Using Model Emulation to Update Projections of Future Fish Tissue PCBs in the Lower Hudson River

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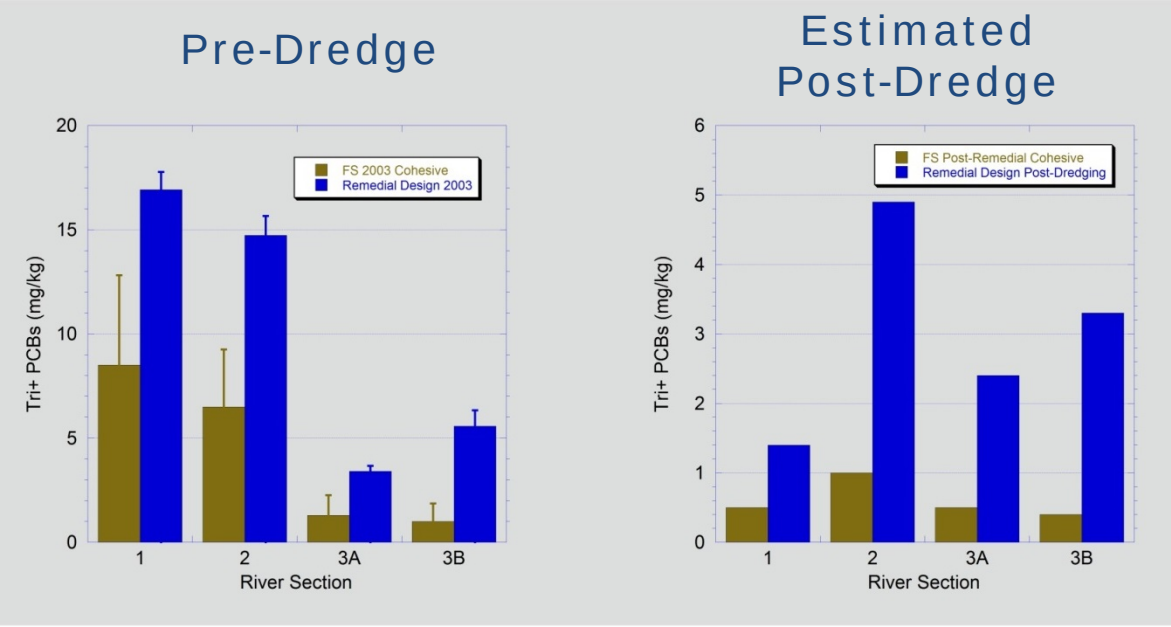
Introduction

- USEPA used complex, integrated mechanistic models to make temporal projections of sediment, water, and biota concentrations for the Hudson River PCBs Superfund Site in NY
- Model projections of fish PCB concentrations played an important role in the comparison of remedial alternatives in the 2002 Record of Decision (ROD)
- Post-ROD findings showed that the models overestimated the rate of natural recovery in surface sediment

Updated Surface Sediment Concentrations



Remedial design PCBs in surface sediments exceeded the upper bound of model predictions

Estimated post-remediation PCBs for the selected remedy were 3-5X higher than model predictions

Tri+ PCBs: Trichloro-biphenyl and higher chlorinated PCBs

Assessing the Impact of Post-ROD Findings on Model Predictions

- Re-running the original mechanistic models with new data was not an option because of the cost and effort involved
- Statistical model emulation provides a fast and inexpensive alternative approach to efficiently condense complex integrated models into a simple, easy-to-use model that retains the underlying properties of the mechanistic model.
- Model emulation recently used effectively in numerical ocean and climate change models

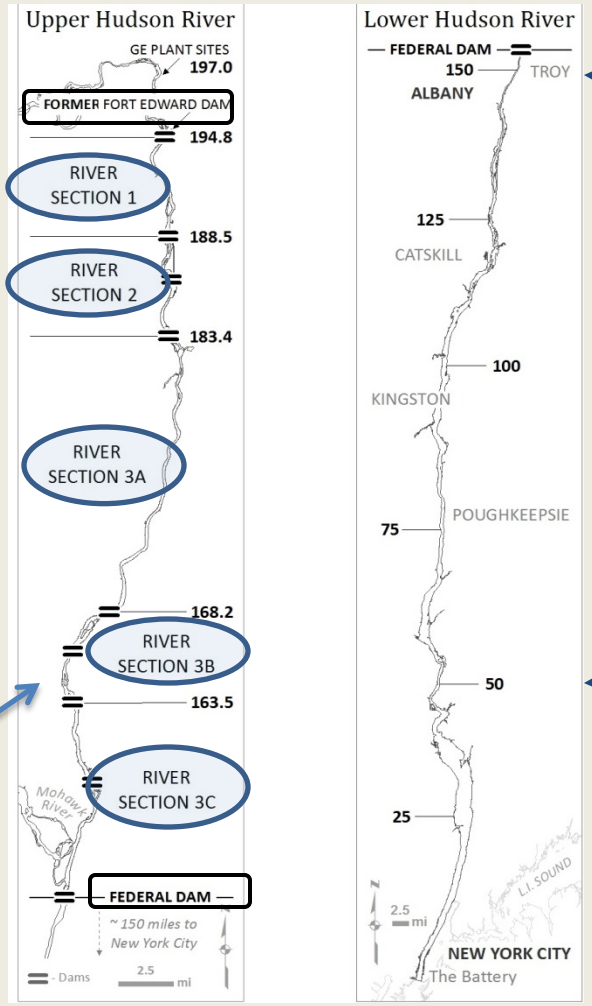
Model Emulation Approach

- Develop statistical models to reproduce EPA mechanistic model projections for surface sediment and water concentrations in the Upper Hudson River (UHR) and fish in the Lower Hudson River (LHR) for Monitored Natural Attenuation (MNA) and the selected remedy (REM)
- Use the emulated model with updated surface sediment PCB concentrations and an updated sediment decay rate to assess the impact of the post-ROD findings on model predictions of LHR fish concentrations

Upper and Lower Hudson River

UHR: ~ 40 miles between Former Ft Edward Dam and Federal Dam at Troy

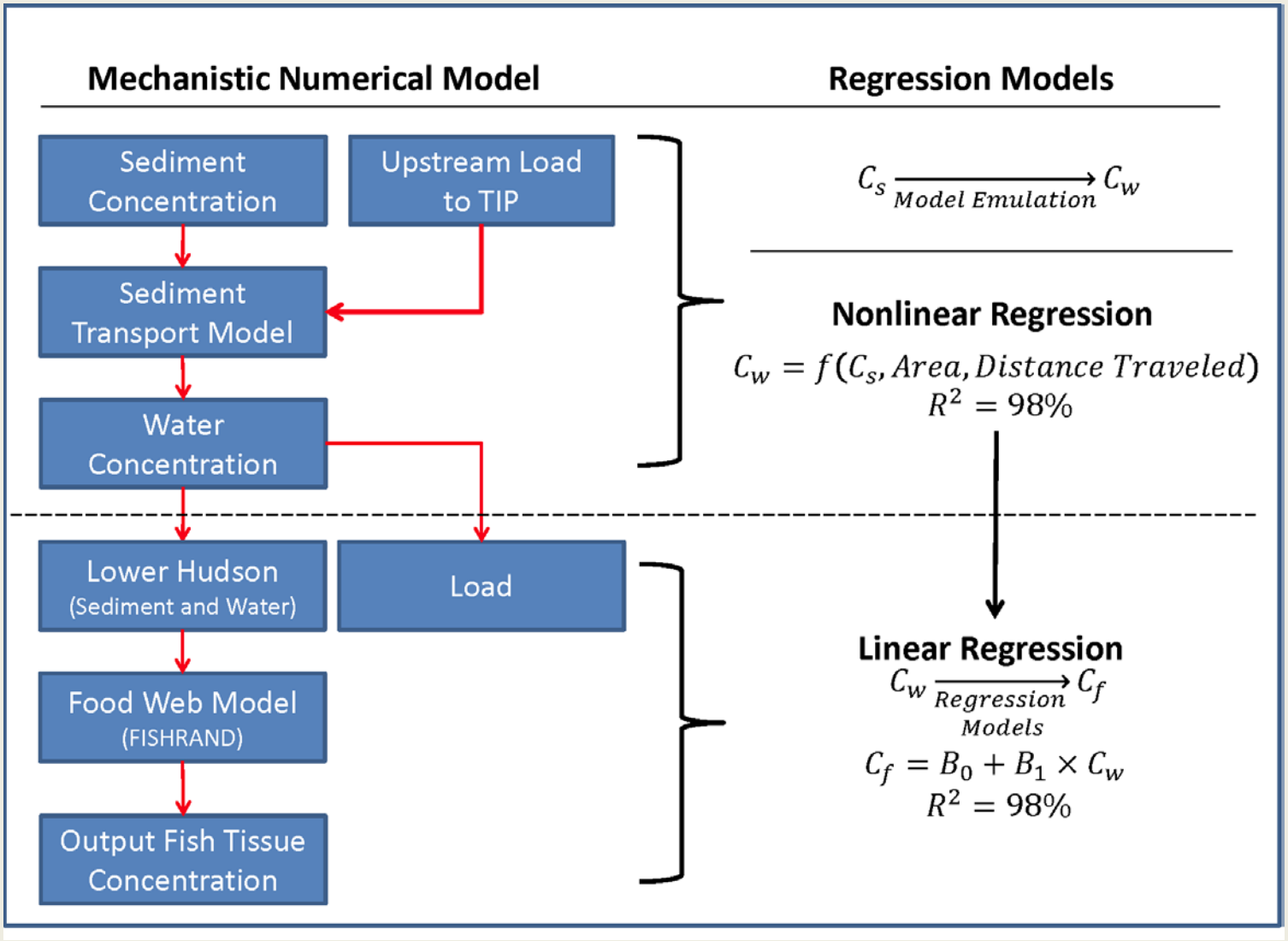
- UHR Remedy: Dredging and MNA, including source control
- Mechanistic models projected sediment & water PCBs for 5 model subsections
- Water/Load from Waterford (RS3B) used as input to LHR models



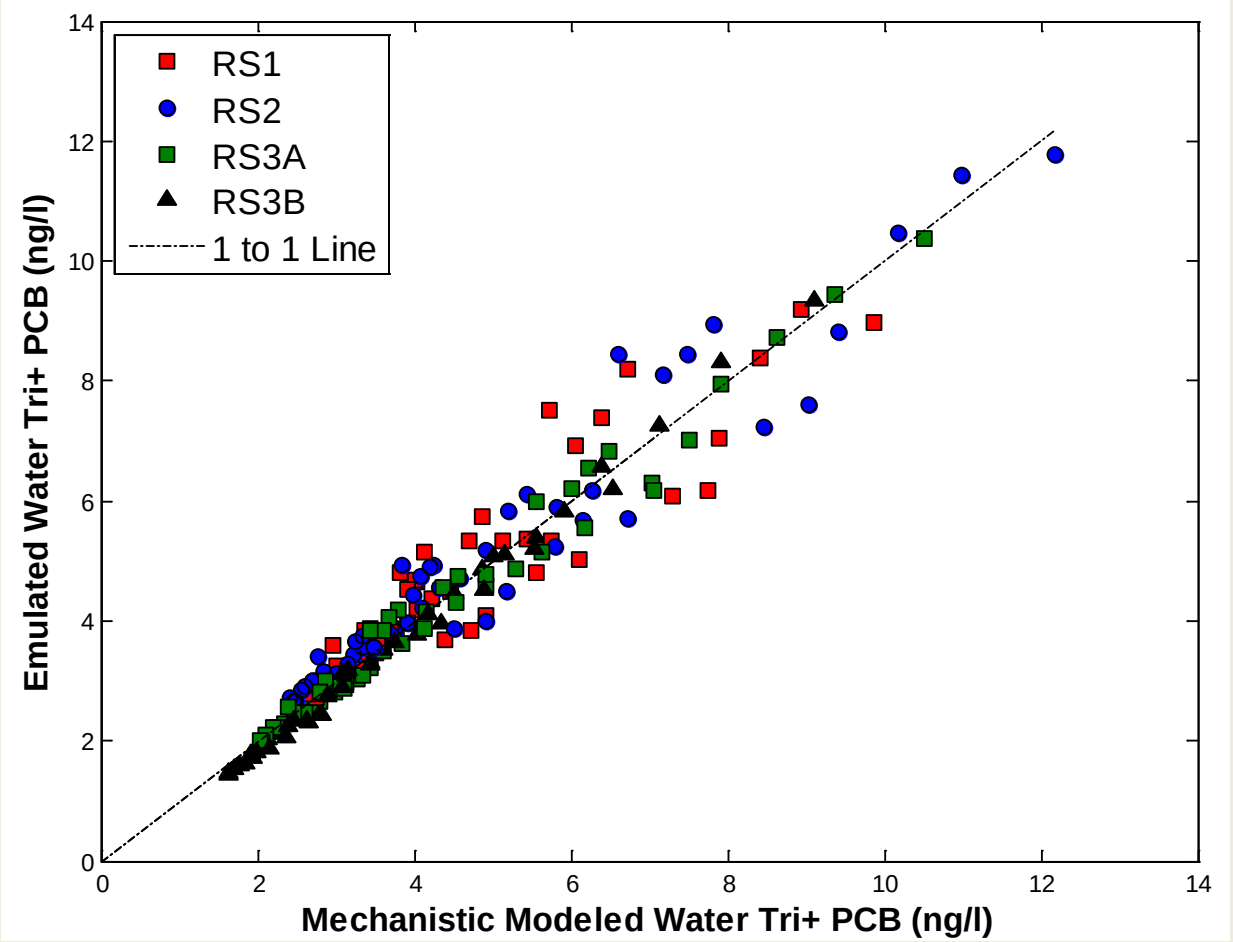
LHR: ~ 150 miles tidal estuary between Federal Dam at Troy and New York Harbor

Output from UHR models used as input to LHR models to project PCB concentrations in fish (White Perch, Largemouth Bass, Brown Bullhead, Yellow Perch) at 4 LHR locations between RM152 and RM50

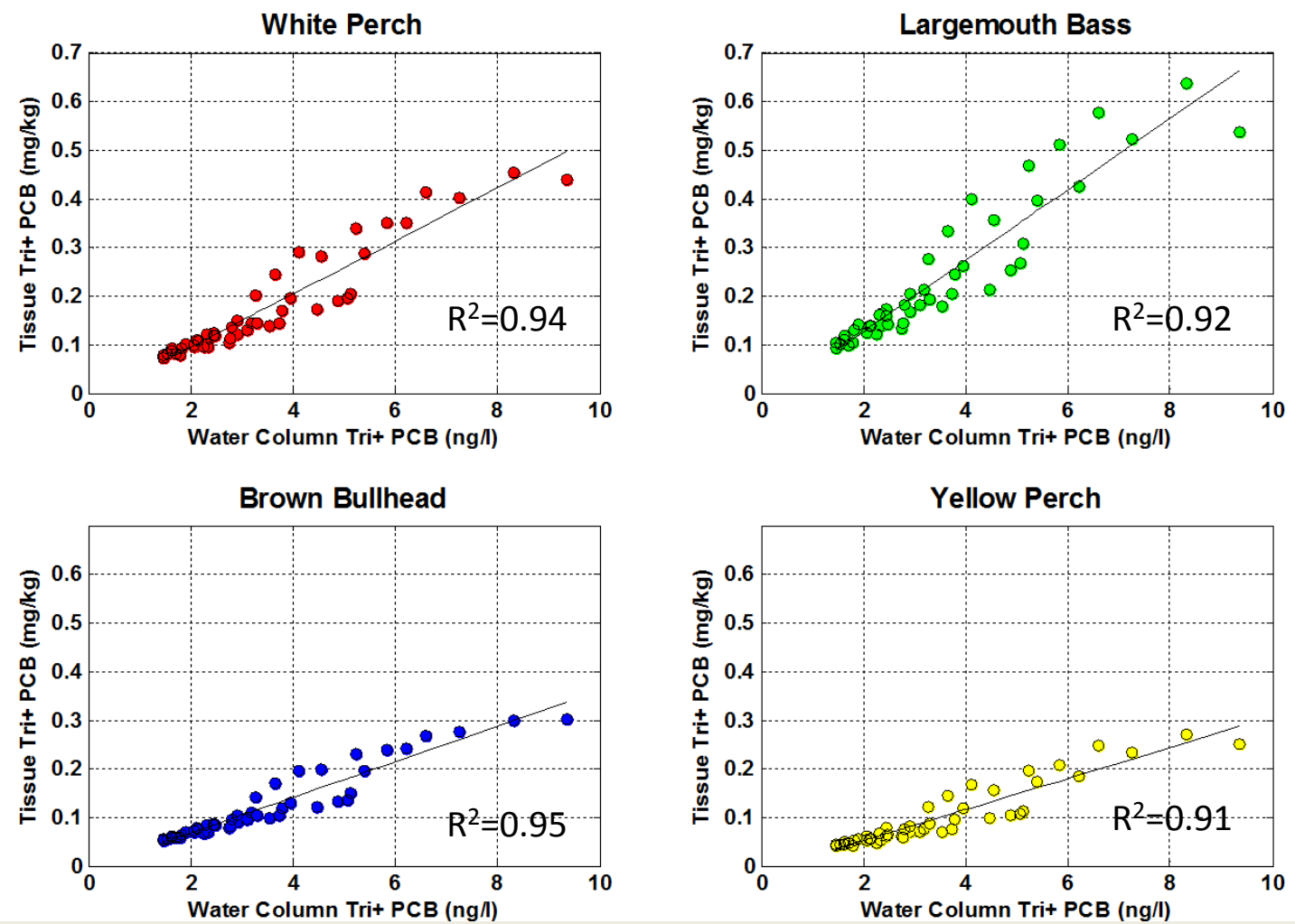
Model Emulation Schematic



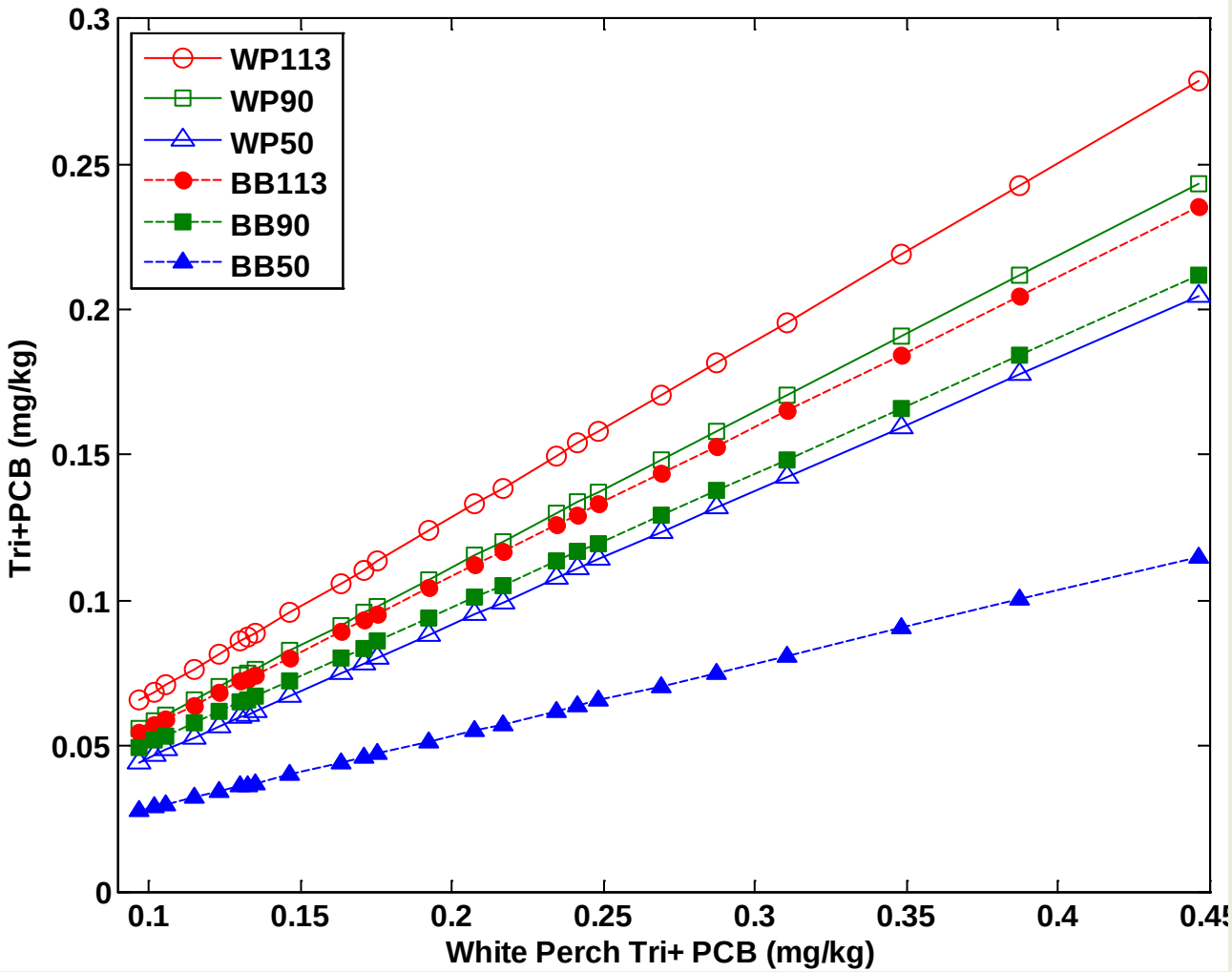
Emulated vs Mechanistic Model Water Concentrations (Tri+ PCB, ng/L)



Mechanistic Model Projections: Water vs Fish PCBs at RM152



Mechanistic Model Projections: White Perch at RM152 (WP152) Compared to WP and Brown Bullhead (BB) from Other Locations



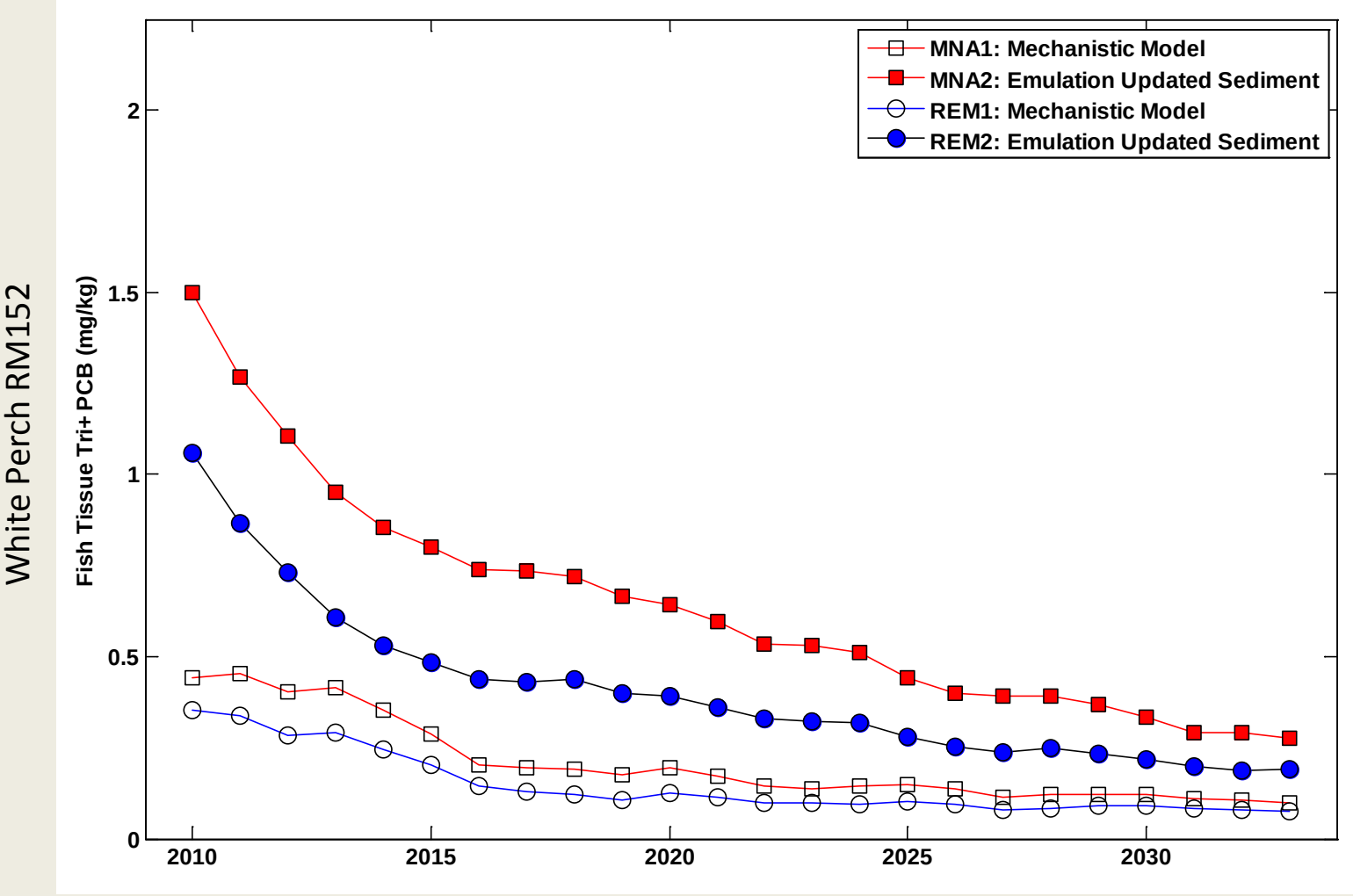
Updated Estimate of Natural Recovery Rate

	Average Tri+PCB (mg/kg) in Surface Sediment		
Model Subsection	UHR Transect Survey 1991 (Cohesive Sediment)	Remedial Design Data 2002-2005[1]	Exponential Decay Rate
1	20	16.9 (3414)	1.4%
2	18	14.7 (1540)	1.7%
3A	4.3	3.4 (2129)	2.0%
3B	5.7	5.6 (685)	0.1%
Mean			1.3%
95% UCL			2.6%

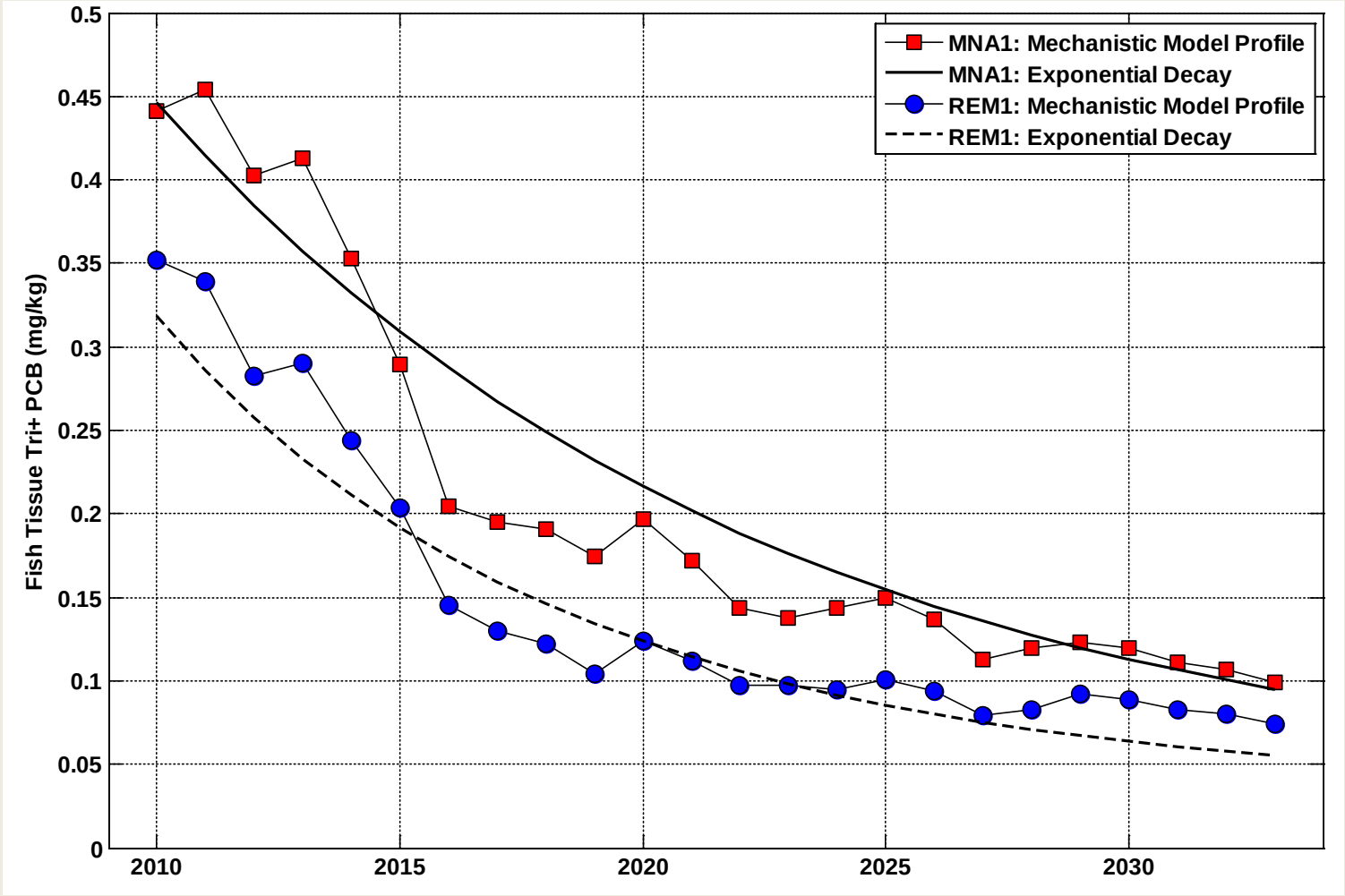
~ 3%

[1] Includes cohesive and non-cohesive sediments in River Section 1 and cohesive only in Sections 2 and 3. Data collected 2002-2005, considered to represent concentrations in 2003.

Emulated Model Projections of Fish PCBs with Original (MNA1, REM1) and Updated (MNA2, REM2) Sediment

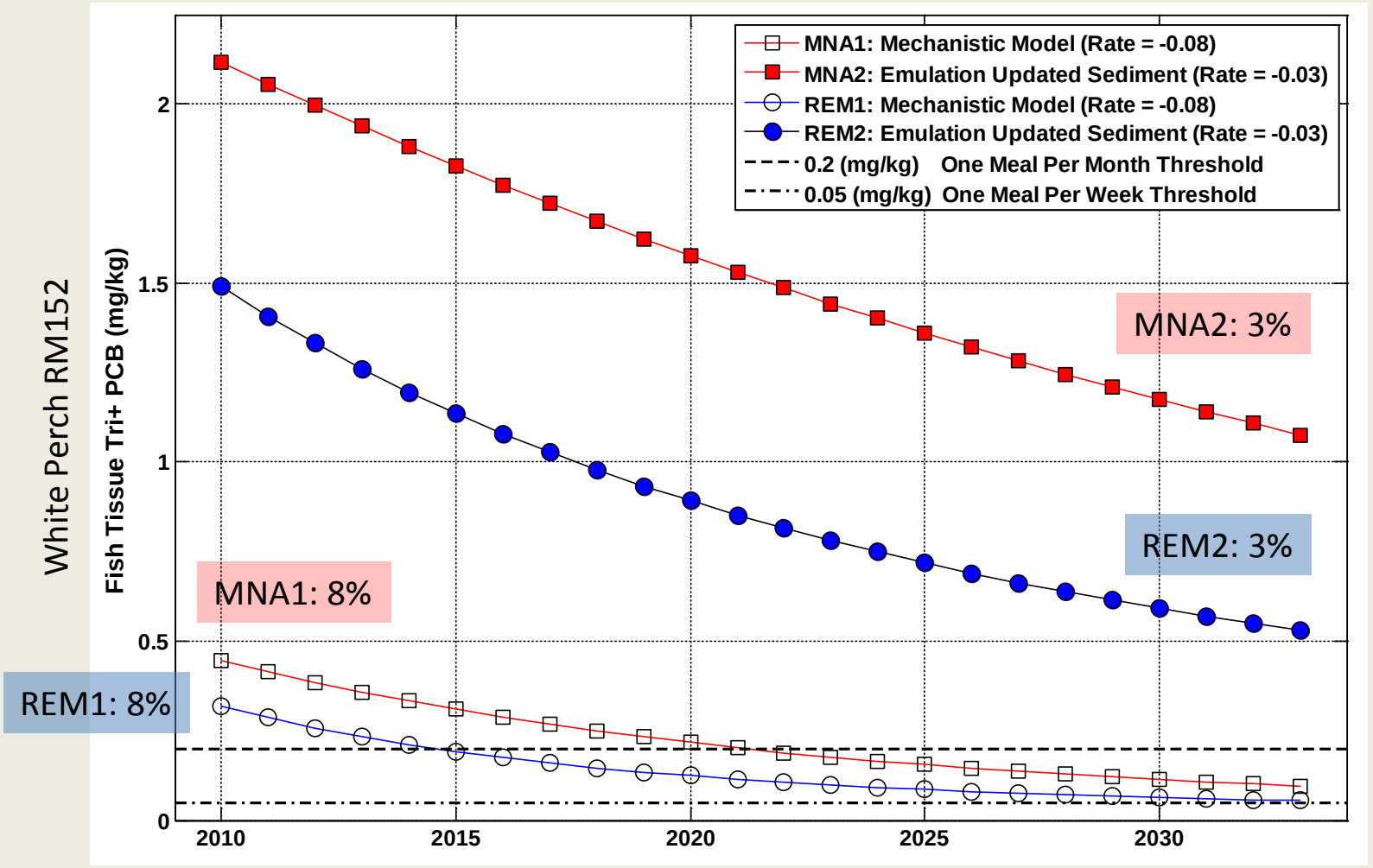


Mechanistic Model Projections vs Exponential Decay (8%) Model

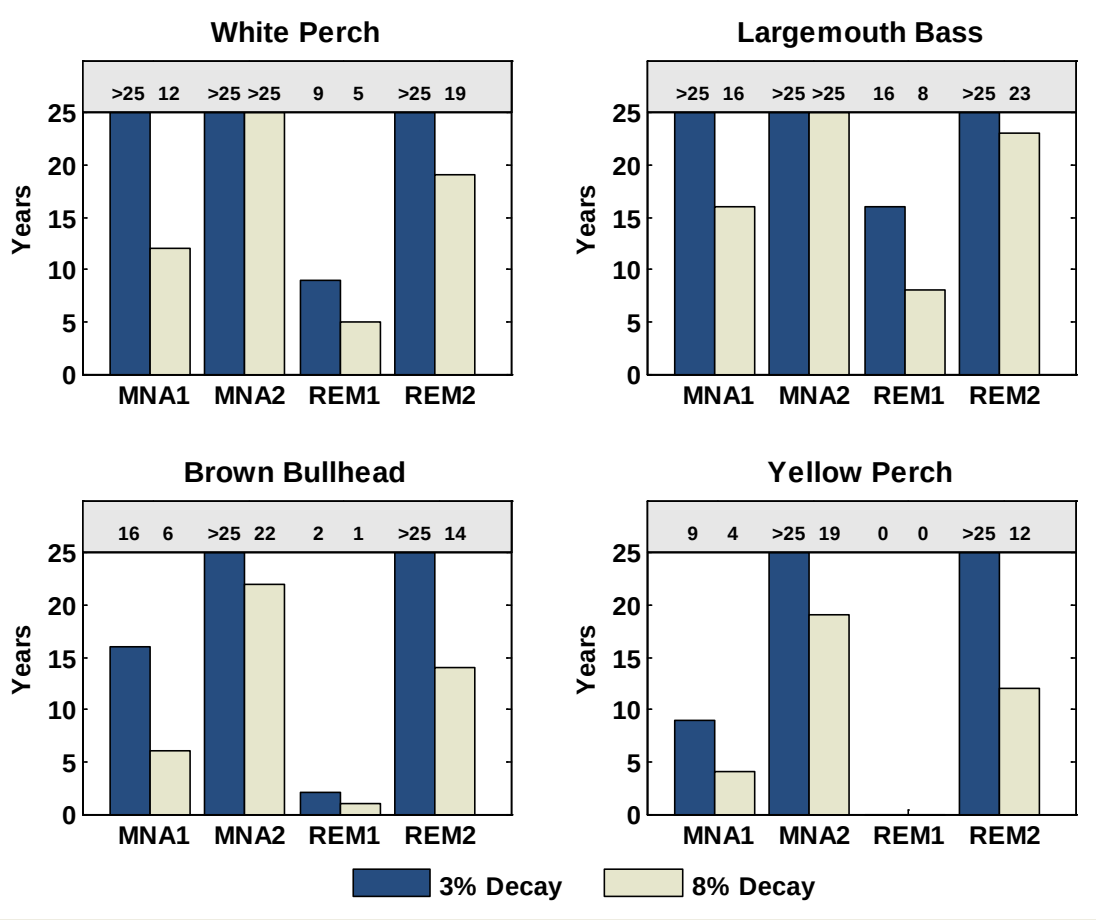


Time to Reach Fish PCB Risk Thresholds

Emulated Model Projections with Original and Updated Sediment PCBs and Decay Rates of 8% and 3%



Emulated Model Projections with Original and Updated Surface Sediment and Decay Rate
Time to reach 0.2 mg/kg Tri+ PCB in 4 species at RM152 for MNA and the selected remedy (REM)



MNA1/REM1: Original model estimated initial sediment concentrations
MNA2/REM2: Emulated model with updated initial sediment concentrations

Summary: Model Emulation

- **Application of Model Emulation to Hudson River Models**
  - Reproduced mechanistic model projections of surface sediment and water Tri+ PCB concentrations in the UHR and fish Tri+ PCB concentrations in the LHR under MNA and the selected remedy
  - Enabled application of updated sediment concentrations and estimated decay rate to develop temporal projections of fish tissue concentrations in the LHR without recalibration and computation of the original model
- **Other Advantages of Model Emulati**on
  - Useful for statistical uncertainty evaluations not possible with complex mechanistic models
  - Tool for more accurate model calibration and validation

Summary: Hudson River Sediment and Fish

- Recovery of surface sediment in UHR much slower than models predicted
- Emulated projections of PCB concentrations in LHR fish post-remediation using updated sediment concentrations and updated rate of sediment recovery are much higher than original mechanistic model projections
- Modeled LHR Fish are projected to take much longer to reach PCB threshold concentrations than the time frame identified in the 2002 ROD for the Hudson River

Use of Models in Decision-Making

- Overestimation of the rate of natural recovery resulted in minimizing the difference in time to reach thresholds between remedial alternatives
- Accurate estimation of the rate of natural recovery is essential for mechanistic models to provide useful information for comparisons of remedial alternatives
- Without good sediment data to assess the rate of natural recovery, relative comparisons of remedial alternatives may be misleading
- Uncertainty in model projections important to decision-making

Sediment Data for Model Development, Validation, and Decision-Making

- Model validation requires representative sediment concentration time-series data to evaluate model predictions of the rate of natural recovery
- Sediment cores collected for geochronology (e.g.,“high resolution cores”) in riverine and estuarine sites are typically unrepresentative of general site conditions and may provide misleading information on the rate of recovery
- We recommend systematic sediment sampling for unbiased and representative estimates of temporal trends in sediment concentrations for any site where natural recovery is expected to play an important role in decision-making