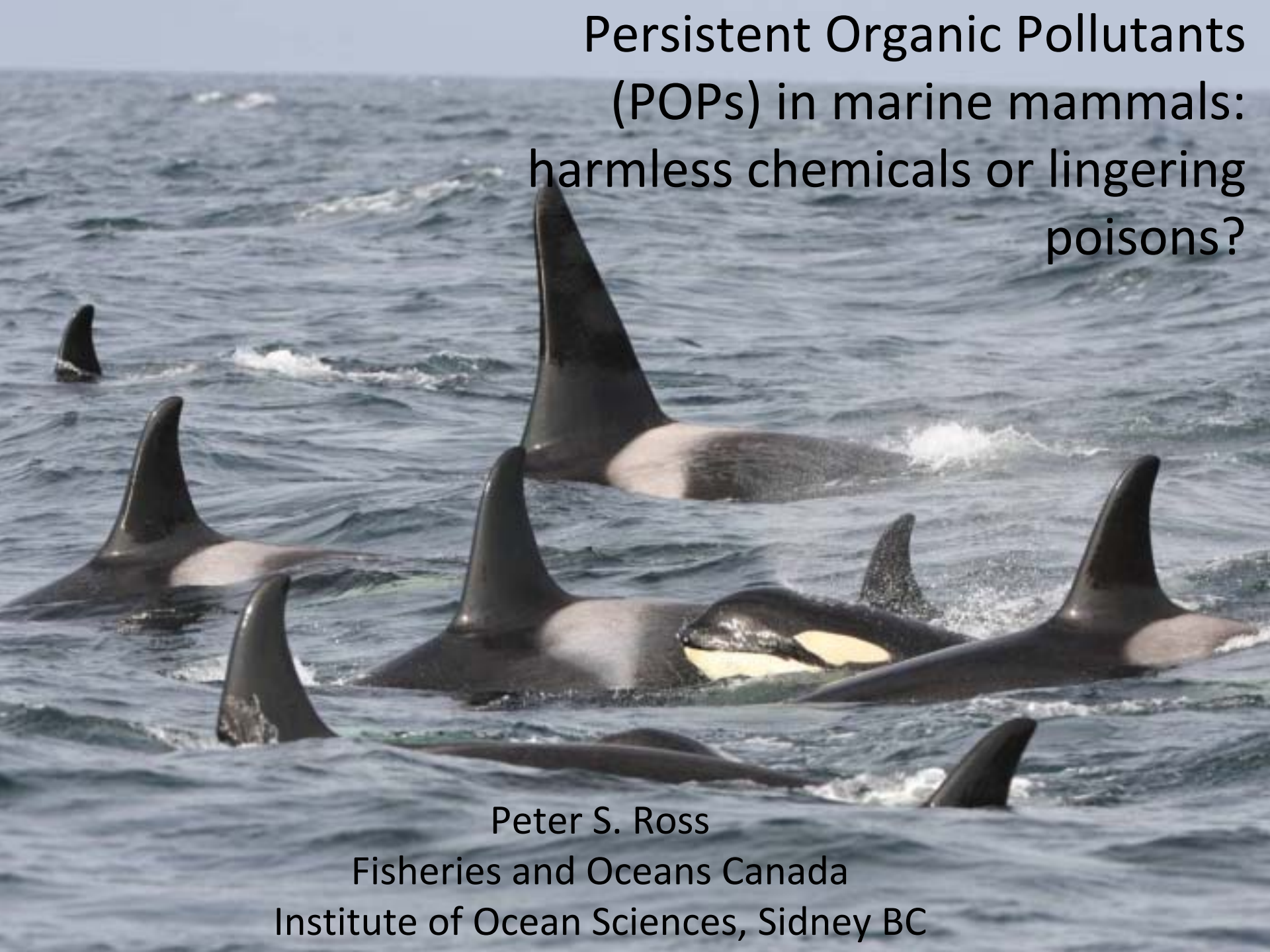
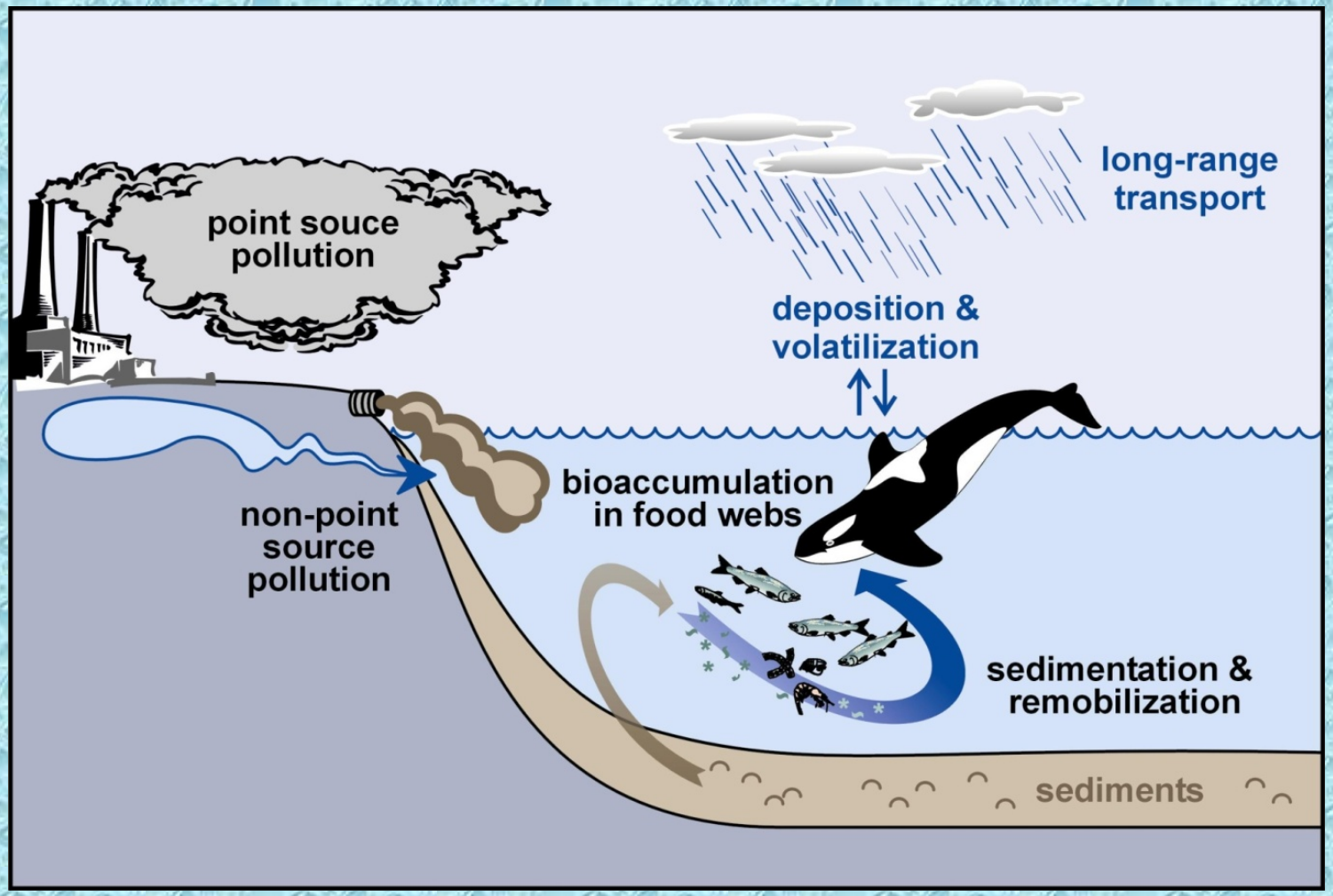
Persistent Organic Pollutants (POPs) in marine mammals: harmless chemicals or lingering poisons?



Peter S. Ross
Fisheries and Oceans Canada
Institute of Ocean Sciences, Sidney BC

Marine mammals can serve as integrated indicators of marine pollution

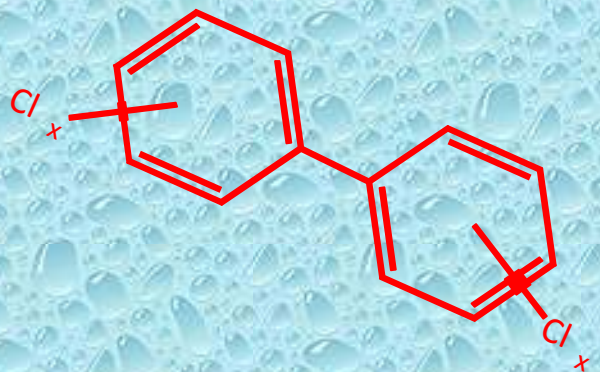


But only when we understand biology and ecology (~confounding factors)

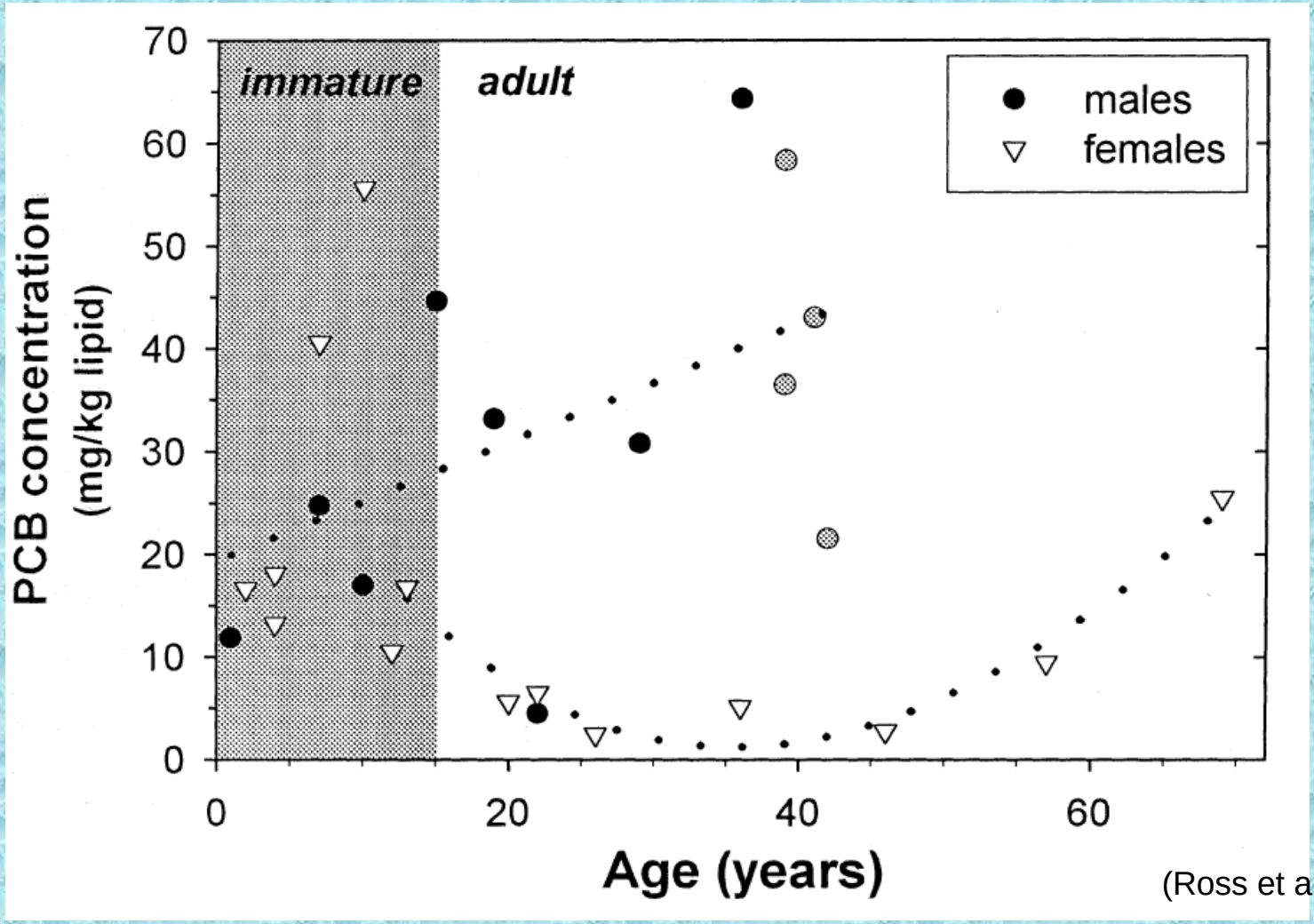
- Age
- Sex
- Feeding ecology
- Habitat use
- Biomagnification: trophic level, metabolism
- Physico-chemical properties of pollutant
- Complex pollutant mixtures

Marine mammals are not good sentinels for all pollutants, but can be for those contaminants considered to be:

- Persistent (do not break down in environment)
- Bioaccumulative (are not metabolized and amplify in food webs)
- Toxic (endocrine-disrupting)
- Subject to long-range transport (trans-Pacific!)
- E.g. PCBs, DDT, dioxins, PBDEs, etc
  - (i.e. pollutants considered by Stockholm Convention)

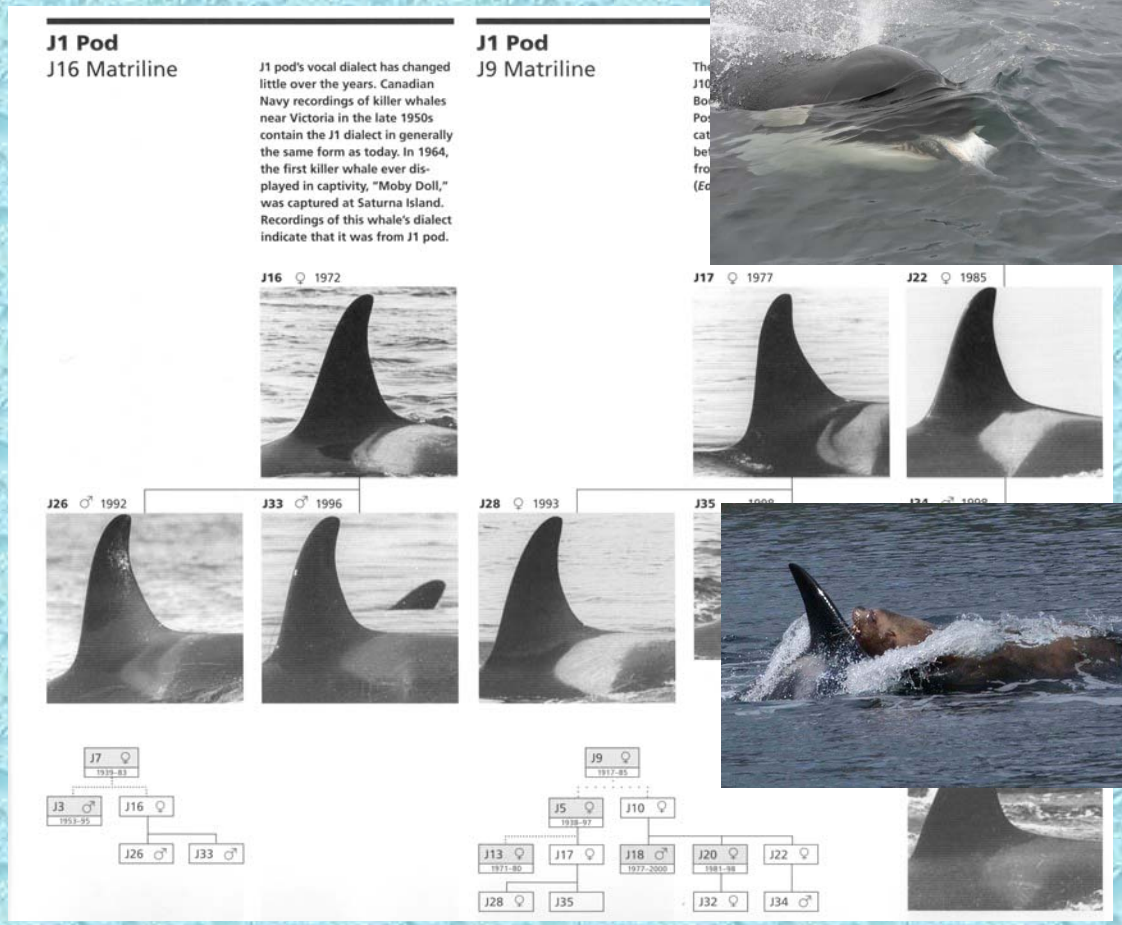


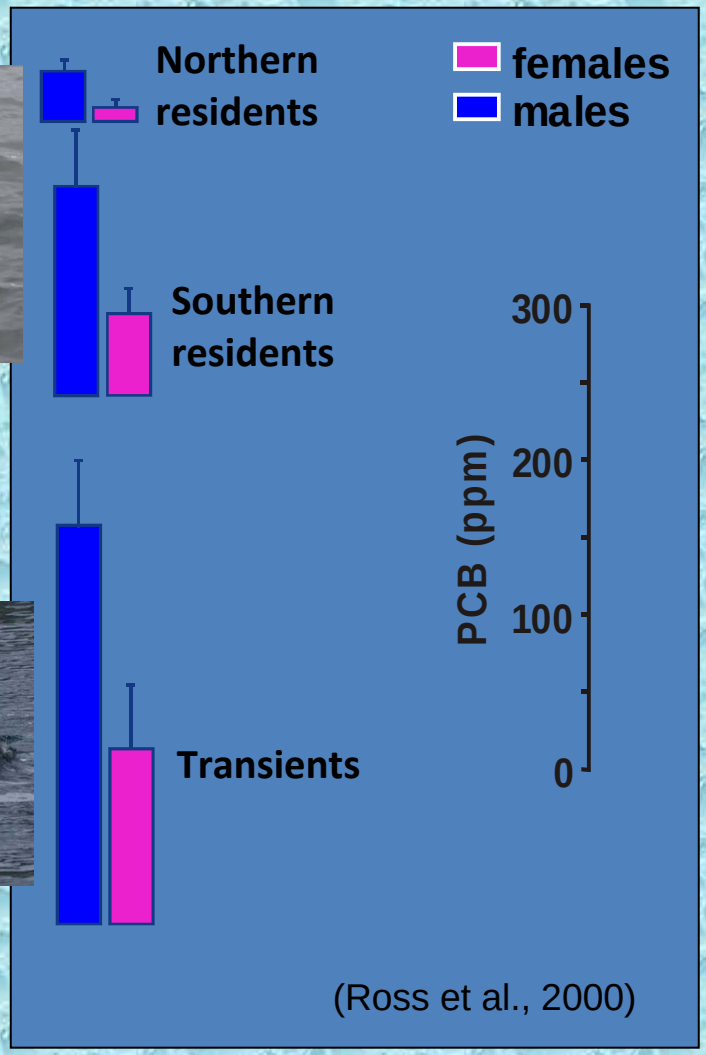
Age and sex: PCBs increase with age in male killer whales (circles), but decrease in reproductively active females (triangles)



(Ross et al., 2000)

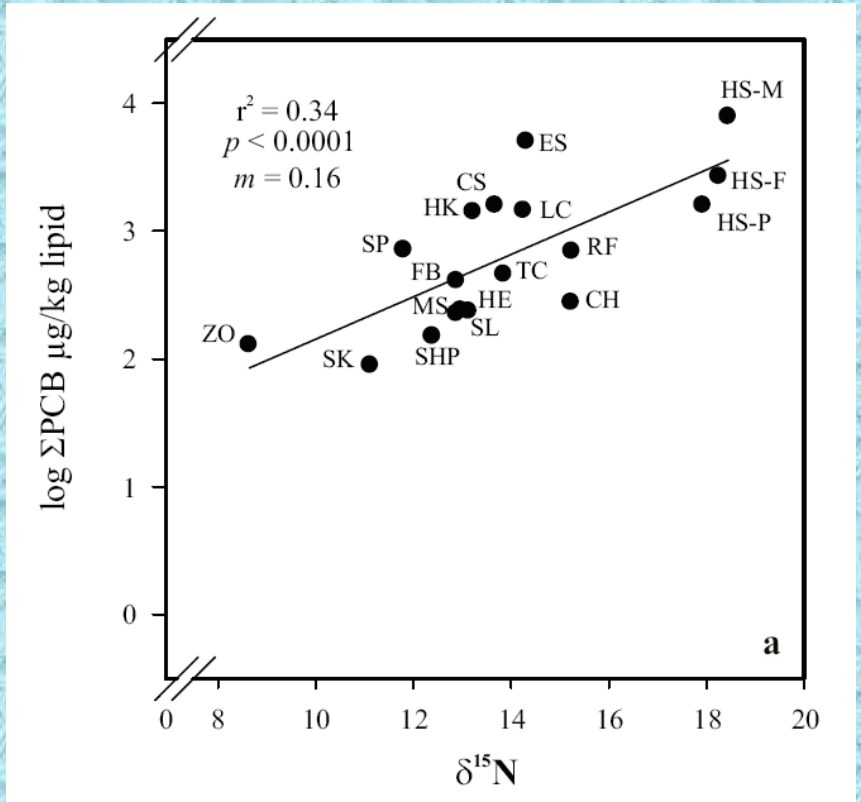
Feeding ecology: PCBs are higher in marine mammal-eating Transient killer whales than in salmon-eating Resident killer whales





Trophic level: total PCBs biomagnify in harbour seal food web

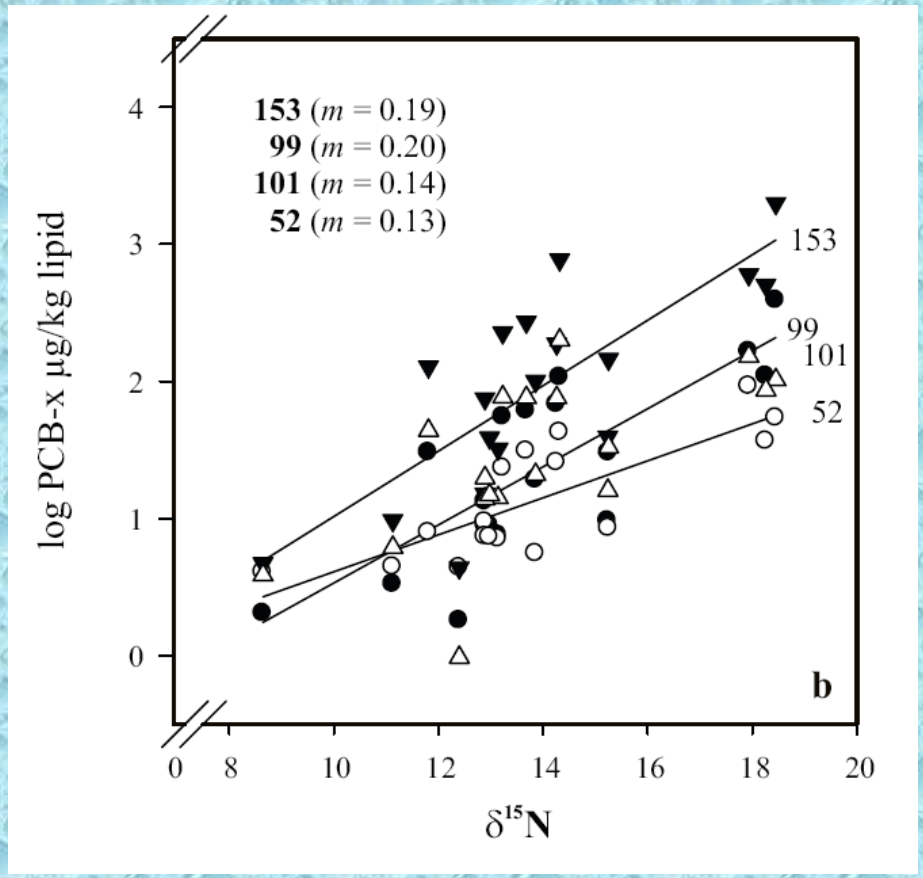
- PCB concentration in lipid increases with trophic level in food web
- PCBs are persistent
- Fat soluble
- Recalcitrant
- Stable isotopes of nitrogen (15N: 14N) provide measure of trophic level



(Cullon et al., 2012)

Metabolism: individual PCBs behave differently in marine food webs

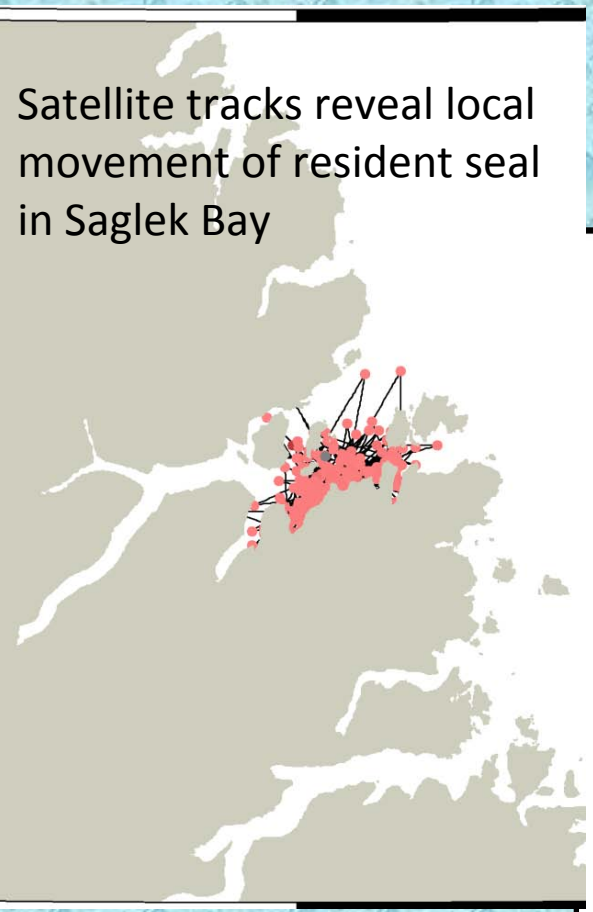
- Influence of log Kow
- Influence of metabolism on different congeners
  - Black circles: recalcitrant
  - Open circles: metabolizable



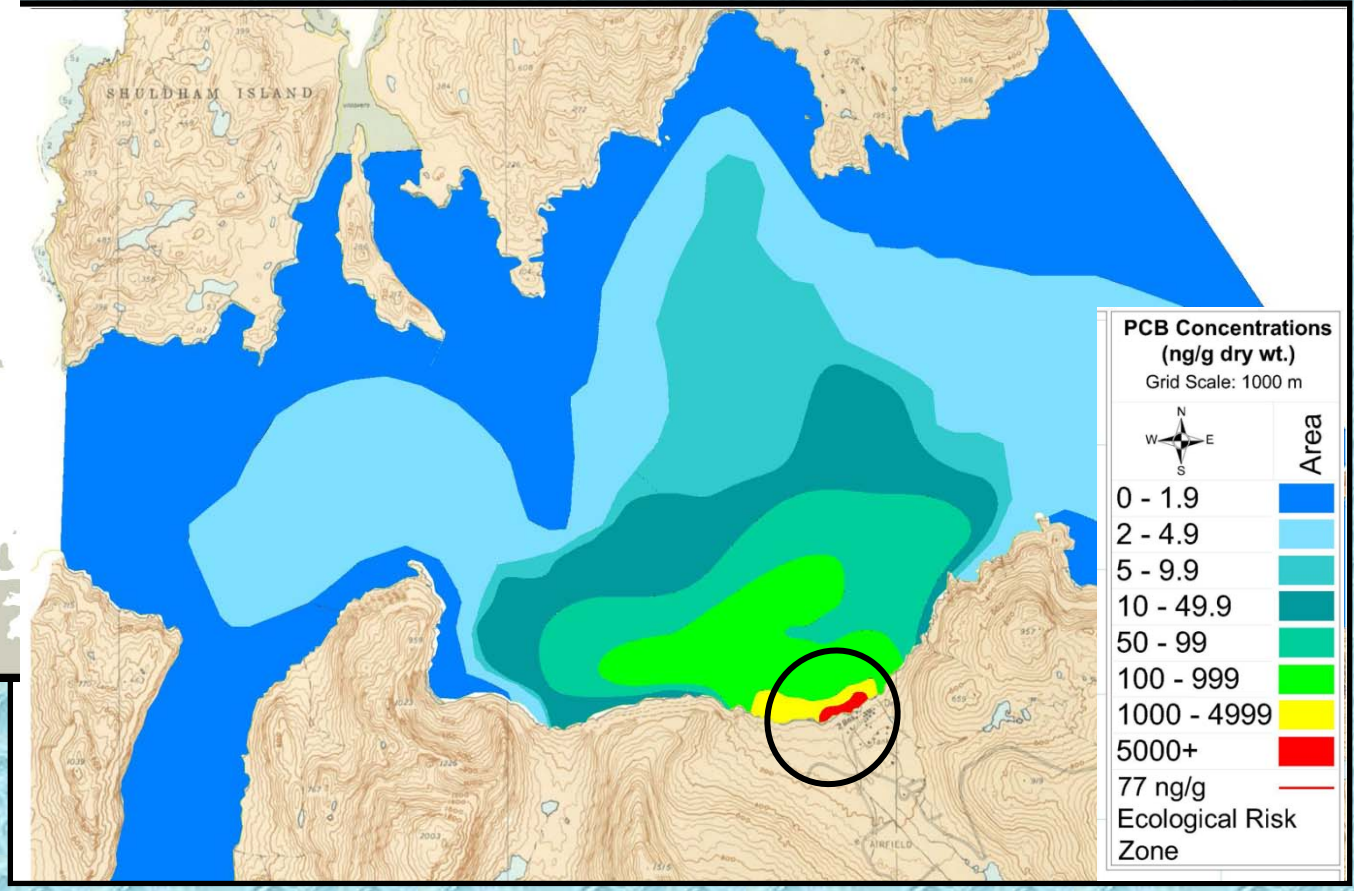
(Cullon et al., 2012)

Habitat use: Local PCB releases can contaminate local marine mammal food webs

Satellite tracks reveal local movement of resident seal in Saglek Bay

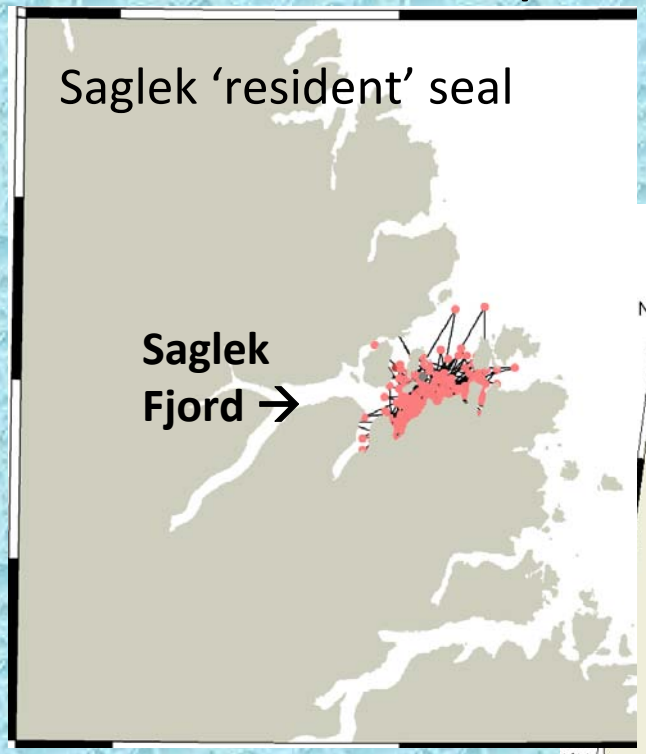


Contaminated sediments deliver PCBs to ringed seal food web

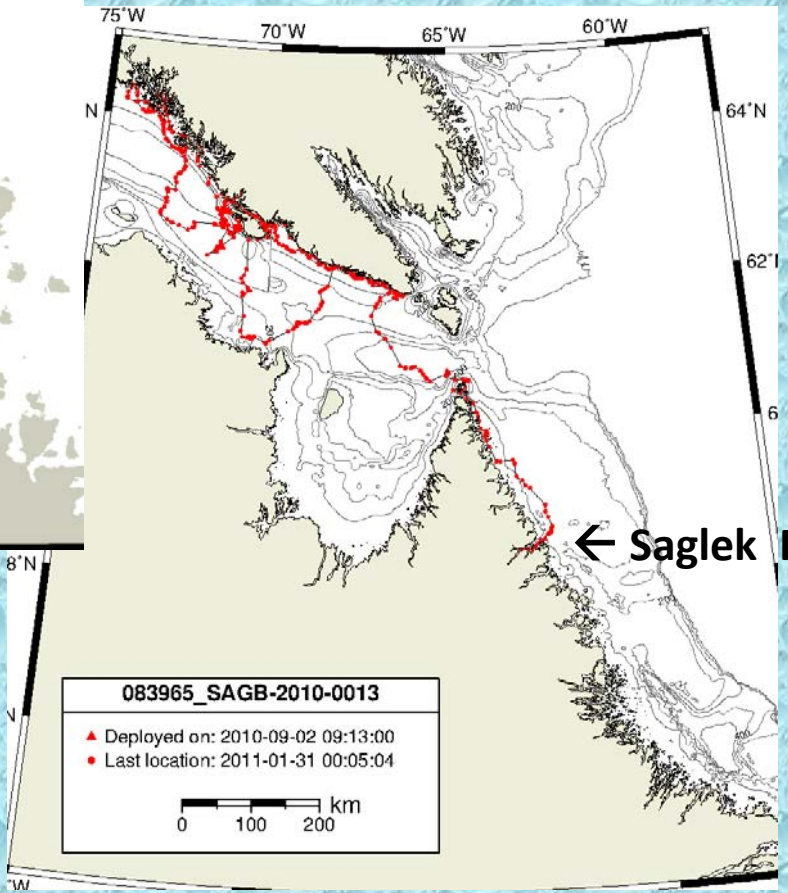


Brown et al. 2009, ES&T; Kuzyk et al. 2005, Sci. Tot. Environ

Habitat use: some individuals move hundreds of kilometers, and may be more exposed to global PCB 'background', while others are more localized and can be exposed to contaminated sites

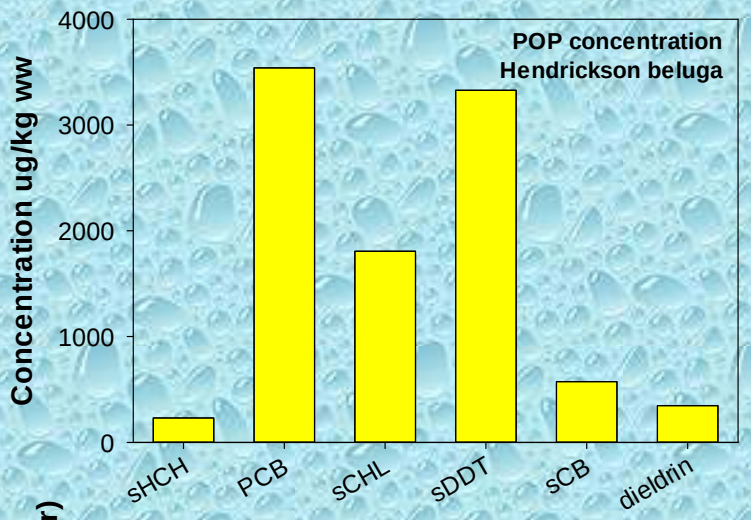


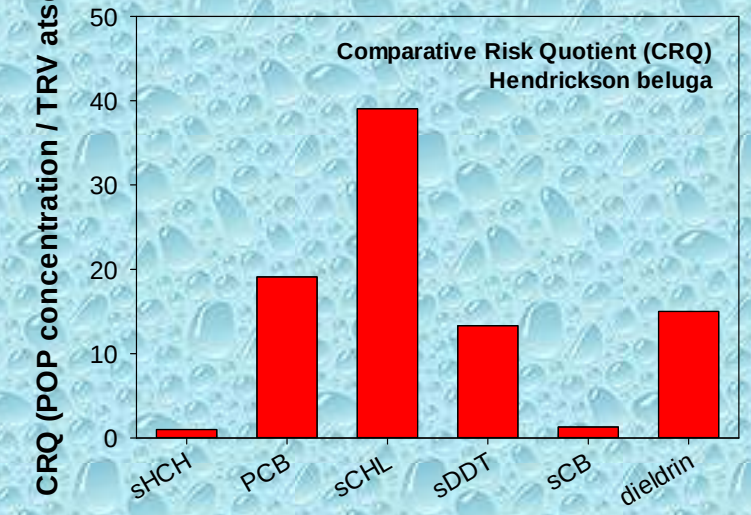
Migratory seal



Complex mixtures: which pollutant poses the greatest risk? Comparative risk approaches

POPs in Beaufort Sea beluga whales:
1) Concentration vs 2) Relative risk based on relative toxicity in rodent studies

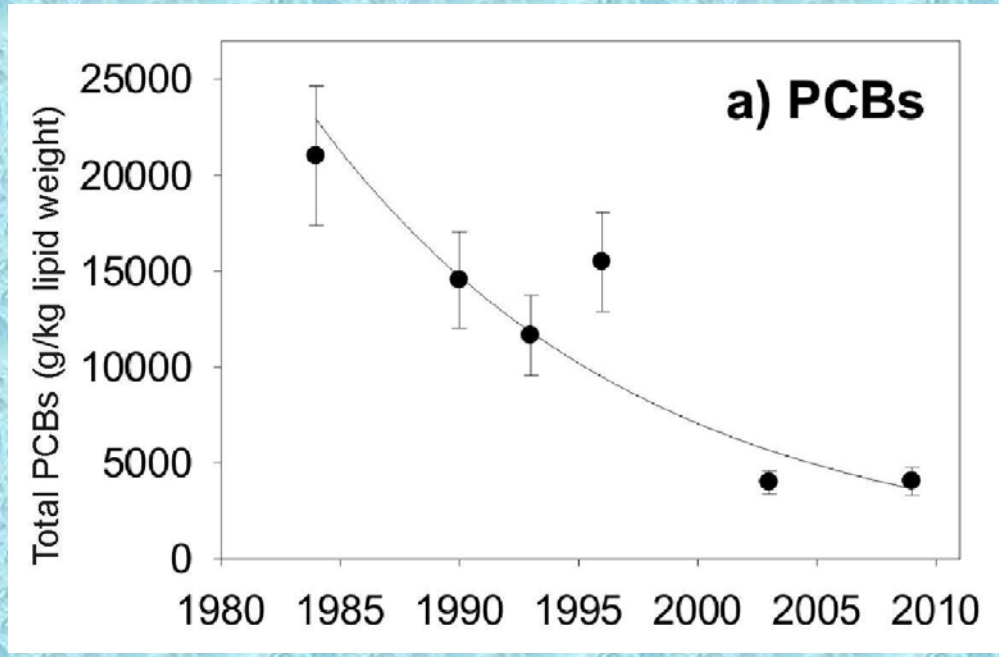




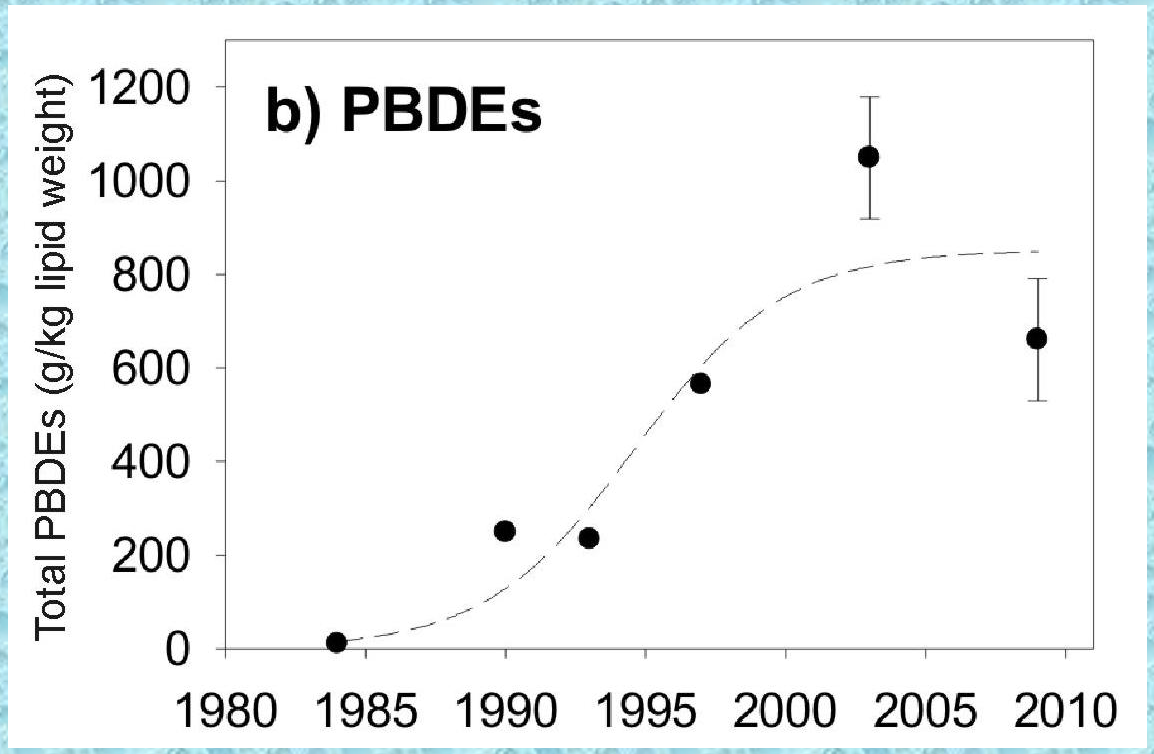
When we address such factors, marine mammals provide integrated information of PCB trends in the NE Pacific

- Same age harbour seals (4 weeks old);
- Live captured in good condition;
- Feeding ecology is documented.

(Ross et al., 2013)



Flame retardant PBDEs were going up, but they were banned starting in 2004



(Ross et al., 2013)

PCB-related health effects in harbour seals: effects on thyroid and vitamin A physiology and immune function

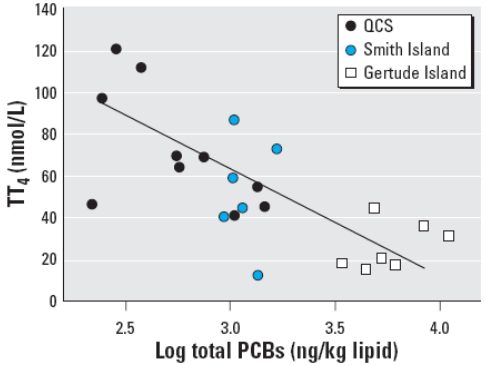


Figure 3. Correlation analysis of circulating TT_4 levels with ΣPCB measured in blubber of harbor seal pups from the southern coast of British Columbia and northern Washington State. A significant negative correlation is noted. $R = -0.711$; $p < 0.01$.

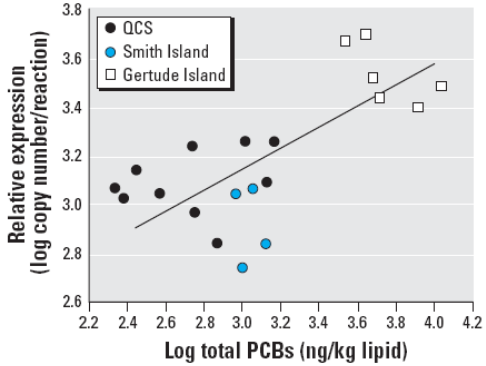
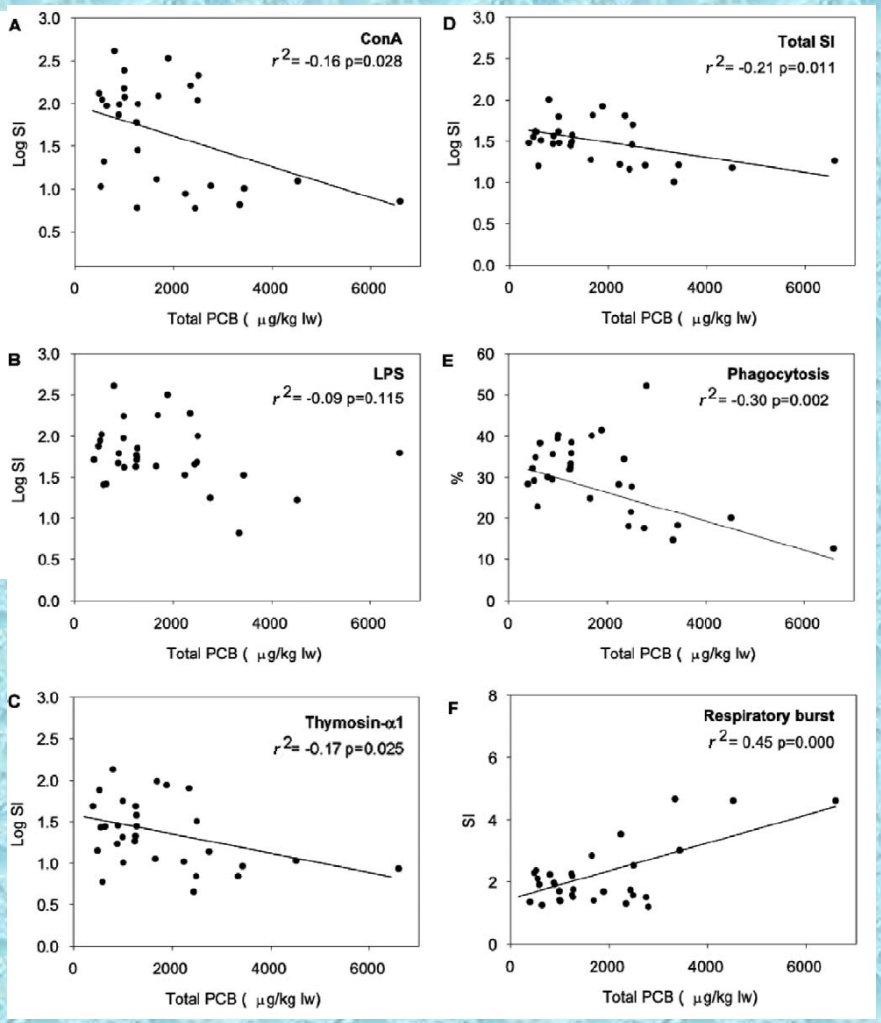
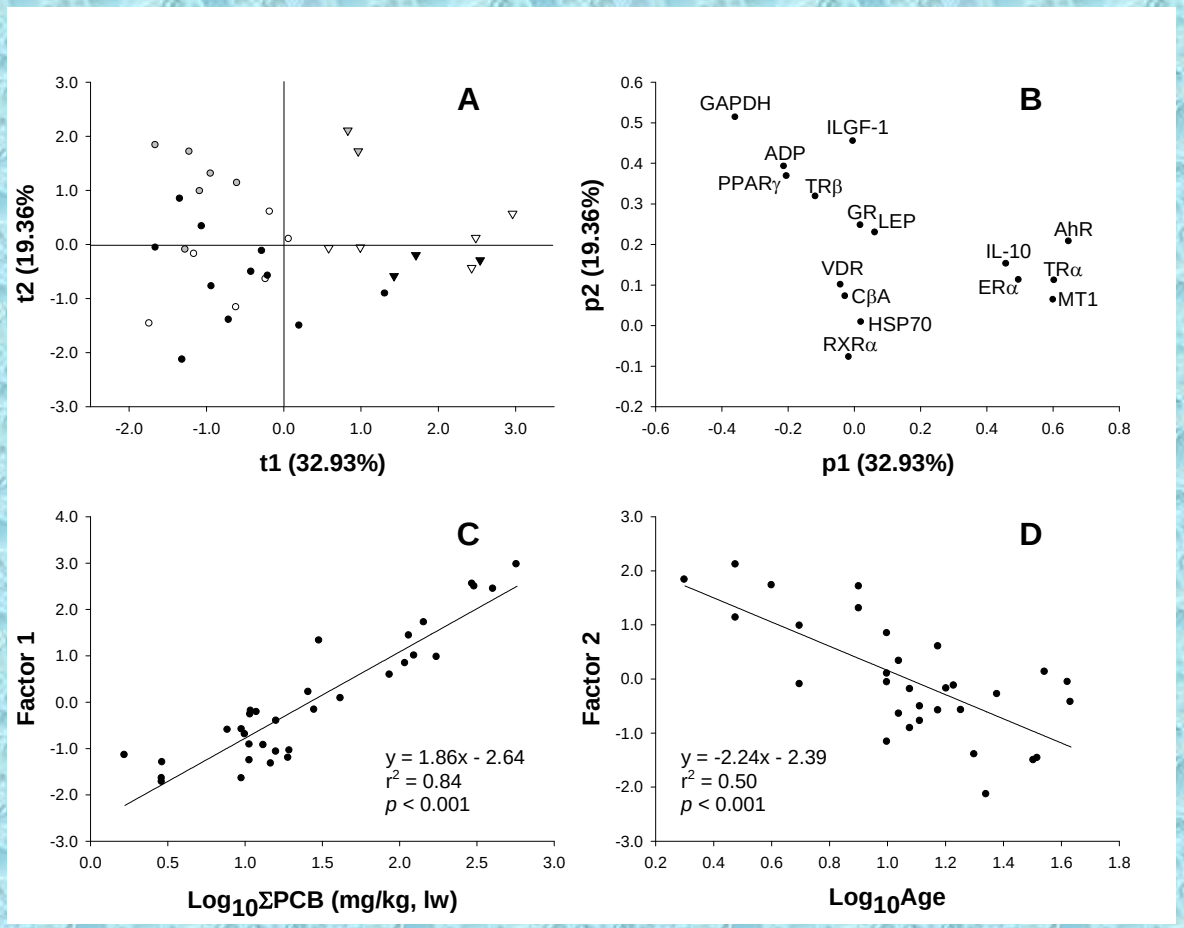


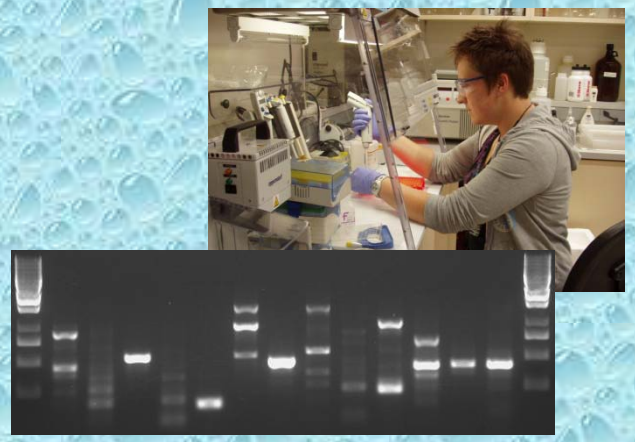
Figure 4. Correlation analysis of relative TR-α mRNA expression with ΣPCB concentrations measured in the lower blubber biopsy section of harbor seal pups from the southern coast of British Columbia and northern Washington State. A significant positive correlation is noted. $R = 0.679$; $p < 0.01$.

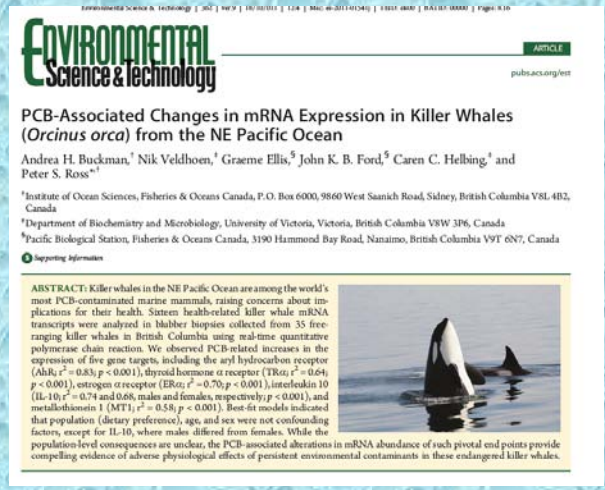


(Tabuchi et al., 2007; Mos et al. 2007)

PCB-related health effects in wild killer whales: Gene expression profiles (PCA) in biopsies correlate with PCBs (33%) and age (19%)







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PCB-Associated Changes in mRNA Expression in Killer Whales (*Orcinus orca*) from the NE Pacific Ocean

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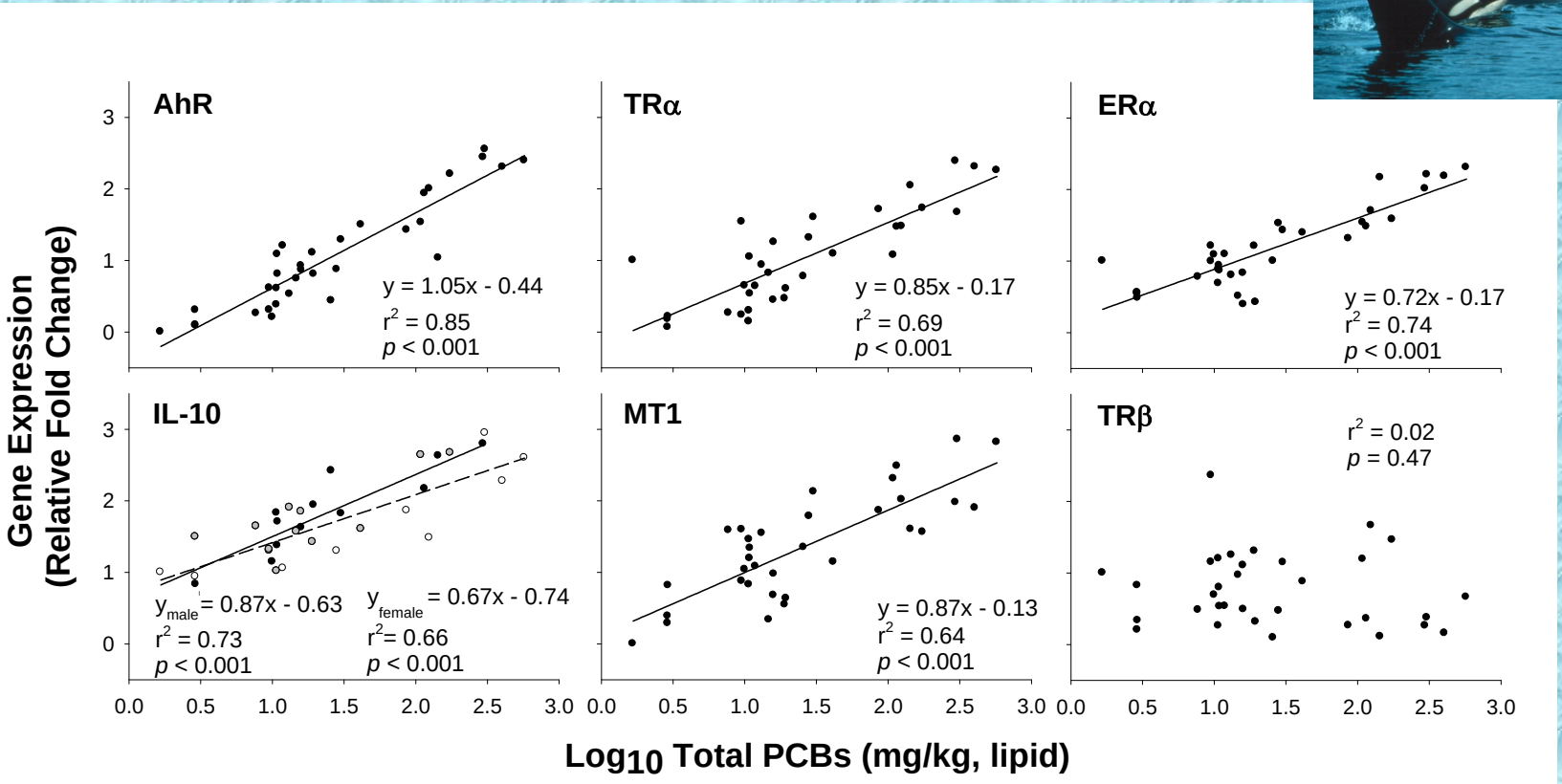
Supporting Information

ABSTRACT: Killer whales in the NE Pacific Ocean are among the world's most PCB-contaminated marine mammals, raising concerns about implications for their health. Sixteen health-related killer whale mRNA transcripts were analyzed in blubber biopsies collected from 35 free-ranging killer whales in British Columbia using real-time quantitative polymerase chain reaction. We observed PCB-related increases in the expression of five gene targets, including the aryl hydrocarbon receptor (AhR; $r^2 = 0.83$; $p < 0.001$), thyroid hormone α receptor ($TR\alpha$; $r^2 = 0.64$; $p < 0.001$), estrogen α receptor ($ER\alpha$; $r^2 = 0.70$; $p < 0.001$), interleukin 10 (IL-10; $r^2 = 0.74$ and 0.68, males and females, respectively; $p < 0.001$), and metallothionein 1 (MT1; $r^2 = 0.58$; $p < 0.001$). Best-fit models indicated that population (dietary preference), age, and sex were not confounding factors, except for IL-10, where males differed from females. While the population-level consequences are unclear, the PCB-associated alterations in mRNA abundance of such pivotal end points provide compelling evidence of adverse physiological effects of persistent environmental contaminants in these endangered killer whales.

(Buckman et al, 2011)

Health effects in killer whales: Five gene transcripts were strongly correlated with PCBs, including the thyroid hormone receptor (TRa), the estrogen receptor (Era) and the Aryl hydrocarbon receptor (AhR)



(Buckman et al, 2011)

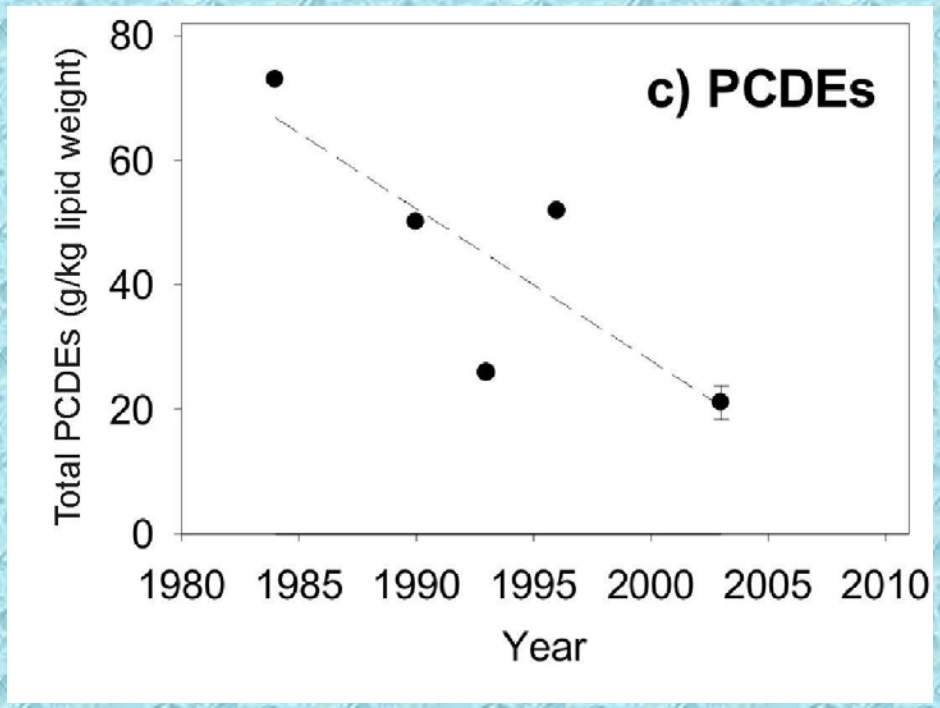
Marine mammals can serve as useful sentinels of marine food web contamination, but only when we understand the biology and ecology of the study animals, and incorporate these into study design and interpretation

Thank you

- Species at Risk Act Science Fund (DFO), Ecosystem Research Fund (DFO), Federal Contaminated Sites Action Plan, Northern Contaminants Program (AANDC), Washington Department of Fish and Wildlife
- Neil Dangerfield, Graeme Ellis, John Ford, Graeme Ellis, Lance Barrett-Lennard
- Andrea Buckman, Donna Cullon, Maki Tabuchi Lizzy Mos
- Photo credits Graeme Ellis, Brian Gisborne, Peter S. Ross, John K.B. Ford

Habitat use: Local PCB contamination: Saglek Bay military radar site 1950-70s (Labrador, eastern Canada)

PCDEs are going down



Lag time between regulations and response

PCBs are declining very slowly in most ecosystems (environmental half-life ~20 to >40 years).

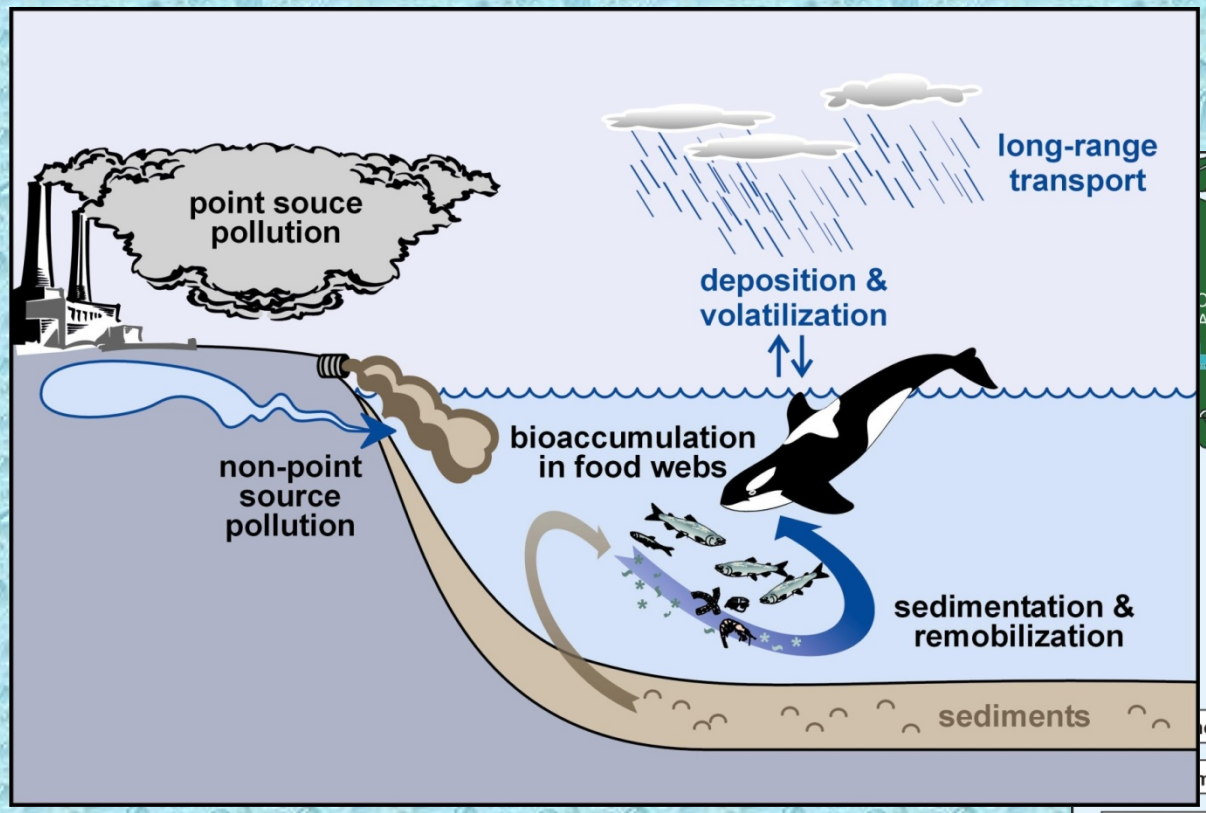
Projected times for 95% of population members to fall below the least protective 17 mg/kg effects threshold (**t½ = 30 yrs**):

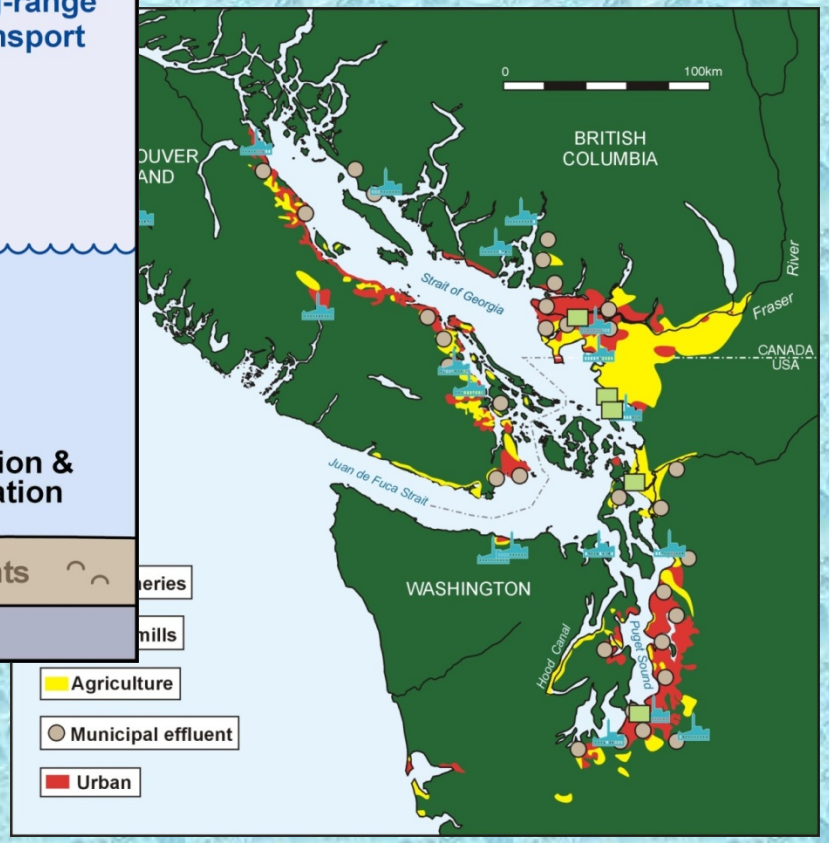
Northern Residents ~ 2030

Southern Residents ~2089

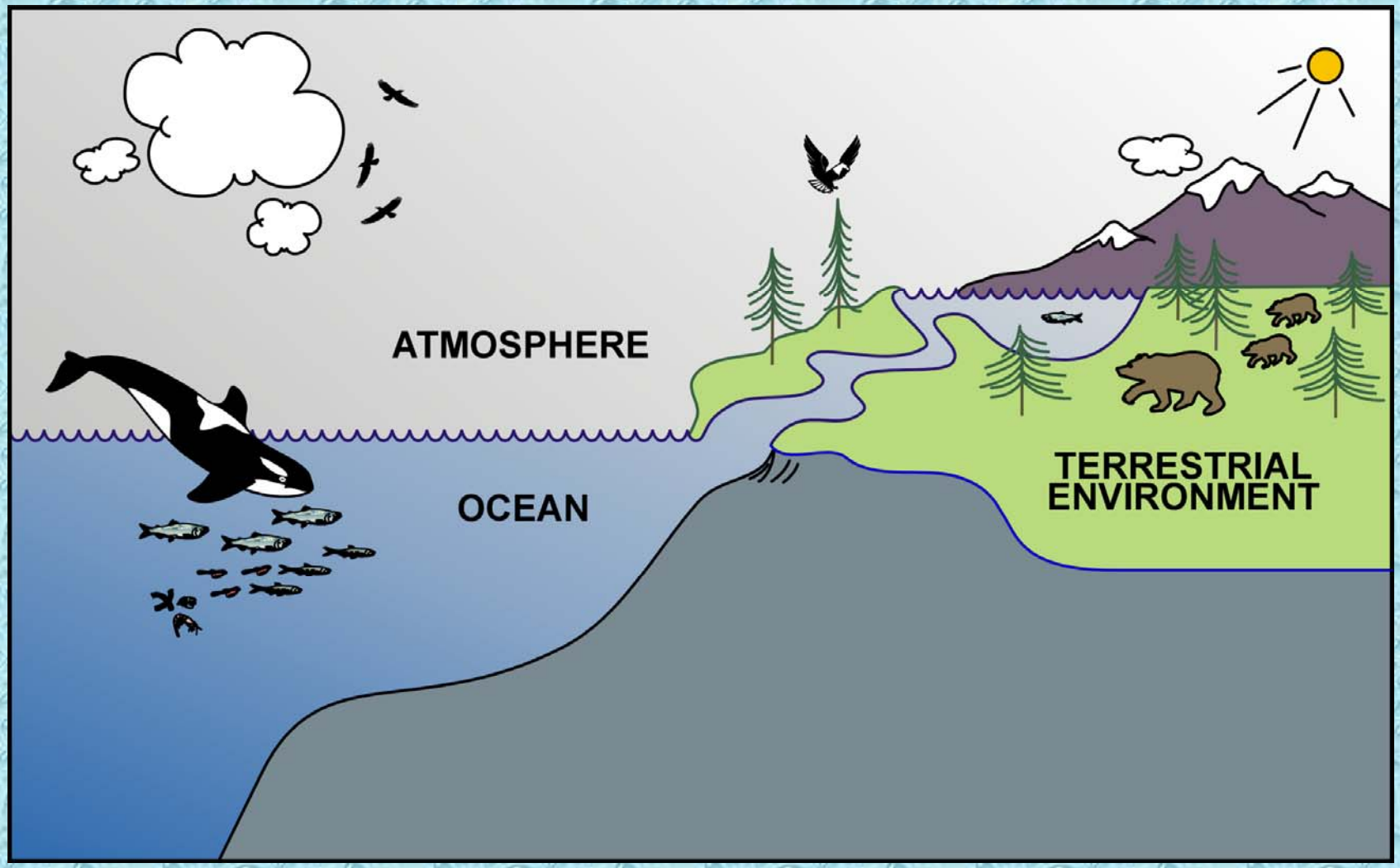
(Hickie et al., 2007)

We have been evaluating ocean disposal practices to determine if sediment PCB ‘reservoirs’ might be a concern to killer whales or their Critical habitat

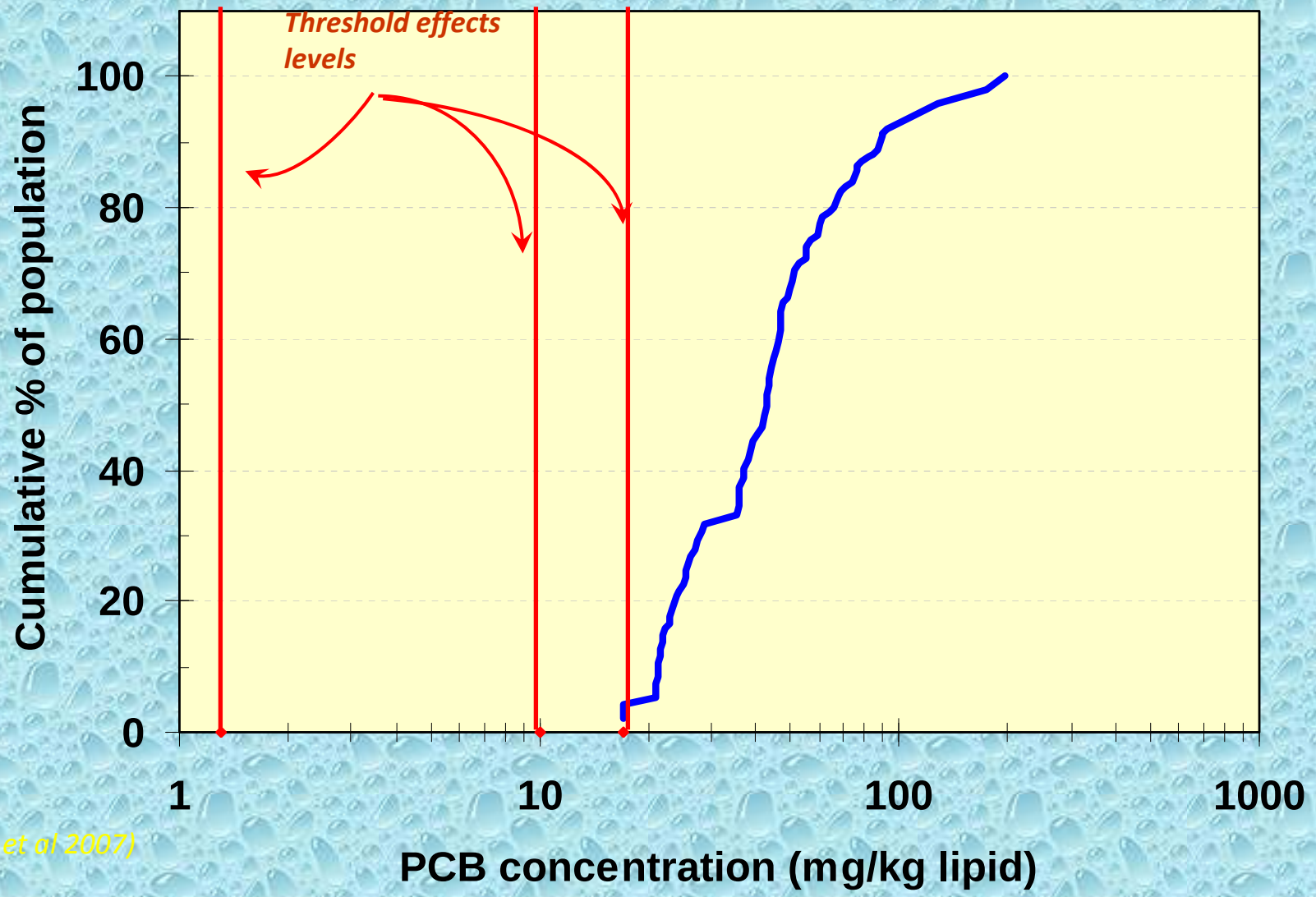




Every thing is connected

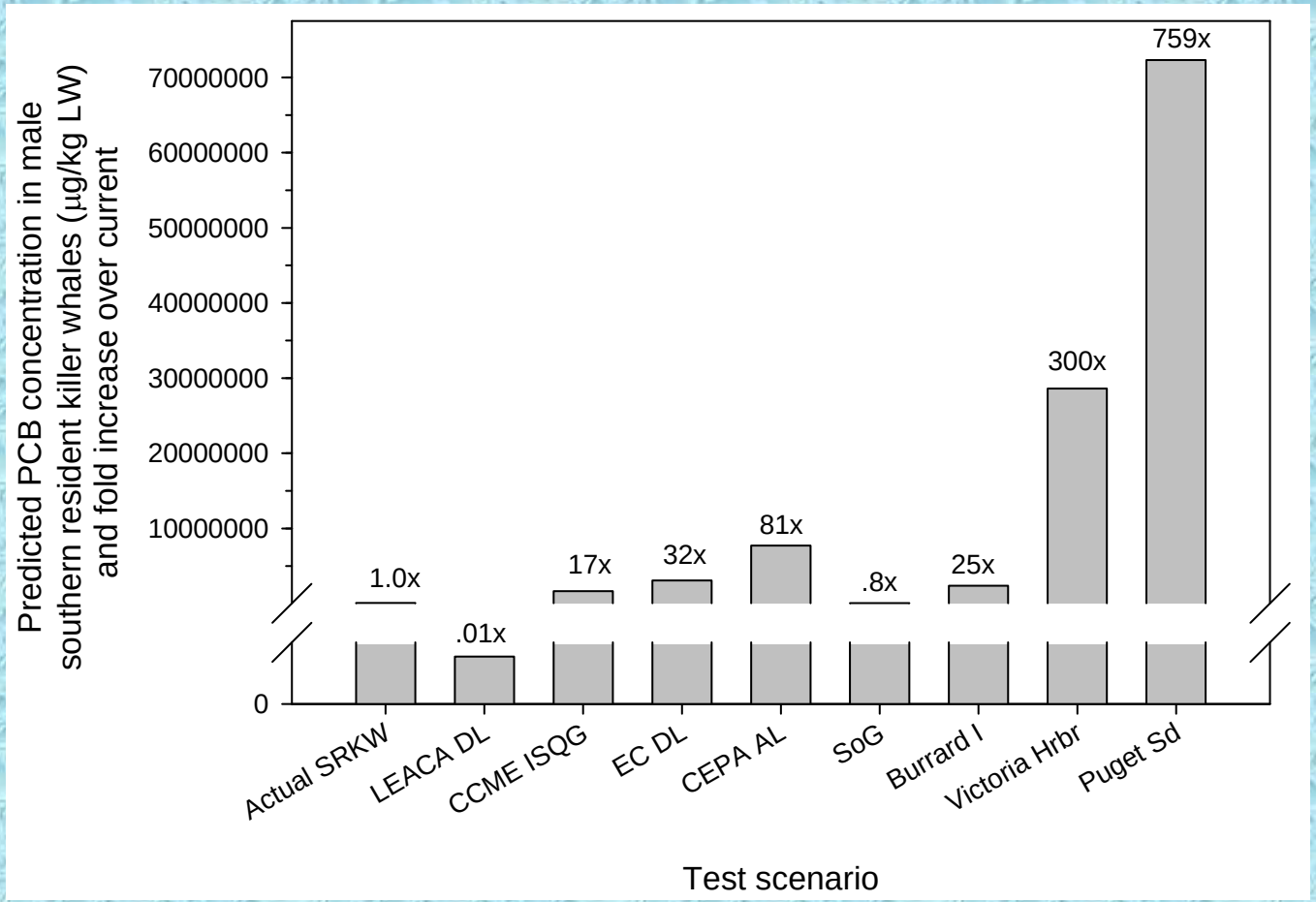


Almost all Southern Resident killer whales still exceed health effects thresholds for marine mammals: higher risk of endocrine, immune, developmental effects



(Hickie et al 2007)

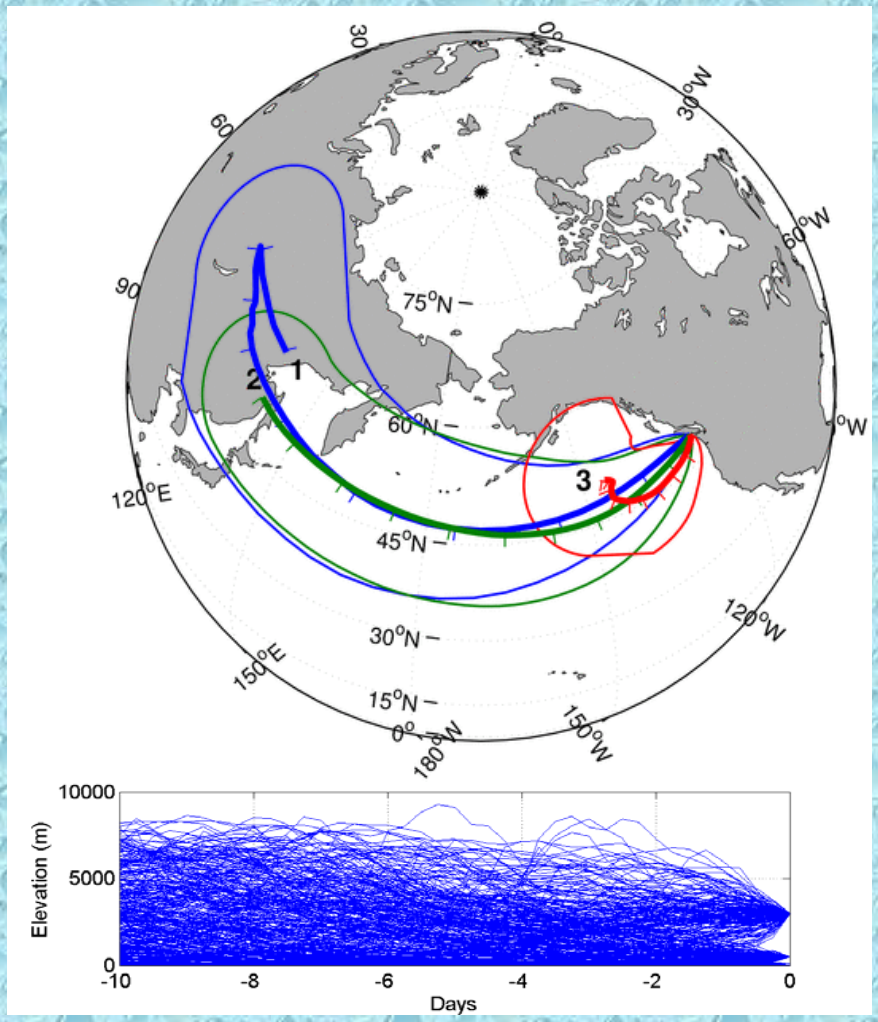
Killer whale food web modelling reveals failure of SQGs to protect killer whales (these scenarios reflect theoretical implications of a killer whale living 'above' the stated guideline)



Evaluating guidelines, laboratory practices and habitat quality. We used the model to predict what the PCB burden in a hypothetical killer whale would become if it lived in an environment where the sediments had PCB concentrations equivalent to one of eight scenarios. Numbers above each bar represent the fold-difference over the actual SRKW predicted value.

(Lachmuth et al 2010; Alava et al 2012)

Marine mammals in the North Pacific are subject to both local POP sources and a common 'global background'



- 12,000 back trajectories calculated: Prevailing air mass movement supports notion of trans-Pacific delivery of PBDEs to coastal British Columbia
- PCBs and PBDEs travel across the Pacific from the west in 5-10 days;
- 42% of back trajectories originate over Asia, consistent with our 40% of background PBDEs levels estimated for Strait of Georgia;
- These pollutants fall out and become incorporated into aquatic food webs.

(Noel et al, 2009: 10-day back trajectories, 4x per day, three elevations, two sites)

"Is it safe to eat traditional seafoods…?"

-Vancouver Island Region Wildlife Management Society letter to HC, DFO and INAC in 2005

- Concerns expressed by numerous communities about PCBs, dioxins, mercury, biological pollution and toxic algal blooms in the ocean;
- However, concern also about the loss of connection with nature's bounty as people shift towards supermarket foods;
- Can we do a better job of balancing health risks with health benefits?

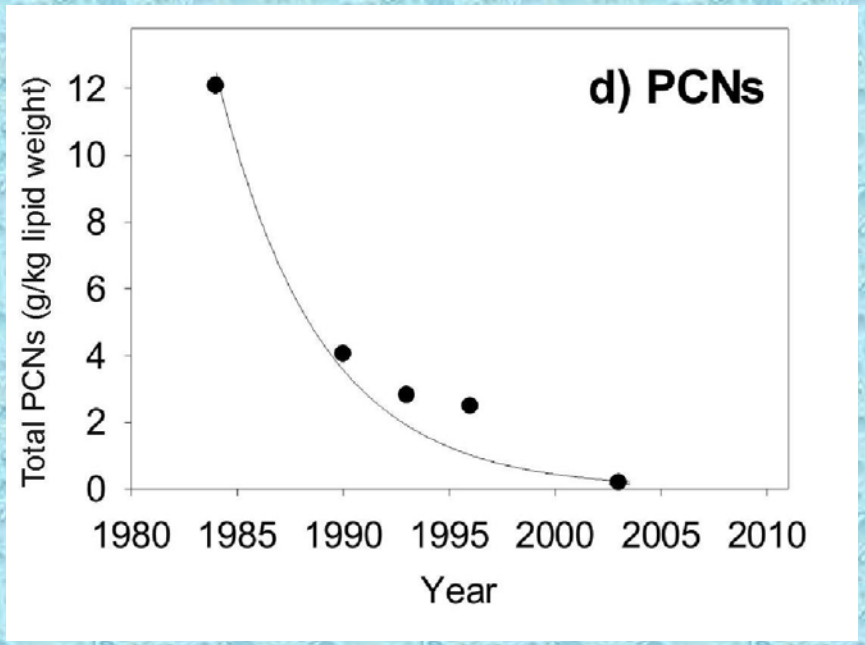
We posed three research questions:

1) How much traditional seafoods are consumed by Vancouver Island First Nations?

2) How contaminated are traditional seafoods?

3) Is it safe to eat traditional seafoods? (Questions 1 and 2 combined)

PCNs are going down



‘Structural pollutants’ present a visible and obvious threat to marine wildlife

(Mapoon Aboriginal Shire Council, 2006)

(Beach Envtal Awareness Campaign Hawaii)

Most pollutants are invisible but can cause acute or chronic effects