atlantic Puffin	- coastal and offshore	- unknown, may winter well offshore	- piscivorous (mainly pelagic fish) but probably invertebrates outside the breeding season	- capelin, sandlance, cod - capelin, sandlance, amphipods	- Newfoundland - Labrador	- summer - summer	Nettleship, unpubl. Bradstreet, 1983
Common Eider	- coastal (littoral and terrestrial	- relatively sedentary - many wintr on Scotian shelf	- omnivorous (mainly molluscs and other invertebrates)	- mussels, gastropods and amphipods	- Gulf of St. Lawrence	- summer	Cantin _et al_, 1974
King Eider	- coastal	- e. arctic birds winter along coast Newfoundland to Maine	- omnivorous (mainly molluscs and other invertebrates)	- mussels, crabs, sea urchins, midge larvae and plants	- Arctic	- summer	Bellrose, 1976

Appendix 7: Table 2.

DIET AND SEASONAL MOVEMENT OF ATLANTIC COAST SEABIRDS

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Leach's Storm-petrel	- offshore/oceanic - surface-feeder	- probably moves offshore	- omnivorous (zooplankton, fish, oily offal)	- euphausiids, squid, barnacles, fish and offal	- California	- winter	Ainley and Sanger, 1979
Fork-tailed Storm-petrel	- offshore/oceanic - surface-feeder	- probably moves offshore	- omnivorous: zooplankton, fish, and offal)	- euphausiids and fish	- Pacific coast	- ----	Ainley and Sanger, 1979
				- offal from fishing boats	- B.C.	- incidental	Martin, 1942
				- whale carcasses	- Alaska	- incidental	Gill, 1977
Double-crested Cormorant	- coastal - underwater pursuit	- resident along B.C. coast	- piscivorous: on benthic and mid-water schooling fish	- gunnels, sandlance, sea perch, pricklebacks	- Mandarte I., B.C.	- chick diet	Robertson, 1974
				- shrimp, anchovies, sticklebacks, herring	- Pacific coast	- ----	Palmer, 1962
Pelagic Cormorant	- coastal - underwater pursuit	- resident along B.C. coast	- mainly piscivorous: on benthic and mid-water fish and large crustaceans	- gunnels, sandlance, shrimp, sculpins	- Mandarte I., B.C.	- chick diet	Robertson, 1974
				- herring, anchovies, salmonids, sculpins	- Washington	- ----	Ainley and Sanger, 1979

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Glaucous-winged Gull	- coastal/offshore - opportunistic: mainly surface-feeder and scavenger; occ. predator	- moves offshore in winter	- omnivorous: shellfish, crustaceans, herring, sandlance, fish offal, garbage	- decapods, shellfish, herring, sandlance and offal	- Mandarte I., B.C.	- ----	Ainley and Sanger, 1979
				- garbage and shellfish	- Strait of Georgia	- adults	Vermeer, 1982
				- herring and garbage	- Strait of Georgia	- chick diet	Vermeer, 1982
				- barnacles, shellfish	- W. Vancouver I.	- adults	Vermeer, 1982
				- sandlance, herring and sauries	- W. Vancouver I.	- chick diet	Vermeer, 1982
				- pelagic barnacles, shellfish and decapods	- N. Pacific	- winter	Sanger, 1973
Pigeon Guillemot	- coastal/inshore - pursuit diving	- resident in coastal B.C.	- mainly piscivorous	- sculpins, gunnels, sandlance, flatfish, herring, decapods	- Pacific coast	- ----	Ainley and Sanger, 1979

SPECIES	HABITAT - FORAGING	SEASONAL MOVEMENT	DIET	RELEVANT STUDIES			REFERENCES
				DIET	LOCATION	REMARKS	
Marbled Murrelet	- inshore - pursuit diving	- winters offshore of breeding areas	- omnivorous: on zooplankton and small fish	- euphausiids, sandlance and sea perch	- Langara I., B.C.	- summer	Sealy, 1975
Ancient Murrelet	- offshore/oceanic - pursuit diving	- winters south, probably to California	- omnivorous: on mysids, euphausiids, sandlance and other small pelagic fish	- euphausiids, sandlance	- Langara I., B.C.	- summer	Sealy, 1975
				- euphausiids, mysids and sandlance	- Alaska	- ----	White _et al_, 1973
Cassin's Auklet	- offshore - pursuit diving	- winters from Vancouver I. to Baja, California	- planktivorous (zooplankton)	- euphausiids, imm. squid and amphipods	- California	- summer	Manuwal, 1974
				- copepod _Calanus_ and euphausiids	- Triangle I., B.C.	- summer	Vermeer, 1982
Rhinoceros Auklet	- offshore - pursuit diving	- winters offshore	- piscivorous (mainly midwater schooling fish)	- sandlance and sauries	- Triangle I., B.C.	- summer	Vermeer _et al_, 1979
				- sandlance and herring	- Protection I. Juan de Fuca	- summer	Wilson and Manuwal, 1986
				- anchovies, and rock fish, herring, smelt, sauries	- Destruction I., Washington coast	- summer	Wilson and Manuwal, 1986
Tufted Puffin	- inshore/offshore - pursuit diving	- probably winters offshore south of the breeding sites	- piscivorous (mainly midwater schooling fish)	- sandlance, rock fish and sauries	- Triangle I., B.C.	- summer	Vermeer _et al_, 1979
				- sandlance, capelin, gadids, squid and polycheates	- Alaska	- summer	Wehle, 1983