

# PCBs, Your Health and the World Around Us

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Environmental Stewardship Concepts

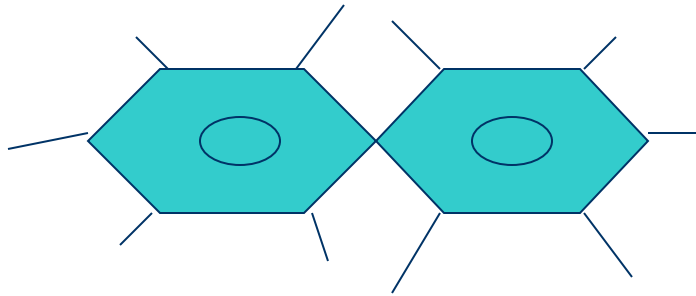
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# Goals

- Review the toxicology of PCBs.
- How do PCBs affect people?
- Do PCBs affect wildlife?
- What can we do about it?



# Effects on Humans



## Cancer

Altered hormone levels (thyroid, sex)

Skin, liver, pancreas, cardiovascular

Neurological development

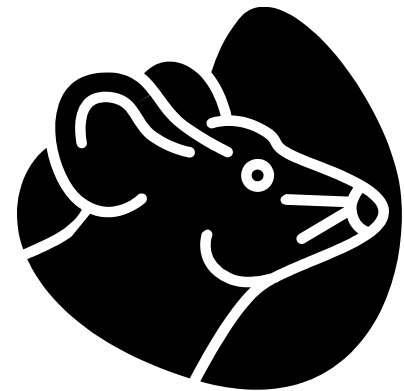
Low birth weight

## Effects on Wildlife Include:

- Reproductive impairment in fish, birds and mink
- Reproductive failure in mink
- Immune suppression in Beluga whales
- Developmental abnormalities in fish, mammals and birds

# Effects on Experimental Animals

- Reproductive impairment
- Altered hormone levels
- Cancer
- Liver dysfunction



# Experimental/ecological data

- Rats, mice, and more
- Mink
- Bald Eagle
- Tern
- Rainbow Trout
- Gulls
- *Ratus, Mus, etc.*
- *Mustela vison*
- *Haliaeetus leucocephalus*
- *Sterna forsteri*
- *Oncorhynchus mykiss*
- *Larus argentatus*

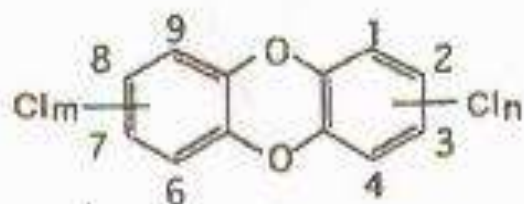
## Data: Con't:

- Spiny Brittle Star
- Snapping Turtle
- Otters
- Beluga Whale
- *Ophiocoma paucigranulata*
- *Chelydra serpentina*
- *Lutra canadensis*
- *Delphinapterus leucas*

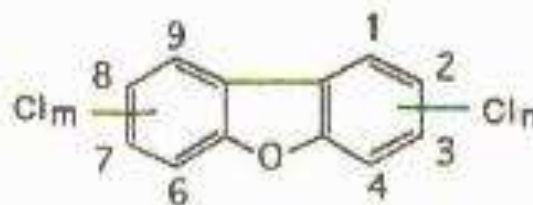
## Data Con't:

- Big Brown Bat
- Polar Bears
- African Clawed Frog
- American Robins
- Atlantic Salmon
- Blue mussels
- Soft clams
- *Eptesicus fuscus*
- *Ursus maritimus*
- *Xenopus laevis*
- *Turdus migratorius*
- *Salmo salar*
- *Mytilus edulis*
- *Mya arenaria*

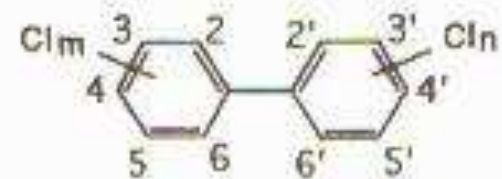
# PCDD, PCDF, and PCB Molecules:



PCDD ( $m + n = 1 \sim 8$ )



PCDF ( $m + n = 1 \sim 8$ )



PCB ( $m + n = 1 \sim 10$ )

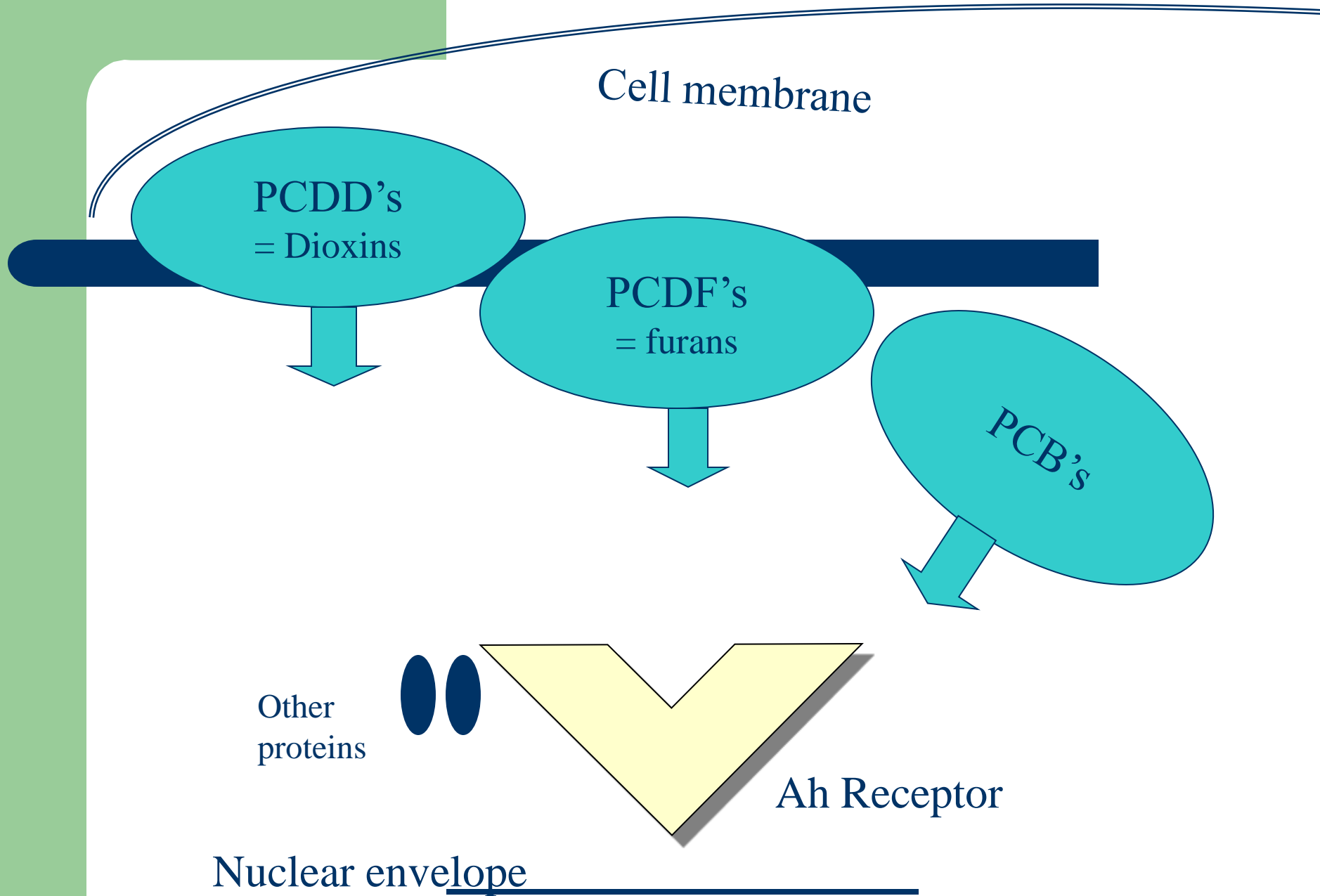
# Important properties of PCBs

- Dissolve in fats and oils, not water
- Do not break down easily, persist
- Accumulate in fatty tissues and organic matter
- Slightly volatile- form vapor in summer
- Most exposures are through food, not water
- Toxic at low levels for long periods

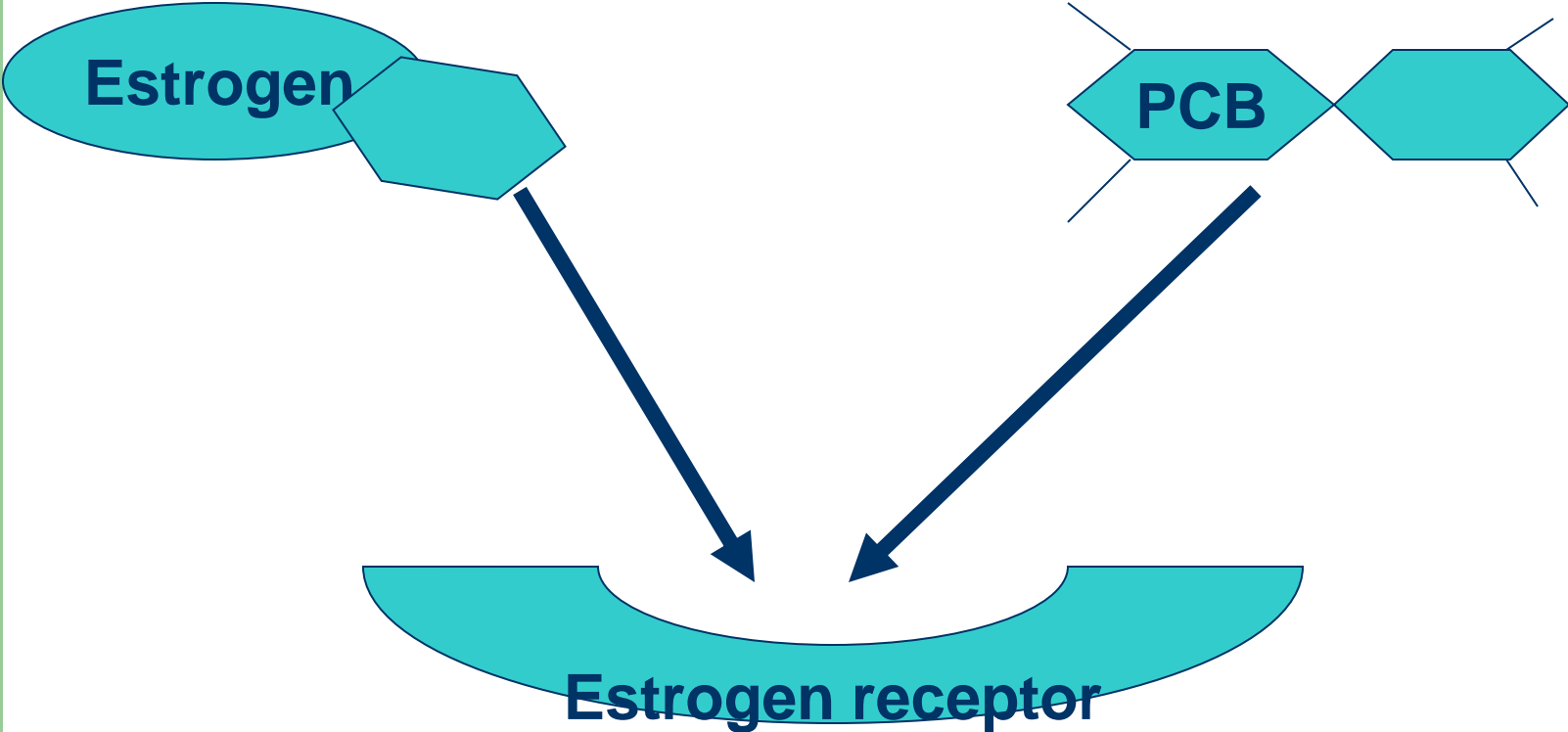
# How do PCBs Act

- Different ways of affecting living systems:
  1. Dioxin-like actions
  2. Estrogenic actions
  3. Direct actions
  4. Neurodevelopment of the brain

# Dioxin –like actions



# Estrogen – like actions



## A summary of the suggested WHO TEFs for PCDDs, PCDFs, and Dioxin-like PCBs

**Table 5.** World Health Organization toxic equivalency factors (TEFs) for humans, mammals, fish, and birds

Congener	TEF		
	Humans/mammals	Fish <sup>a</sup>	Birds <sup>a</sup>
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PentaCDD	1	1	1 <sup>b</sup>
1,2,3,4,7,8-HexaCDD	0.1 <sup>a</sup>	0.5	0.05 <sup>b</sup>
1,2,3,6,7,8-HexaCDD	0.1 <sup>a</sup>	0.01	0.01 <sup>b</sup>
1,2,3,7,8,9-HexaCDD	0.1 <sup>a</sup>	0.01 <sup>c</sup>	0.1 <sup>b</sup>
1,2,3,4,6,7,8-HeptaCDD	0.01	0.001	<0.001 <sup>b</sup>
OctaCDD	0.0001 <sup>a</sup>	<0.0001	0.0001
2,3,7,8-TetraCDF	0.1	0.05	1 <sup>b</sup>
1,2,3,7,8-PentaCDF	0.05	0.05	0.1 <sup>b</sup>
2,3,4,7,8-PentaCDF	0.5	0.5	1 <sup>b</sup>
1,2,3,4,7,8-HexaCDF	0.1	0.1	0.1 <sup>b,d</sup>
1,2,3,6,7,8-HexaCDF	0.1	0.1 <sup>d</sup>	0.1 <sup>b,d</sup>
1,2,3,7,8,9-HexaCDF	0.1 <sup>a</sup>	0.1 <sup>c,d</sup>	0.1 <sup>d</sup>
2,3,4,6,7,8-HexaCDF	0.1 <sup>a</sup>	0.1 <sup>d,e</sup>	0.1 <sup>d</sup>
1,2,3,4,6,7,8-HeptaCDF	0.01 <sup>a</sup>	0.01 <sup>e</sup>	0.01 <sup>e</sup>
1,2,3,4,7,8,9-HeptaCDF	0.01 <sup>a</sup>	0.01 <sup>c,e</sup>	0.01 <sup>e</sup>
OctaCDF	0.0001 <sup>a</sup>	<0.0001 <sup>c,e</sup>	0.0001 <sup>e</sup>
3,4,4',5-TetraCB (81)	0.0001 <sup>a,c,d,e</sup>	0.0005	0.1 <sup>c</sup>
3,3',4,4'-TetraCB (77)	0.0001	0.0001	0.05
3,3',4,4',5-PentaCB (126)	0.1	0.005	0.1
3,3',4,4',5,5'-HexaCB (169)	0.01	0.00005	0.001
2,3,3',4,4'-PentaCB (105)	0.0001	<0.000005	0.0001
2,3,4,4',5-PentaCB (114)	0.0005 <sup>a,d,e,f</sup>	<0.000005 <sup>e</sup>	0.0001 <sup>g</sup>
2,3',4,4',5-PentaCB (118)	0.0001	<0.000005	0.00001
2',3,4,4',5-PentaCB (123)	0.0001 <sup>a,d,f</sup>	<0.000005 <sup>e</sup>	0.00001 <sup>g</sup>
2,3,3',4,4',5-HexaCB (156)	0.0005 <sup>d,e</sup>	<0.000005	0.0001
2,3,3',4,4',5'-HexaCB (157)	0.0005 <sup>d,e,f</sup>	<0.000005 <sup>d,e</sup>	0.0001
2,3',4,4',5,5'-HexaCB (167)	0.00001 <sup>a,f</sup>	<0.000005 <sup>e</sup>	0.00001 <sup>g</sup>
2,3,3',4,4',5,5'-HeptaCB (189)	0.0001 <sup>a,d</sup>	<0.000005	0.00001 <sup>g</sup>

Abbreviations: CDD, chlorinated dibenzodioxins; CDF, chlorinated benzofurans; CB, chlorinated biphenyls; QSAR, quantitative structure–activity relationship.

<sup>a</sup>Limited data set.

<sup>b</sup>*In vivo* CYP1A induction after *in vivo* exposure.

<sup>c</sup>*In vitro* CYP1A induction.

<sup>d</sup>QSAR modeling prediction from CYP1A induction (monkey, pig, chicken, or fish).

<sup>e</sup>Structural similarity.

<sup>f</sup>No new data from 1993 review (1).

<sup>g</sup>QSAR modeling prediction from class specific TEFs.

# Key differences in TEFs

● PCB	human	fish	birds
● 4-PCB	0.0001	0.0005	0.1
● 5-PCB	0.1	0.005	0.1
● 6-PCB	0.01	0.00001	0.001
● TCDF	0.1	0.05	1.0

# Effects on Mink

- Reproductive failure
- Wild populations declined or lost
- Fish consumption is key pathway
- Great Lakes

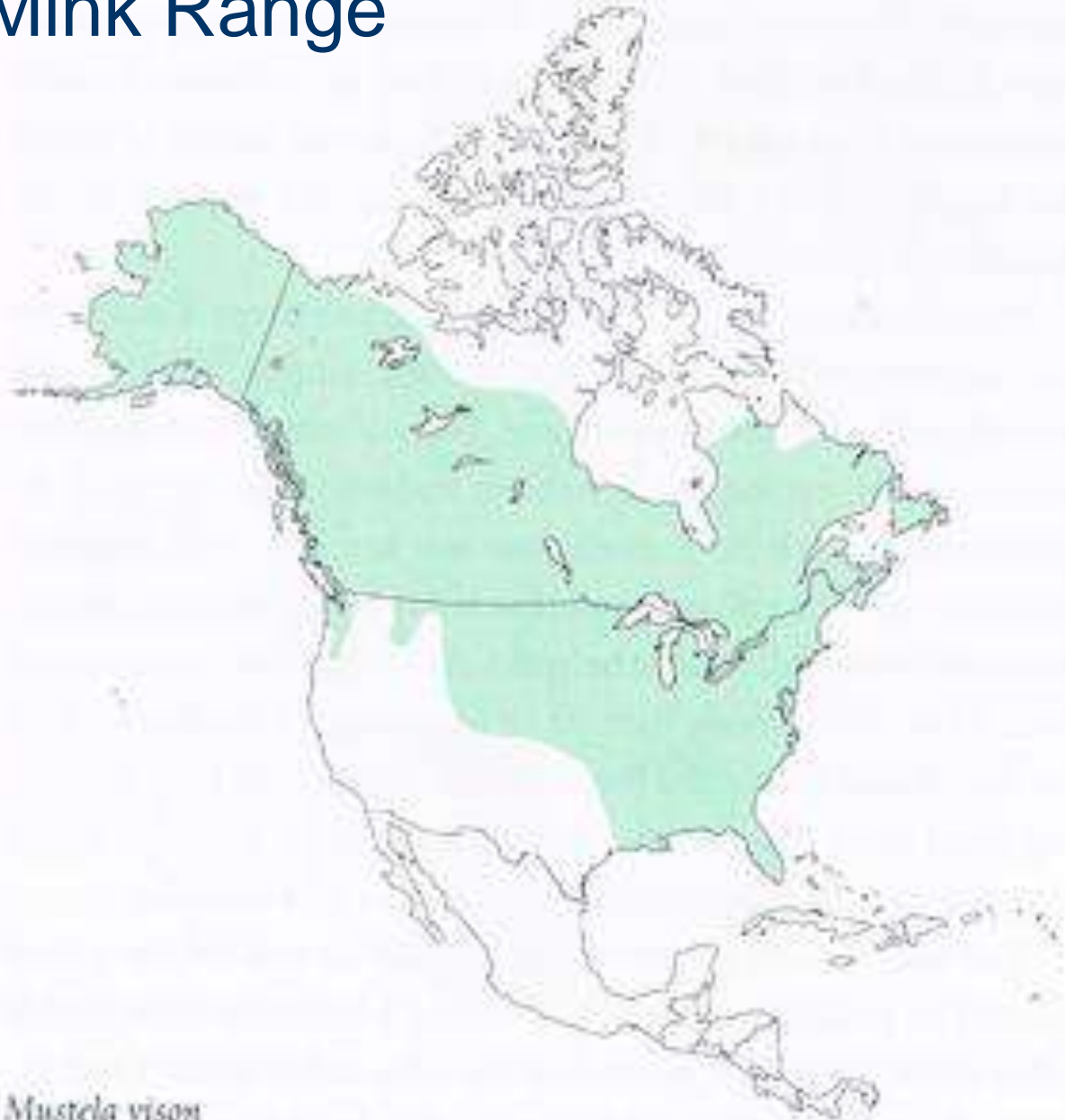
# Mink:



# River Otters



# Mink Range

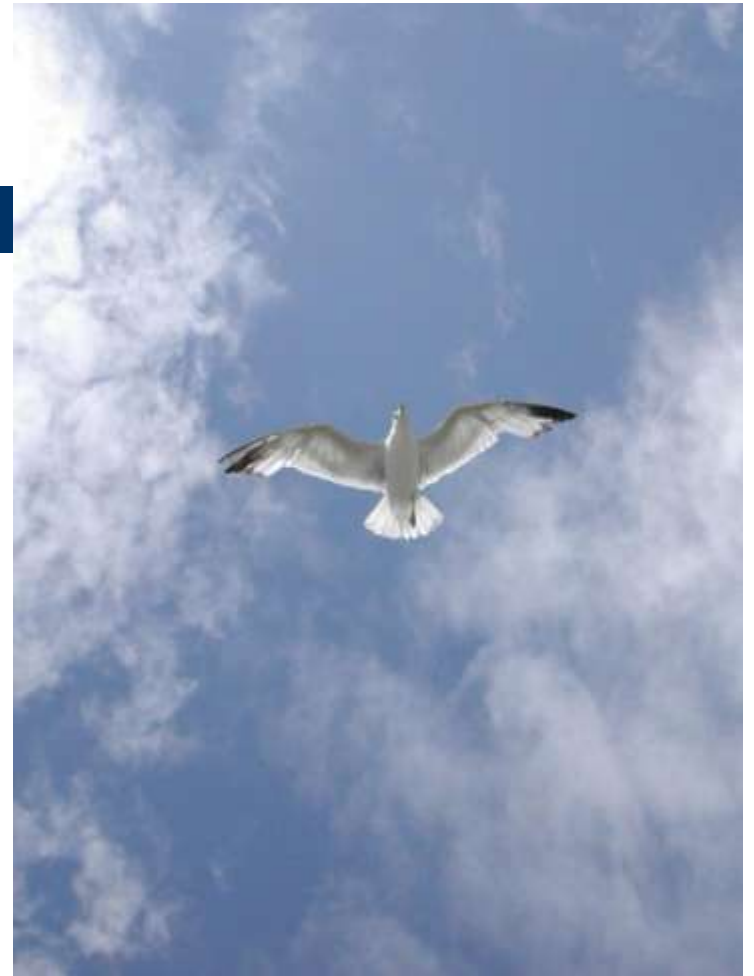


*Mustela vison*

# Effects on Bird Species

- Mortality
- Population declines and limitations
- Developmental abnormalities
- Behavioral abnormalities
- Still food contamination





Gulls



Bald Eagle

Tern



# Effects on Fish

- Developmental abnormalities
- Population declines
- Behavioral problems?
- Mortality
- Migration

Rainbow Trout



# PCBs in Lake trout in Great Lakes

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PRINCIPLES AND PROCESSES FOR EVALUATING ENDOCRINE DISRUPTION

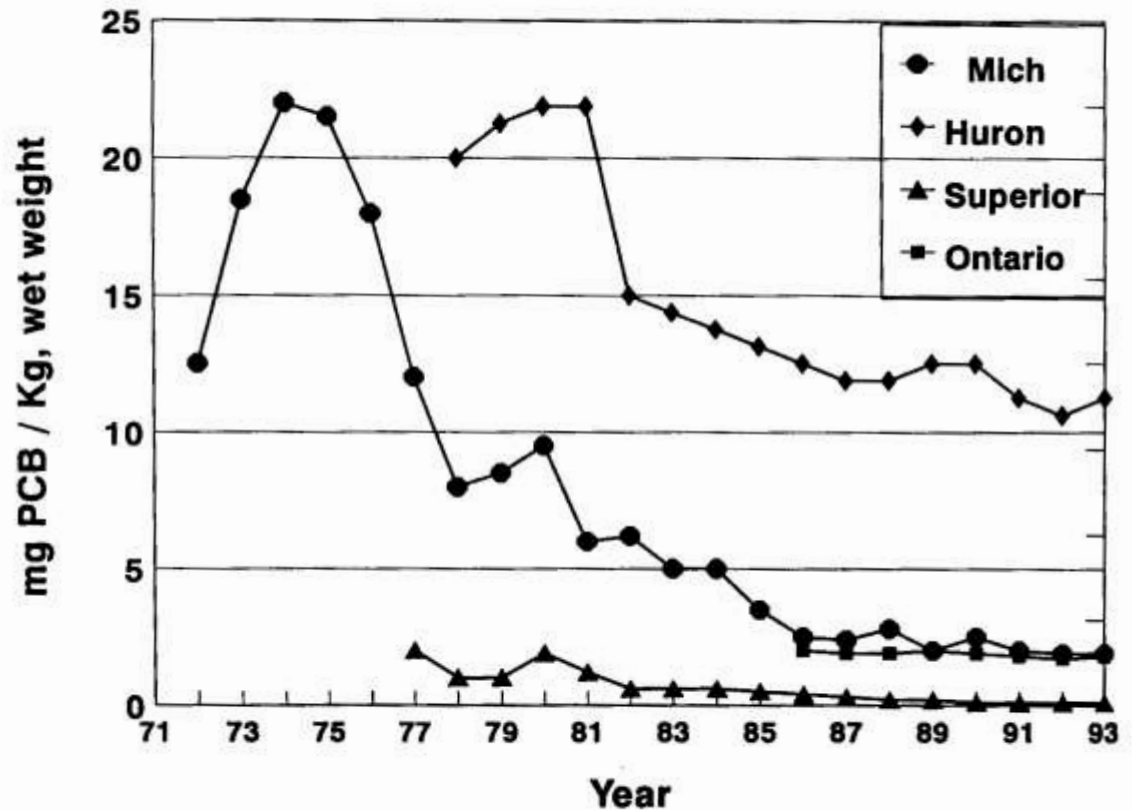


Figure 8-2

Mean total concentrations of PCBs (reported as mg total PCB/kg, w/w) in whole lake trout from North American Great Lakes, 1972–1990. Reprinted with permission from *Michigan Fish Contaminant Monitoring Program 1994 Annual Report*.



Blue Sac Disease

# Beluga whales

- Compounds that dissolve in fat
- Immune system impairment
- Developmental problems

Beluga Whale





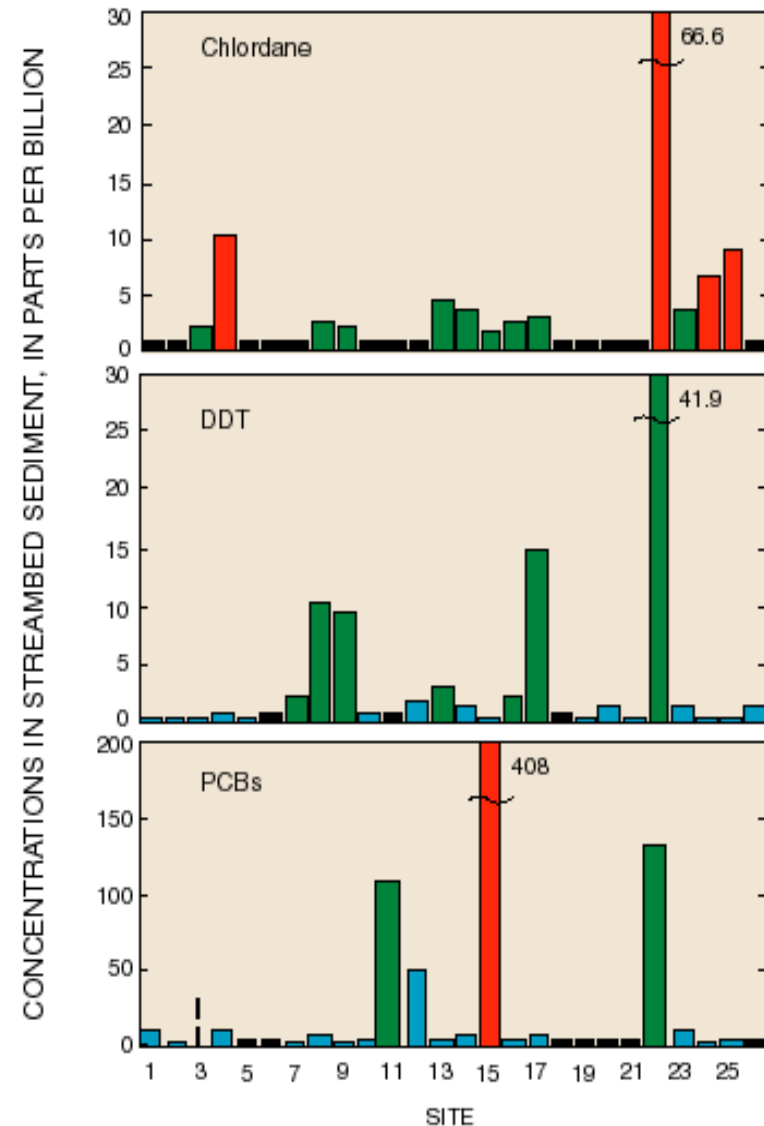
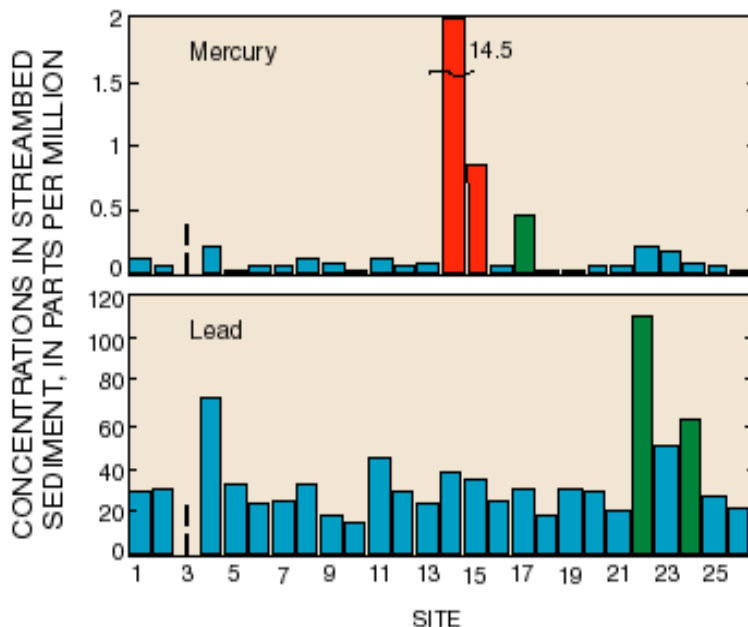
# Chronological Examination of Human Exposure

- **1929-** PCBs first introduced
- **1938-** First DDT manufactured
- **WWII (1939-45)-** First widespread human exposure to chemicals
- **1940-50-** First generation exposed postnatally
- **1950-70-** First generation exposed in the womb
- **1970-2000-** First generation exposed in the womb reaches reproductive age

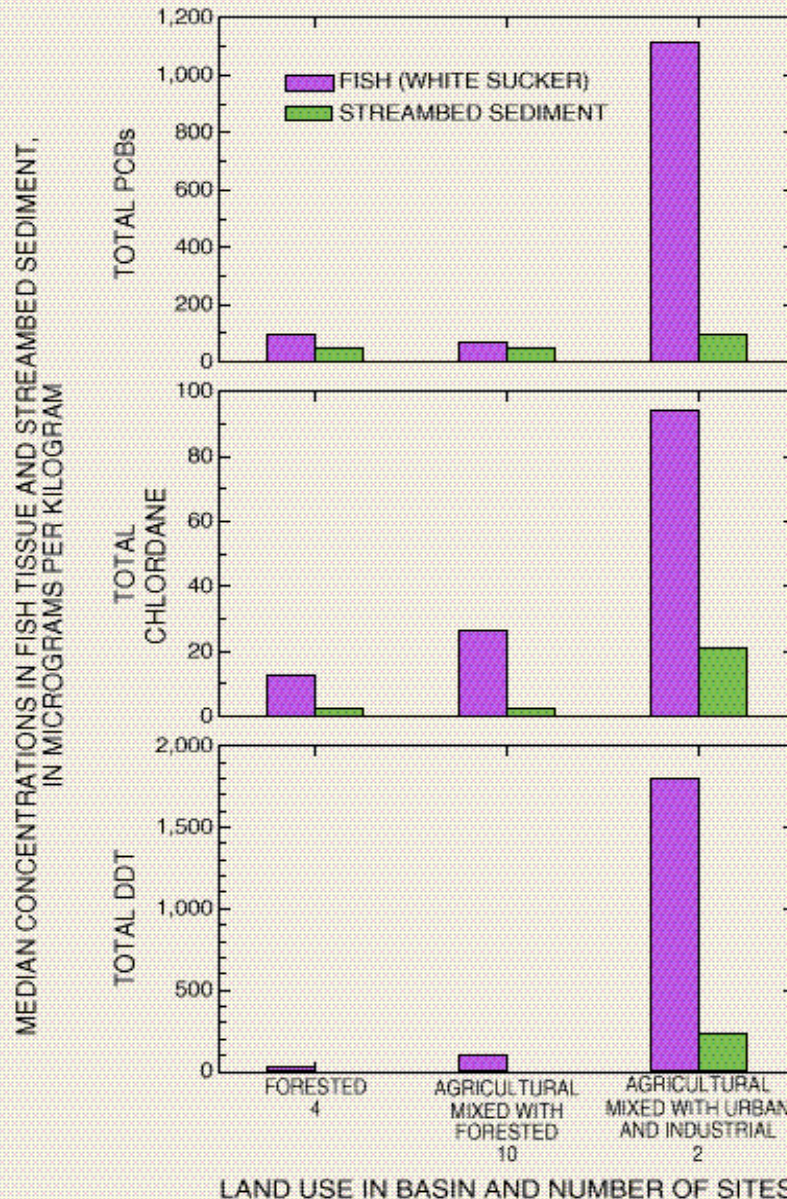
## EXPLANATION

Probability of organic contaminants or metals in streambed sediment causing adverse effects on aquatic life — Mercury and lead concentrations were adjusted for particle-size distribution for screening purposes

- High
- Intermediate
- Low
- Not detected
- Not sampled
- △ Site location and number



# Fish Tissue and Sediment Levels of PCBs etc.

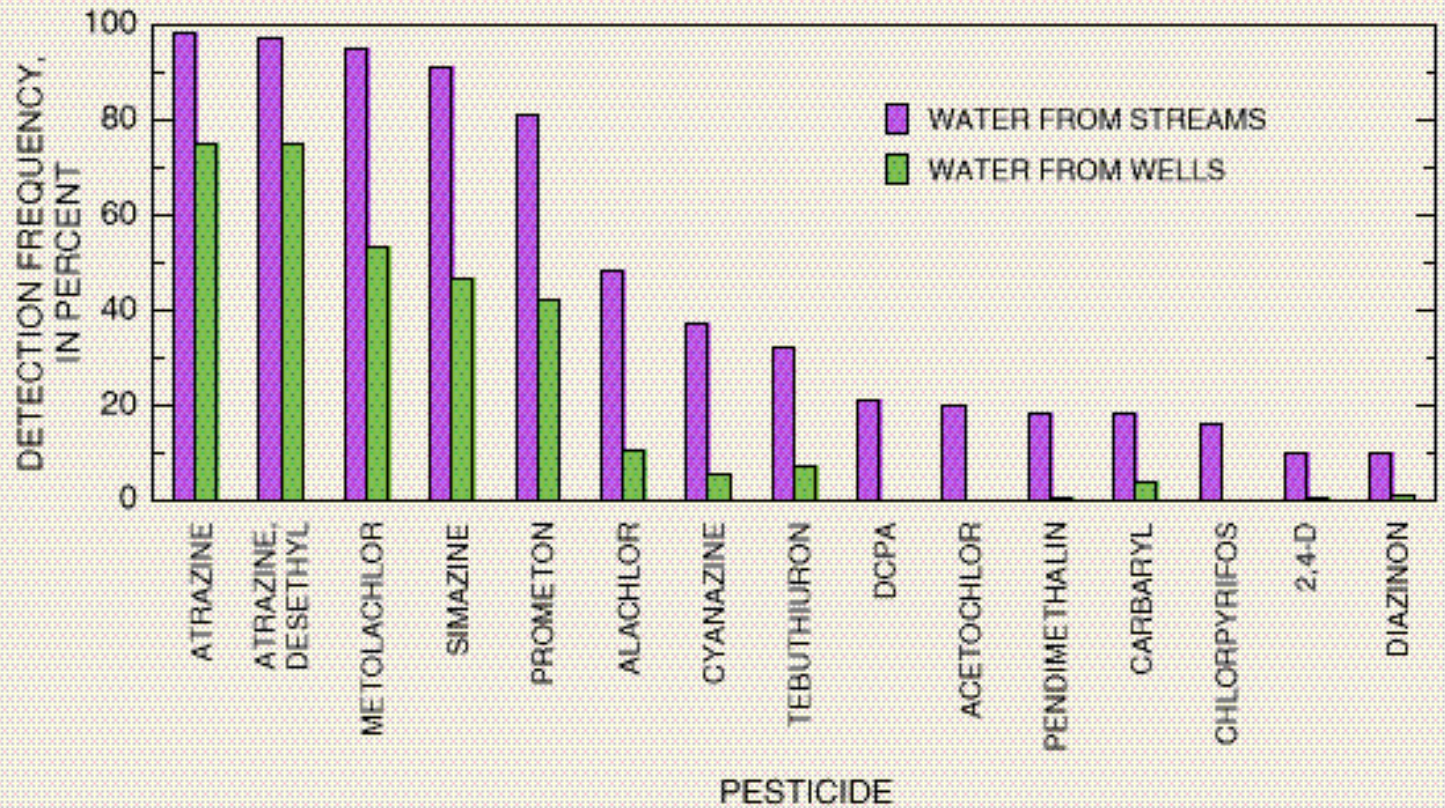


Median concentrations of total organochlorine pesticides and total PCBs in white sucker tissue and streambed sediment are grouped by the predominant land use in the basin to illustrate the effects of land use.

Sites representing basins with a mixture of agricultural, urban, and industrial land uses had the highest concentrations of total PCBs, total DDT, and total chlordane. PCB concentrations were associated with the highest percentages of urban land use, and DDT and chlordane were associated with the highest percentages of agricultural land use.

(3 large river sites not included)

# PCBs Occur with Pesticides in the Environment



The six most frequently detected pesticides were the same for water from wells and water from streams.

## Herbicides:

2,4-D  
2,4,5-T  
Alachor  
Amitrole  
Atrazine  
Metribuzin  
Nitrofen  
Trifluralin

## Fungicides:

Benomyl  
Ethylene thioura  
Fenarimol  
Hexachlorobenzene  
Mancozeb  
Maneb  
Metriam-complex  
Tri-butl-tin  
Vinclozolin  
Zineb  
Ziram

## Insecticides:

Beta-HCH  
Cabaryl  
Dicofol  
Dieldrin  
DDT and metabolites  
DDE  
Endosulfan  
Heptachlor/ H-expoide  
Lindane  
Methomyl  
Methoxychlor  
Mirex  
Oxychlorane  
Parathion  
Synthetic pyrethroids  
Transnonachlor  
Toxaphene

## Nematocides:

Aldicarb  
DBCB

## Industrial Chemicals:

BPA  
BHA  
Cadmium  
Dioxins  
Furans  
Lead  
Methyl Mercury  
PBBs  
PCBs  
PCP  
Phenols  
Phthalates  
Styrene  
And many more...

**All Disrupt**  
**Endocrine and/or**  
**Reproductive**  
**Systems!**

# Neurotoxicology

Jacobson Series 1983-1992

Prenatal human

Rogan et al. 1986

Prenatal human

Lilienthal & Winneke 1991

Prenatal Rats

Tilson et al. 1990

Human model (more sensitive)

# Lake Ontario Findings

“The findings of poorer reflex functioning and greater autonomic immaturity from the high-fish group are consistent with Jacobson’s findings... these babies are more reactive to unpleasant events than non-exposed babies in an additional test.”

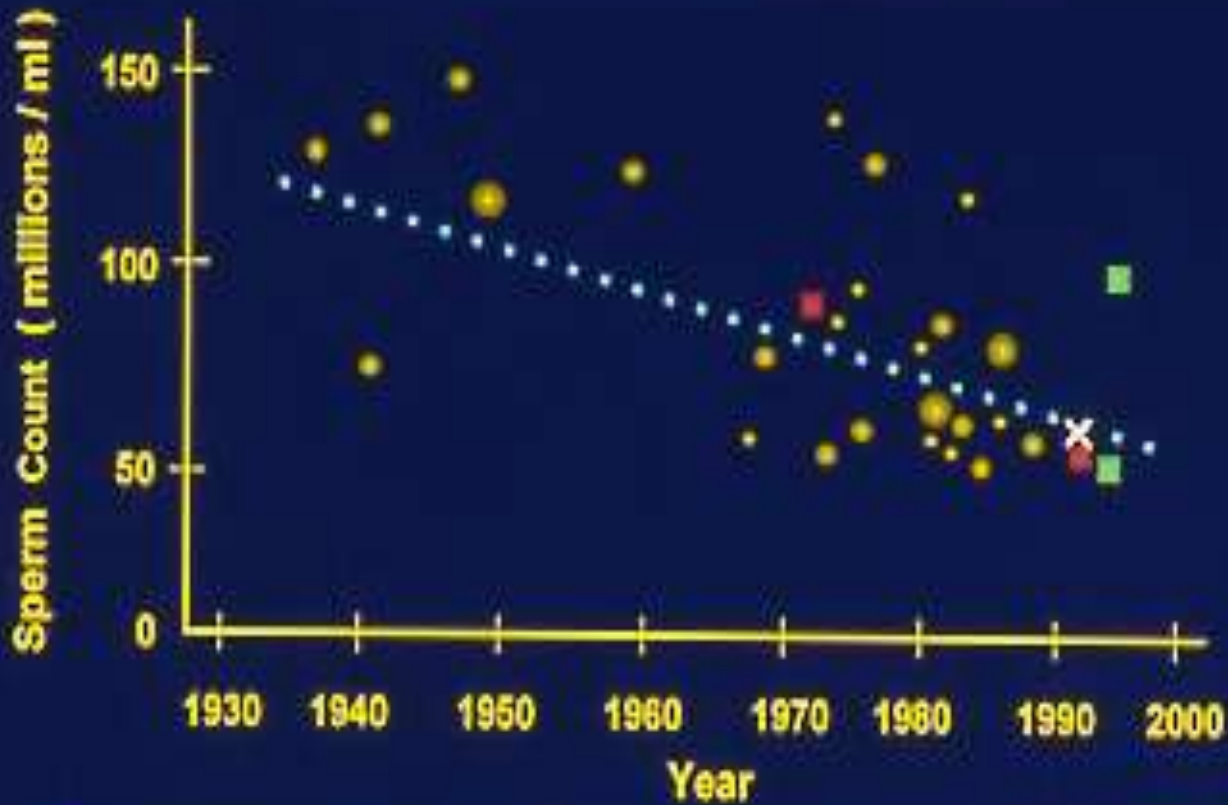
-Jacobson 1983-92



# Dioxin affects male reproduction

- PCBs and dioxin can act through the same mechanism
- R. Peterson and Co-workers at Univ Wisconsin (1992, Advan Modern Environ Toxicol).
- Dosed pregnant rats on day 15 of gestation
- Male offspring- reproductive problems that include structure, function, behavior

## CHANGES IN SPERM COUNT



Carlson, et al., 1992

Abell, et al., 1994

Auger, et al., 1995

# Scope of Contamination

- EPA has identified 934 waterways impaired by PCBs
- TMDLs in place for 107
- EPA evaluating at least 60 contaminated sites across the country
- Many more examined at the state level

# Summary and Conclusions

- PCBs are widespread globally and most abundant in aquatic sediments
- PCBs persist and accumulate
- Low levels continue to affect mink, fish and birds
- PCBs occur with pesticides, metals and other organic contaminants

# What are we going to do next

- GE/ EPA corrective Measures Study – the CSM– March 26 in CT and March 27 in MA
- Will propose cleanup activities
- Expect nothing in Connecticut and very little in Southern Mass
- Anticipate “Natural Recovery”

# Partial Bibliography

- Kendall, Ronald; Dickerson, Richard; Giesy, John; Suk, William. 1998. Principles and Processes for Evaluating Endocrine Disruption in Wildlife. Pensacola: SETAC Press,
- Rolland, Rosalind M.; Gilbertson, Michael; Peterson, Richard E. 1997. Chemically Induced Alterations in Functional Development and Reproduction of Fishes. Pensacola: SETAC Press,
- deFur, Peter L.; Crane, Mark; Ingersoll, Christopher; Tattersfield, Lisa. 1999. Endocrine Disruption in Invertebrates: Endocrinology, Testing, and Assessment. Pensacola: SETAC Press,

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