Predicting reductions in fish tissue PCB concentrations

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What can we reasonably expect for lag in decreased load and response in fish tissue in the Spokane River?

Pathway to prediction

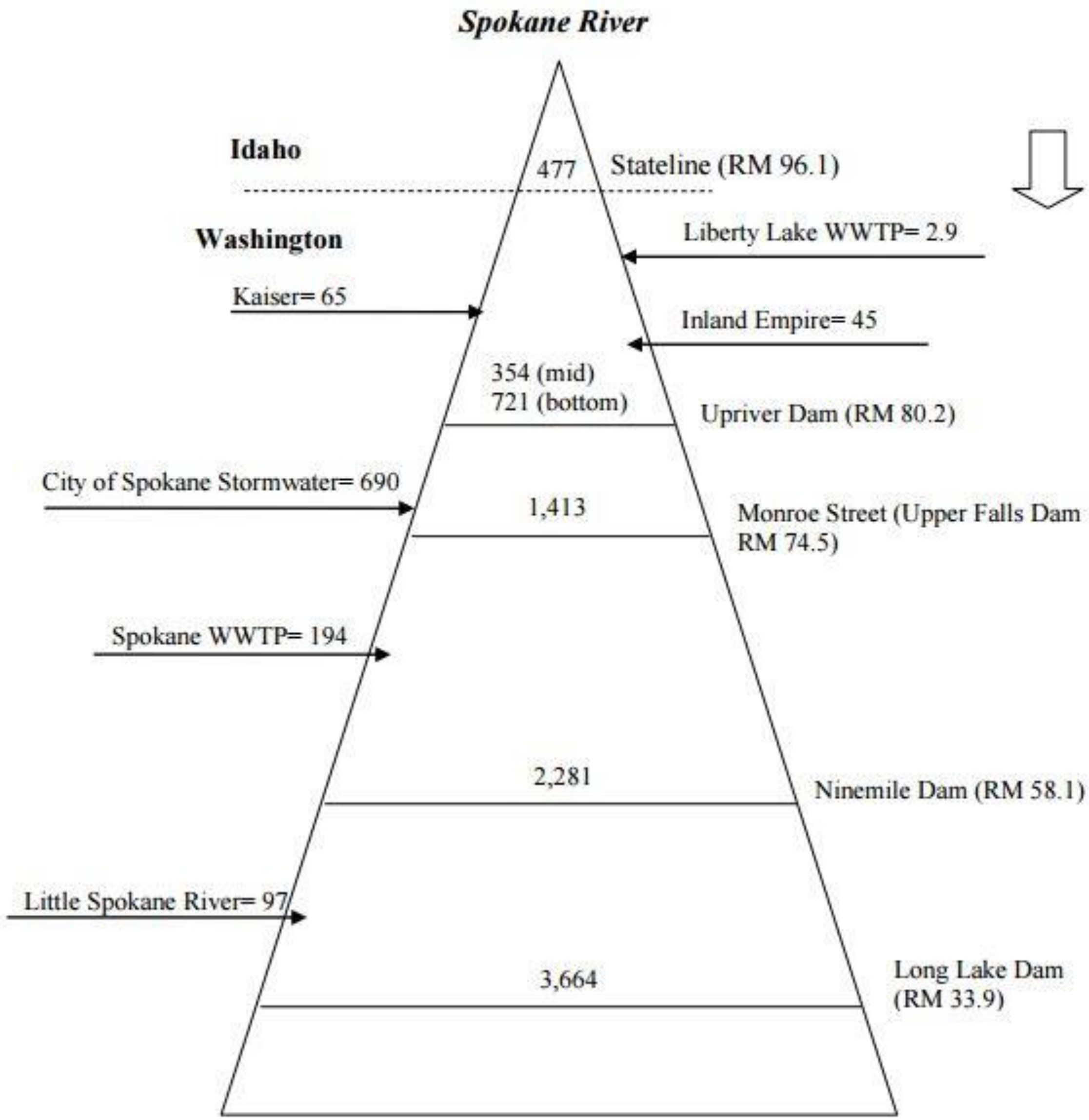
measured	modeled	modeled	measured and modeled
inputs	**transport**	**fate**	**bioaccumulation**

Take-home Message: Must understand the inputs, transport, fate and bioaccumulation of PCBs in the river

This Talk

- Review the models used to make predictions
- Review empirical data on fish tissue reductions over time: Case Studies and the Spokane

Mass Balance of PCB inputs



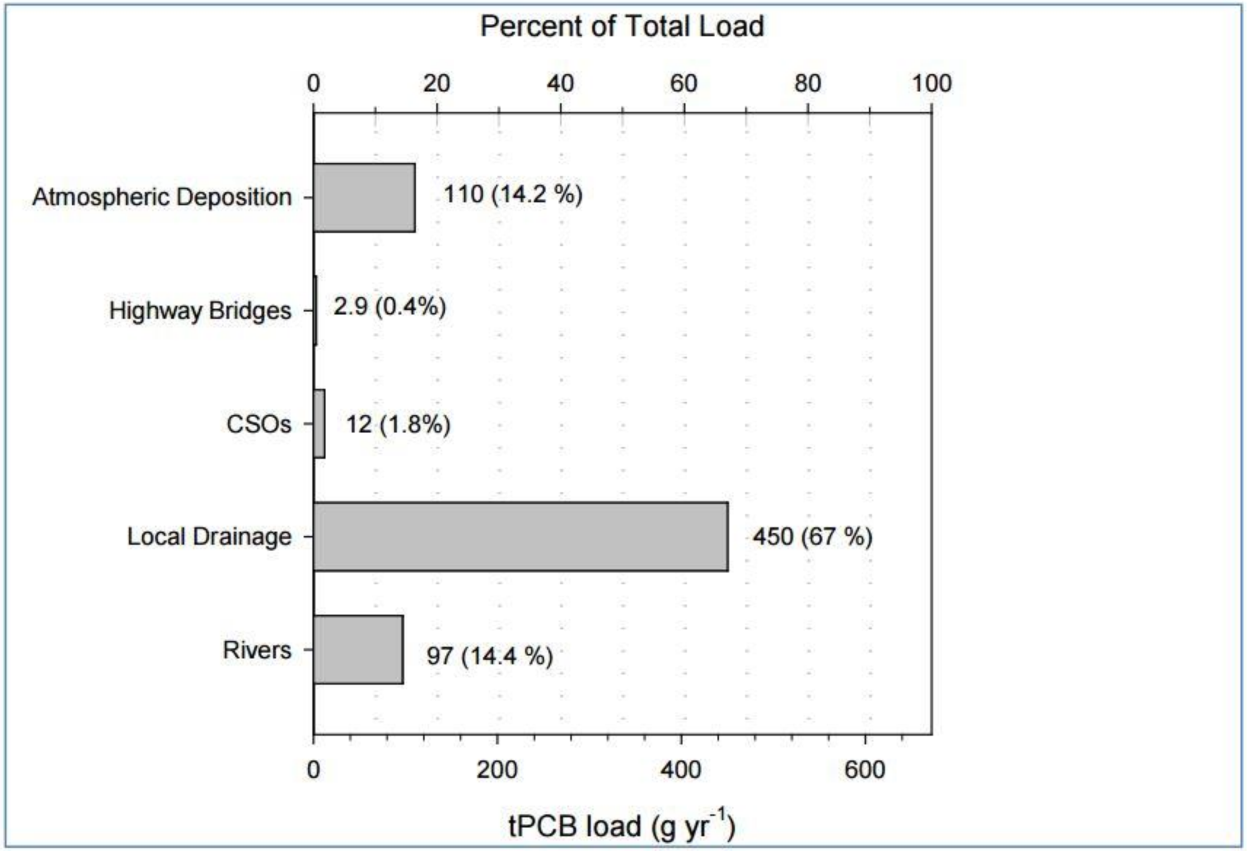
First Step: understand the inputs and movement of PCBs in the system

- Mass balance (Under revision)

Technical Issues (uncertainties):

- Groundwater inputs
- Sediment accumulation and feedback
- Atmospheric deposition (inputs and losses)

Mass Balance of PCB inputs

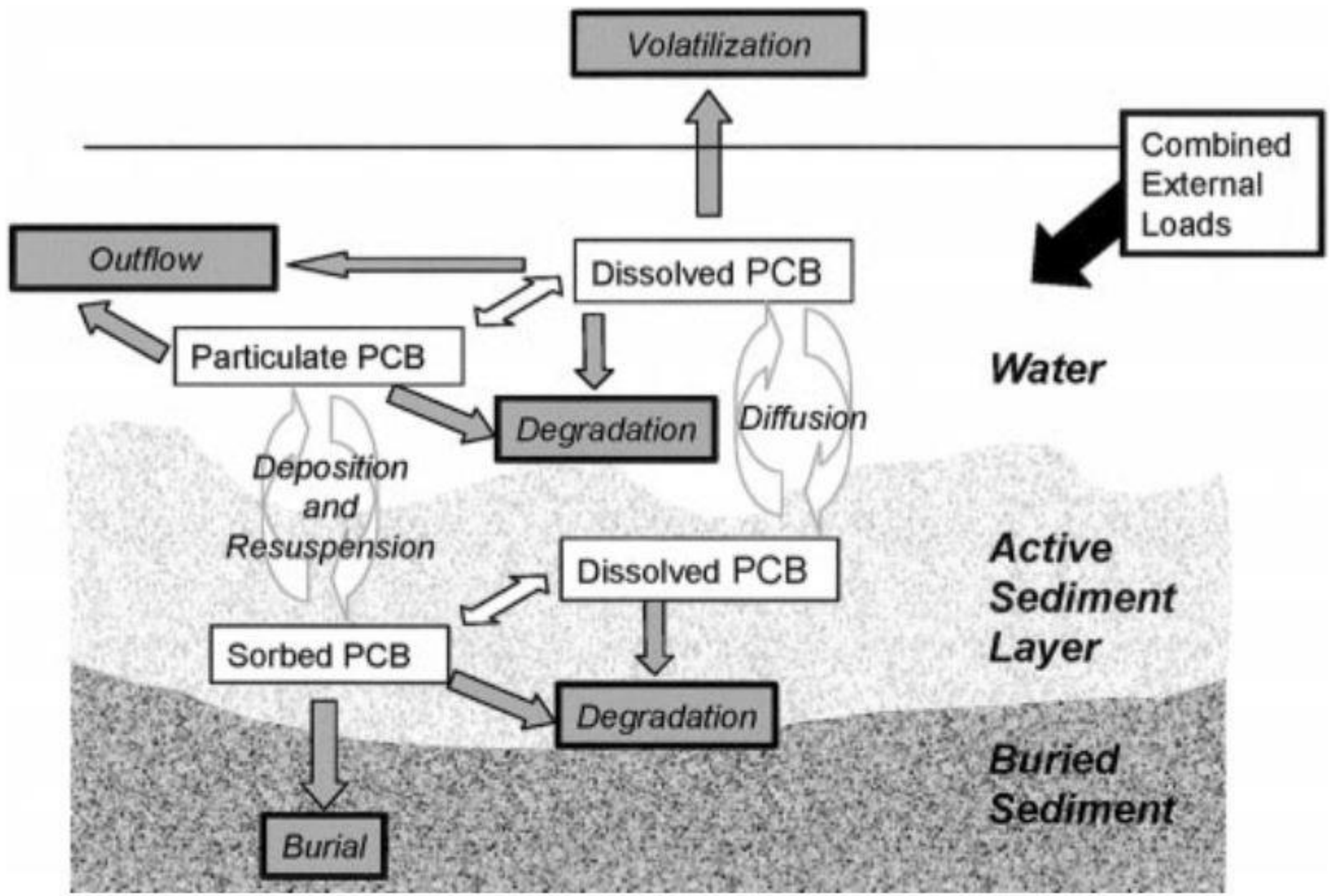


DeGasperi 2013. King Co report.

Lake Washington:

- Stormwater inputs most significant
- Atmospheric deposition directly to the lake surface and indirectly captured by 'Rivers' inputs

Modeling Fate and Transport of PCBs

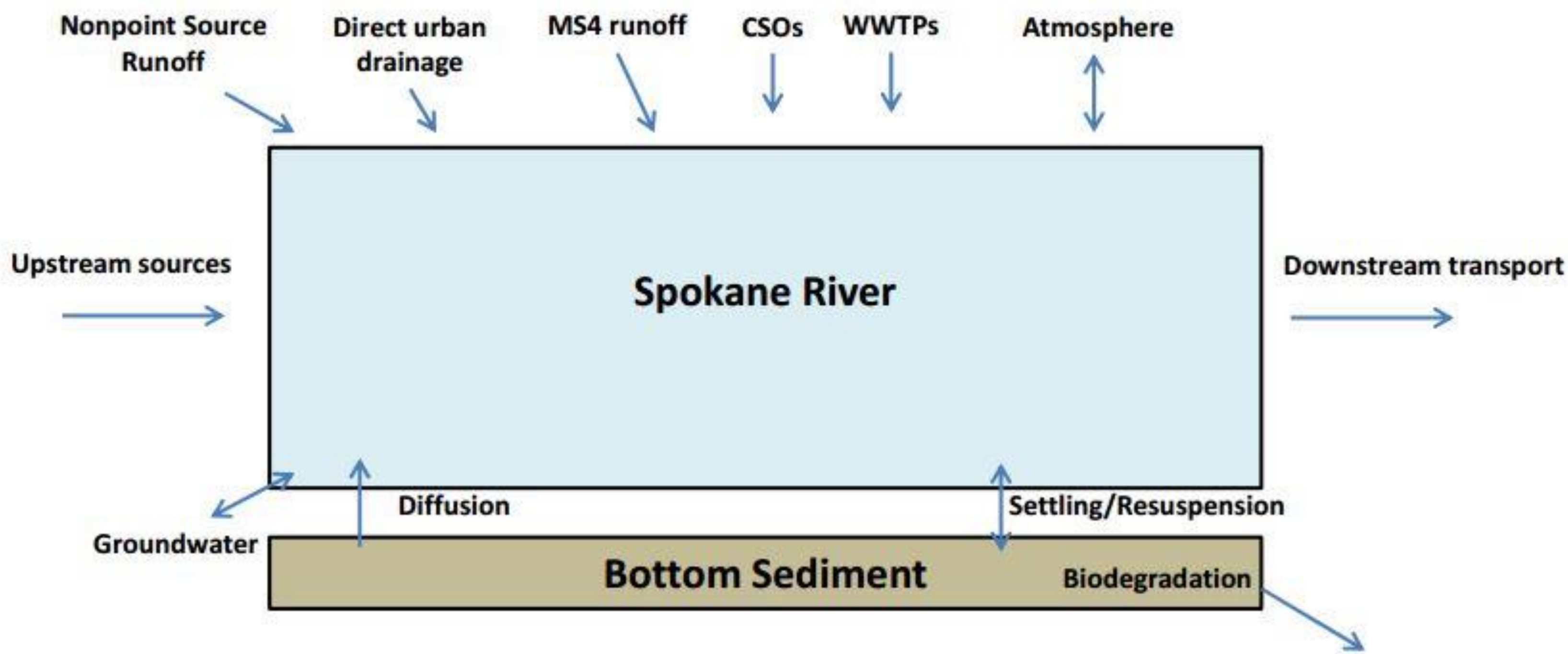


Davis. 2004. Env Tox Chem. 23:2396

Modeling Fate and Transport of PCBs

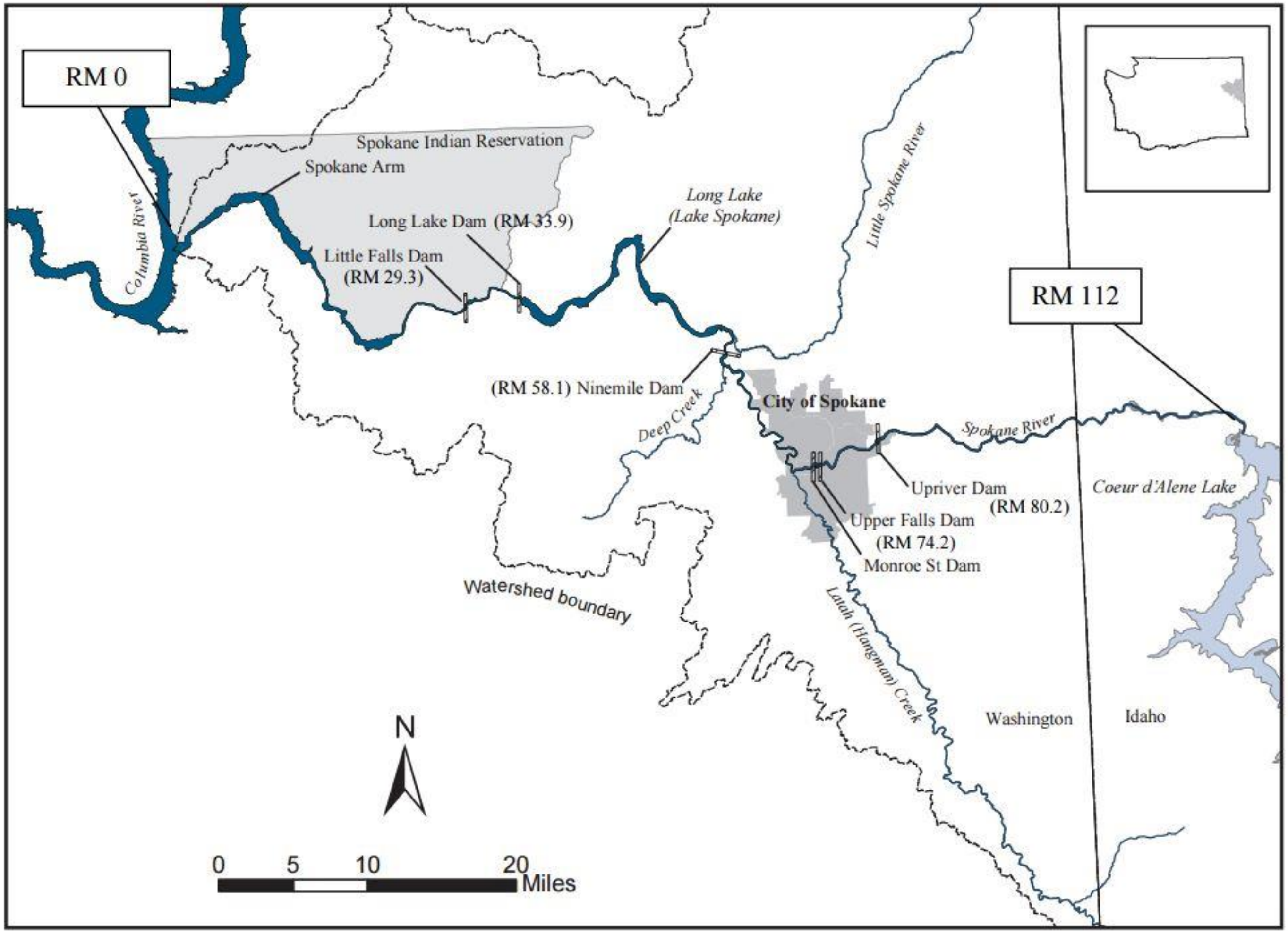
Second Step: a conceptual model to base the construction of the fate and transport model on.

- Fate and transport models describe the inputs of PCBs, how they are transformed in the river, and how they move in the river
- Often uses a single congener or number of congeners



Modeling Fate and Transport of PCBs

- Often multiple models for different sections of the ecosystem.



A validated fate and transport model allows for predictions of water and sediment concentrations under scenarios of different inputs.

Modeling Fate and Transport of PCBs

- Use the fate and transport to run scenarios to predict water concentration.
- Example from Lake Washington study

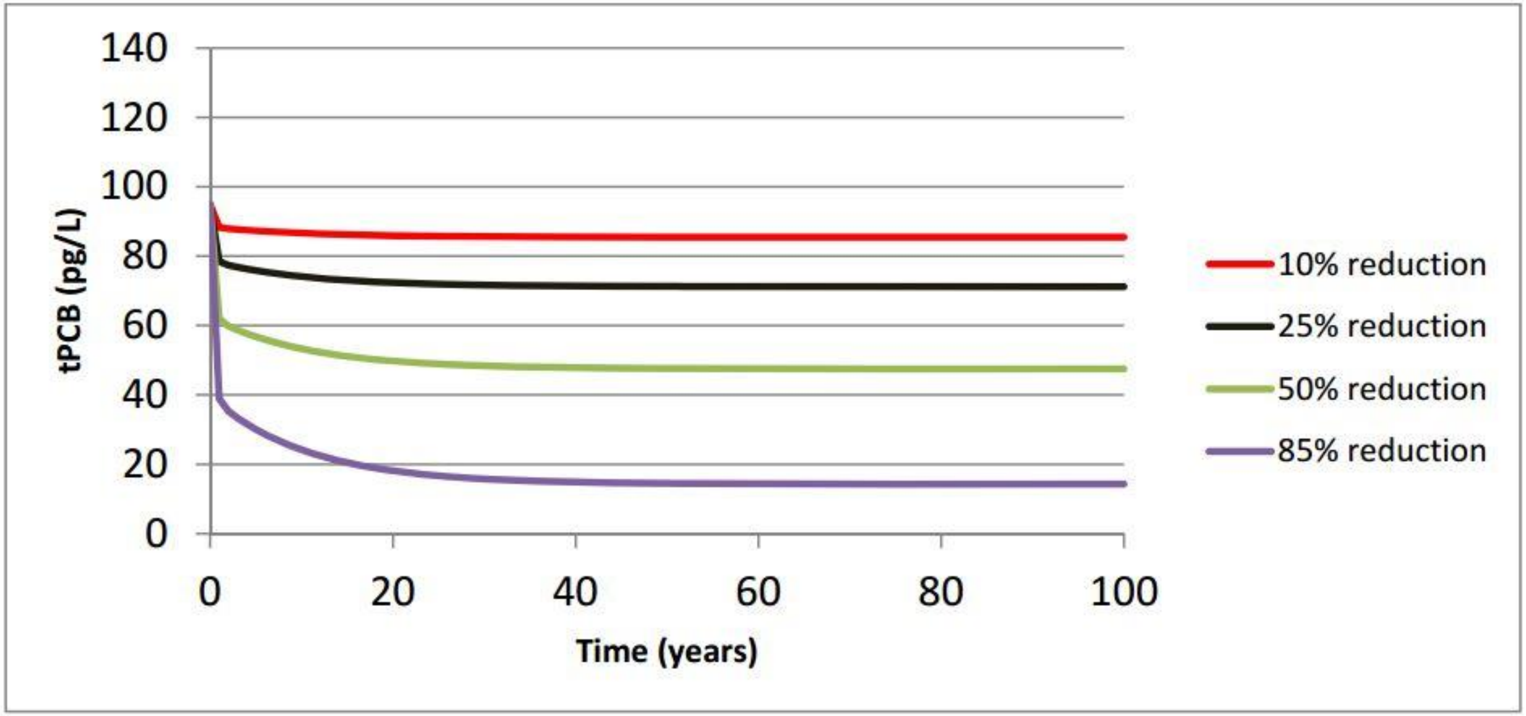
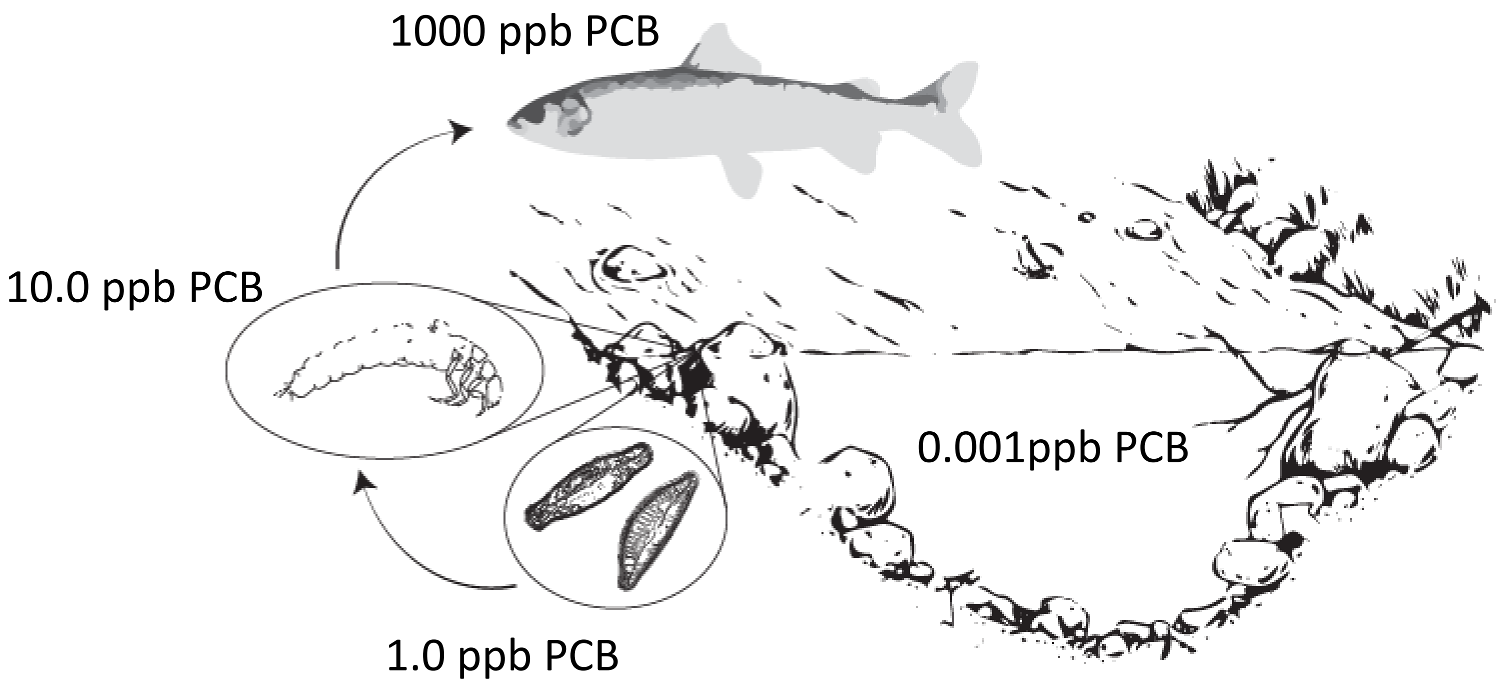


Figure 5. **Predicted response of water column tPCB concentrations to 10, 25, 50, and 85 percent tPCB load reductions.**

Modeling Bioaccumulation of PCBs

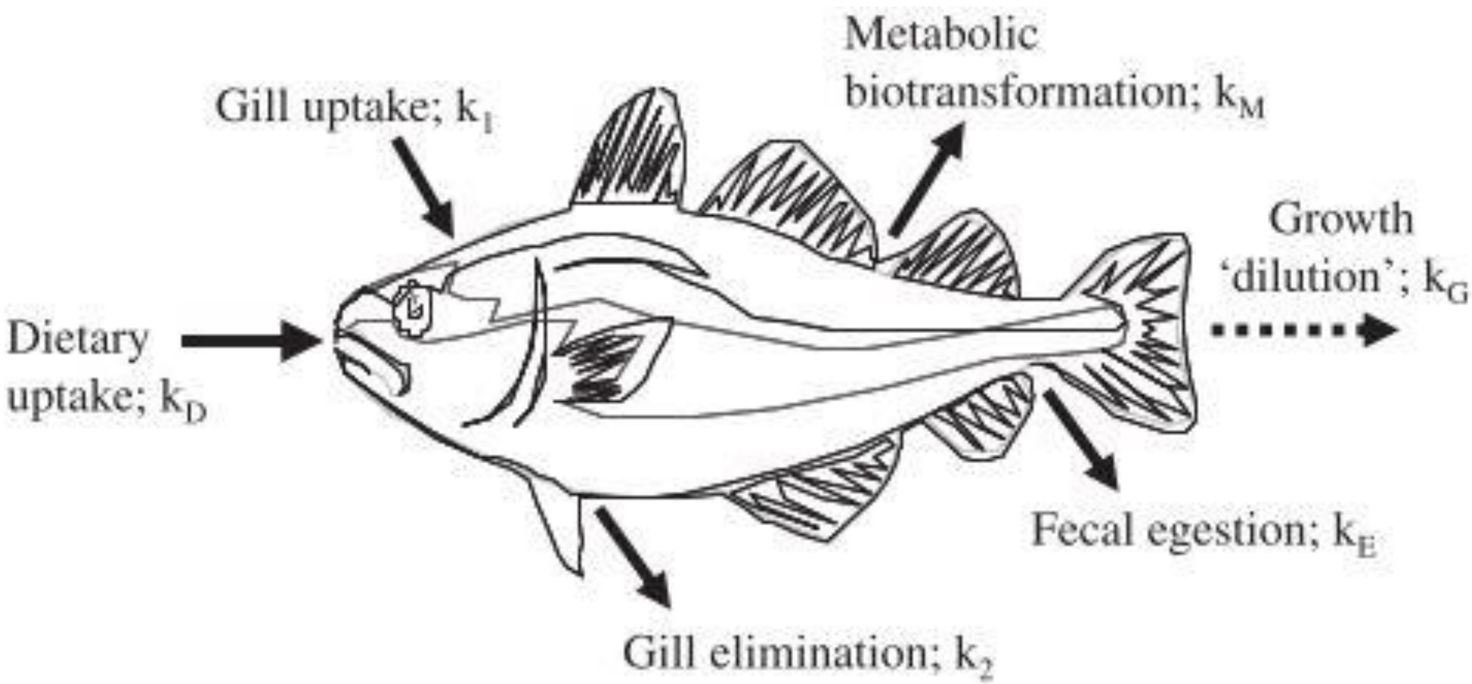
Third Step: understanding the transfer and accumulation of PCBs in Spokane food web.



- Bioaccumulation describes the net accumulation of PCBs from diet and directly from water (i.e. all environmental sources)
- Includes uptake and elimination

Modeling Bioaccumulation of PCBs

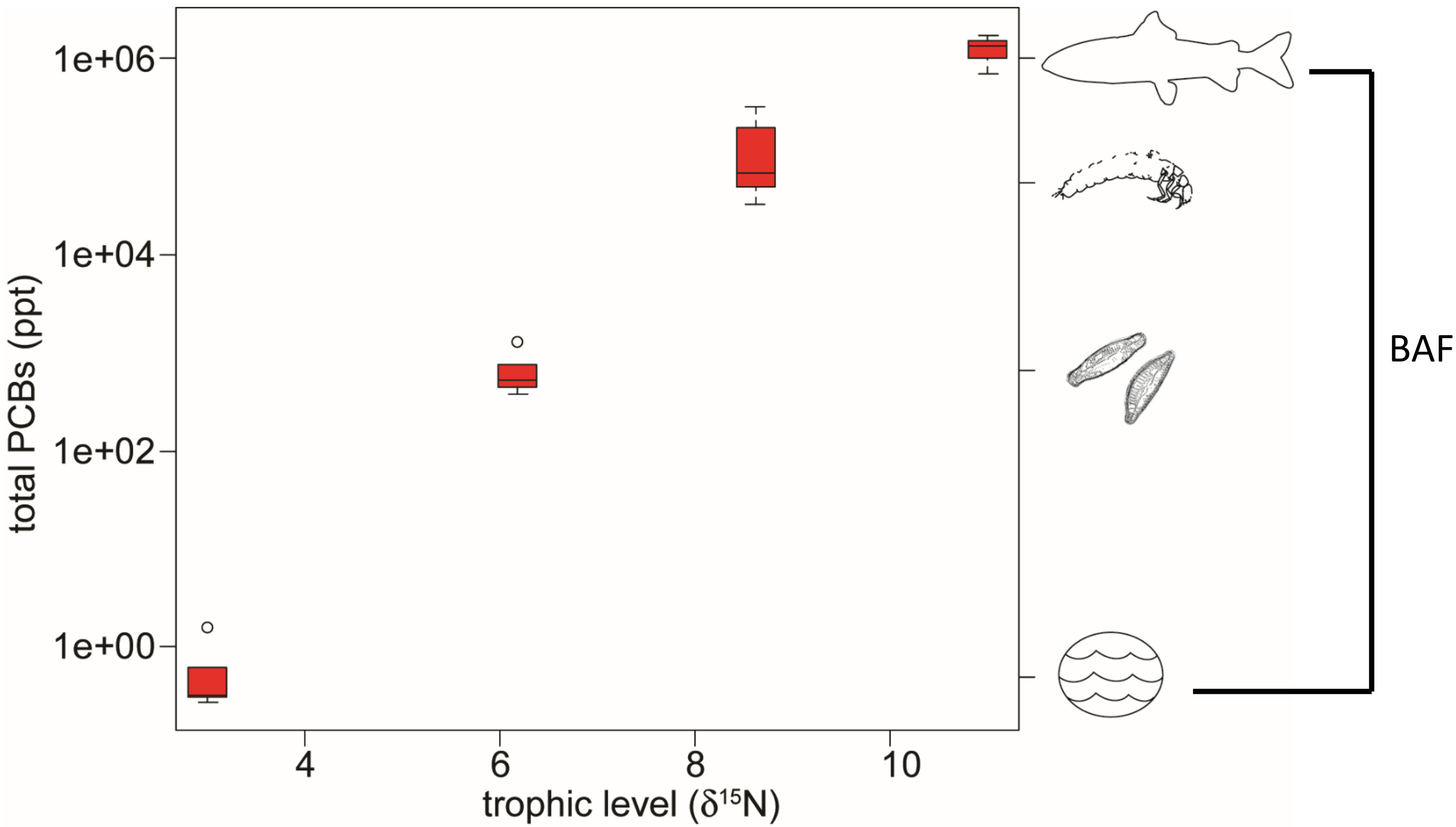
- Arnot and Gobas model commonly used in the PNW.



$$BAF = C_B / C_{WD} = \{k_1 + k_D\,(C_B / C_{WD})\} \,/\, (k_2 + k_E + k_M + k_G)$$

Arnot and Gobas. 2004. Env Tox Chem. 23:2343

Observed Bioaccumulation of PCBs in Wenatchee River



- An understanding of the food web accumulation is necessary to model bioaccumulation

Modeling Bioaccumulation of PCBs

- Preliminary Spokane bioaccumulation model was compiled following Source Assessment (Serdar et al. 2011. ECY pub 11-03-013)
  - Relies on a number 'default' values
  - Run on 5 river sections
  - Did produce a decent prediction of fish tissue concentrations

Data gaps in Spokane Food Web characterization

- What are the distributions of PCB concentrations at the base of the food web (i.e. periphyton)?
  - Diet of largescale suckers
- What are the concentrations of PCBs in benthic invertebrates?
  - Diet of mountain whitefish
- Does the food web structure vary from among reaches?

Modeling Bioaccumulation of PCBs

Table 45. Target Sediment and Water Total PCB Concentrations Needed to Yield the Spokane Tribe Fish Tissue Criterion (0.1 ng/g) in the Spokane River, Based on the Arnot-Gobas Food web Bioaccumulation Model.

Reach	Target Tissue Total PCB Conc. (ng/g)	Target Sediment Total PCB Conc. (ng/g dw)	Target Dissolved Water Total PCB Conc. (pg/l)	Dissolved PCB Fraction	Target Whole Water Total PCB Conc. (pg/l)	Target Total PCB Load (mg/day)
Stateline-Upriver Dam	0.1	0.06	0.9	0.90	1.0	4.5
Monroe-Ninemile	0.1	0.06	0.6	0.88	0.7	4.9
Lake Spokane	0.1	0.05	1.7	0.83	2.0	18.7
Little Falls	0.1	0.02	0.7	0.83	0.8	7.7
Spokane Arm	0.1	0.04	1.3	0.83	1.6	14.3

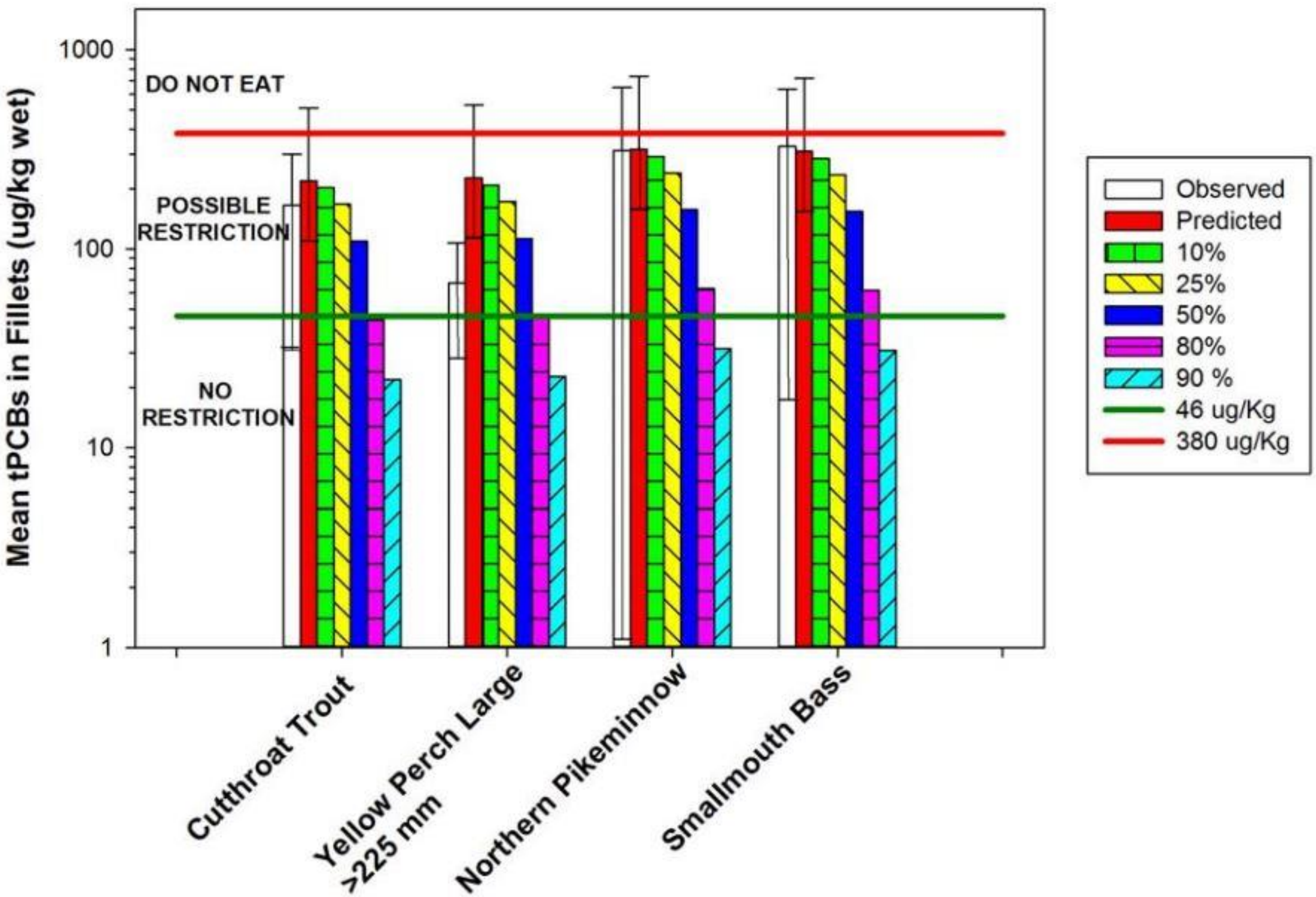
Serdar et al 2011 ECY pub 11-03-013

- No estimate of recovery time

A validated bioaccumulation model can be used to predict tissue concentrations under scenarios of water concentration or vice versa.

Modeling Bioaccumulation of PCBs

- Use the bioaccumulation model to predict associated changes in fish tissue PCBs relative to target thresholds



Predicting PCBs in Fox River, MI

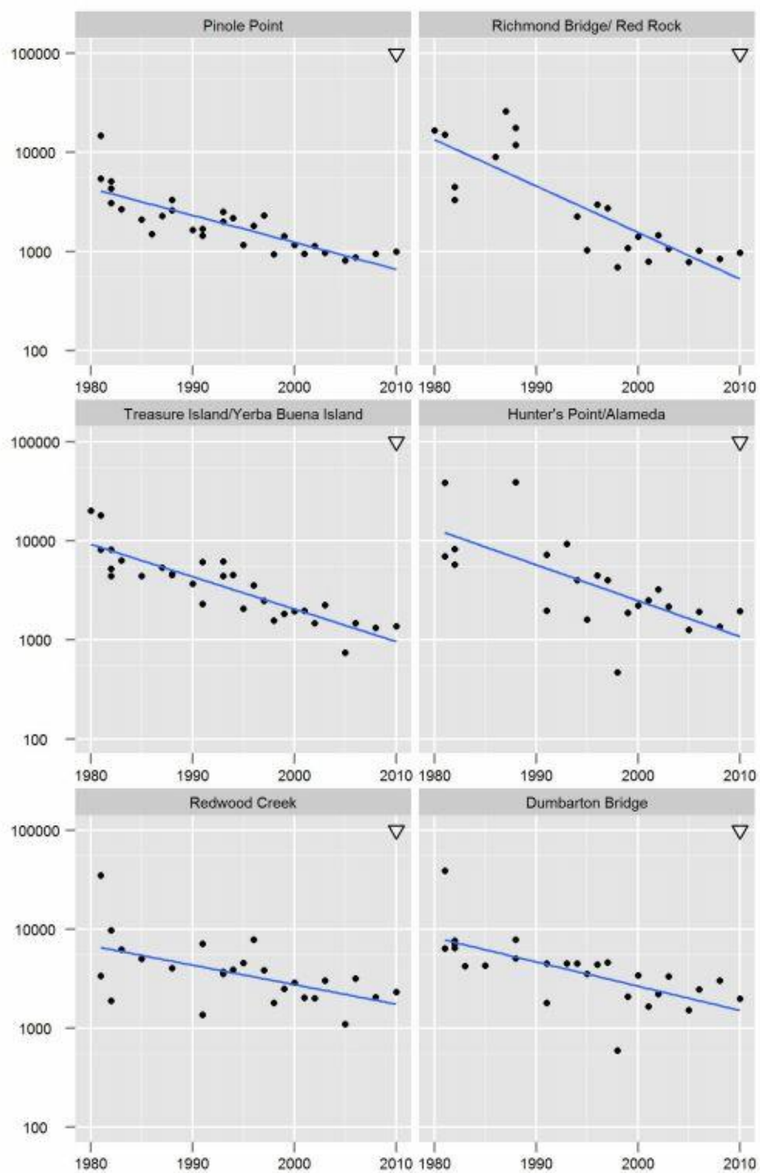
Table 3. Estimated Years to Reach Human Health and Ecological Thresholds to Achieve Risk Reduction for the Lower Fox River at an Action Level of 1.0 ppm

OU	Whole Fish Threshold Con. (µg/kg)	Fish	Risk Level	Receptor	Estimated Years
# 1	288	Walleye	RME hazard index of 1.0	Recreational angler	<1
	181	Walleye	RME hazard index of 1.0	High-intake fish consumer	4
	106	Walleye	RME 10^{-5} cancer risk level	Recreational angler	9
	71	Walleye	RME 10^{-5} cancer risk level	High-intake fish consumer	14
	121	Carp	NOAEC	Carnivorous bird deformity	14
	50	Carp	NOAEC	Piscivorous mammal	29
# 3	288	Walleye	RME hazard index of 1.0	Recreational angler	9
	181	Walleye	RME hazard index of 1.0	High-intake fish consumer	17
	106	Walleye	RME 10^{-5} cancer risk level	Recreational angler	30
	71	Walleye	RME 10^{-5} cancer risk level	High-intake fish consumer	42
	121	Carp	NOAEC	Carnivorous bird deformity	22
	50	Carp	NOAEC	Piscivorous mammal	43
# 4	288	Walleye	RME hazard index of 1.0	Recreational angler	20
	181	Walleye	RME hazard index of 1.0	High-intake fish consumer	30
	106	Walleye	RME 10^{-5} cancer risk level	Recreational angler	45
	71	Walleye	RME 10^{-5} cancer risk level	High-intake fish consumer	59
	121	Carp	NOAEC	Carnivorous bird deformity	20
	50	Carp	NOAEC	Piscivorous mammal	45

Note:
RME indicates the reasonable maximum exposure; NOAEC is the no observed adverse effect concentration.

- Depending on risk target recovery times range

Direct measurement of reductions in tissue PCBs



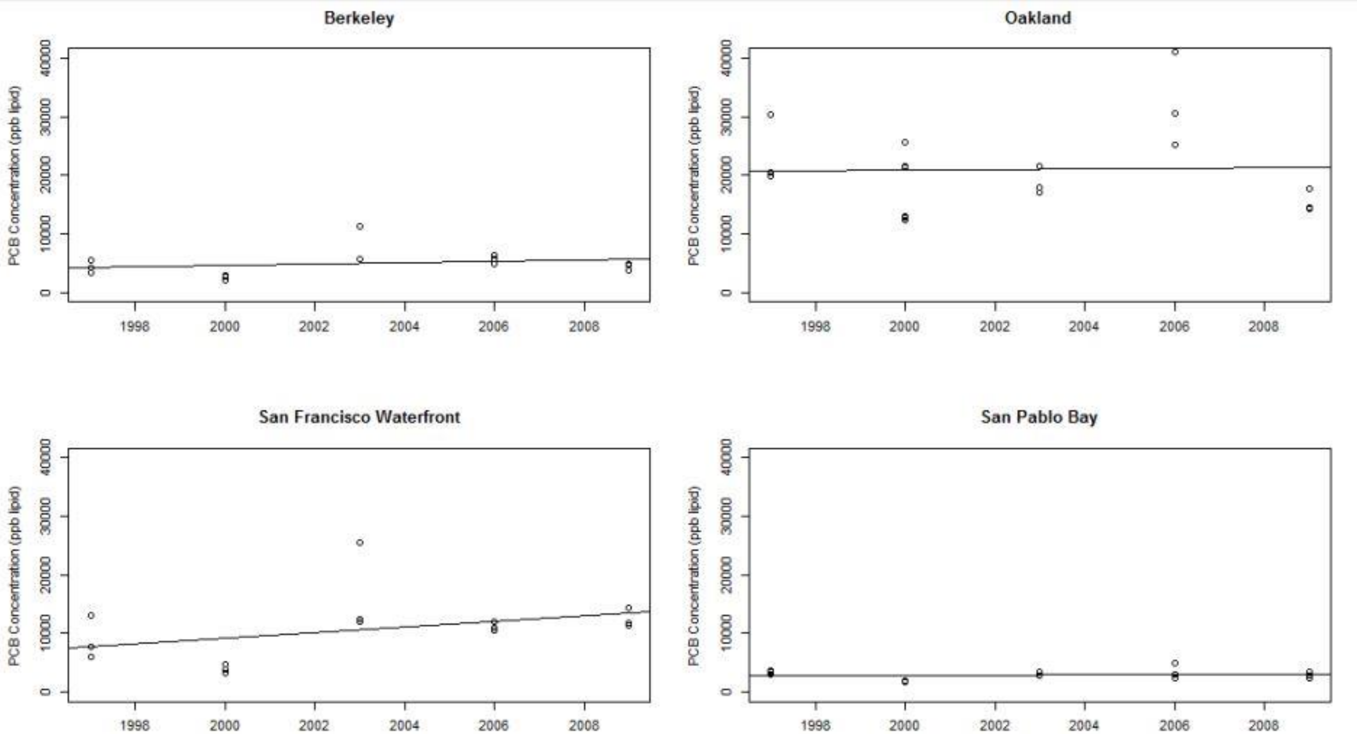
- An empirical approach
- Based on selected target species

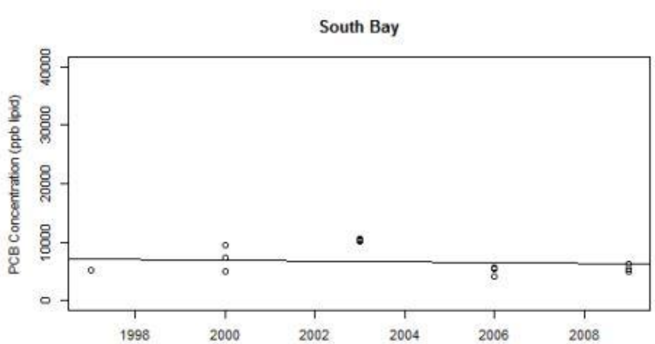
Case studies: San Francisco Bay

- Some successes – reductions in mussel PCB concentrations
- Halving rate of **6** to **15** years
- Some evidence that the trend is slowing down post-2000
- Sediments act as an ongoing supply of PCBs

Davis et al (2014) SFEI RMP contribution No.727

Case studies: San Francisco Bay

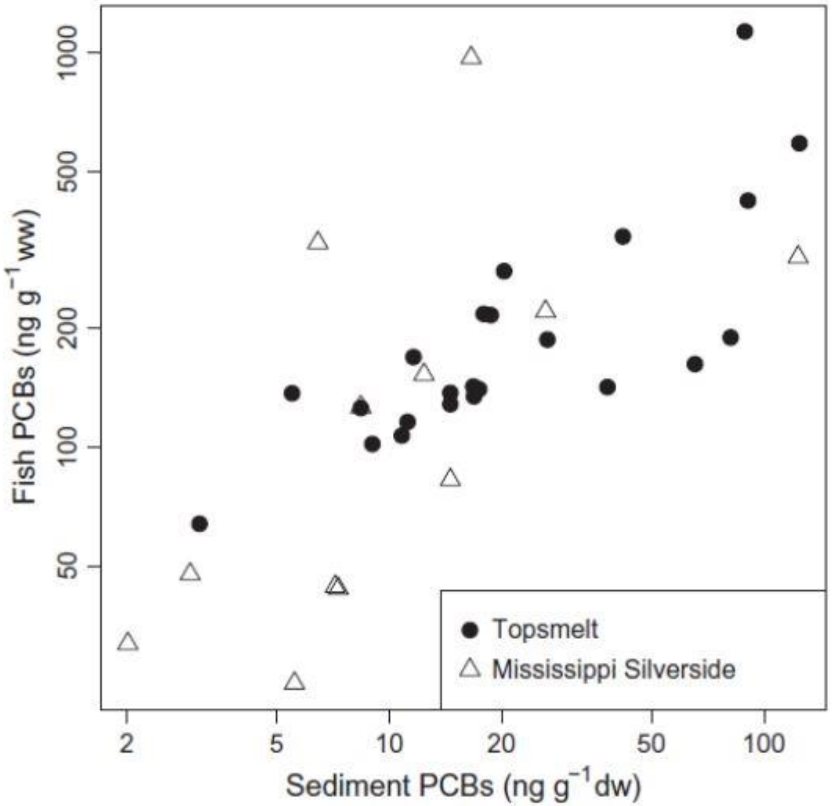




- PCBs in sport fish tissue – shiner surfperch and white croaker
- Little evidence that sport fish tissue PCBs have declined

Davis et al (2014) SFEI RMP contribution No.727

Case studies: San Francisco Bay

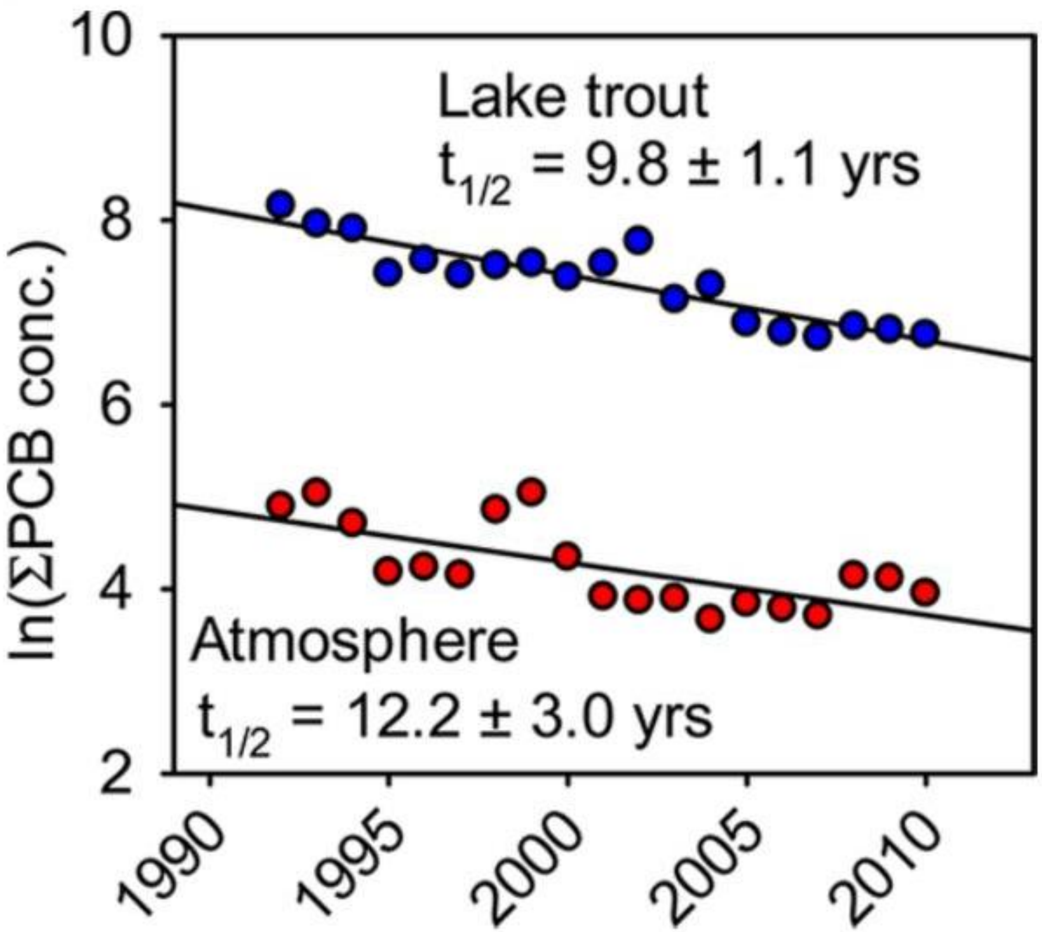


- Strong positive relationship between sediment PCBs and sport fish tissue PCBs
- 10ppb is the TMDL target for sport fish tissue

Dominant source of PCBs to SF Bay food web = sediment archive and urban inputs

Greenfield and Allen (2013) Chemosphere 90: 1693

Case studies: Great Lakes



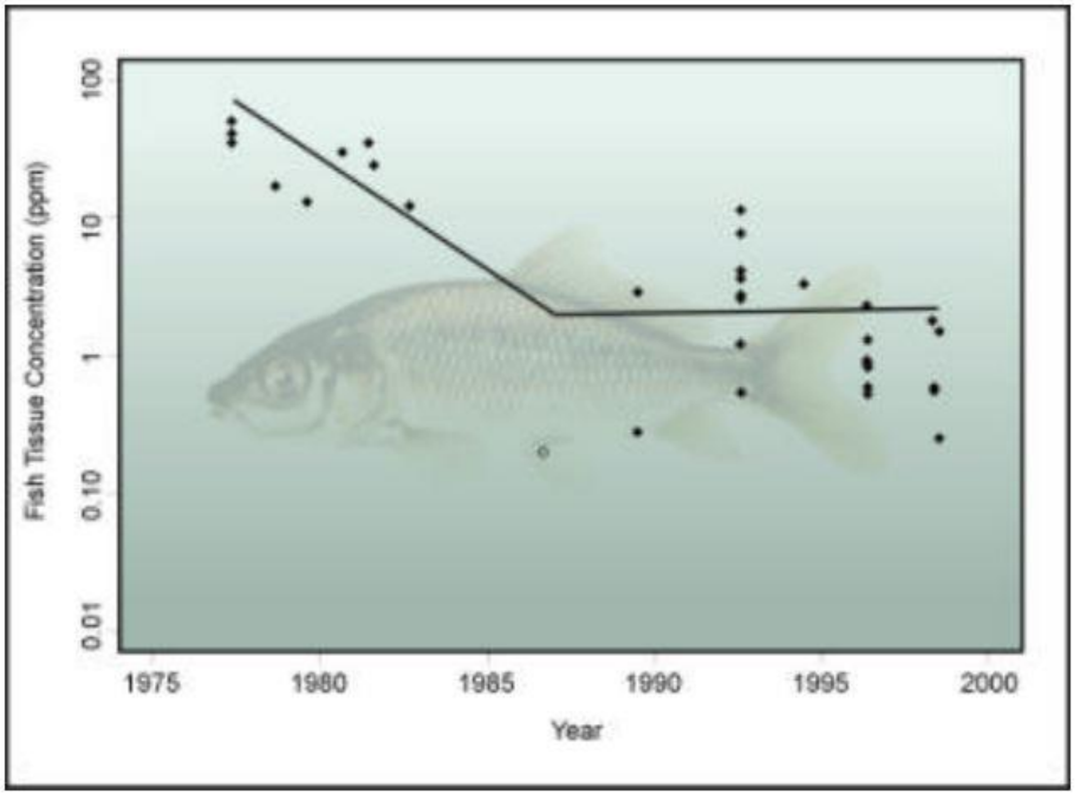
- Lake Michigan halving rates in lake trout
- Lake Superior = 13.7 ± 6.6 yrs
- Lake Erie = 15.2 ± 7.0 yrs

Dominant source of PCBs to Great Lakes = Atmosphere

Salamova et al (2013) ES&T 47: 9109

Case studies: Fox River, MI

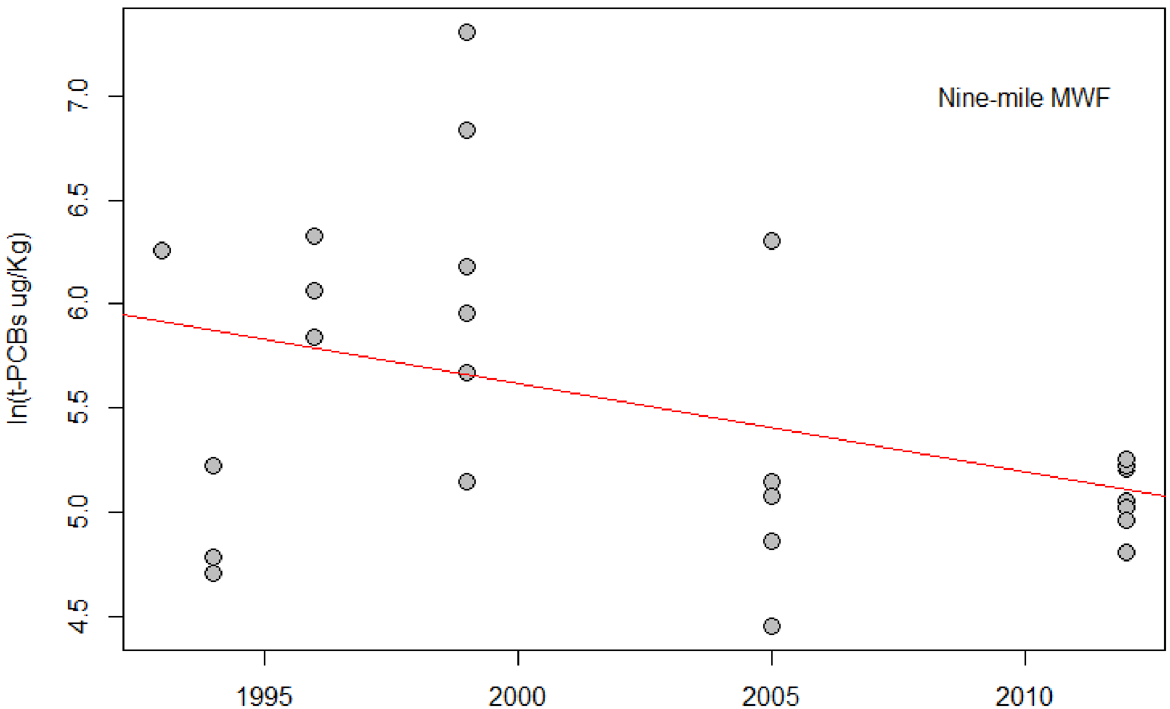
Figure 9 - PCB Concentration (ppm) in Little Lake Butte des Morts Carp, Whole Body, versus Time



- 1970s the point source discharges were reduced dramatically
- ~15 year lag to see change close to target
- Little overall change in the 10 years after declines – sediments
- Sediments capped in 2008

Observed PCB half-lives in Spokane fish tissue

- Tracking recovery rate using mountain whitefish tissue concentrations at the Nine-mile site

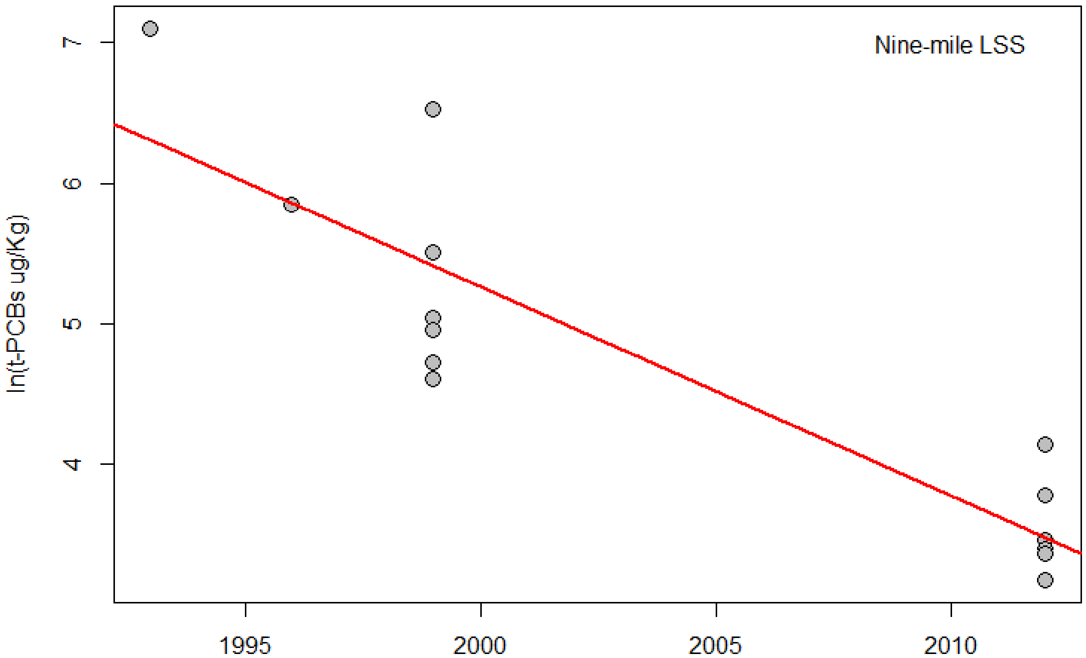


- significant decline over time (p=0.04)
- Suggests half-life of 16.0 ± 7.5 yrs

Projected date to reach 5.3 ug/Kg = 2092

Observed PCB half-lives in Spokane fish tissue

- Tracking recovery rate using sucker tissue concentrations at Nine-mile site

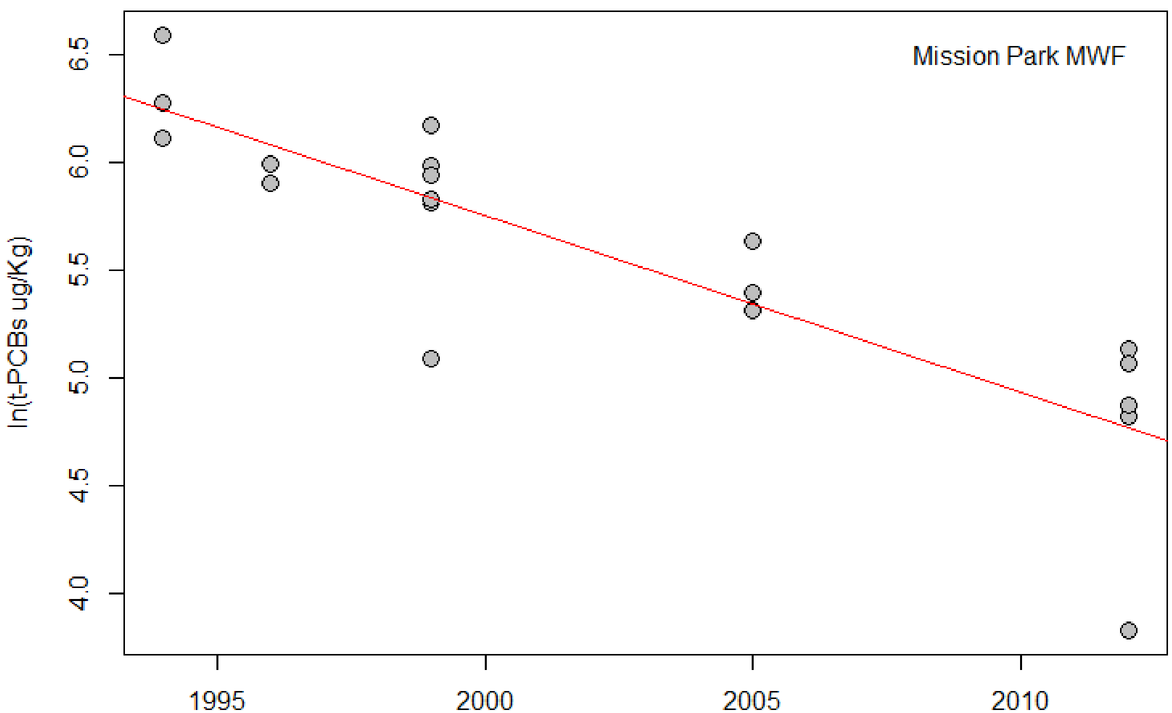


- significant decline over time ($p<<0.001$)
- Suggests half-life of 4.6 ± 0.6 yrs

Projected date to reach 5.3 ug/Kg = 2024

Observed PCB half-lives in Spokane fish tissue

- Tracking recovery rate mountain whitefish tissue concentrations at Mission Park site

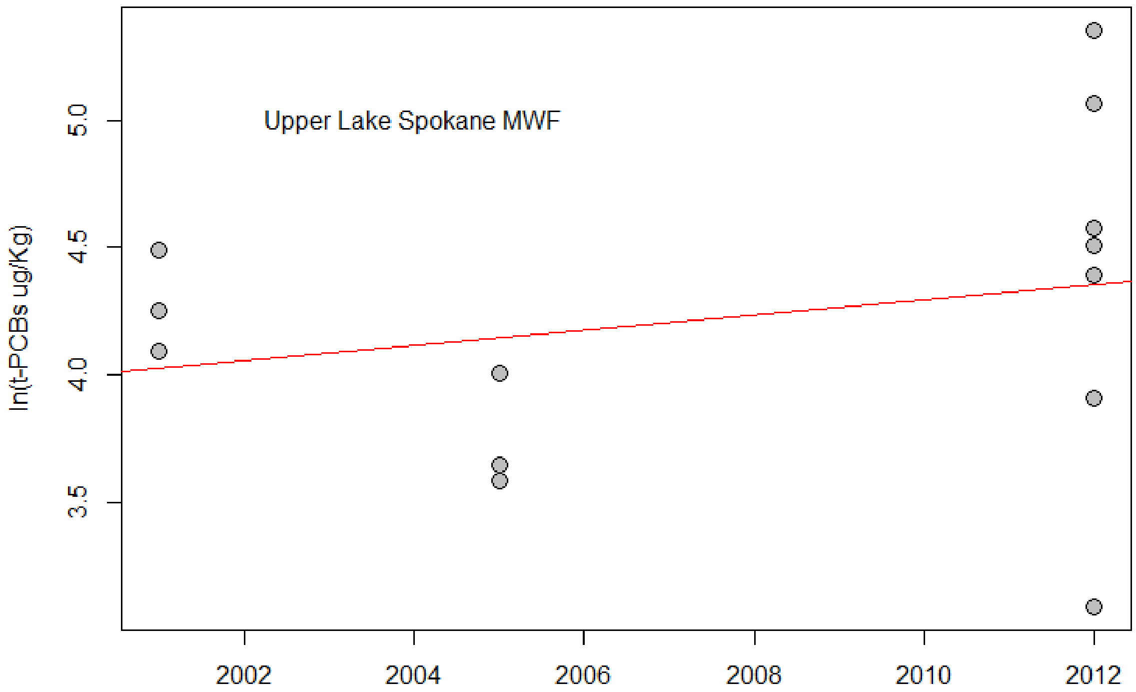


- significant decline over time (p<<0.001)
- Suggests half-life of 8.5 ± 1.2 yrs

Projected date to reach 5.3 ug/Kg = 2050

Observed PCB half-lives in Spokane fish tissue

- Tracking recovery rate using sucker and mountain whitefish tissue concentrations



- No significant decline over time
- Variability in trends and half-lives across sites

Summary

To answer: **What can we reasonably expect for lag in decreased load and fish tissue the Spokane River?**

- Will require construction of models
- Will likely vary in different river sections
- Should be monitored and tracked; previous studies use a combination of modeling and empirical relationships

Models

- A validated fate and transport model allows for predictions of water and sediment concentrations under scenarios of different inputs.
- A validated bioaccumulation model can be used to predict tissue concentrations under scenarios of water concentration or vice versa.
- Requires significant investment in time and effort

Factors that affect the calculation of lag / recovery times

- Environmental sinks of PCBs (e.g. sediment deposits)
- Unknown sources
- Poor model calibration