



**Contaminants Past, Contaminants Future:
The Unique Story of Lake Superior**

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A Jewel among Jewels



- **Contains 10% of world's fresh water**
- **Has largest surface of any lake in world**
- **Is third-largest lake in world by volume**
- **Holds more than half water in Great Lakes**
- **Has retention time of 190 yrs**
- **Has busiest seaport in Great Lakes**

With European Settlement Came Pollution

- Land clearing and settlement
- Sewage discharges
- Industrial expansion



Organochlorine Contaminants

Fish

- 1965-68: DDT
- 1967-68: chlordane, dieldrin, lindane
- 1970-71: PCBs

Water

- 1972: PCBs
- 1974-75: PCBs, DDT, lindane, endrin
heptachlor, chlordane, methoxychlor

Long Range Atmospheric Transport



Siskiwit Lake on Isle Royale



Image © 2007 TerraMetrics
Image © 2007 DigitalGlobe

Image NASA

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Siskiwit Lake on Isle Royale

Journal of Great Lakes Research 1978, 4, 398-407

Wayland R. Swain

“Chlorinated Organic Residues in Fish Water and Precipitation from the Vicinity of Isle Royale, Lake Superior”

Environ. Sci. Technol. 1988, 22, 543-548

Deborah L. Swackhamer and Ronald A. Hites

“Occurrence and Bioaccumulation of Organochlorine Compounds in Fishes from Siskiwit Lake, Isle Royale, Lake Superior”

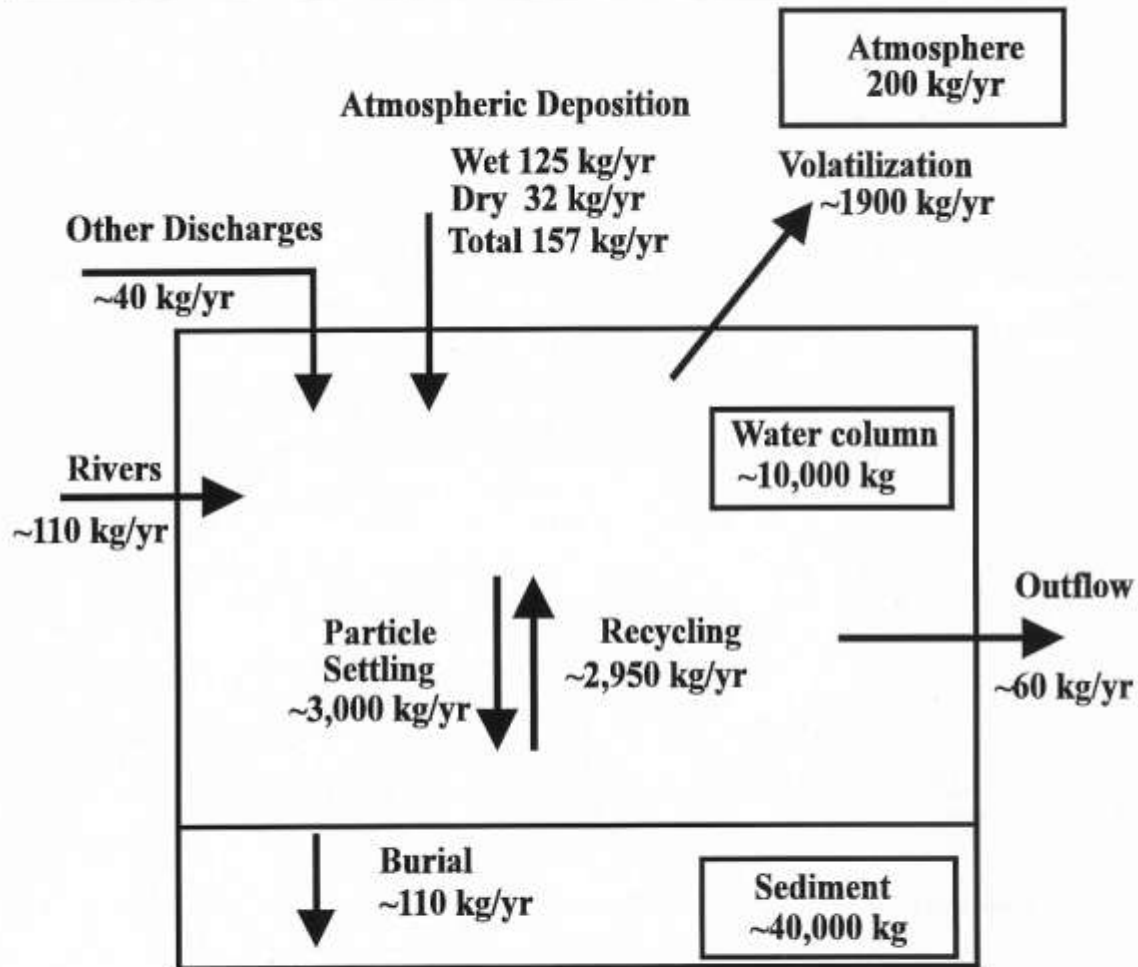
Compounds Found all from atmosphere

- PCBs
- DDT
- PeCB
- HCB
- HCH
- OCS
- Dieldrin
- Dachthal
- Pentachloroanisole
- Oxychlordane
- Chlordane
- Nonachlor
- Heptachlor Epoxide
- Toxaphene
- Mirex
- PCDE -10
- Endosulfan
- PCDD/DFs

Why is Lake Superior so Susceptible?

- Large surface area
- Cold water
- Low sedimentation rate
- Long water retention times
- Continental wind patterns

PCB Budget for Lake Superior, 1986



1st Order Loss Rate = -0.20 yr^{-1}

1986 1st Order Loss = ~1,800 kg

1992 1st Order Loss = ~400 kg

Effects of PBTs



Congenital Malformations in Young Fish-eating birds in Great Lakes, 1971-1985



Species:

Double-Crested Cormorant
Herring Gull
Ring-Billed Gull
Forsters' Tern
Common Tern
Caspian Tern
Virginia Rail

Areas of Concern in the Great Lakes - St. Lawrence River Basin



- Legend**
- Canada
 - U.S.A.
 - Delisted AOC
 - Connecting Channels

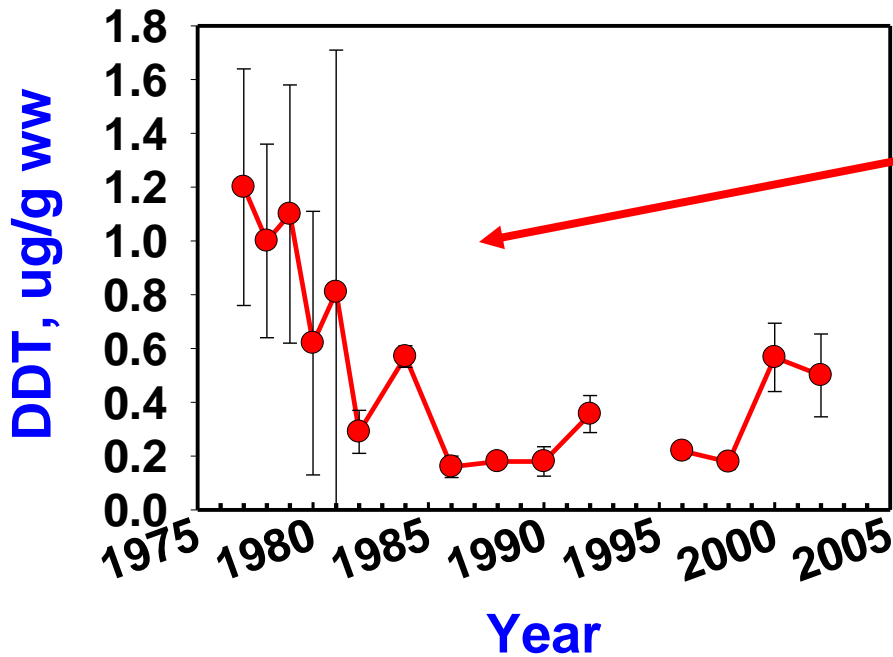
50 0 250 km



Areas of Concern: Superior



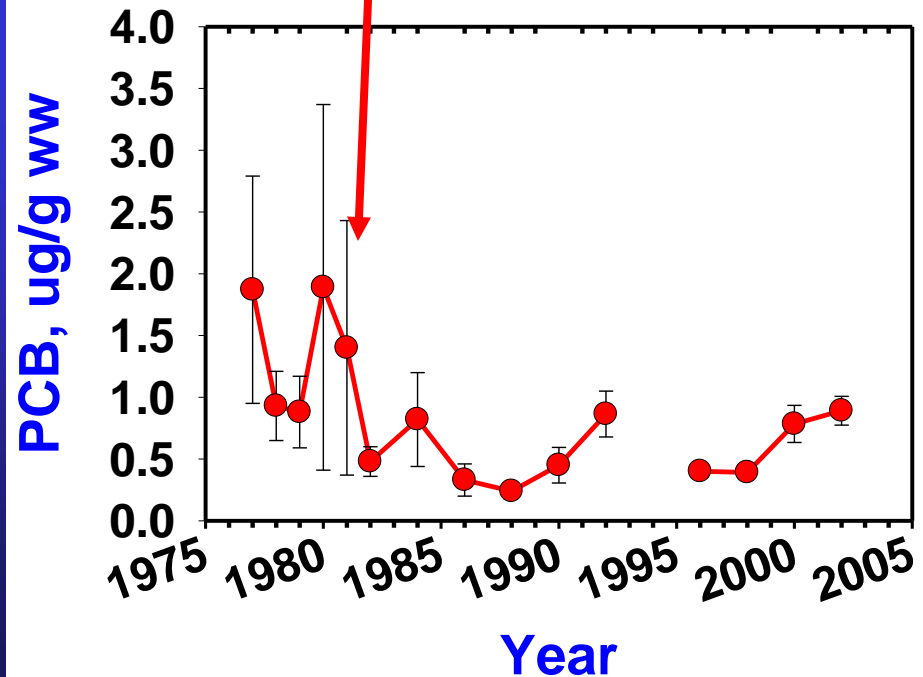
Lake Superior Lake Trout



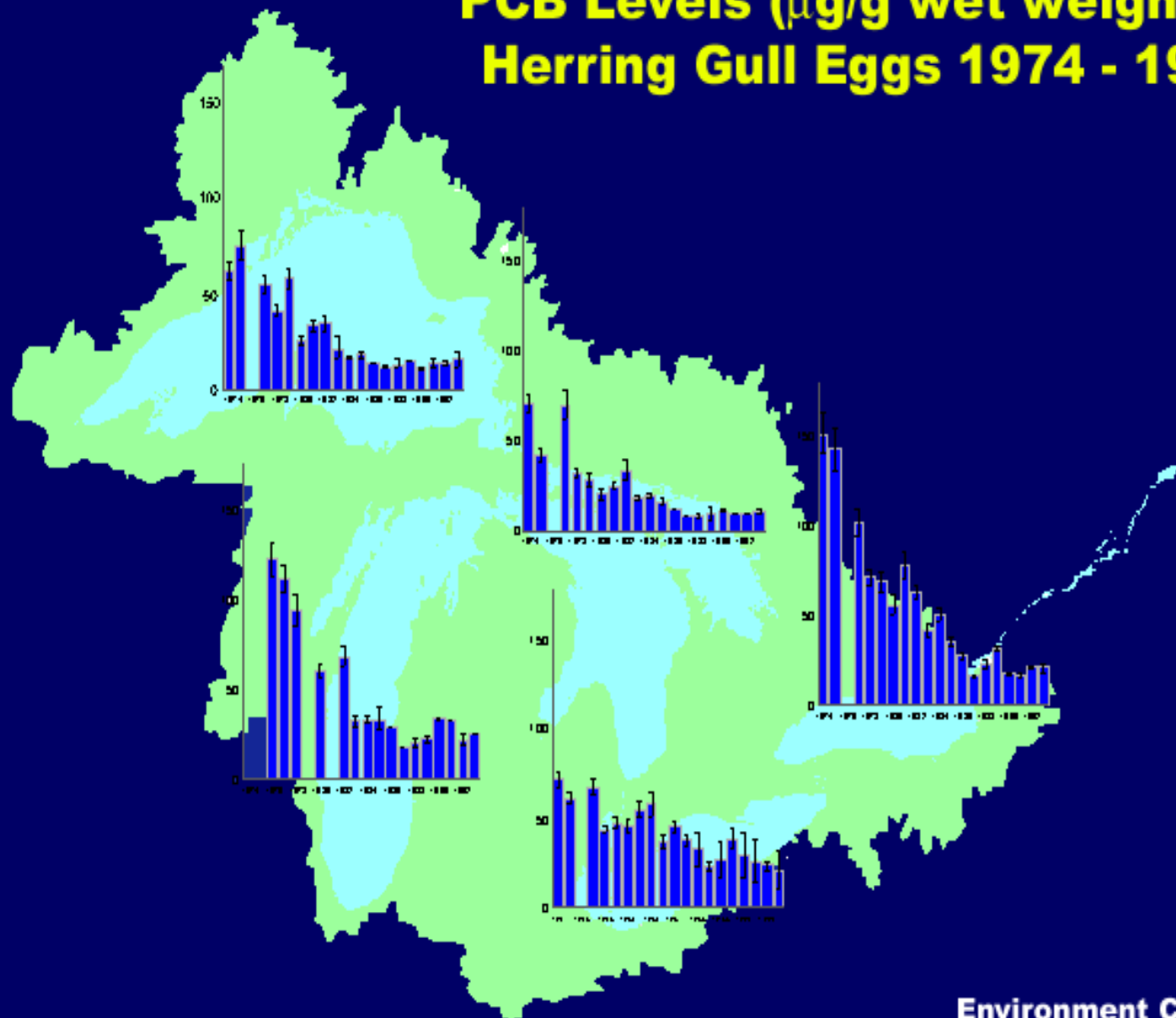
1977-1988:

$T_{1/2} = 3-4$ yr

Decline has
slowed since 1990



PCB Levels ($\mu\text{g/g}$ wet weight) in Herring Gull Eggs 1974 - 1993

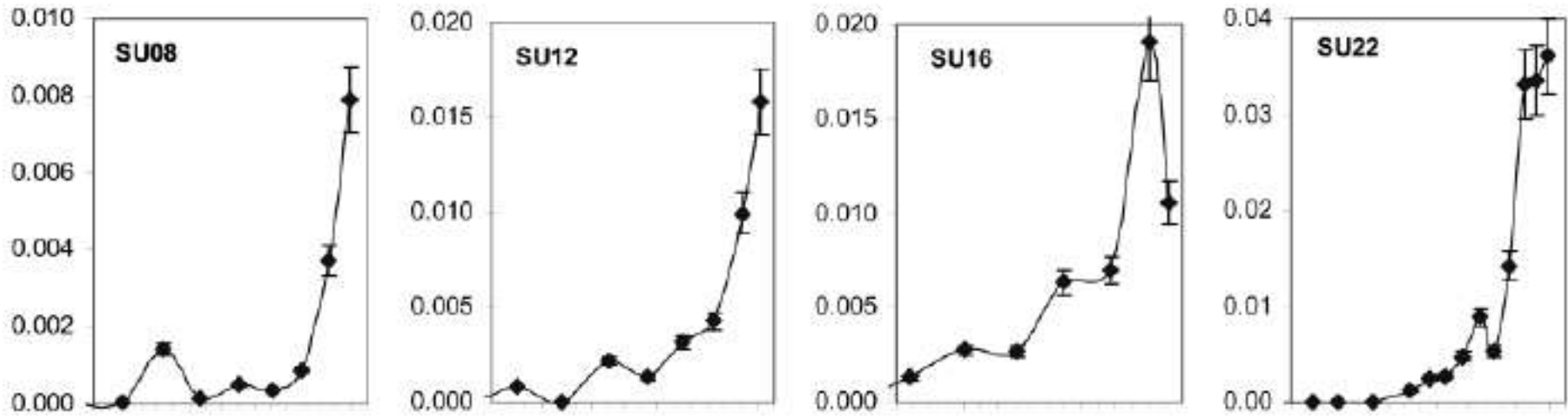


“Emerging” Contaminants

of Emerging Concern – not “new”

- Flame Retardants
 - PBDEs
- Fluorinated Surfactants
 - PFOS, PFOA
- Personal Care Products
 - Triclosan
- Pharmaceuticals
 - Hormones, OTCs
- Detergent additives
 - Alkyl phenols
- Plasticizers
 - Bisphenol-a
- Current-use pesticides
 - Methoxychlor, DEET
- Industrial compounds
 - SCCPs

PBDEs in Lake Superior Sediments: 1840-2000



Emerging Effects

Such as.....Endocrine disruption

Fish, wildlife, birds, humans

- Reproductive impairment
- Metabolism effects
- Developmental deficits
- Behavior effects
- Growth effects



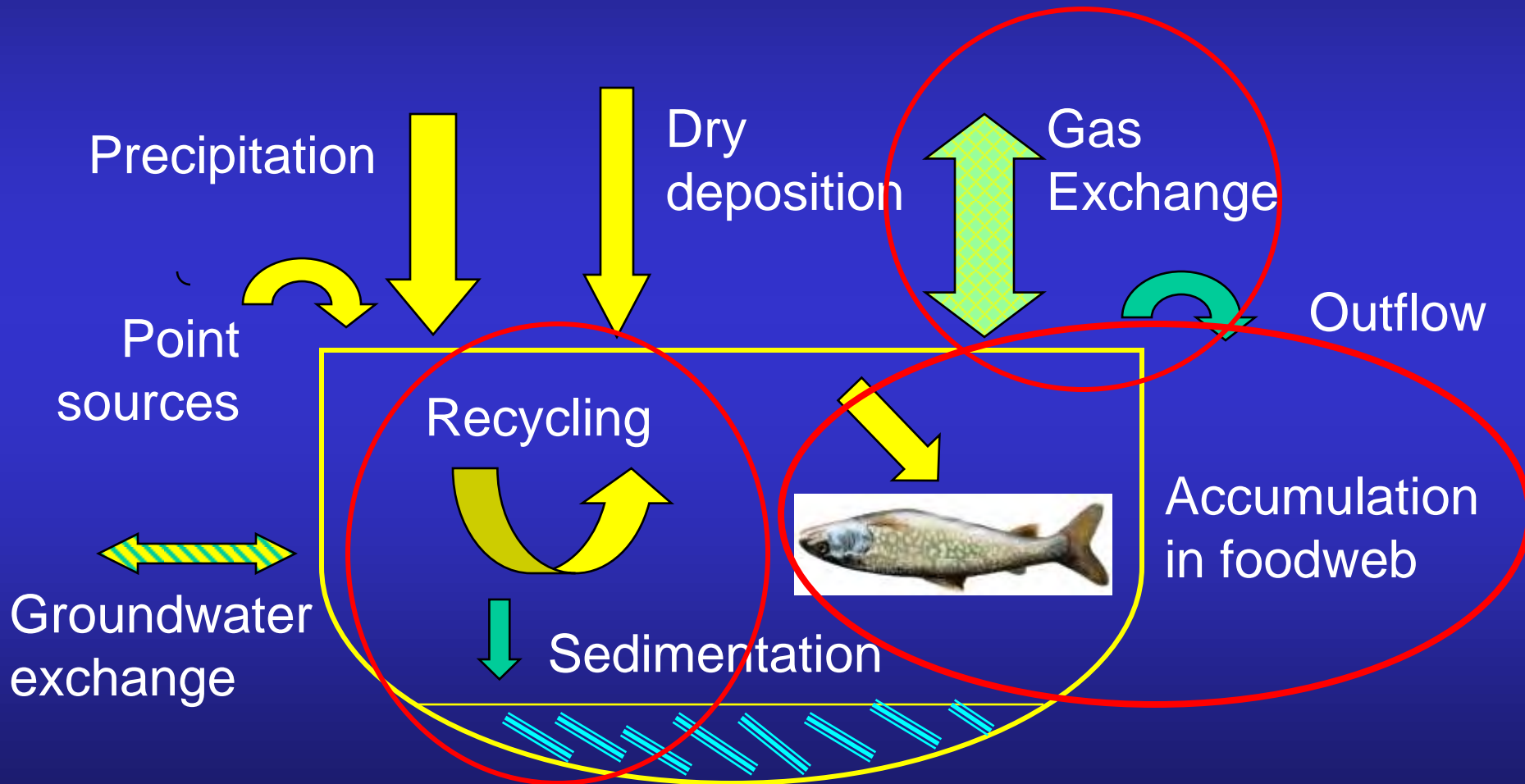
What makes Lake Superior so different?

- Largest surface area
- Ultra-oligotrophic, lowest productivity
- Lowest sedimentation rate
- Lowest particulate concentrations, all biogenic and mostly microbes
- Coldest

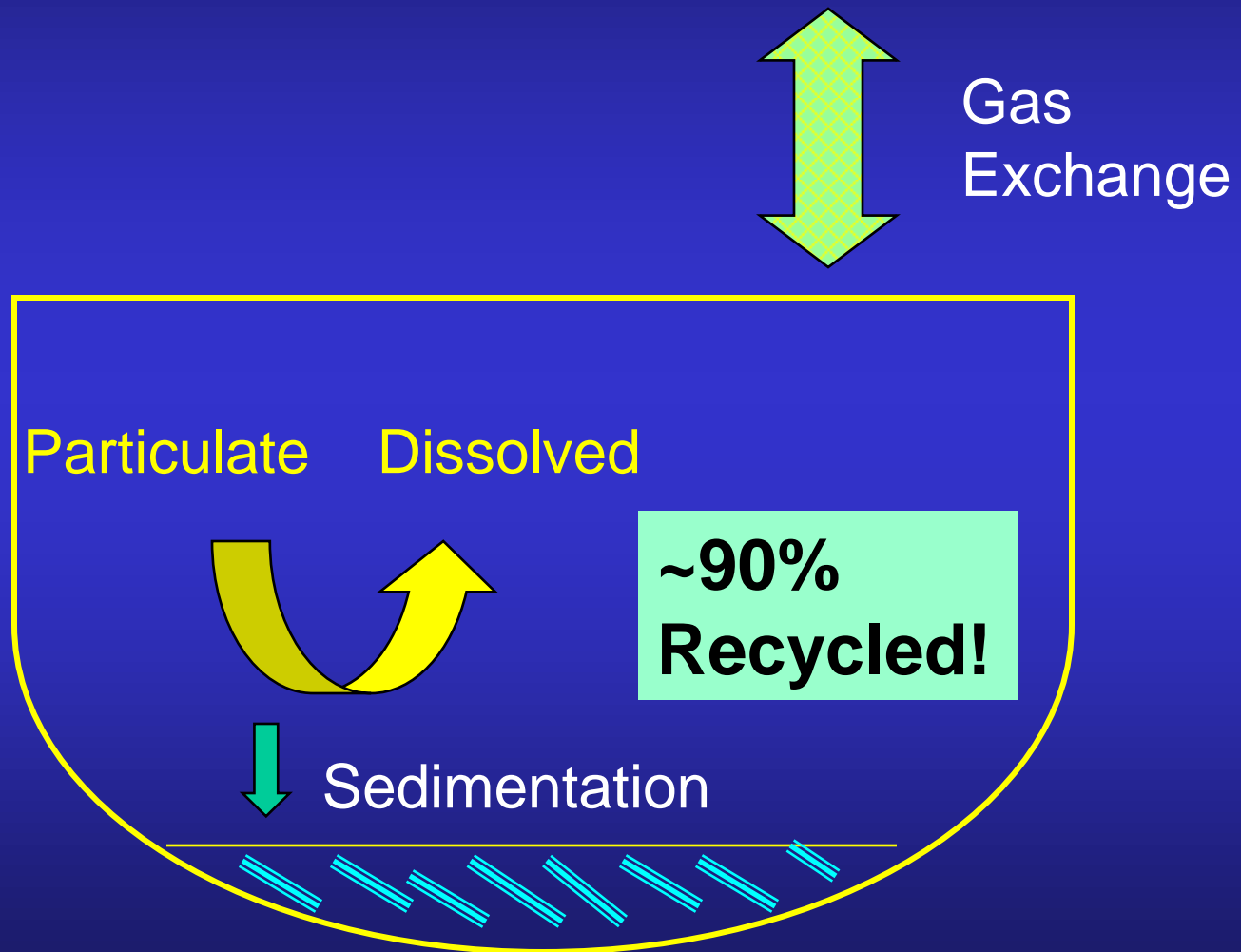


**Superior processes
contaminants differently**

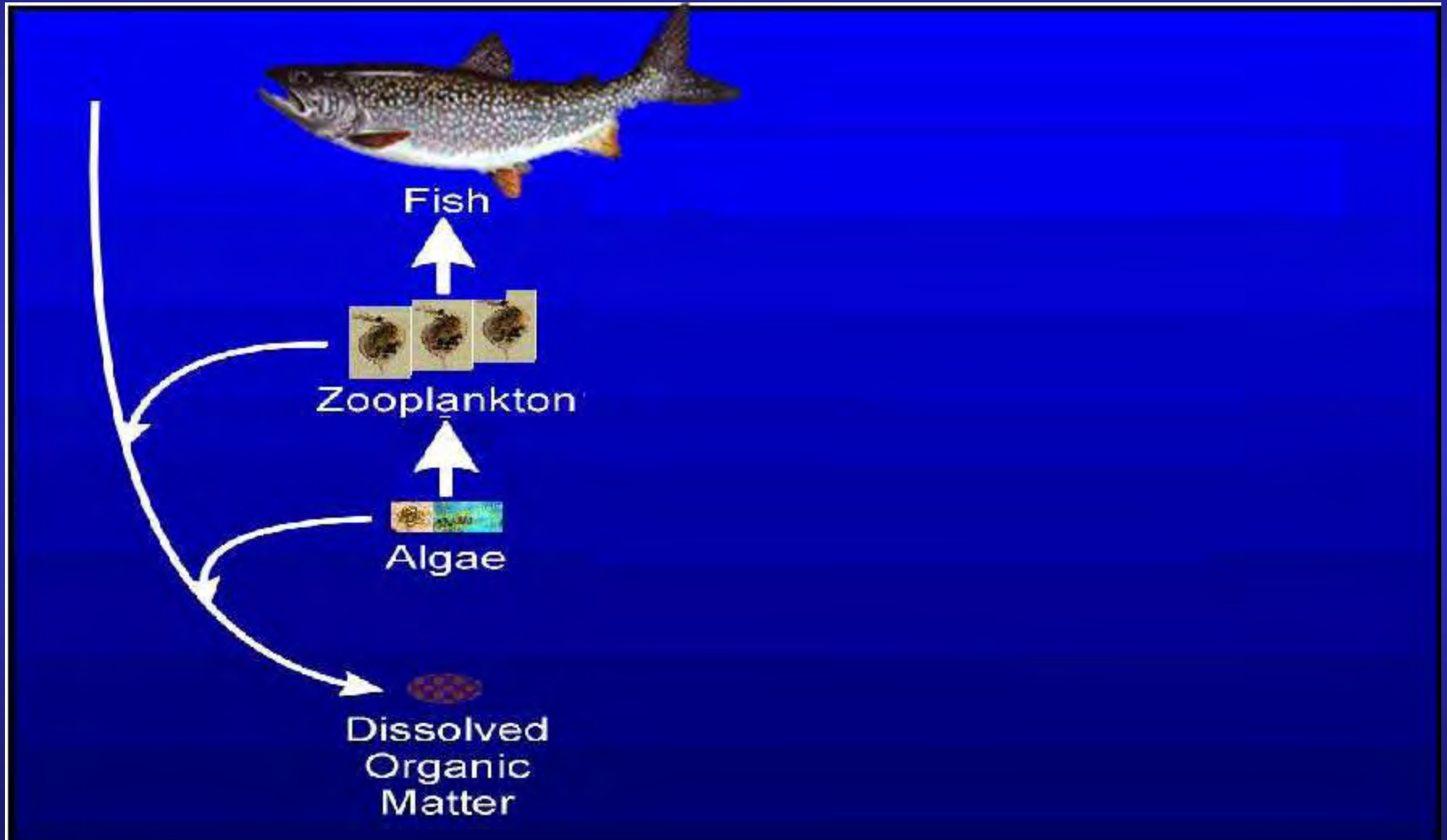
Processes Controlling PBTs



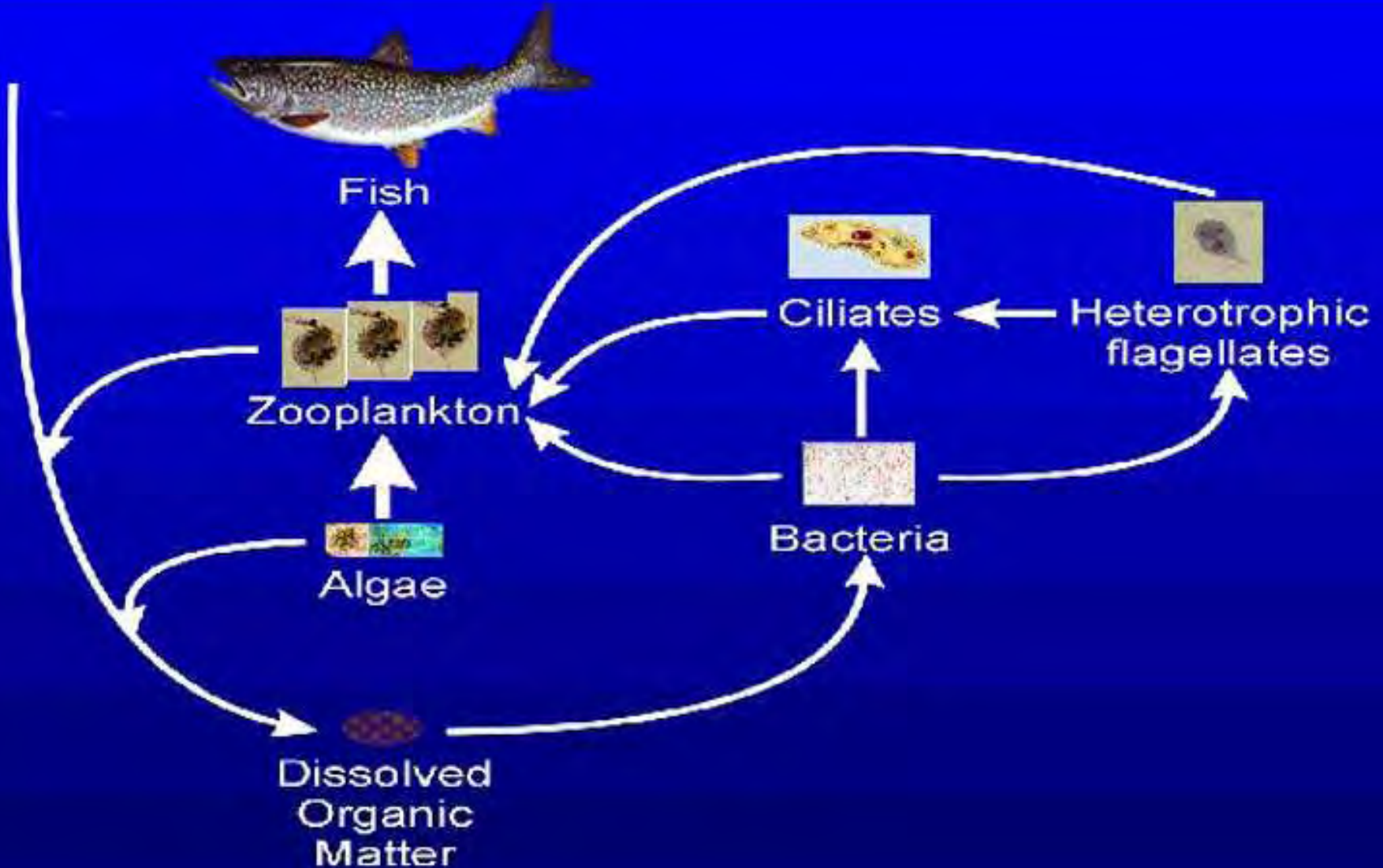
Inefficient Burial in Sediments



Traditional Pelagic Foodweb

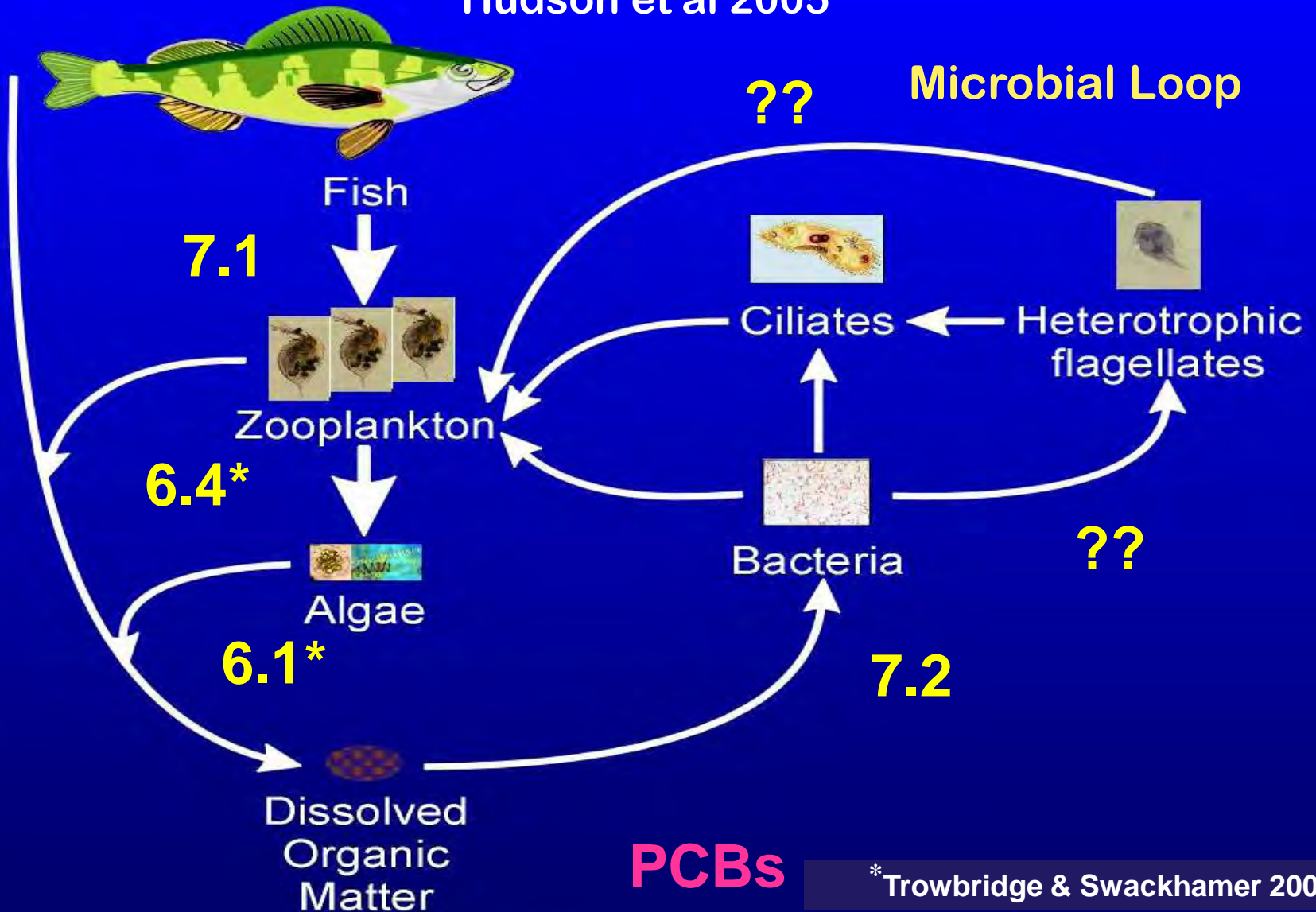


Complete Food web with Microbial Loop



Potential Implications for Bioaccumulation

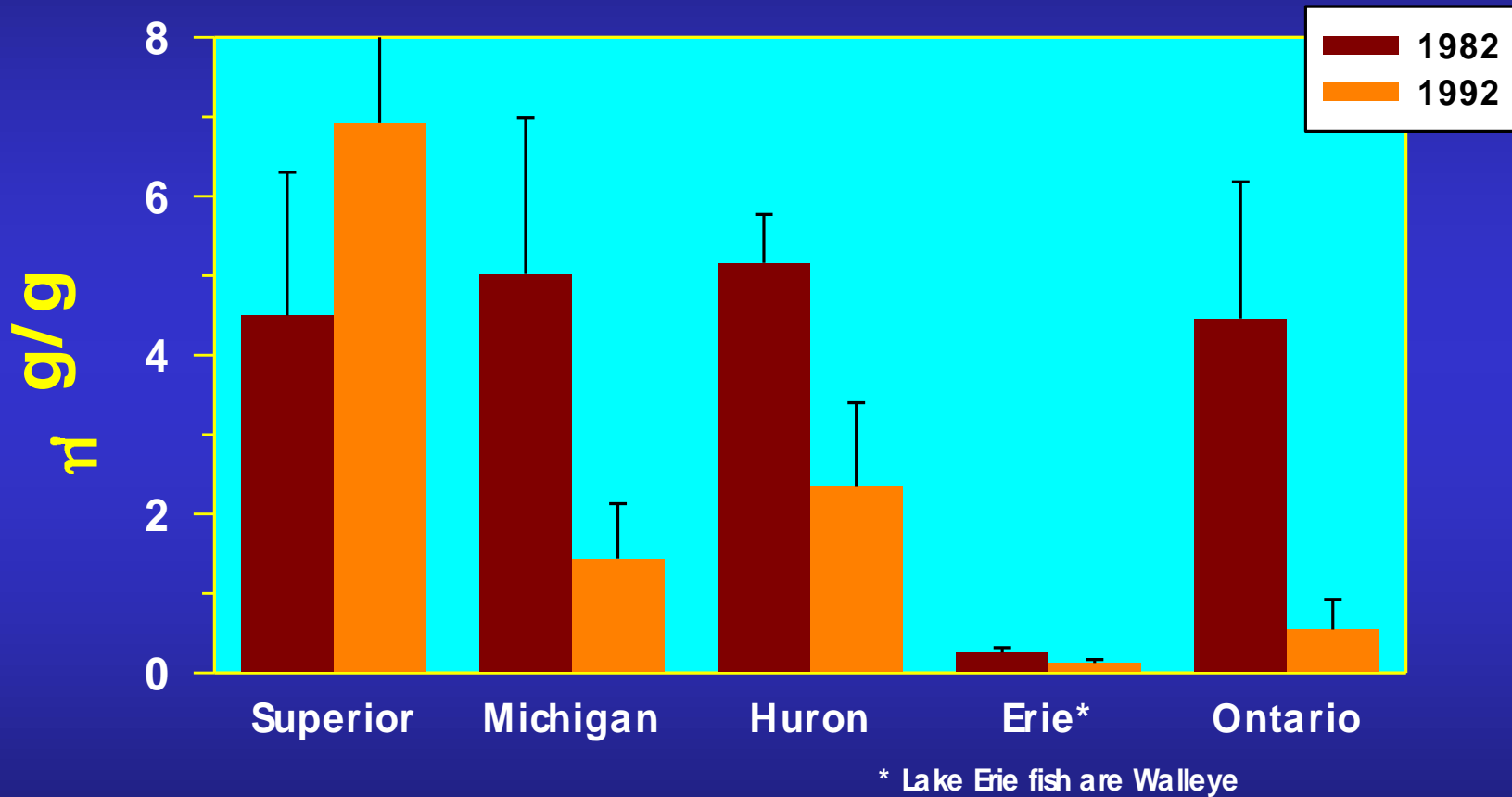
Hudson et al 2005



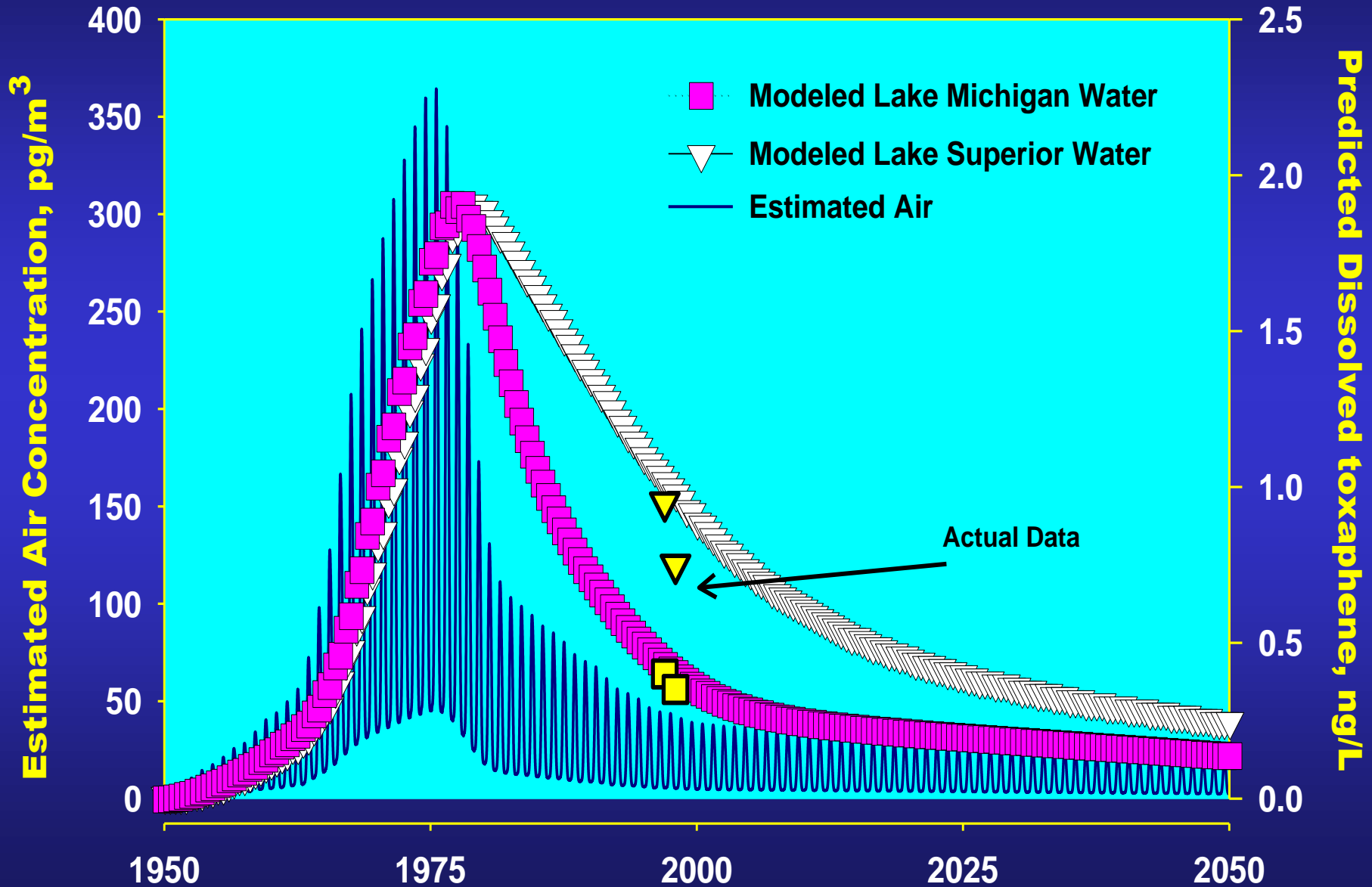
PCBs

*Trowbridge & Swackhamer 2001

Toxaphene in Lake Trout, $\mu\text{g/g}$ wet wt.



Toxaphene Trends in Air and Water



Summary of the Superior Story

- **Atmospheric deposition major source of PBTs**
- **Unique physical and biological properties that make it retain PBTs**
- **Climate change will affect how Superior processes contaminants**
- **Contaminants and effects of emerging concern – need to get ahead of the curve**