Environmental Indicator: Persistent Chemicals in Wildlife in British Columbia

Primary Indicator: ***Concentration of DDE and PCBs in Great Blue Heron eggs.***

Selection and Use of Indicator: The concentration of dichlorodiphenyldichloroethane (DDE) and polychlorinated biphenyls (PCBs) in Great Blue Heron eggs is a *state* or *condition* indicator. It shows the presence of persistent contaminants in the environment and the effects of these long-lived organochlorines. These compounds have a high fat solubility and accumulate in the tissues of some animals (*bioaccumulation*). As a result, concentrations of these contaminants increase at each step up the food web, and can reach high levels in predators that feed at the top of their food chain (*biomagnification*). Measurements of contaminant concentrations in living organisms, particular in top predators such as herons, can be used to detect potential threats to the integrity of ecosystems and to human health.

The presence in the environment of organochlorine compounds, such as DDE, PCBs, furans and some dioxins, is of particular concern because it is known that they can pose a threat to both wildlife and human health (Environment Canada, 1996). For example, at high concentrations these compounds affect health and survival of bird chicks. DDE, which is a breakdown product of the pesticide DDT, interferes with the enzymes that produce calcium carbonate for eggshells in female birds. With less calcium carbonate, eggshells are thinner and prone to cracking or breaking during the incubation period. These compounds can also mimic the activity of the female hormone estrogen or otherwise disrupt the endocrine system. This may result in reproductive and immune system dysfunction, neurobehavioural and developmental disorders, and other problems.

In Canada, DDT was widely used to control agricultural and forest insects from 1947 to 1969. Most uses of DDT were banned in 1970, although some limited use was permitted until 1990. Although PCBs were never manufactured in Canada, they were imported in electrical products. PCBs are a mixture of compounds used predominately as coolant-insulants and heat transfer agents in some types of electrical equipment. PCB production in the United States was significantly reduced in 1970, and completely banned in North America in 1977. Organochlorine levels in the environment in Canada have declined since the 1970s, however, because these compounds are highly stable and resistant to chemical breakdown, low concentrations will likely continue to recirculate in the environment for the foreseeable future (Environment Canada 1996).

The Great Blue Heron is a good indicator species for marine, estuarine, and aquatic environments because it occupies a wide range of habitats. It is a top predator that consumes primarily first-year age class fish, which means that most of the contaminants in these fish have been acquired locally. In coastal British Columbia, Great Blue Heron populations are also non-migratory, which makes it even more likely that contaminants detected in their eggs can be attributed to local sources.

Data and Sources:

The data for this indicator came from the Great Blue Heron colony at the University of British Columbia (UBC), located near the mouth of the Fraser River in Vancouver. This colony was selected for research because it is a large one (not jeopardized by egg sampling) and because it would be an indicator of the level of contaminants in the Fraser River.

Table 1. Concentrations of DDE and PCB in Great Blue Heron eggs at the UBC research colony near the mouth of the Fraser River, British Columbia

Year	DDE (mg/kg)	PCB (mg/kg)	Comments
1977	2.4	7.3	Geometric Mean of 12 eggs
1982	1.4	4.4	Pool of 11 eggs
1983	0.6	1.6	Pool of 10 eggs
1985	1.0	2.4	Geometric Mean of 10 eggs
1986	0.3	1.1	Geometric Mean of 7 eggs
1987	0.5	1.2	Geometric Mean of 25 eggs
1988	0.4	1.3	Geometric Mean of 13 eggs
1989	0.5	0.8	Geometric Mean of 5 eggs
1990	0.4	1.0	Geometric Mean of 8 eggs
1991	0.8	1.8	Pool of 5 eggs
1992	0.3	1.0	Geometric Mean of 10 eggs
1993	1.6	1.7	Pool of 6 eggs
1994	1.0	1.9	Pool of 5 eggs
1996	0.9	3.4	Pool of 5 eggs
1998	0.3	0.9	Pool of 5 eggs
2000	0.4	1.1	Pool of 10 eggs

Source: Environment Canada, Canadian Wildlife Service, 2001.

Methodology and Reliability: Data used in this indicator were derived from egg sampling studies conducted by the Canadian Wildlife Service. Samples were taken from eggs collected from nests in the colony; each egg collected in a season was taken from a different nest. The egg contents were placed in glass jars with a chemically cleaned foil liner between the lid and jar, or wrapped in aluminum foil and then frozen until analysis. The residues of DDE and PCBs were determined for the Canadian Wildlife Service at the National Wildlife Research Centre in Hull, Quebec. Data are presented as geometric means since residue concentrations are often skewed and exhibit a log normal distribution. The term "pool" refers to the process of taking equal volumes from a specified number of eggs and combining them to make one sample for analysis.

References:

Wilson, L. K., M. Harris, J. E. Elliott. 1999. Contaminants in wildlife indicator species from the Fraser Basin. In: C. Gray and T. Tuominen (eds), *Health of the Fraser River Aquatic Ecosystem: A Synthesis of Research Conducted under the Fraser River Action Plan*, DOE FRAP, 98-11.

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Environment Canada. 1998. *Toxic Contaminants in the Environment: Persistent Organochlorines*. Canada's National Environmental Indicator Series. Background document to SOE Bulletin No. 98-1. http://www.ec.gc.ca/soer-ree/English/Indicators/Issues/Toxic/default.cfm

Secondary Measure: ***PCB, dioxin and furan concentrations in Harbour Seals.***

Selection of Indicator: The concentration of polychlorinated-biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (dioxins) and polychlorinated dibenzofurans (furans) in Harbour Seals is a *state* or *condition* indicator, showing the presence of these contaminants in the environment. Organochlorines like dioxins, furans and PCBs are highly persistent in the environment because of their chemical stability. They are also fat soluble and build up (or *bioaccumulate*) in the tissues of some animals. Contaminant concentrations increase as they move up the food chain; this process, called *biomagnification*, results in top predators carrying the heaviest loads.

Harbour Seals can serve as a indicator species for environmental contamination because they occupy a position high on the marine food chain and are widely distributed. They are also year-round residents with a high degree of site fidelity. They feed on a wide variety of fish and invertebrates, making them a good indicator of contaminant levels throughout the coastal food chain in the region. Two of their preferred prey species, herring and hake, however, are migratory, moving inshore during certain times of year. Thus, levels of contaminants in Harbour Seals could come from both local sources and international sources introduced to coastal food chains by migratory fish stocks. Observed health effects of elevated organochlorine levels in Harbour Seals include immunotoxicity, retinoid disruption, reduced levels of vitamin A and thyroid hormone, impaired reproduction and skeletal lesions. These chemicals may also play a role in facilitating outbreaks of disease and mass mortality in populations of seals and other marine mammals.

In the past, dioxins and furans entered the marine environment as by-products from a variety of industrial activities, such as chlorine-bleaching in kraft pulp mills, and through incomplete combustion during incineration of municipal and industrial waste. Most industrial processes that produced dioxins and furans were banned in 1989. Since 1994, regulations under the Canadian Environmental Protection Act have strictly limited the allowable discharge of dioxins and furans from coastal pulp mills.

PCBs largely enter the environment through leakage and improper disposal of electrical equipment. The manufacture, importation and most non-electrical applications of PCBs were prohibited in North America in 1977. Electrical applications are now being phased out and there are stringent government requirements for handling, storage and disposal.

Data and Sources:

The data for the report were provided by Dr. Peter S. Ross, Institute of Ocean Sciences, Sidney, BC. The numerical data will be made available upon official publication of his research.

Methodology and Reliability:

The data came from blubber biopsy samples taken from healthy, free-ranging Harbour Seal pups in various locations. Samples were collected in 1996 from Gertrude Island (in south Puget Sound near Seattle, Washington) and five British Columbia locations: Victoria, Vancouver, Crofton, Hornby Island and Queen Charlotte Sound.

Contaminants in the blubber were analyzed using high-resolution gas chromatography-mass spectrometry. By sampling only pups, researchers could ensure that all subjects were of a known age (four to six weeks old). Virtually all contaminants carried by pups come from their mothers' milk.

References:

Health Canada. 2000. *It's Your Health: PCBs and Human Health.* http://www.hc-sc.gc.ca/english/iyh/environment/pcb.html

Health Canada. 2000. *It's Your Health: Dioxins and Furans*. http://www.hc-sc.gc.ca/english/iyh/environment/dioxins.html

Ross, P.S., M. Ikonomou, R. Addison, and S. Jeffries. 1998. Elevated PCB Levels in Puget Sound Harbour Seals (*Phoca vitulina*). In: Proceedings of Puget Sound Research Conference, 12-13 March 1998, Seattle, WA. http://www.wa.gov/puget_sound/Publications/98_proceedings/sessions/toxic_effects.html

Transboundary Georgia Basin–Puget Sound Working Group on Environmental Indicators. 2002. Georgia Basin–Puget Sound Ecosystem Indicators Report: Persistent Organic Pollutants in Harbour Seals. http://wlapwww.gov.bc.ca/cppl/gbpsei/index.html

Secondary Measure: ***Levels of dioxins and furans in Dungeness Crabs.***

The level of dioxins and furans in Dungeness Crabs is a *state* or *condition* indicator, showing the contamination of sediment at sites adjacent to pulp mill outfalls, where effluent is discharged. The Dungeness Crab is an ideal indicator species because of its long life span, fecundity, widespread distribution, relatively stationary habit and preference for sandy-bottomed waters where contaminated sediments often accumulate. These crabs concentrate high levels of fat-soluble contaminants, like dioxins and furans, in their fat-rich digestive gland, the hepatopancreas. The value of this shellfish species in commercial, recreational and First Nations harvests underlines the importance of this species as an indicator.

Initial monitoring from 1987 to 1989 documented elevated dioxin and furan levels in edible finfish and shellfish collected near pulp mill outfalls. In response, the federal government issued harvesting restrictions on various species, implemented a monitoring program and introduced legislation to control dioxin and furan discharges.

Between 1989 and 1996, operational and equipment changes at pulp and paper mills reduced effluent contaminant loadings by 95 percent for dioxins and 99 percent for furans. Both are now present only in minute quantities that fall within federal discharge limits. However, dioxins and furans have a strong affinity for sediments and may remain present in the marine environment for many years. Sediment contamination levels at different sites depend on a variety of factors, such as dispersion by tidal currents, sediment transport, burial by river sediment, sediment particle size and biological mixing of sediments.

Data and Sources:

Table 3. Dungeness Crab Hepatopancreas Dioxin/Furan Levels at Outfall Sites (TEQ[1], pg/g)

MILL	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Crofton		179.1	82.4	130.2	97.1	49.3	57.1	57.4	29.9	45.3
Elk Falls		104	116.3	103.8	68.5	63.3	28.1	21.3	14.5	26.1
Gold River		1075	510	178	59.8	46	17.6	30.7	19.4	45.6
Harmac		228.7	164.1	92.2	22.7	8.2	4.6	15.9	8.9	5.8
Port Alberni		16.2	41.8	52.7	20.2	26.5	57.2	26.9	17.3	
Port Mellon	1490	482	196	79.3	143	35.8	67.9	20.9	16.5	12.8
Powell	490	116	78.2	140.2	87.5	2.2	8.5	25.2	14.2	11.4
Skeena	617	306	344.1	142.4	30.8	30.4	34.8	37	25.5	23.5
Squamish	664	67.2	113.2	48.6	27.5	15.6	19.3	12.5	44.6	12.1
TOTAL	**3261**	**2574**	**1646**	**967**	**557**	**277**	**295**	**248**	**191**	**183**
AVERAGE	**815**	**286**	**183**	**107.5**	**61.9**	**30.8**	**32.8**	**27.5**	**21.2**	**22.8**

[1] TEQ = Toxic Equivalents; used to standardize comparisons of different chemicals with the most toxic congener of the group.

Source: Pollution Prevention and Assessment, Environmental Protection, Environment Canada, 2001. http://www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/dioxin_e.cfm

Methodology and Reliability: The federal Dioxin and Furan Trend Monitoring Program was initiated in 1990. Sampling locations, species and numbers of samples are specified annually by the Department of the Environment (DOE) following consultation with the Department of Fisheries. The participating mills are responsible for collection and analyses and the results are submitted to DOE for evaluation.

Dungeness Crabs selected for sampling were legal-sized males (minimum carapace width is 165 mm). They were collected from sites near mill outfalls, usually in February or March. Dioxin and furan analyses werw conducted via ultra-trace high resolution gas chromatography/high resolution mass spectrometry (Hagen et al 1997). Toxic equivalents (TEQs) were derived using an internationally accepted procedure that compares the toxicity of 17 different forms of dioxins and furans to the most toxic member of this group (2,3,7,8-chlorodibenzo-*p*-dioxin or T4CDD).

References:

Environment Canada. 2001. *Dioxin/Furan Levels: An Indicator of Toxic Contaminants in Coastal BC*. Environment Canada, Pacific and Yukon Region.
http://www.ecoinfo.ec.gc.ca/env_ind/region/dioxinfuran/dioxin_e.cfm

Hagen, M. E., A.G. Colodey, W. D. Knapp, and S.C. Samis. 1997. Environmental response to decreased dioxin and furan loadings from British Columbia coastal pulp mills. Chemosphere. 34(5-7):1221-1229.