Connecticut River Fish Tissue Contaminant Study (2000) – Ecological and Human Health Risk Screening

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EPA New England

Outline of Presentation

- Study objectives and design
- Mercury results
- PCB and Dioxin results
- DDT results
- Fish age
- General state fish consumption advisories
- Summary of findings
- Recommendations

Project Background

- CRJC's (1997) six volume CT River Corridor Management Plan and NEIWPCC's (1998) The Health of the Watershed recommended fish contaminant sampling;
- Previous state-specific studies had different target species, fish collection methods, sample preparation and handling, and laboratory analysis;

More Background

- June 16, 1998 meeting developed this four state comprehensive fish tissue monitoring program for the Connecticut River;
- ***Broad Goal:*** A watershed-wide fish tissue monitoring program to document current contaminant concentrations in species of different trophic (feeding) levels, sampled from the mainstem of the Connecticut River;

CT River Study Partners

EPA-New England

US Fish and Wildlife Service

USGS

CTDEP

CT Fish and Game

- MADEP
- NHDES
- NH Fish and Game
- VTDEC
- VT Fish and Game
- NEIWPCC
- CRJC and CRWC

Study Objectives

- Screening study to establish a baseline of contaminant residues in fish species of different trophic classes for future trend analysis of contaminant uptake by fish in the river;
- Focused on ***Priority Persistent, Bioaccumulative and Toxic (PBT) Chemicals***, including total mercury, total PCBs, coplanar PCBs, dioxins and furans, chlorinated organic pesticides
- Also sampled cadmium in two VT/NH Reaches;

Priority Persistent, Bioaccumulative and Toxic (PBT) Chemicals

- “PBT pollutants are chemicals that are toxic, persist in the environment and bioaccumulate in food chains and, thus, pose risks to human health and ecosystems….The (human) populations at risk, especially to PBTs such as ***mercury, dioxins, and polychlorinated biphenyls (PCBs),*** are children and the developing fetus”(USEPA, 2002);

Study Objectives (cont'd)

- Data of adequate quality for use in current and future ecological risk assessments;

- Data of adequate quality to support human health risk assessments for subsistence and recreational fishers and state fish consumption advisories;

Importance of Data Validation

- Project data from a contract laboratory proved highly problematic, requiring protracted data validation by EPA and its contractors. Final data validation for dioxins and furans was ultimately only completed in the fall of 2004;

- Given the implications of this study for human health and state fish advisories, data quality was considered one of the highest priorities;

Study Reaches

- CT River mainstem divided into eight (8) sampling Reaches;

- Reach divisions determined by EPA and State biologists to correspond to major dams and presumably fairly discrete fish populations;

- Location of individual fish sampling within Reaches generally not recorded. Thus data analyses are by species and Reach;

Sampled Wild Fish Species

Reaches 1-8 Species

- **106 Smallmouth Bass**
  (resident)

- **106 Yellow Perch**
  (resident)

- **109 White Sucker**
  (resident)

(Only White Suckers sampled in Reach 8)

Reach 3 Only Species

- **4 Striped Bass**
  (migratory)

- **15 American Shad**
  (migratory)

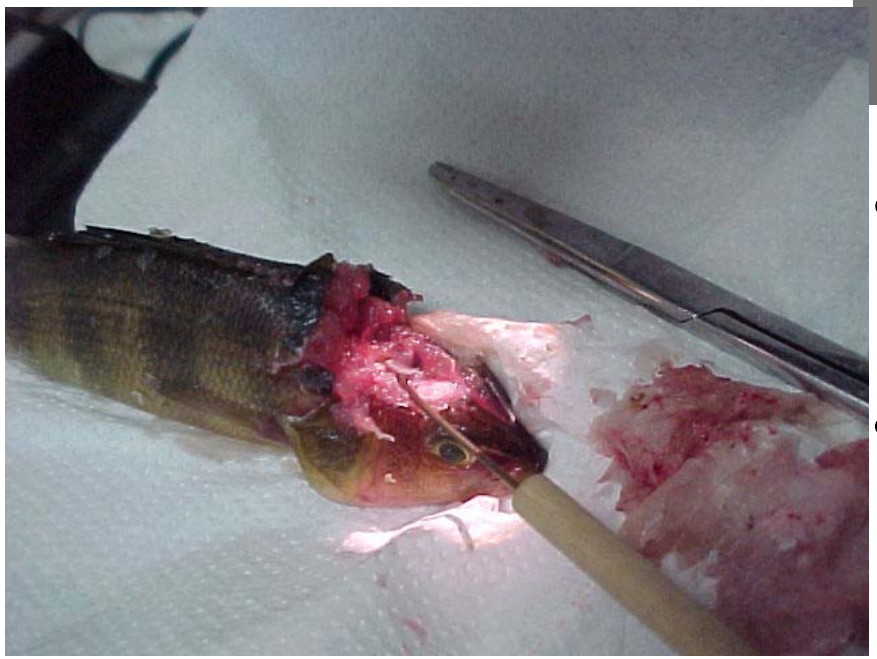
- **15 Brown Bullhead**
  (resident)

Control (Reference) Fish Species

- State of Connecticut Hatchery Brook Trout

Fish Sampling and Processing

- ***Electrofishing***
- Gill Nets
- Rod and Reel



- ***355 sampled fish*** processed at EPA lab June – October, 2000;
- Chemical Analyses done at other labs;

Data Analyses

- Contaminant levels were compared to EPA or other published human health and ecological screening levels;

- Contaminant levels were also compared with fish condition (weight and length) data and smallmouth bass age;

- Analysis of Variance (ANOVA) was used to statistically compare differences between species and Reaches;

Mercury

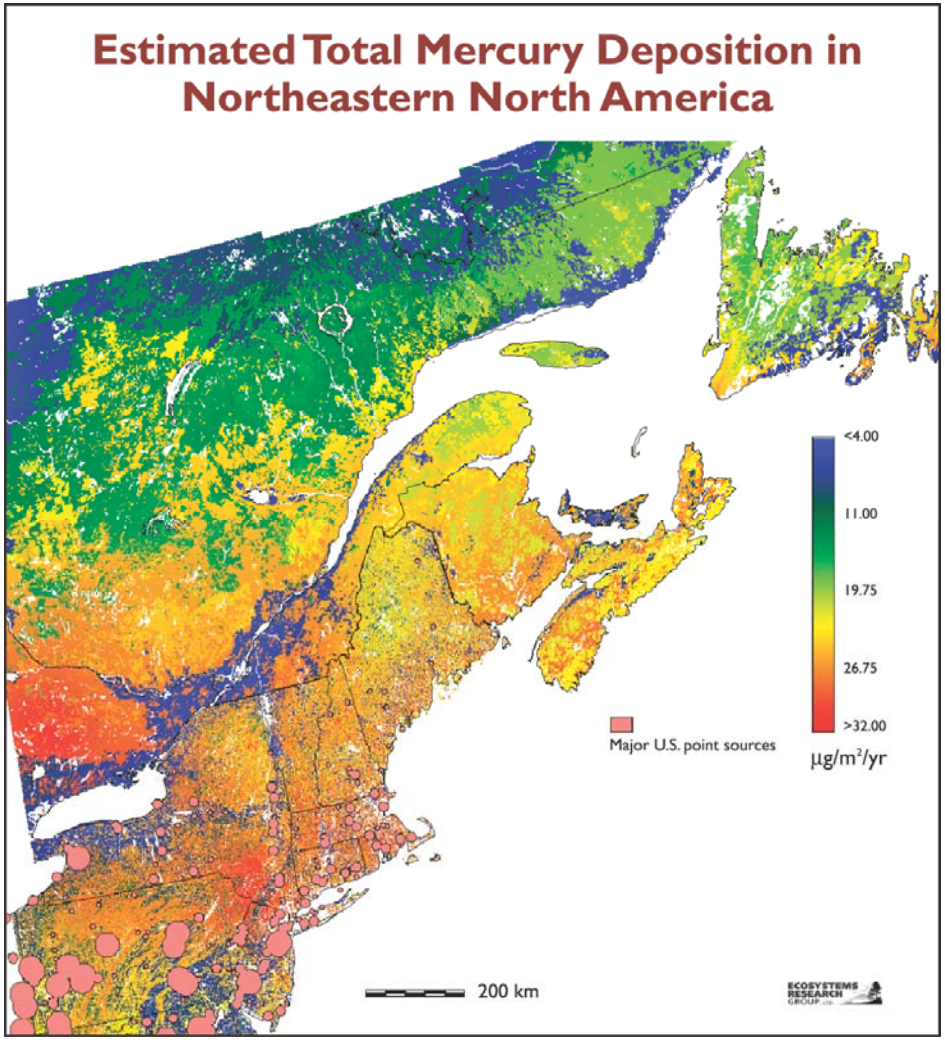
- Mercury is mostly deposited in the Connecticut River watershed from the atmosphere. Much of this mercury originates from coal-fired power plants and incinerators in the eastern U.S.;

- EPA New England has worked with all New England states and the Eastern Canadian provinces to substantially reduce regional mercury emissions about 55% since 1998;

Mercury (cont'd)

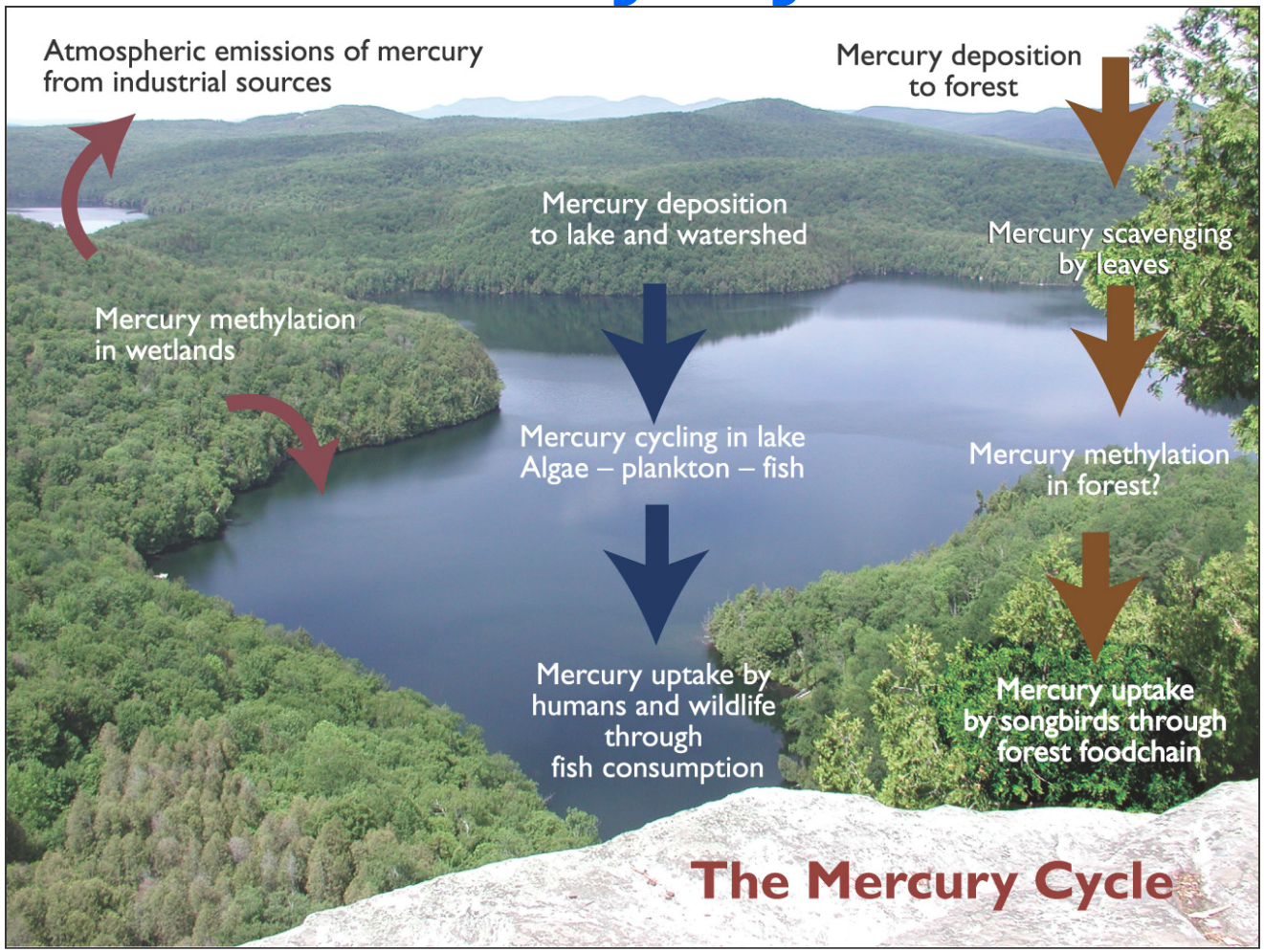
- Once in the river, mercury bioaccumulates to high levels in the food chain;
- Older fish tend to have higher levels of mercury and other contaminants;
- Higher levels of mercury in the upper Reaches may, in part, be a result of water level manipulations, particularly in reservoirs;

Estimated Total Hg Deposition in Northeastern North America



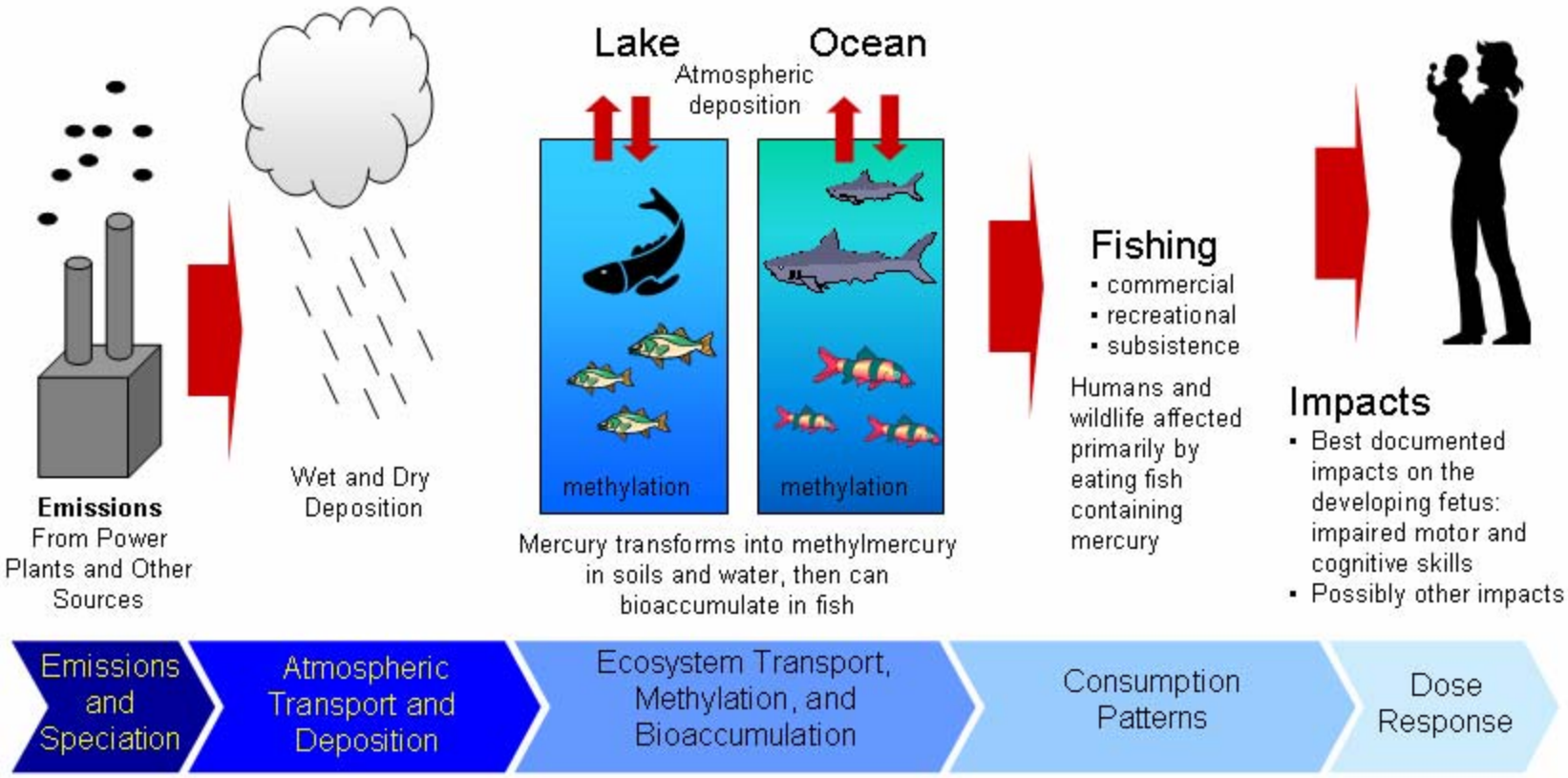
Source: Miller and others (2005)

The Aquatic *and* Terrestrial Mercury Cycle



Source: Evers (2005)

Mercury Exposure Pathway



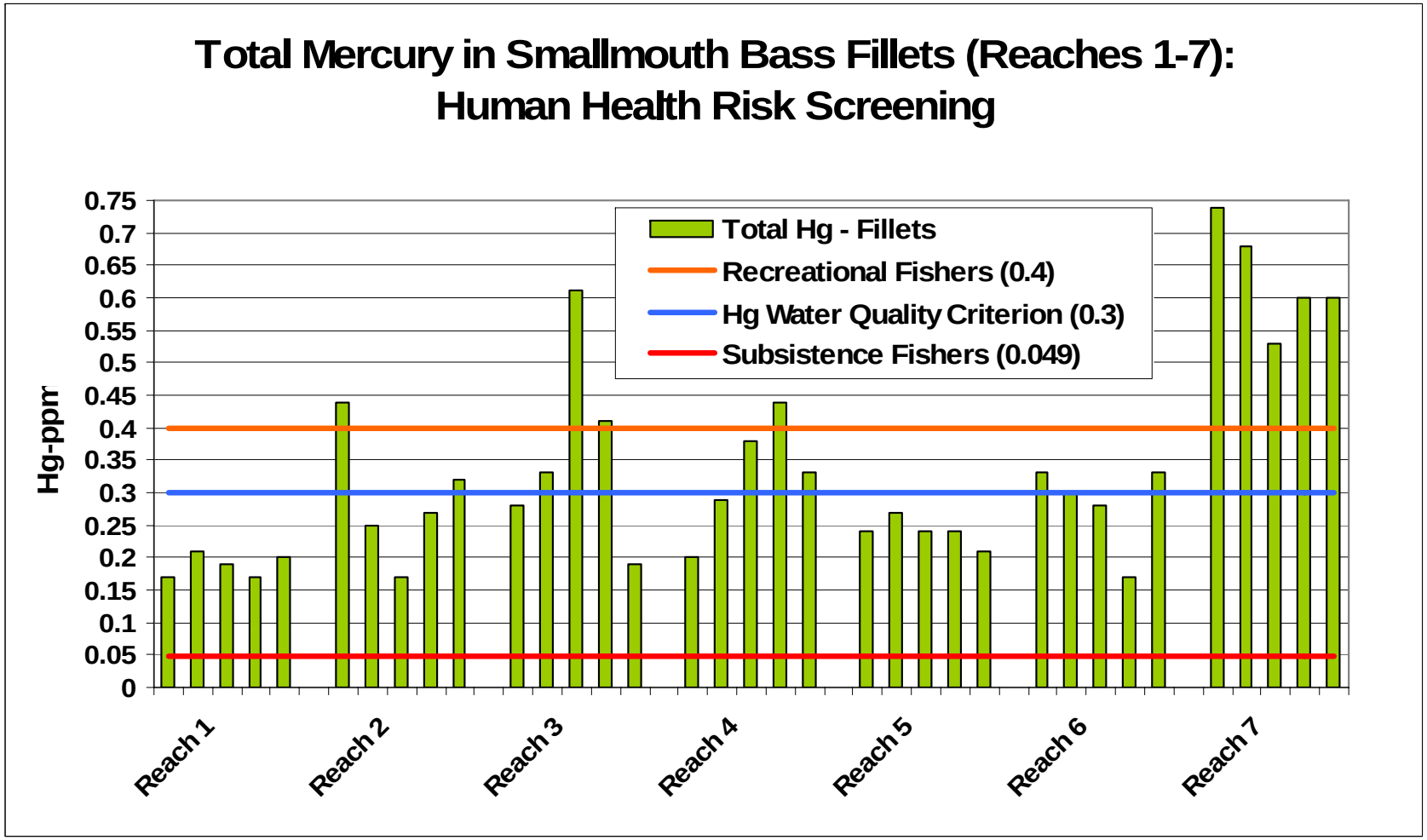
Source: USEPA (2006)

EPA Mercury Human Health and Eco-Risk Screening Criteria (ppm)

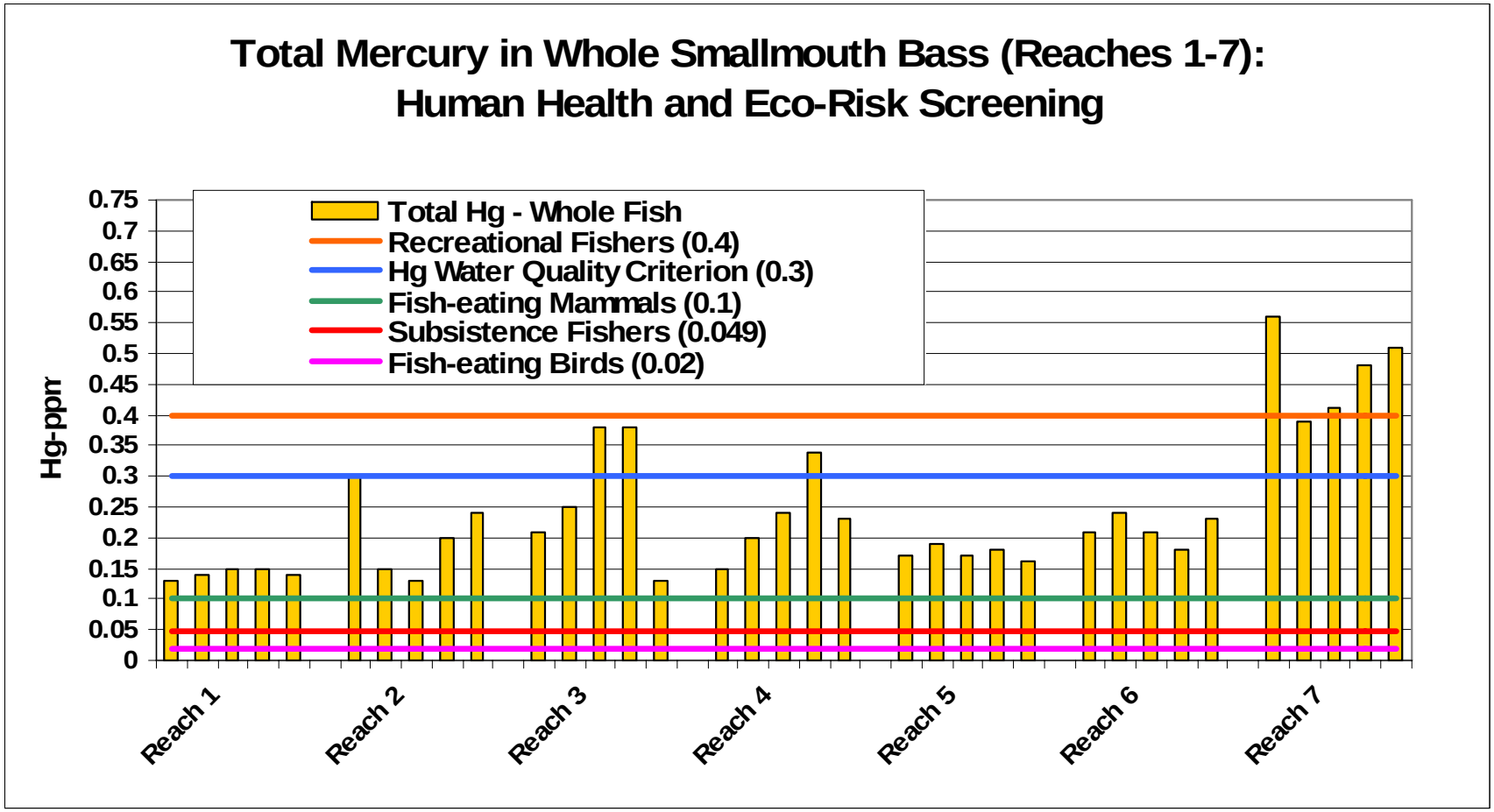
Human Health Criteria			Eco-Risk Criteria	
Recreational/ Sport Fishers	Subsistence Fishers	EPA Water Quality Criterion	Fish-eating Birds	Fish-eating Mammals
0.4	0.049	0.3	0.02	0.1

The EPA mercury "water quality criterion describes the maximum advisable concentration of methylmercury in freshwater and estuarine fish and shellfish tissue to protect consumers of fish and shellfish among the general population." -U.S. EPA (2001a)

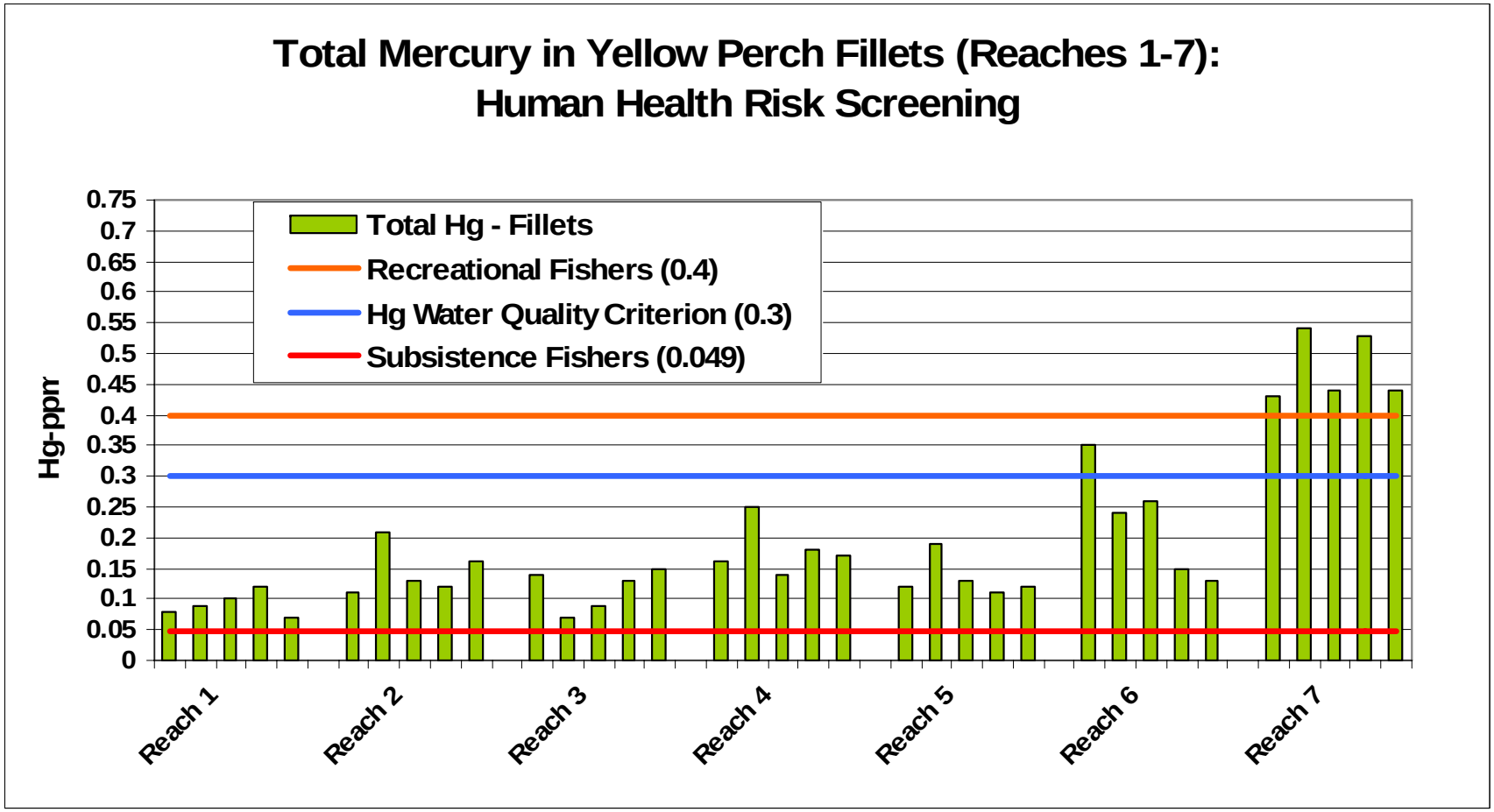
Total Hg in Smallmouth Bass Fillets (Reaches 1-7)



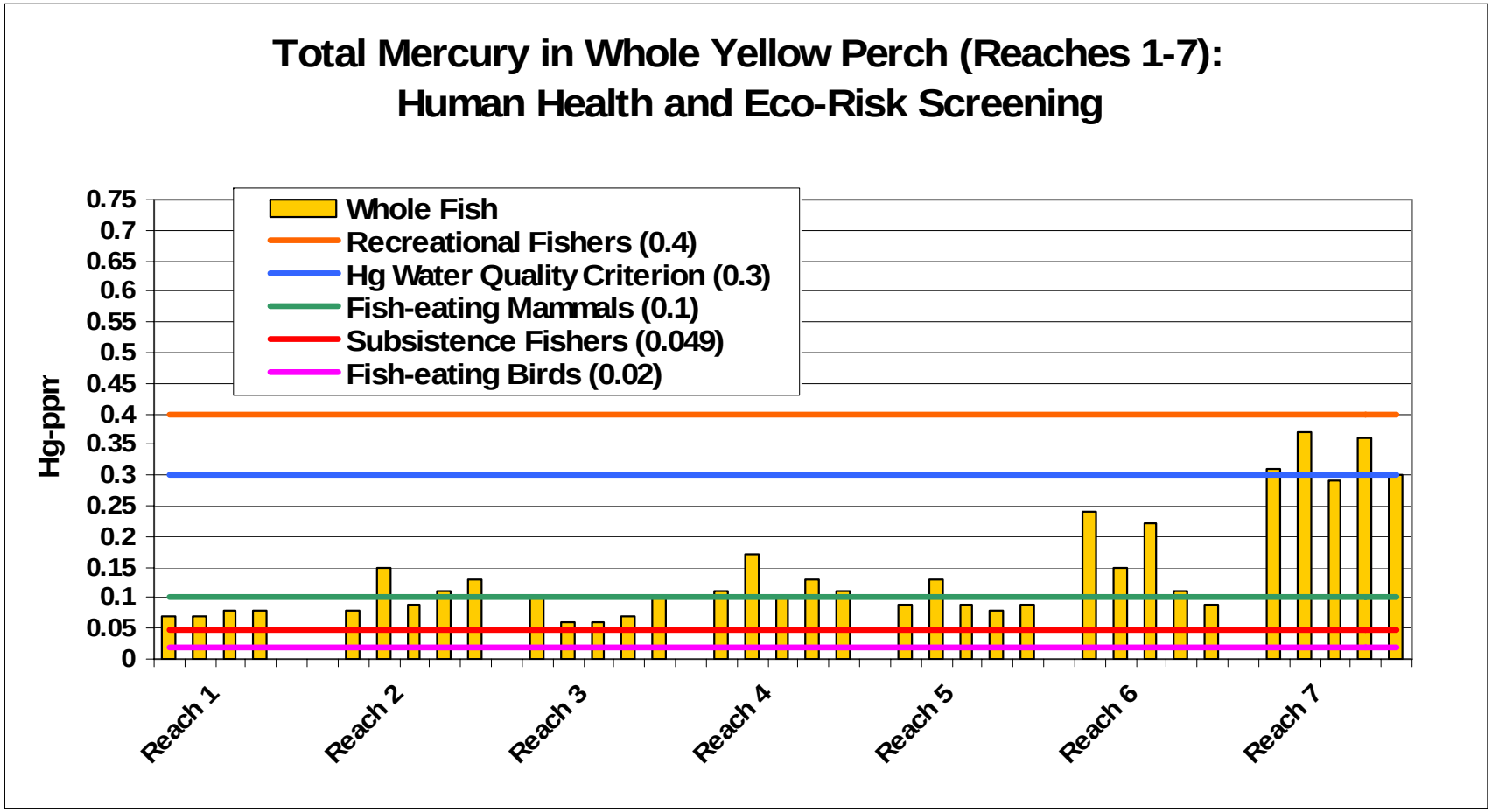
Total Hg in Whole Smallmouth Bass (Reaches 1-7)



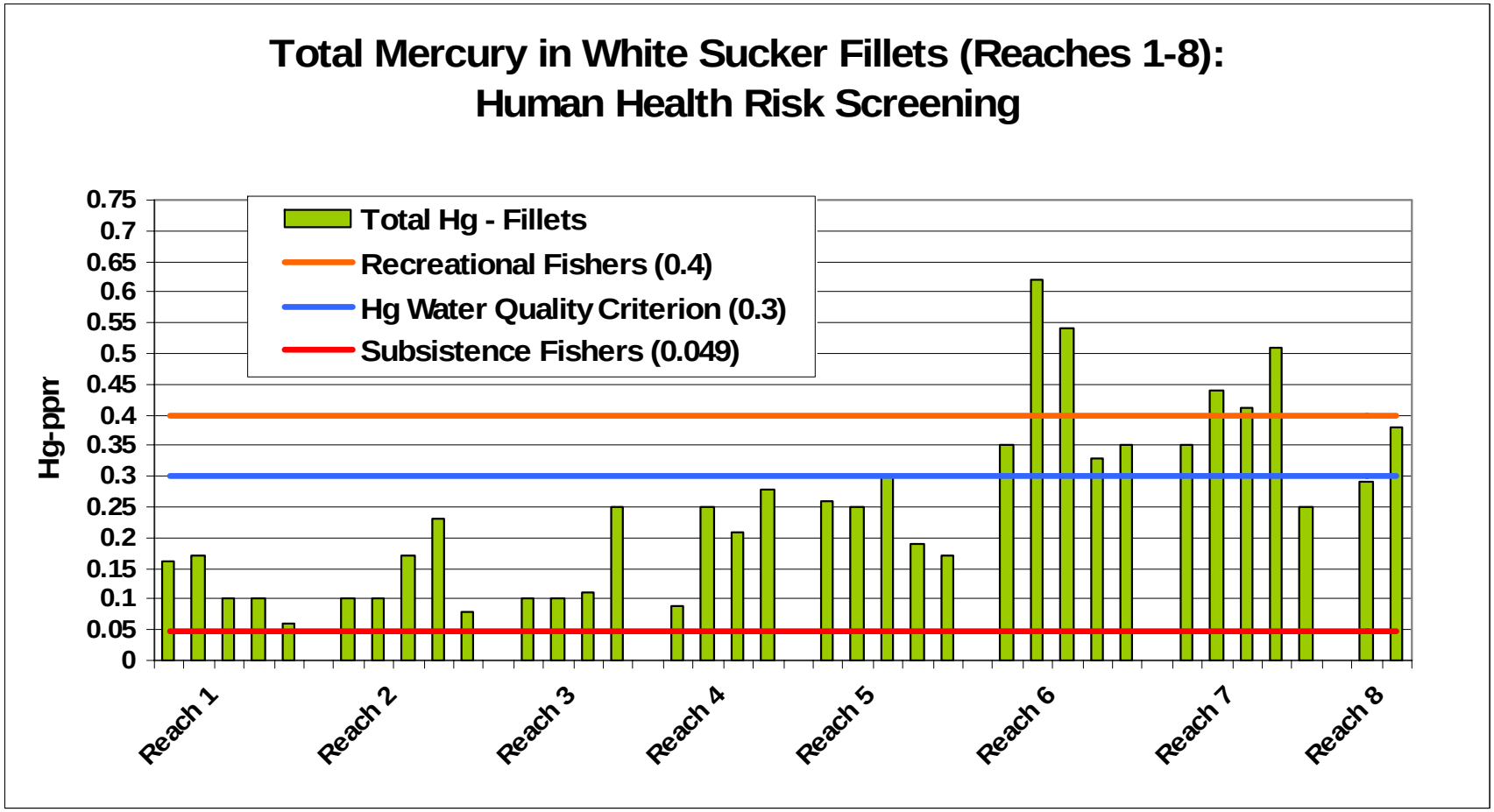
Total Hg in Yellow Perch Fillets (Reaches 1-7)



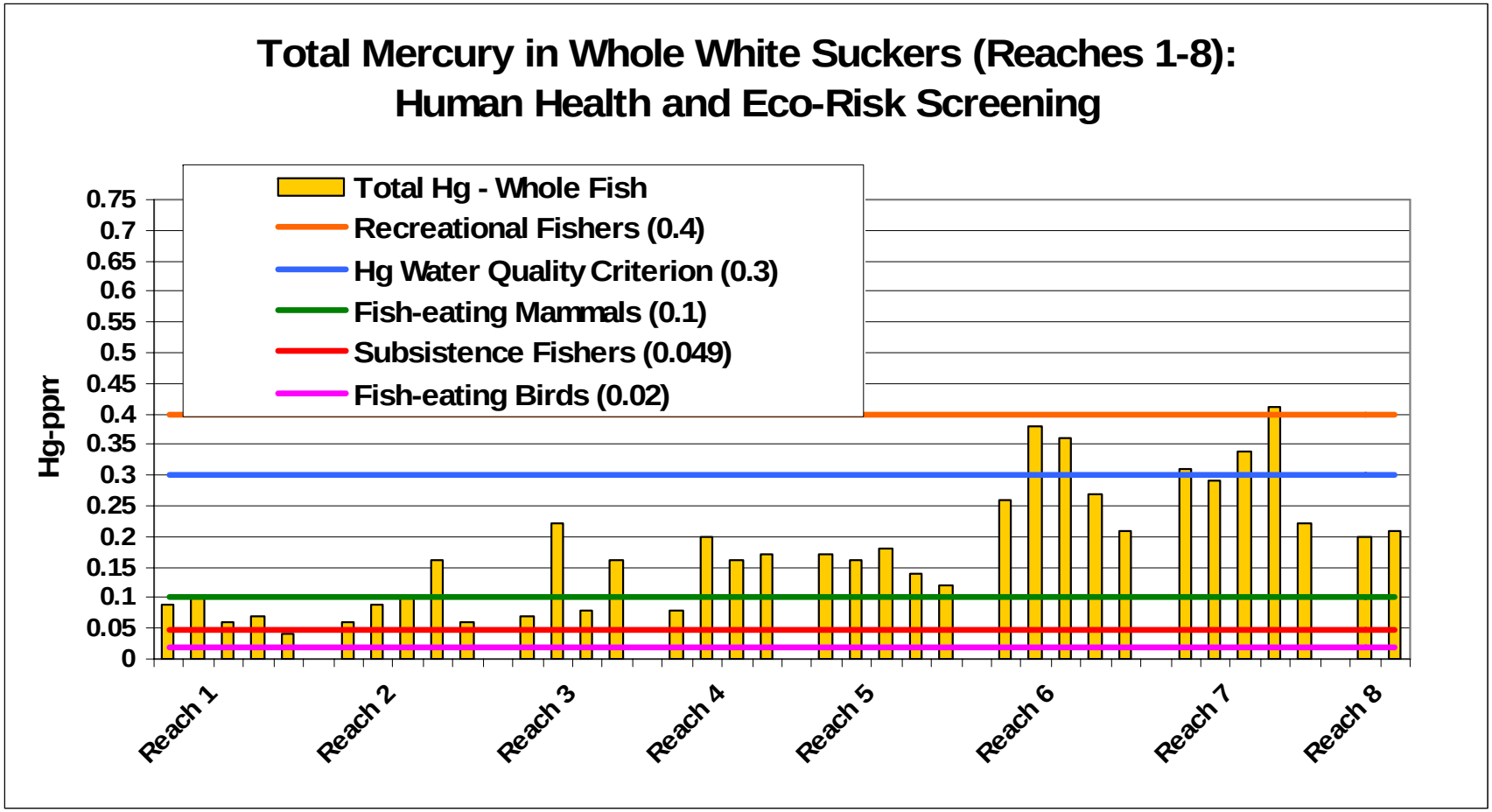
Total Hg in Whole Yellow Perch (Reaches 1-7)



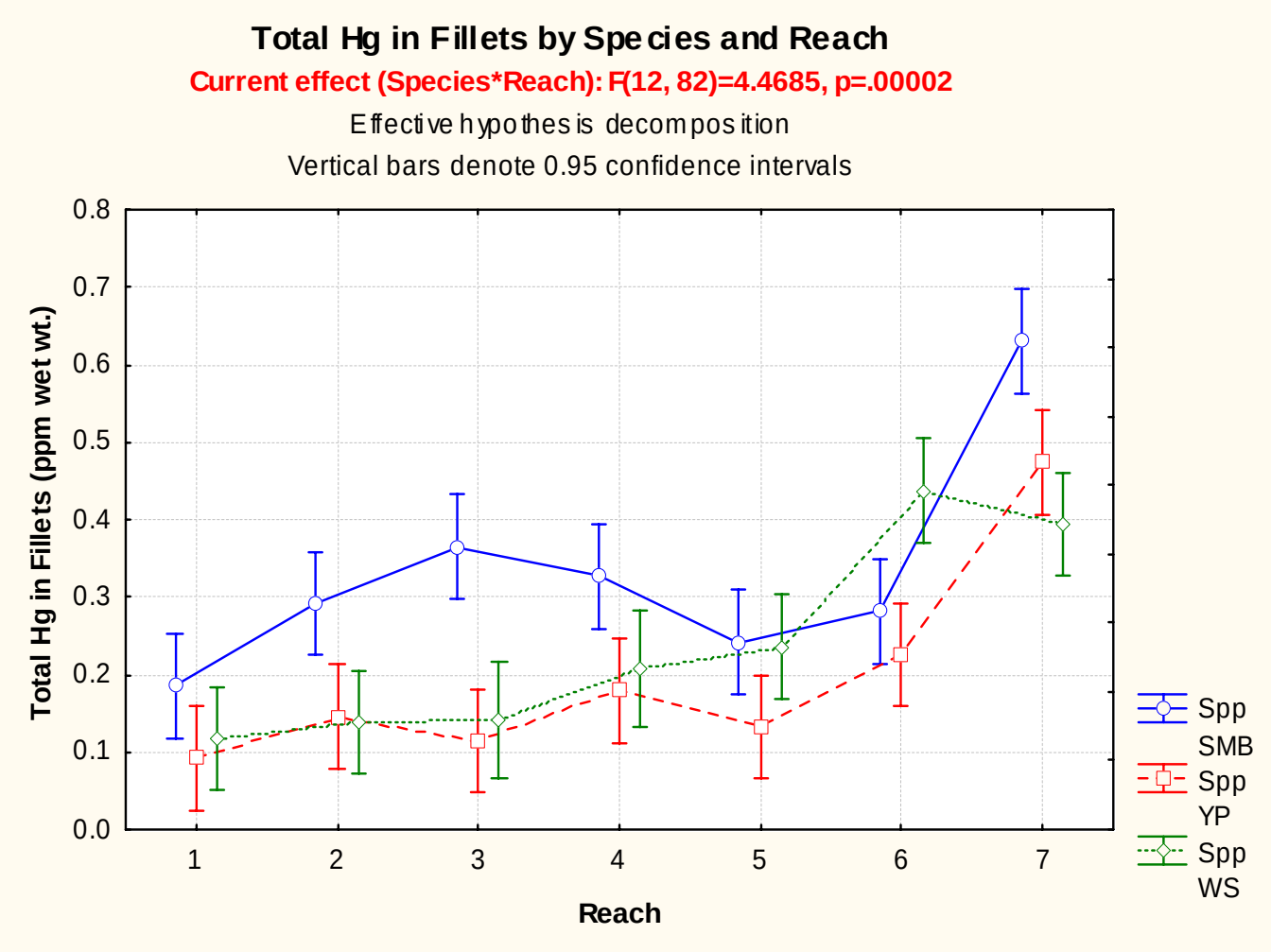
Total Hg in White Suckers Fillets (Reaches 1-8)



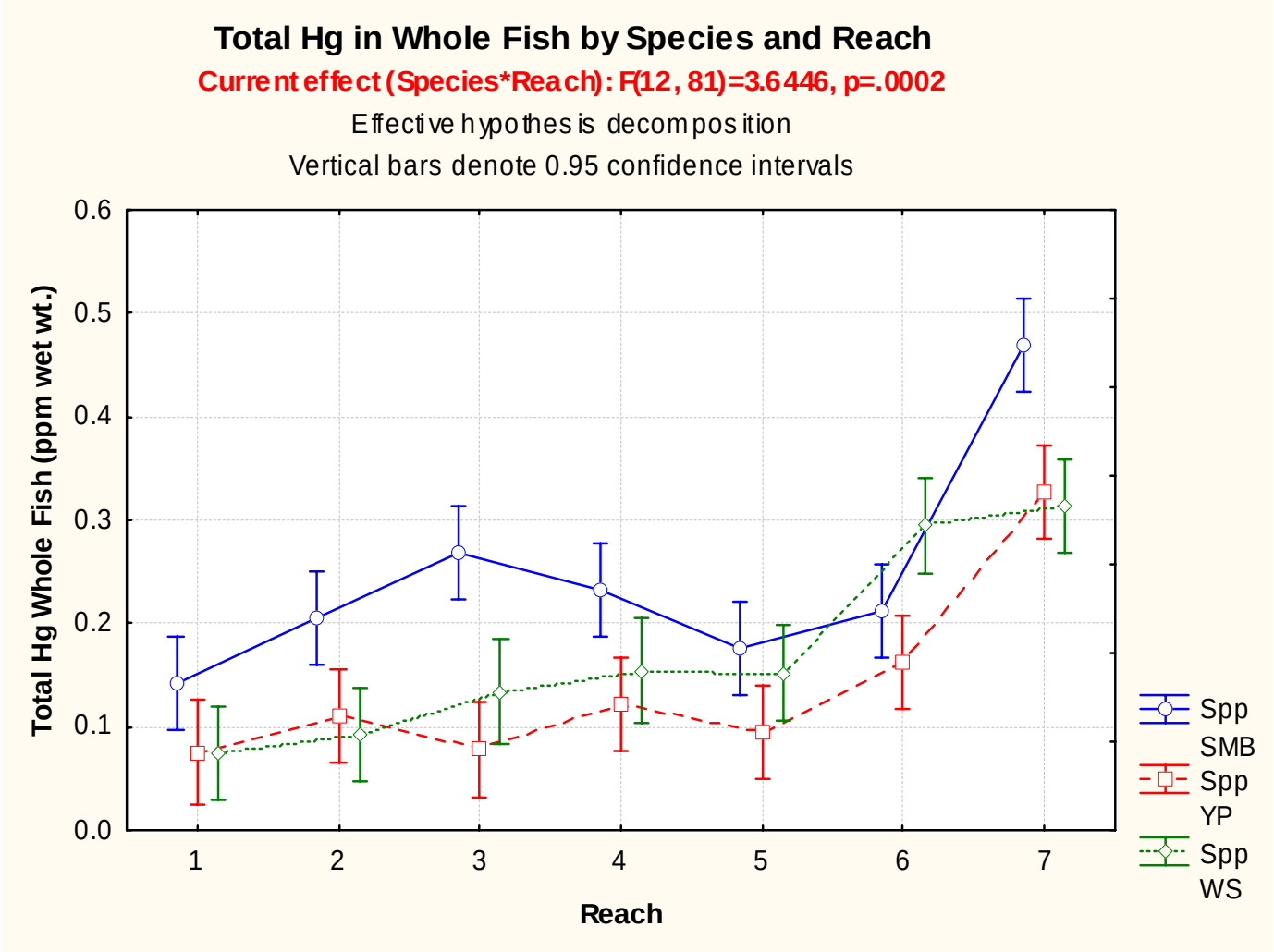
Total Hg in Whole White Suckers (Reaches 1-8)



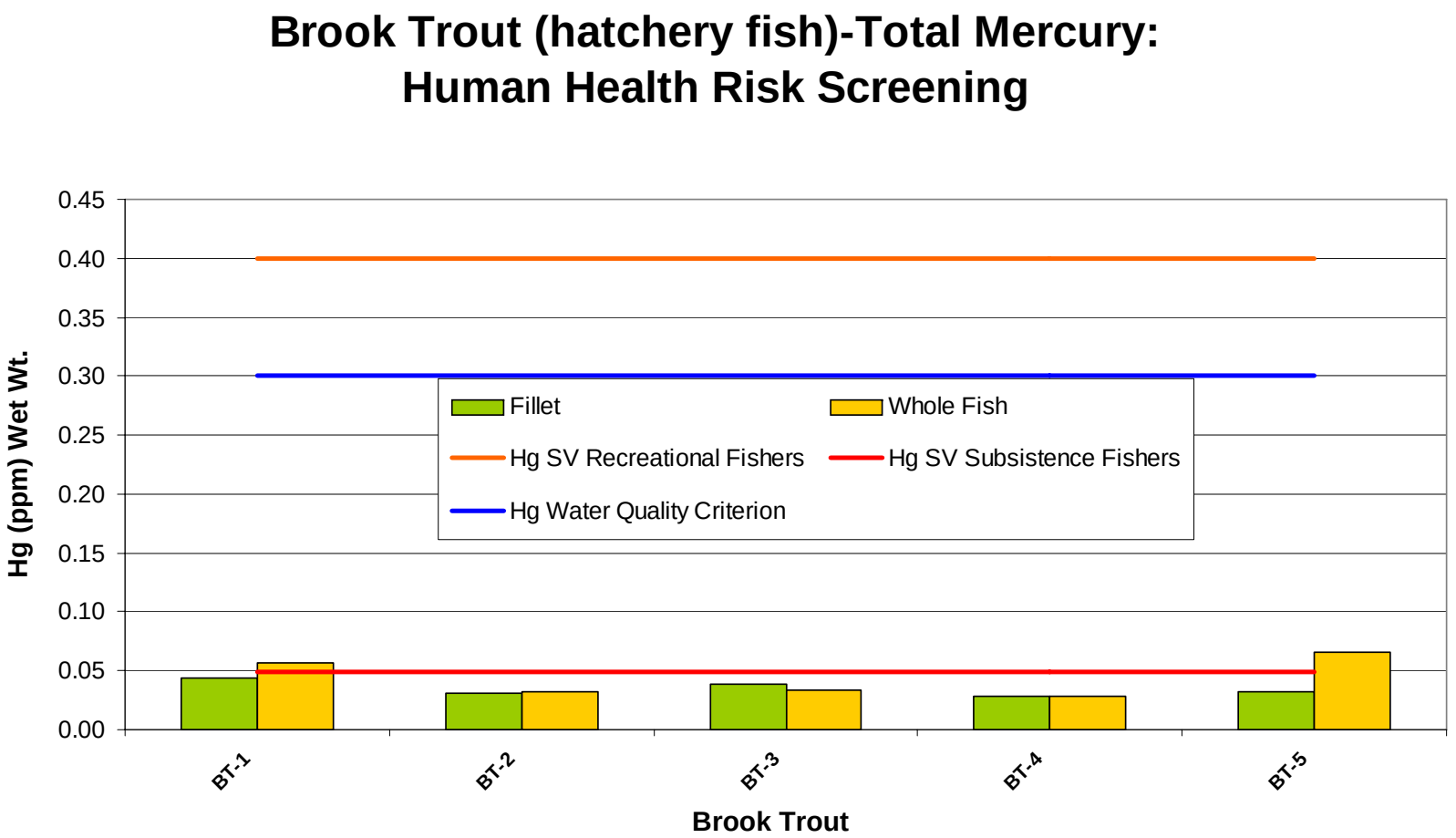
Total Hg in Fillets by Species and Reach 1-7



Total Hg in Whole Fish by Species and Reach 1-7



Total Hg in CT Hatchery (control) Brook Trout



Note: Hg in whole fish inferred from weight of offal and fillet, as total weight of fish not taken

% of Fillet and Whole Fish Samples above Mercury Human Health and Eco-Risk Screening Criteria (all Reaches)

Species	Fillet or Whole Fish	% > Subsistence Fisher SV (0.049 ppm)	% > EPA Water Quality Criterion (0.3 ppm)	% > Recreational Fisher SV (0.4 ppm)	% > Bird SV (0.02 ppm)	% > Mammal SV (0.1 ppm)
Smallmouth Bass	Fillets	100%	46%	26%		
	Whole	100%	26%	11%	100%	100%
Yellow Perch	Fillets	100%	17%	13%		
	Whole	100%	12%	0%	100%	39%
White Sucker	Fillets	100%	31%	14%		
	Whole	97%	14%	3%	100%	71%

- 97- 100% of fillets and whole fish > subsistence fisher SV;
- 0-26% of fillets and whole fish > recreational fisher SV;
- 12-46% of fillets and whole fish > EPA WQC
- 100% of whole fish > fish-eating Bird SV;
- 39-100% of whole fish > fish-eating Mammal SV;

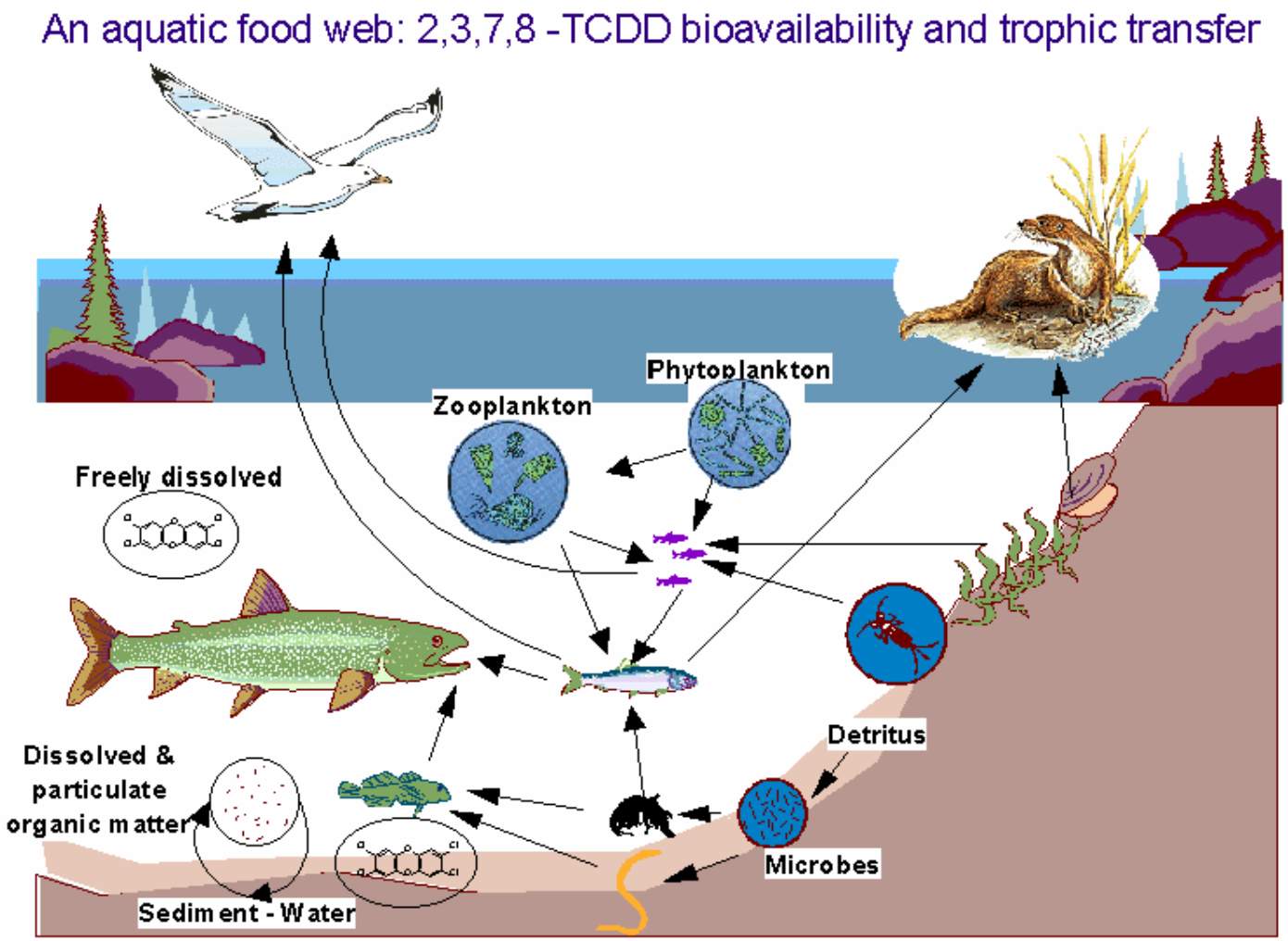
Some PCB and Dioxin History

- Use and manufacture of PCBs was banned in the U.S. in 1977 after production of over 1.5 billion pounds. Dioxins and PCBs break down very slowly in the environment and bioaccumulate in food chains;

- Dioxins are produced in nature and inadvertently by humans; often through combustion processes such as at waste incinerators;

- Levels in Connecticut River fish reflect historic and possibly current sources;

Simple Aquatic Dioxin Food Web



Source: Dr. Phil Cook (USEPA – Duluth)

EPA Coplanar PCB/Dioxin TEQs: Human Health Criteria

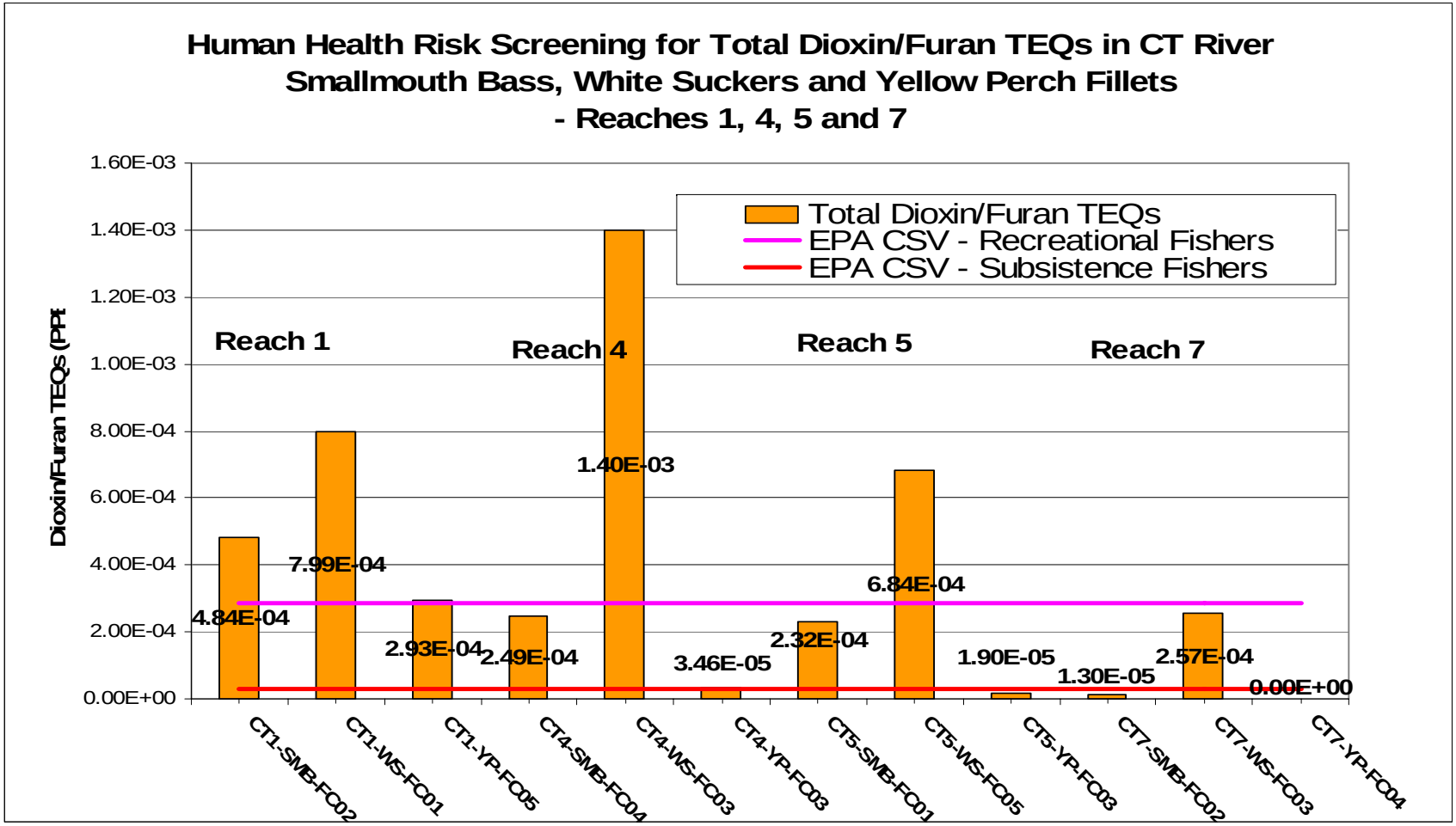
Human Health Carcinogenic Screening Values (CSV) (ppb)	
Recreational Fishers	Subsistence Fishers
2.56E-04	3.15E-05

TEQs are a standardized measure of dioxin/furan and dioxin-like (coplanar) PCB toxicity agreed upon by the USA, Europe and the World Health Organization (Van den Berg and others 1998);

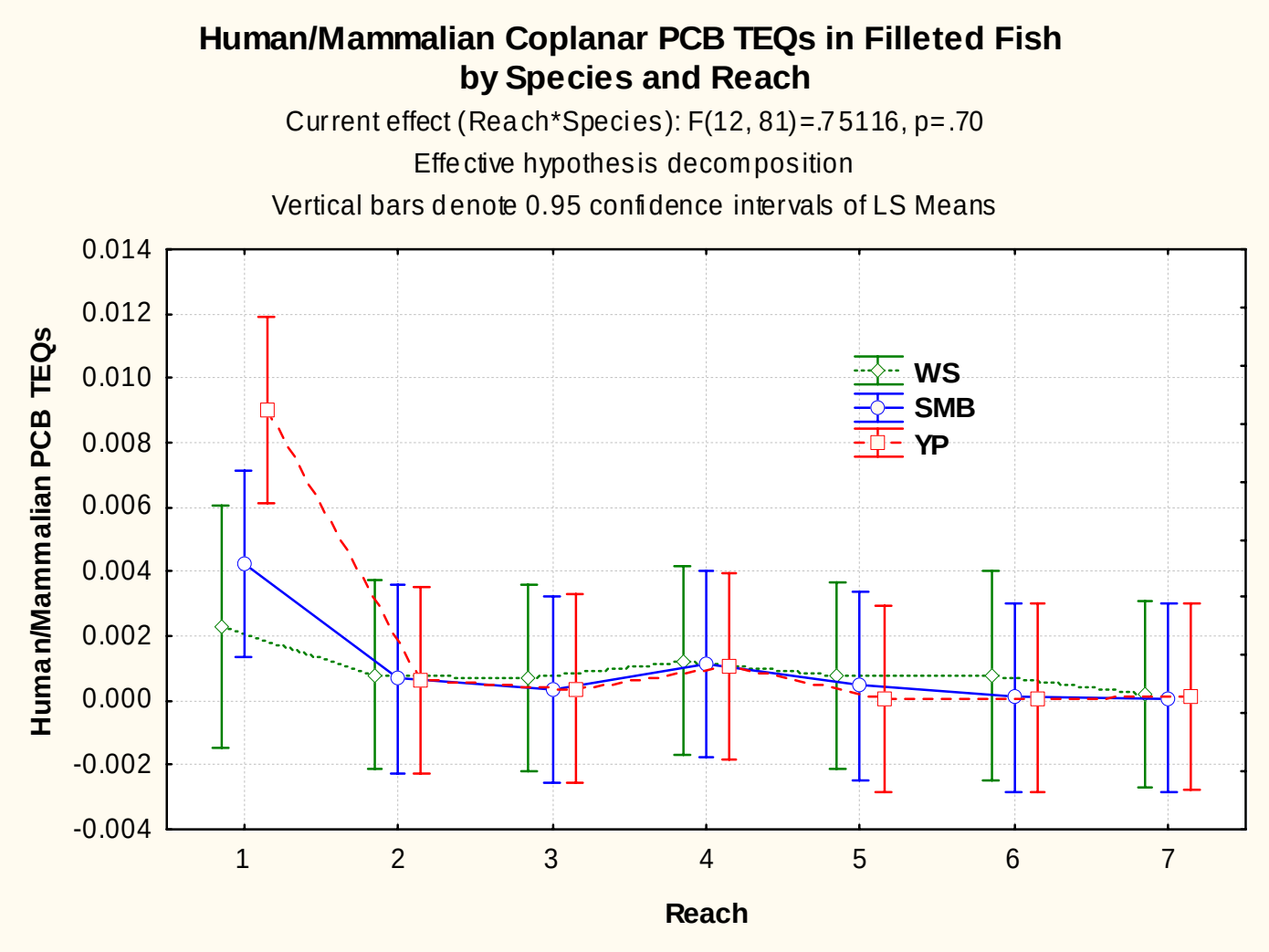
EPA Coplanar PCB/Dioxin TEQs: Eco-Risk Criteria

Fish-eating Wildlife Receptor	Fish Concentration (ppb)
Low Eco-Risk	
Mammals	7.00E-04
Birds	6.00E-03
Fish	5.00E-02
High Eco-Risk	
Mammals	7.00E-03
Birds	6.00E-02
Fish	8.00E-02

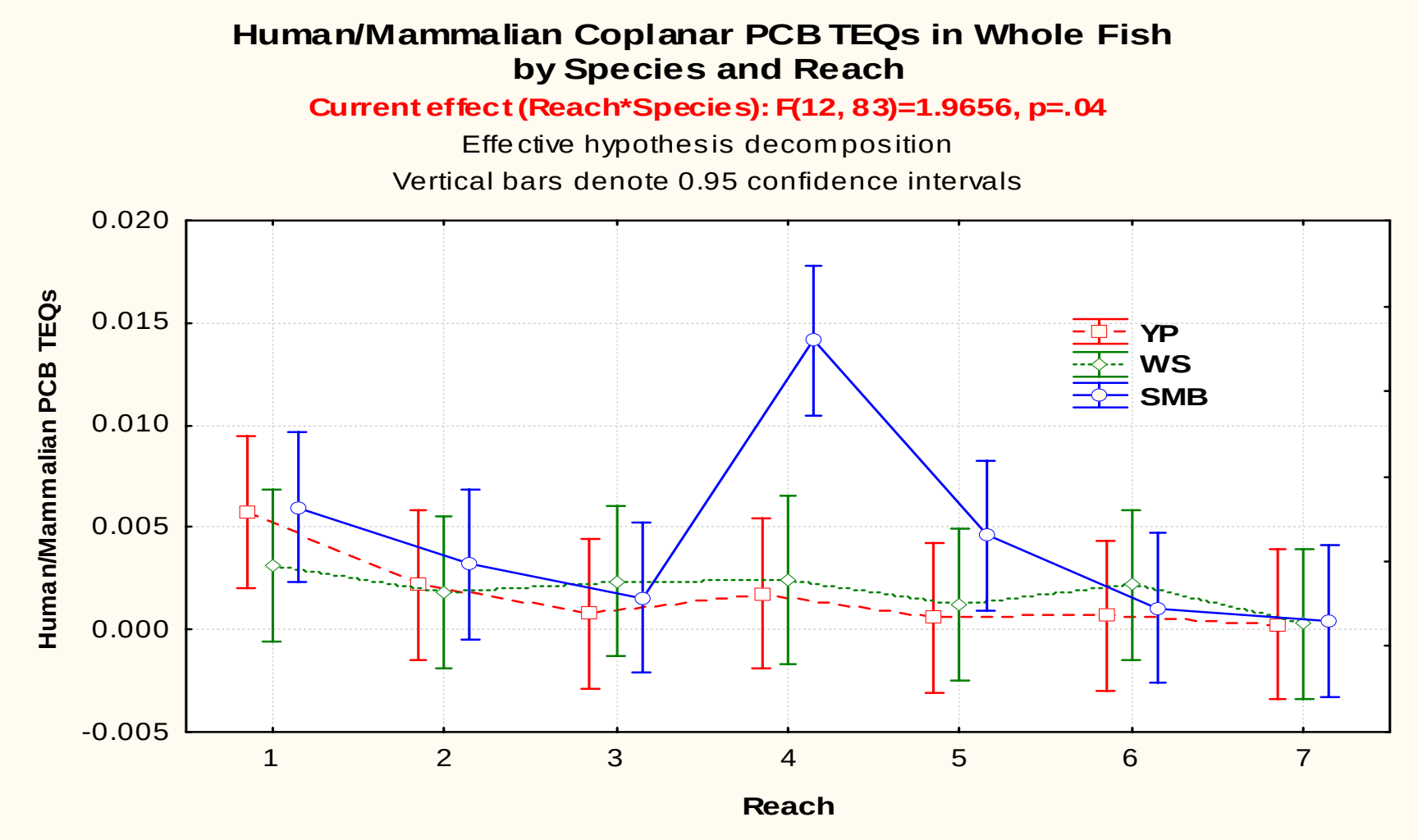
Human Health Risk for Dioxin TEQs in SMB, WS, & YP Fillets



Human/Mammalian Coplanar PCB TEQs in Fish Fillets by Spp. & Reach



Human/Mammalian Coplanar PCB TEQs in Whole Fish by Spp. & Reach



% of Fillet & Whole Fish Samples > PCB TEQ Human Health & Eco-Risk Screening Values (all Reaches)

Species	Fillet or Whole Fish	% > Subsistence Fisher CSV	% > Recreational Fisher CSV	% > Mammal Low and High Eco-Risk SV		% > Bird Low and High Eco-Risk SV		% > Fish Low and High Eco-Risk SV	
		3.15E-05 ppb	2.56E-04 ppb	7.00E-04 ppb	7.00E-03 ppb	0.006 ppb	0.06 ppb	0.05 ppb	0.08 ppb
Smallmouth Bass	Fillets	100%	51.4%						
	Whole	100%	98%	77%	14%	31%	3%	0%	0%
Yellow Perch	Fillets	86.5%	29.4%						
	Whole	100%	80%	63%	3%	26%	0%	0%	0%
White Sucker	Fillets	100%	73%						
	Whole	100%	86%	73%	0%	35%	3%	0%	0%

- 86-100% of fillets & whole fish > subsistence SV;
- 51-98% of fillets & whole fish > recreational SV;
- 63-73%> low mammal SV; 0-14%> high mammal SV;
- 26-35%> low bird SV; 0-3% > high bird eco-risk SV;
- 0%> fish low and high eco-risk SV

Some DDT History

- DDT use was severely restricted by EPA in 1972 after application of over 1.3 billion pounds during the previous thirty years;
- DDT is very long-lived in the environment in either its original or breakdown forms;
- There are no known current sources of DDT to the Connecticut River so contaminants in fish result from historical contamination in the watershed;

Total DDT Homologs: Human Health Screening Criteria

- Human health screening benchmarks for carcinogenic and non-carcinogenic endpoints for recreational and subsistence fishers were obtained from USEPA (2000b). A risk level of 10^{-5} was used for carcinogenic endpoint screening:
  - A risk level of 10^{-5} corresponds to an estimated increased risk of 1:100,000 of acquiring cancer from a life time's exposure at this level. It is the middle of EPA's acceptable cancer risk range.

Total DDT Homologs: Eco-Risk Screening Criteria

- Ecological screening benchmarks (NOAELs) for belted kingfisher and river otter

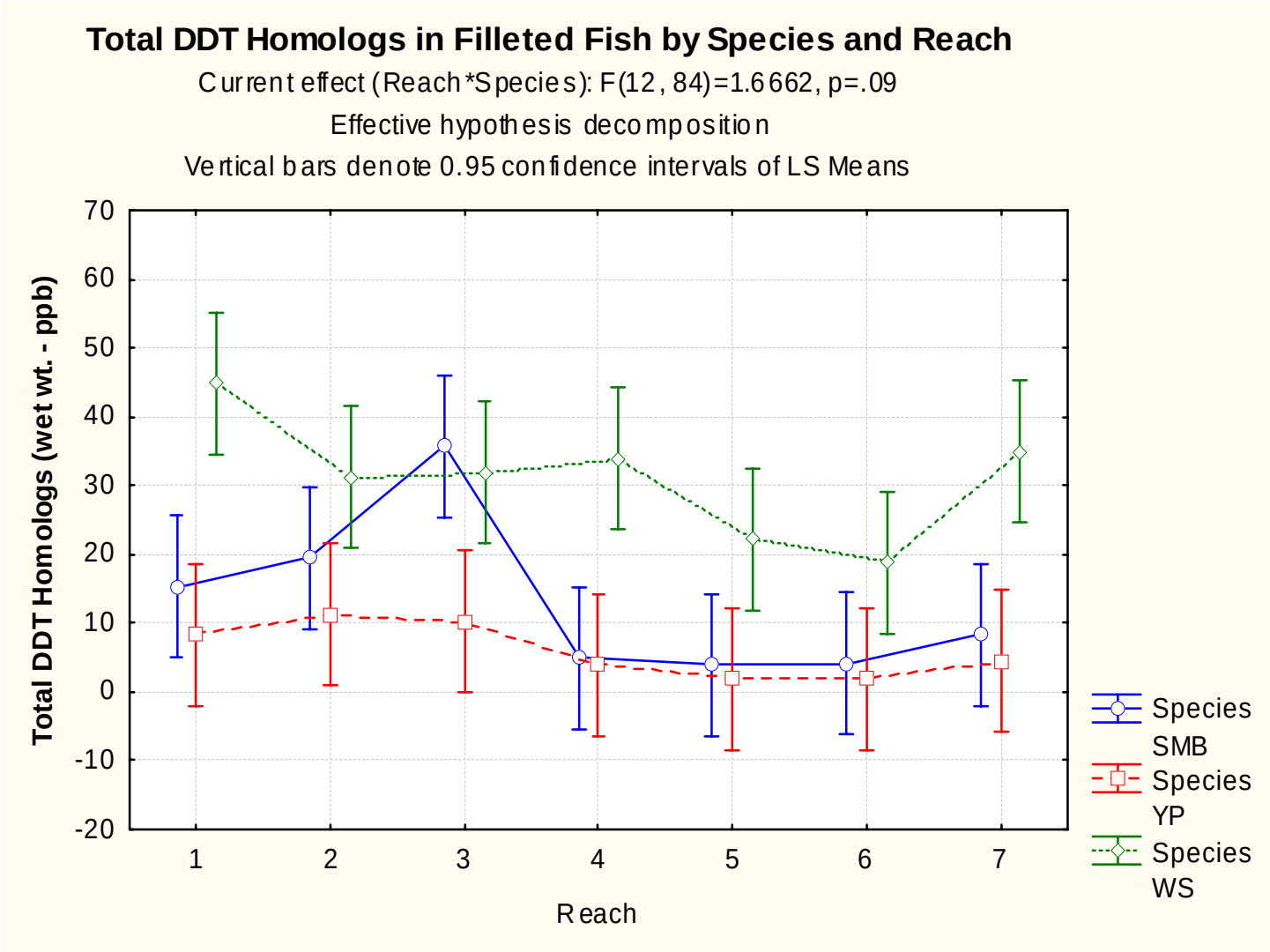
  - No-Observed-Adverse-Effect Level (NOAEL)

- Representative of higher trophic level species that derive large proportions of their diet from fish;

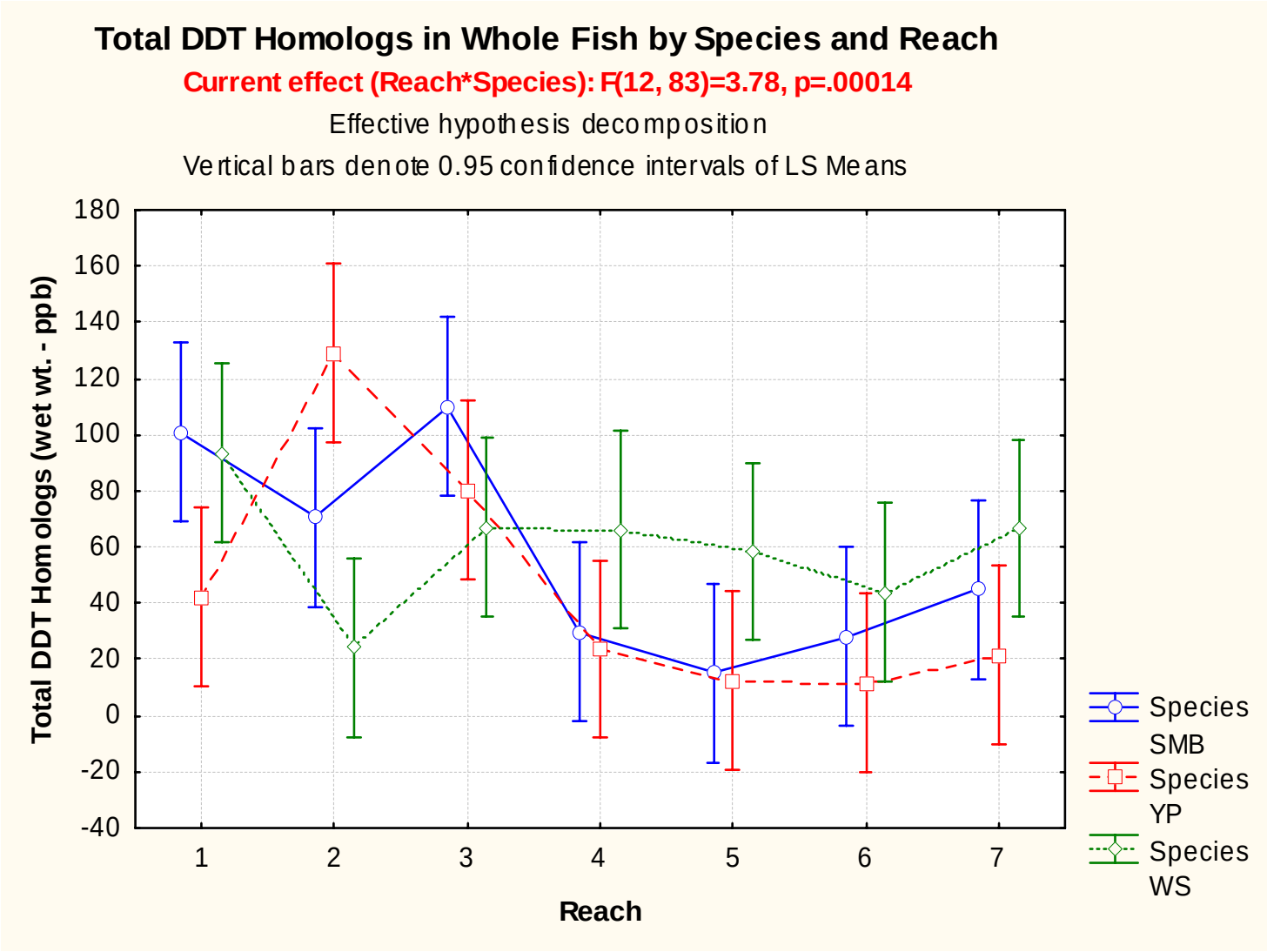
Total DDT Homolog Human Health and Eco-Risk Screening Criteria

Human Health Screening Criteria				Eco-Risk Criteria	
Recreational Fishers (ppb)		**Subsistence Fishers (ppb)**		**Belted King-fisher**	**Otter**
Noncarcinogens	**Carcinogens ($RL=10^{-5}$)**	**Noncarcinogens**	**Carcinogens ($RL=10^{-5}$)**	**NOAEL (ng/g - ppb)**	**NOAEL (ng/g - ppb)**
2,000	117	245	14.4	6	3,250

Total DDT Homologs in Fish Fillets by Species and Reach 1-7



Total DDT Homologs in Whole Fish by Species and Reach 1-7



% of Fillet and Whole Fish Samples above Human Health and Eco-Risk Screening Criteria in all Reaches

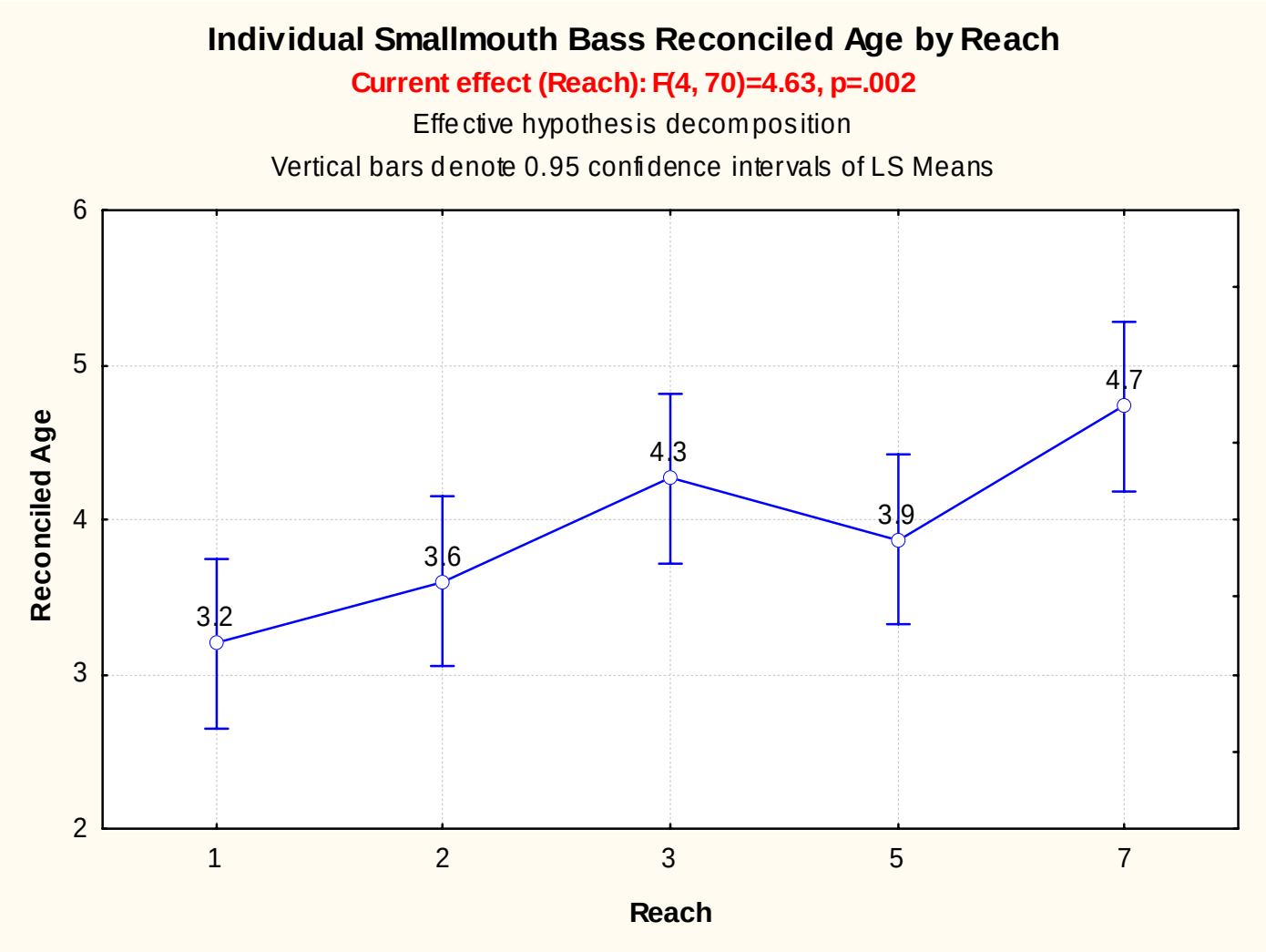
Species	EPA Human Health Risk Screening Values						Eco-Risk Screening Values	
	%> Recreational Fisher SVs		% >Subsistence Fishers SVs				% >River Otter SV	% > Belted Kingfisher SV
	Fillets		Fillets		Whole Fish		Whole Fish (3,250 ppb)	Whole Fish (6 ppb)
	Non-Cancer 2,000 ppb	Cancer 117 ppb	Non-Cancer 245 ppb	Cancer 14.4 ppb	Non-Cancer 245 ppb	Cancer 14.4 ppb		
Smallmouth Bass	0	0	0	37	0	89	0	97
Yellow Perch	0	0	0	9	0	71	0	91
White Suckers	0	0	0	84	3	94	0	97

- 0% of fillets > cancer and non-cancer recreational SV;
- 0% of fillets > non-cancer & 9-84% > cancer subsist. SV;
- 0-3% of whole fish > non-cancer & 71-94% > cancer SV;
- 0% of whole fish > River Otter eco-risk SV;
- 91-97% of whole fish > Belted Kingfisher eco-risk SV;

USFWS Aging of Smallmouth Bass in Reaches 1, 2, 3, 5 and 7

- Age is a factor in higher mercury in Reach 7 and possibly other Reaches for SMB;
- Reconciled age, Reach and total mercury in filleted and whole SMB extremely significantly correlated;
- Coplanar PCB TEQs were significantly negatively correlated with age in whole SMB (i.e. older SMB had lower levels);

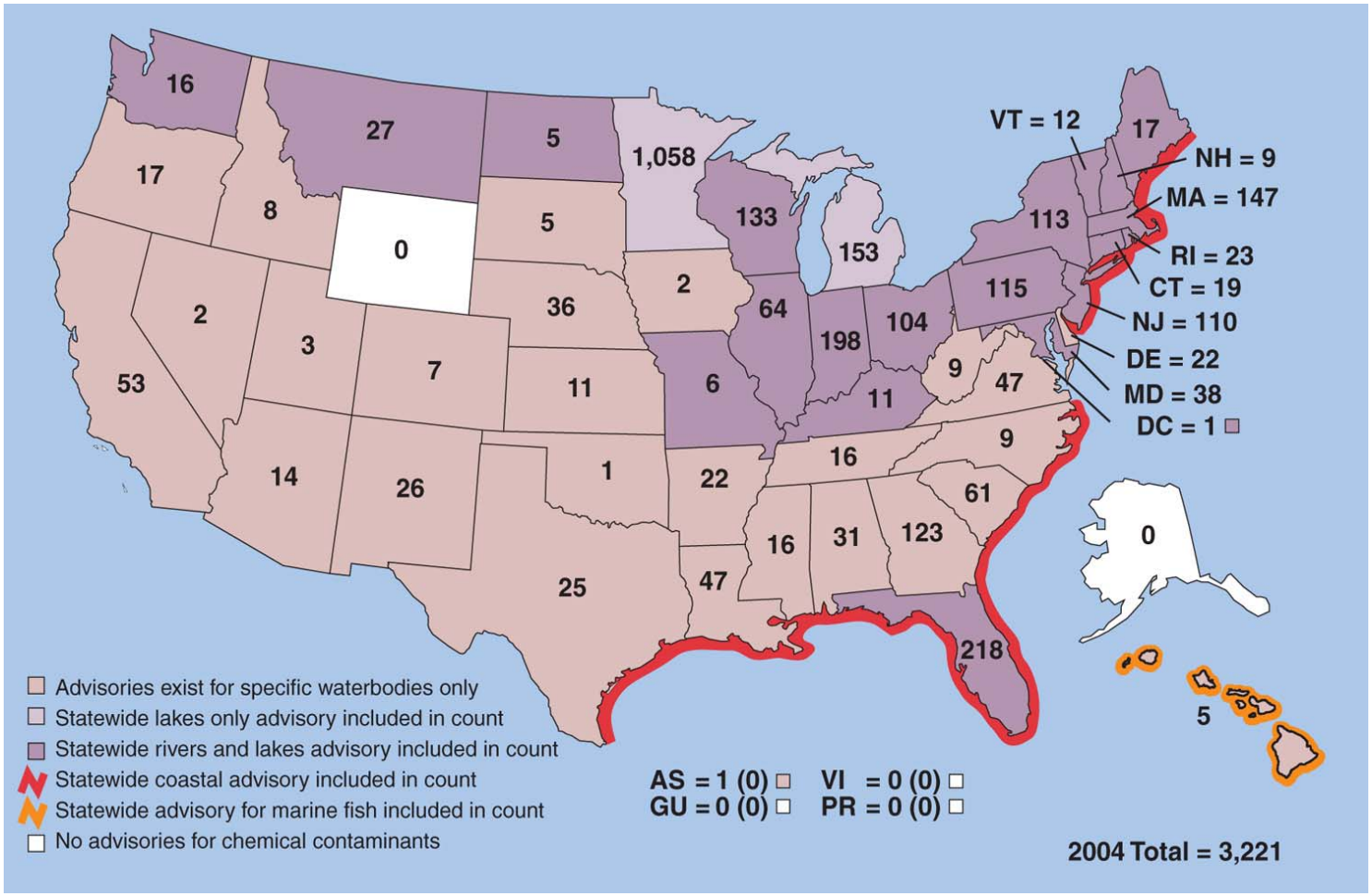
Smallmouth Bass Age (Reaches 1, 2, 3, 5 and 7



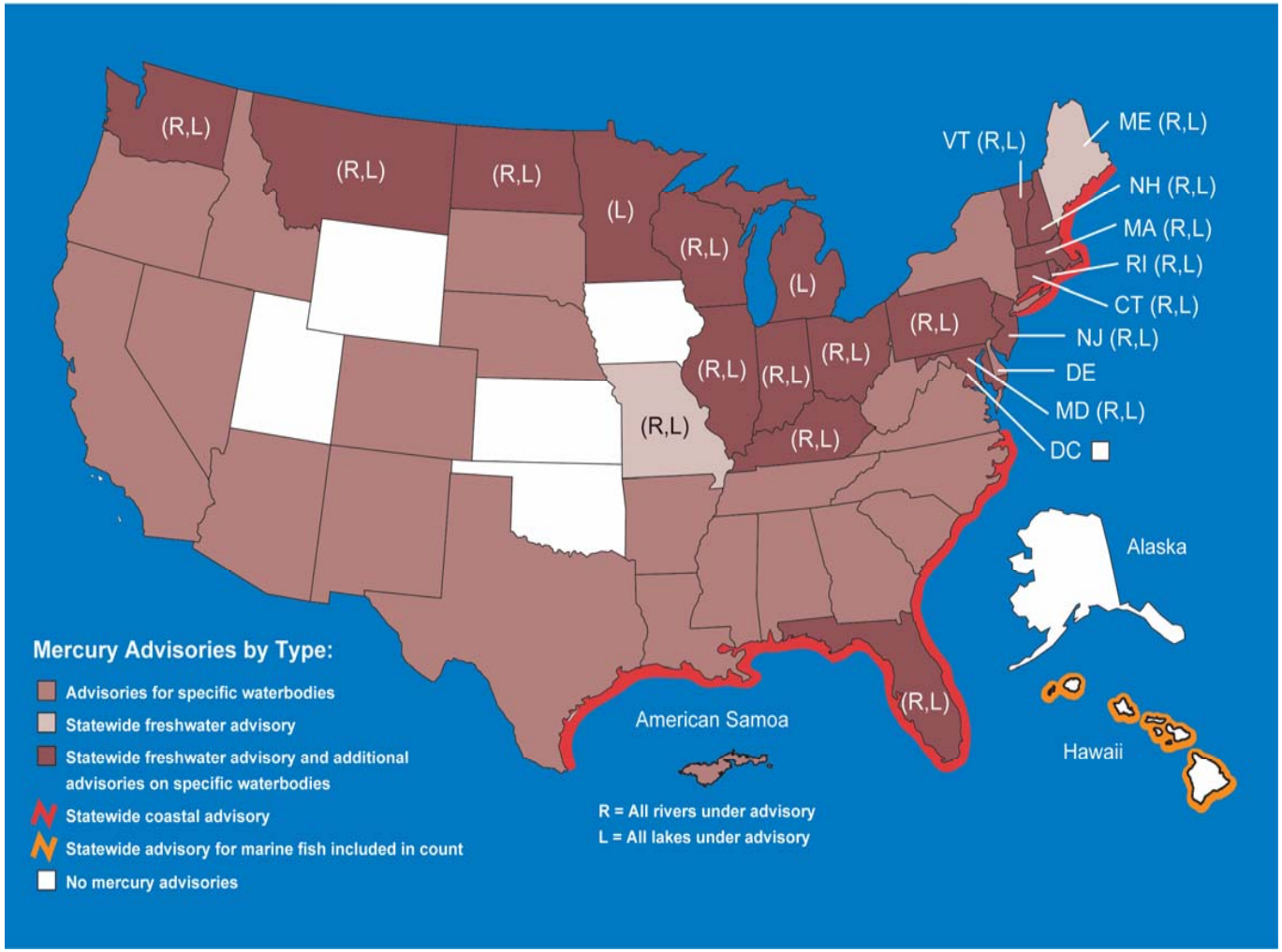
2003 and 2004 Fish Advisories in the Lower 48 States for some PBTs

- **Mercury** 2,436 advisories active in 2004 (up from 2,362 advisories in 2003)
- **PCBs** 873 advisories active in 2004 (down from 884 advisories in 2003)
- **Dioxins** 106 advisories active in 2004 (up from 90 advisories in 2003)
- **DDT and metabolites** 67 advisories active in 2004 (up from 52 in 2003).

Total Number of All Fish Consumption Advisories – 2004



2004 Fish Consumption Advisories for Mercury

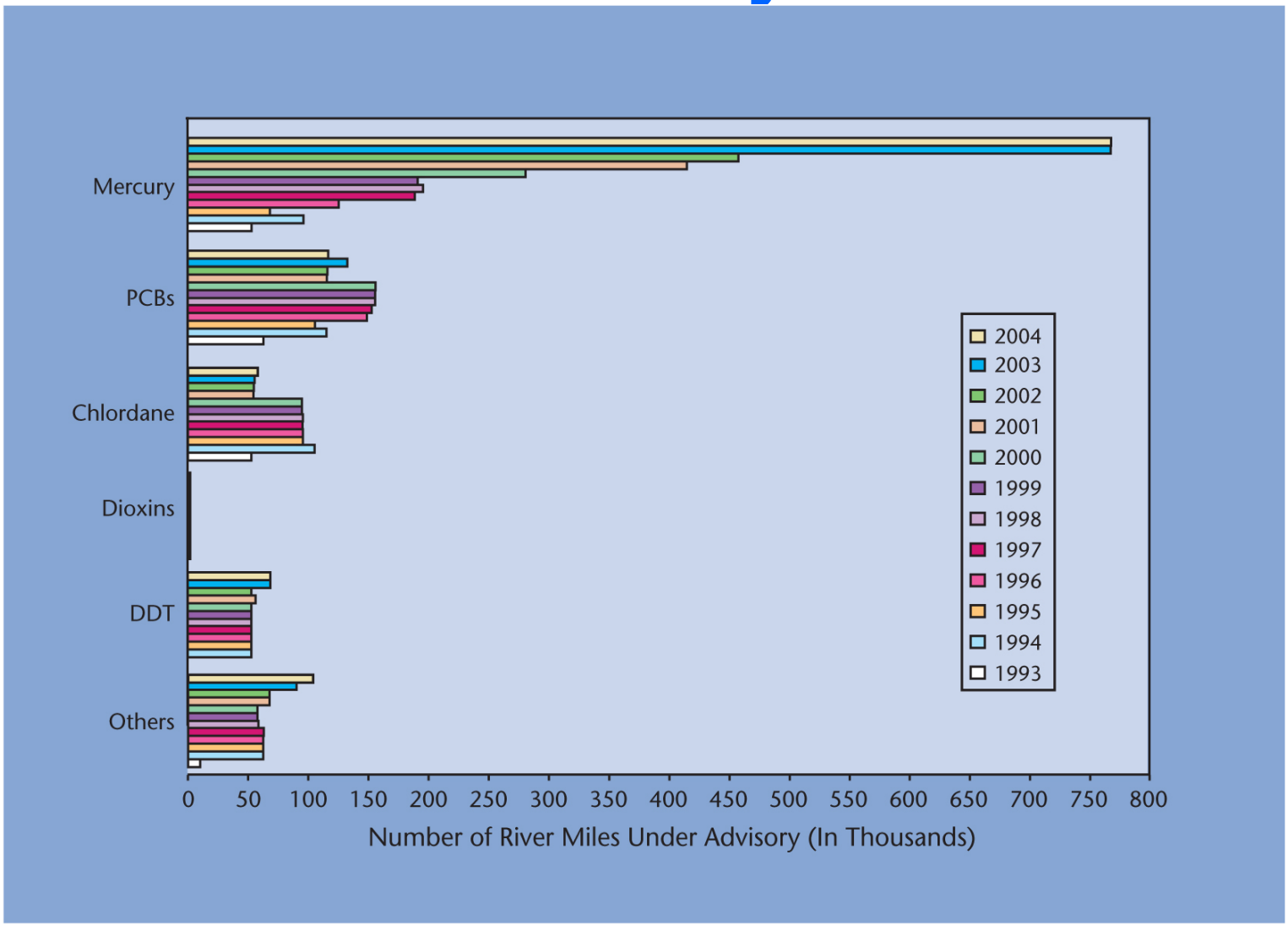


Extent of 2004 New England Fish Consumption Advisories for Hg and Dioxin

- In 2004, 161 mercury advisories in New England coastal and freshwaters. 100% of New England's lake acreage and river miles were under advisory as of 2004 because of statewide mercury advisories for sensitive populations;

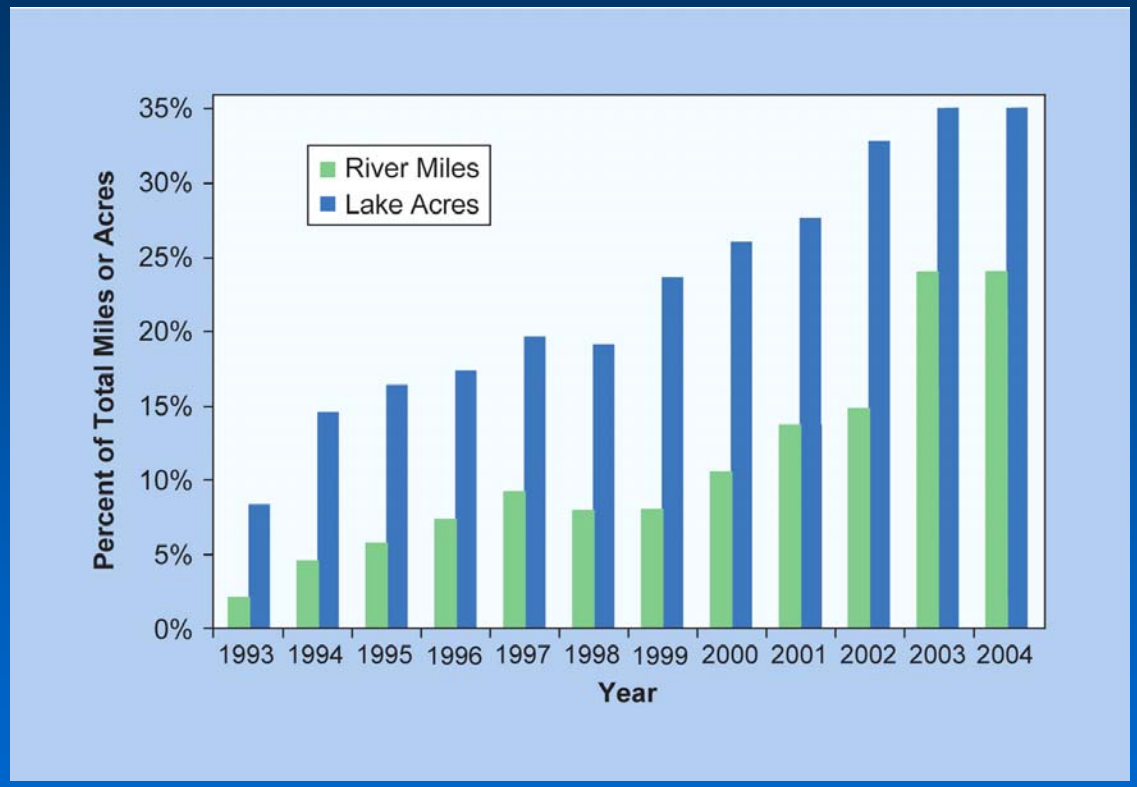
- In New England there were only 11 active dioxin advisories as of the 2003 data (USEPA 2005). In 2004 there were 24 in New England, including coastal and freshwaters;

Change in Lower 48 State River Miles Under Advisory – 1993 to 2004



Change in % of Lower 48 State River Miles and Lake Acres Under Advisory: 1993-2004

Percentage of River Miles and Lake Acres Under Advisory, 1993-2004



Source: 2004 National Listing of Fish Advisories

Current General State Fish Consumption Advisories for the Connecticut River

- State Departments of Health issue fish advisories based on studies of contaminant risks to “at risk” and other populations.

- Connecticut, Massachusetts, New Hampshire and Vermont have slightly differing definitions of at risk groups, that generally include children (of varying ages), pregnant women or those who may become pregnant, and nursing mothers.

Current General State Fish Consumption Advisories (cont'd)

- This report has implications for state fish advisories for the Connecticut River;
- The entire Connecticut River is currently covered by state-wide advisories for mercury;
- Current state fish advisories for PCBs are variable and site-specific;
- No advisories for dioxins or organochlorine pesticides, such as DDT;

Specific State Fish Consumption Advisories:

- **Connecticut**: www.dph.state.ct.us/BRS/EOHA/webfsh.htm
- **Massachusetts:** http://db.state.ma.us/dph/fishadvisory/
- **New Hampshire:** www.wildlife.state.nh.us/Fishing/fish_consumption.htm
- **Vermont:** www.healthvermont.gov/enviro/fish_alert/fish_alert.aspx

Key Findings

Mercury:

- **Total mercury** concentrations in all three species of fish were significantly **higher in upstream Reaches** than in downstream Reaches.

- **Mercury may pose a risk to recreational and subsistence fishers and to fish-eating wildlife;**

Key Findings (cont'd)

Dioxin-like PCBs:

- **Risk from dioxin-like (coplanar) PCBs** was **generally lower in upstream Reaches** than in downstream Reaches; this varied by fish species and for the humans/mammals, birds or fish that eat them;

- **Dioxin-like PCBs may pose a risk to recreational and subsistence fishers and to fish-eating mammals and fish-eating birds;**

Key Findings (cont'd)

Dioxins and Furans:

- **Dioxin toxicity**, in the twelve fillet composites analyzed, **posed a varying risk to both subsistence and recreational fishers and fish-eating wildlife**, even when dioxin-like PCB TEQs were not included in the risk calculations. Therefore, **PCB TEQs** in this report **underestimate human health and ecological risk** from consumption of Connecticut River fish;

Key Findings (cont'd)

DDT:

- **DDT** and related breakdown products from chemical, physical and biological weathering, **may pose a risk to human subsistence fishers and to fish-eating birds, but not to recreational fishers or fish-eating mammals**. A clear geographic gradient was found with **higher levels in downstream Reaches**;

Recommendations

- Future fish tissue contaminant studies should consider using the analyte list developed by the recent EPA National Study of Chemical Residues in Lake Fish Tissue, and should assess inclusion of emerging contaminants such as PDBEs (PolyBrominated Diphenyl Ethers);

- Water quality parameters, including Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), sulfates, Acid Neutralizing Capacity (ANC) and phytoplankton biomass should be collected concurrently with fish sampling as they may affect mercury methylation and bioaccumulation;

Recommendations (cont'd)

- Observed geographic gradients and patterns in mercury, dioxin and organo-chlorine pesticides should be studied further, including possible effects of water level impoundment manipulations on mercury methylation and demethylation;

- Reach 8, the 36 mile cold water portion of the River, needs additional fish sampling and analysis to determine human health and eco-risks of contaminant loads, likely focusing on other native species than those used in the current study;

Recommendations (cont'd)

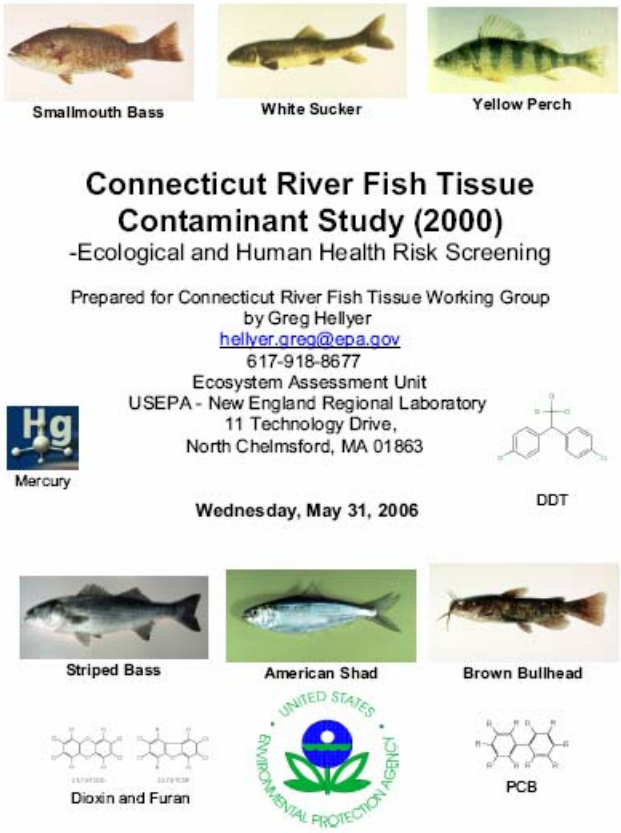
- Statistical comparison between land use/land cover, socio-economic or other ancillary spatial data may further explain observed contaminant levels in Connecticut River smallmouth bass, yellow perch and white suckers;

- Use of the Reach concept in future studies should be re-assessed given the extremely small samples taken for long stretches of river. Fish contaminant levels have been shown to vary over considerably smaller spatial scales than the Reaches used in the current study;

Recommendations (con't)

- Collect GPS coordinates and date of all fish collection and shock boat paths;
- Subsequent fish tissue analysis should use single fish and not composites for tissue analysis;
- Laboratories performing fish tissue analyses should be pre-qualified for all of the methods they will be utilizing;
- Further studies should build upon the collaborative example and baseline data provided by the current study;

Downloadable Final Report



- All Chapters (PDF)
- Appendices (PDF)
- Data Tables (Excel)
- Maps
- Questions and Answers on Study

http://www.epa.gov/ne/lab/reportsdocuments.html