Polychlorinated biphenyl (PCB) tissue-concentration thresholds for survival, growth, and reproduction in fish.

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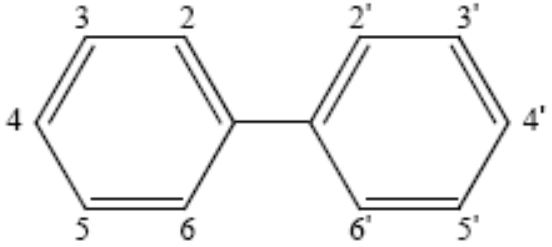
Overview

- Background and impetus for developing meta-analysis of PCBs impacts on fish
- Development of data selection criteria, data harmonization and data analysis methods
- Examine results from meta-analysis of PCB-induced effects on mortality, growth, and reproduction in fish
- Discussion and implications of findings.
- Summary and next steps.

Polychlorinated Biphenyls

- Use:
  - Electrical fluids (transformers)* - major use
  - Carbonless paper
  - Paints and plastics (lesser extent)
- Production:
  - 1930-1979 US 10-30,000 metric tons/yr.
    - Monsanto
      - Anniston, AL
      - Sauget, IL
- Properties:
  - Hydrophobic (low water solubility)
  - Persistent ($t_{1/2}$= years)
  - Bioconcentration/biomagnification



Background

- PCBs persist in the environment despite having been banned for four decades

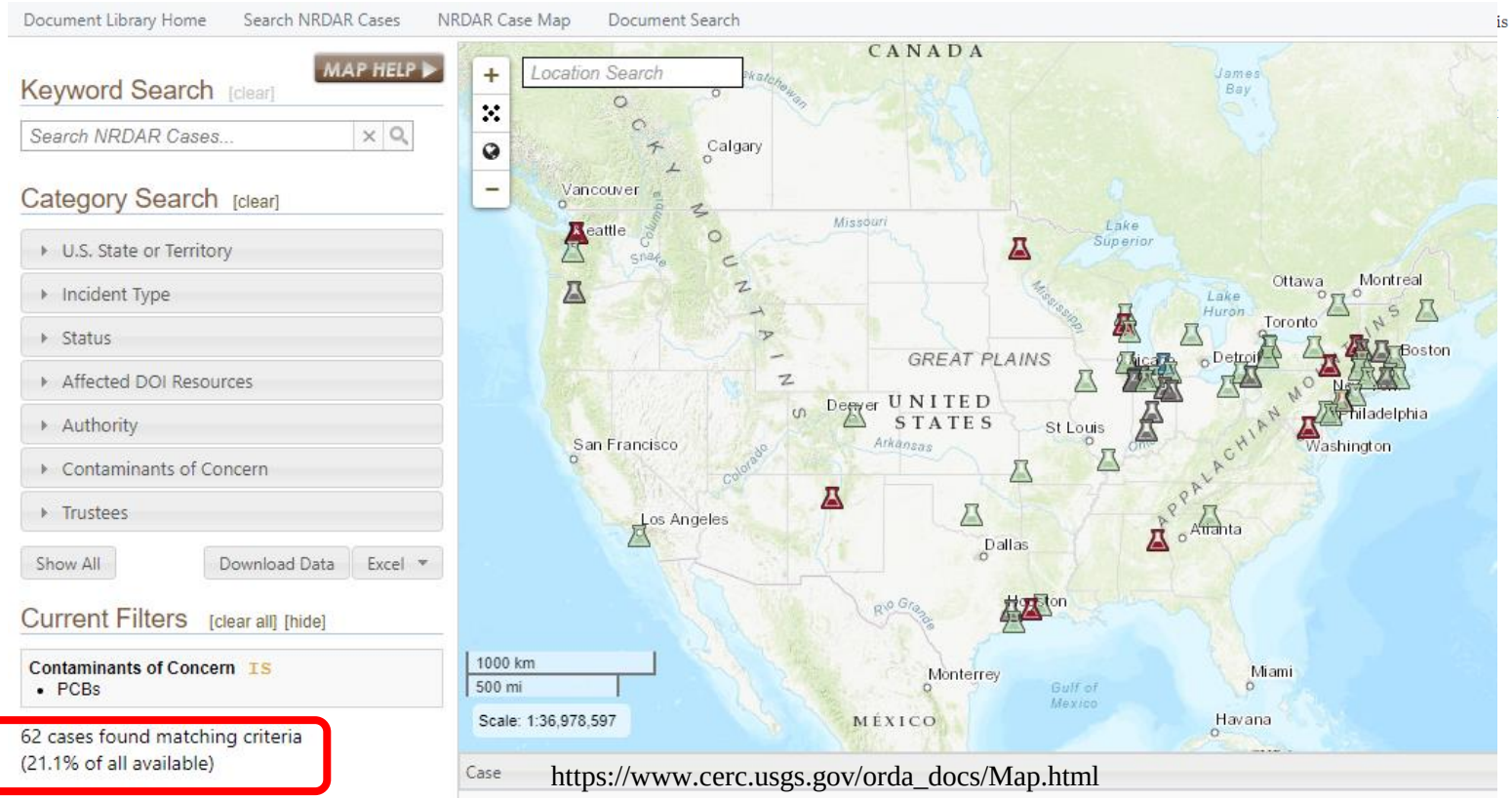
Baltimore Sun headline: 02/19/2019

Baltimore files lawsuit demanding Monsanto pay to clean up PCB chemicals in city waterways

By Scott Dance · Contact Reporter
The Baltimore Sun

FEBRUARY 19, 2019, 2:55 PM

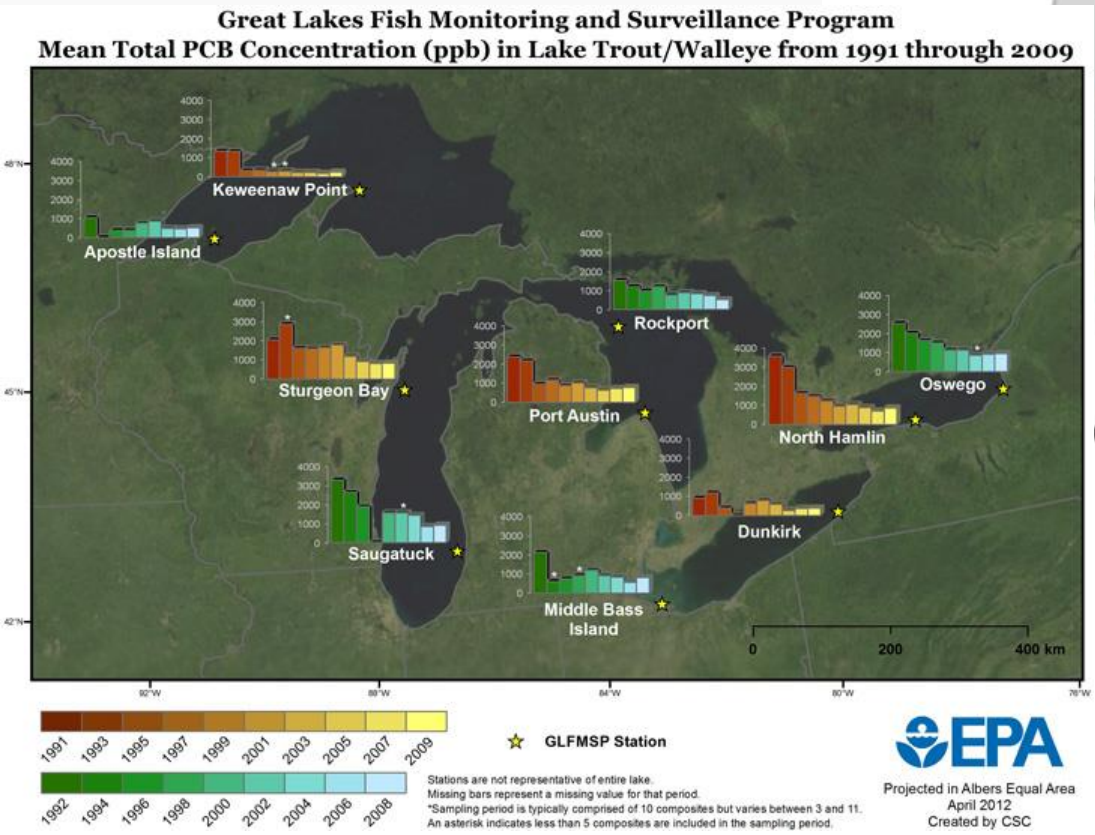
Baltimore is asking a federal judge to force agriculture chemical company Monsanto to pay for cleanup of environmental toxins known as PCBs, following more than a dozen mostly West Coast cities and states that have filed similar lawsuits in recent years.

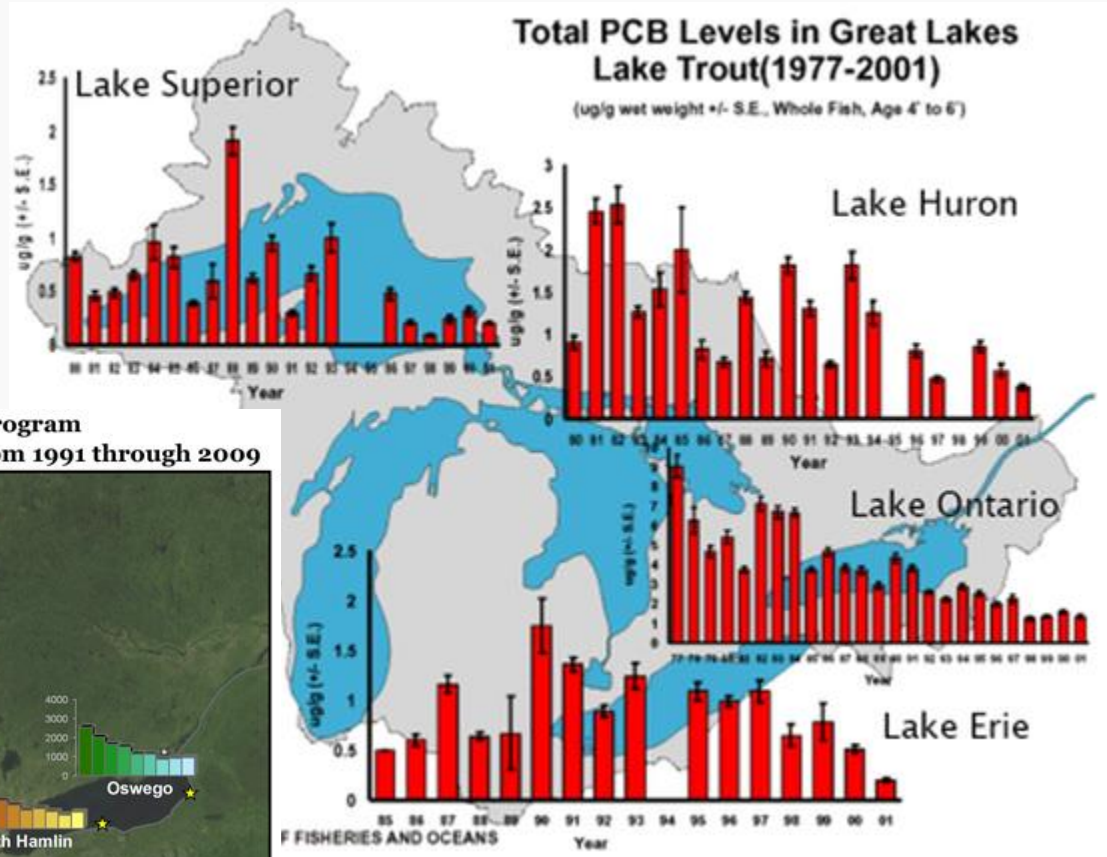


https://www.cerc.usgs.gov/orda_docs/Map.html

Background

- PCBs still have the potential to impact aquatic life.

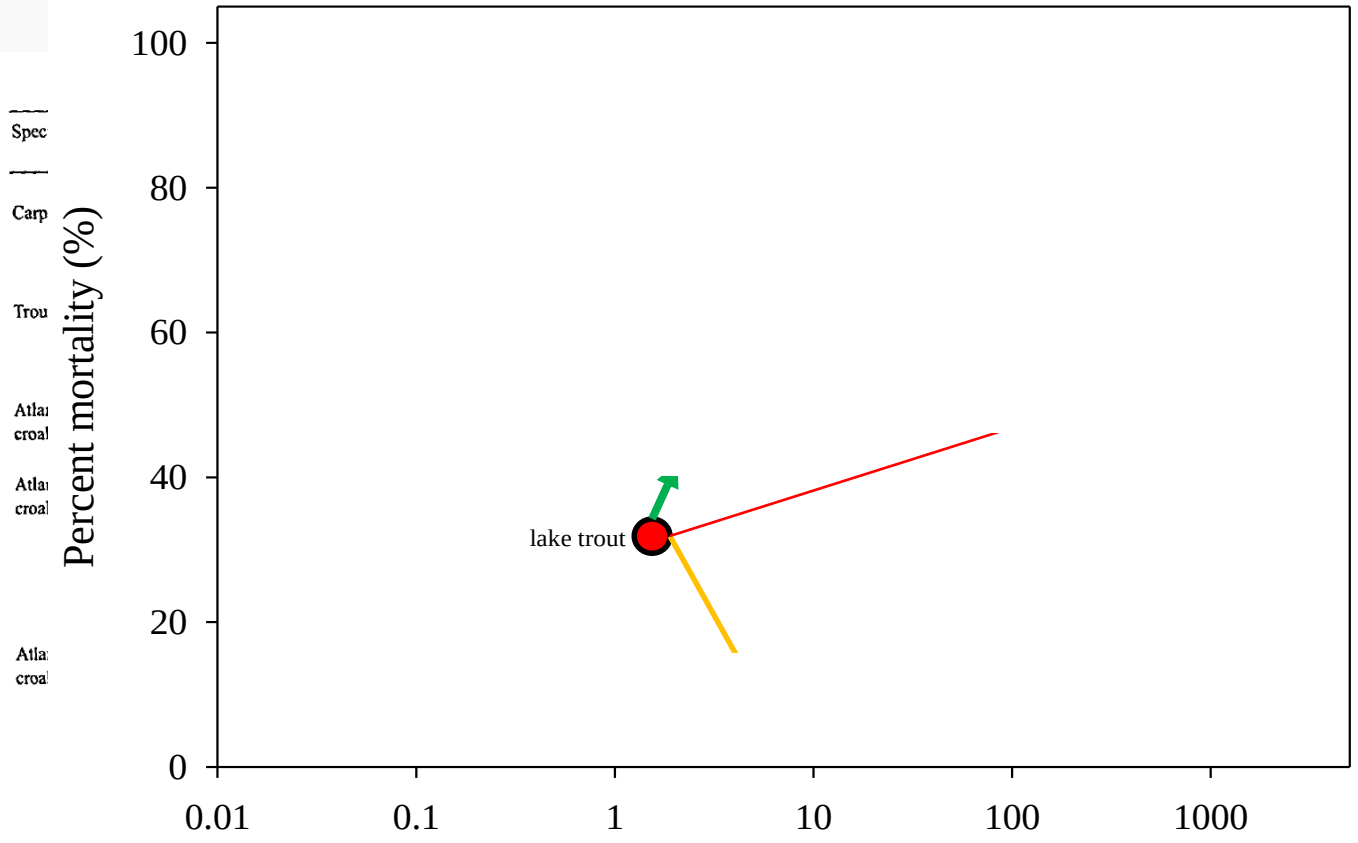




https://www.epa.gov/great-lakes-fish-monitoring/great-lakes-pcb-trends

Background

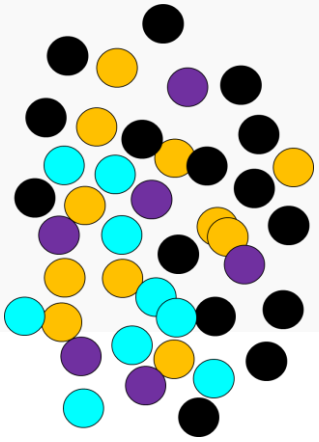
- Little work has been done to evaluate and integrate the available data on PCB-related effects on aquatic organisms



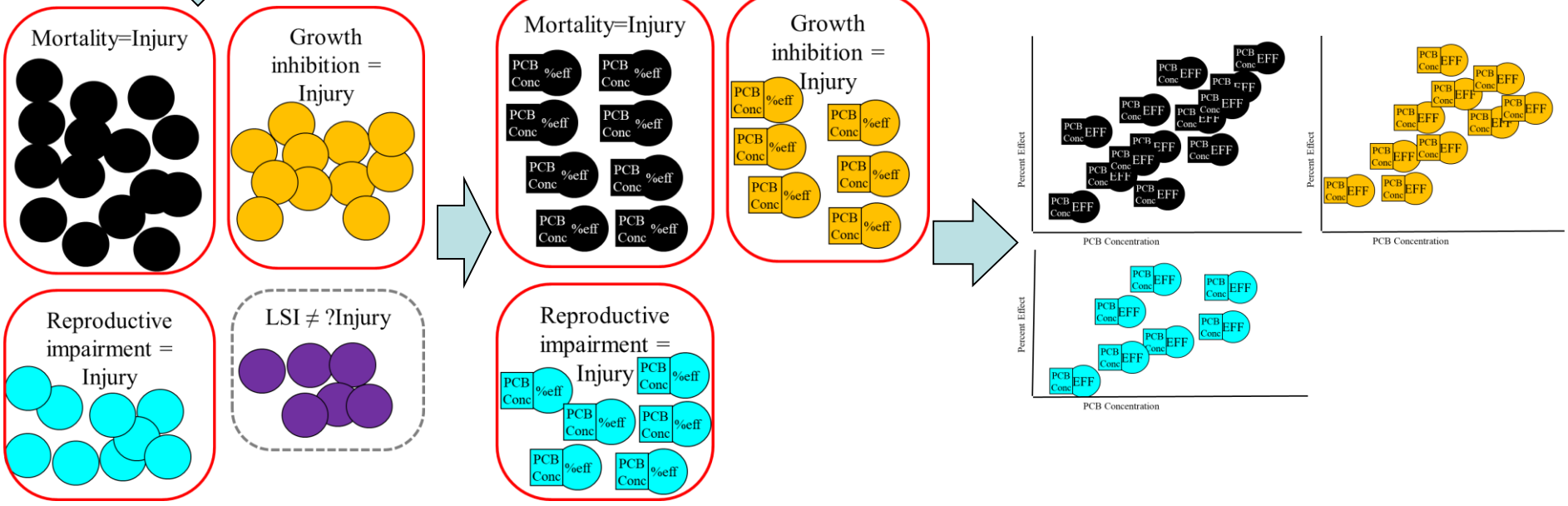
(2002)

itive distribution in rank order of all 15 studies
ect tissue residue (LOER) for a given study.

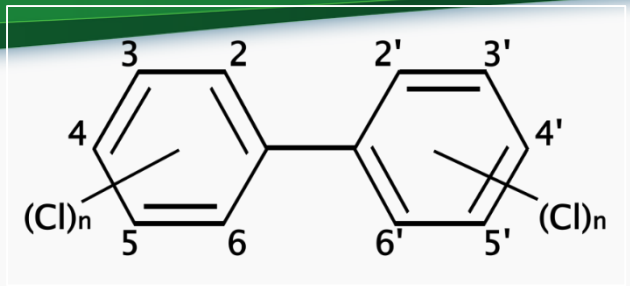
Background



- A need exists among risk/injury assessment practitioners for comprehensive and integrated assessment of PCB-based effects
  - Identify, quantify, integrate and assess



Objectives



- A comprehensive review of the fish-PCB effects literature
- Identify and articulate specific criteria for data-inclusion
- Development of a data-inclusive approach for analysis of PCB exposure-effect/injury relationships across all fish species tested.
- Provide a framework for future analysis of other legacy contaminants under the NRDA jurisdiction.

PCB-Related Effects Data Selection Criteria

1. Mortality, growth, or reproduction effects measured.
2. Effects unequivocally attributable to the PCB exposure.
3. Exposure/effects from PCB mixtures (no single PCB congener studies)
4. PCB exposure concentrations quantifiable as tissue residue concentrations
5. Quantifiable lowest observable adverse effect
6. Effects and exposure paired

Data Analysis

1. Criteria-based data selection
2. Convert data to standard units in datasets for M, G, and R.
3. Probability-based sensitivity distributions of LOAER tissue concentrations data
4. Linear regressions of PCB Tissue concentration and Percent Effect.
   - Quintiles, uncertainty, testing-variable assessment.
5. Estimate cumulative effects of PCBs
6. Corroborate lab-derived PCB effects threshold using field-derived PCB-effects

Key Terms

- **LOAER:** Lowest Observable Adverse Effect Residue-concentration
- **PCB Concentration =** whole body tissue concentration of TOTAL PCBs
- **Percent Effect:** calculated percent change in response between LOAER group and control
- **Quintiles:** data condensed based on 20^{th} percentiles of tissue concentrations

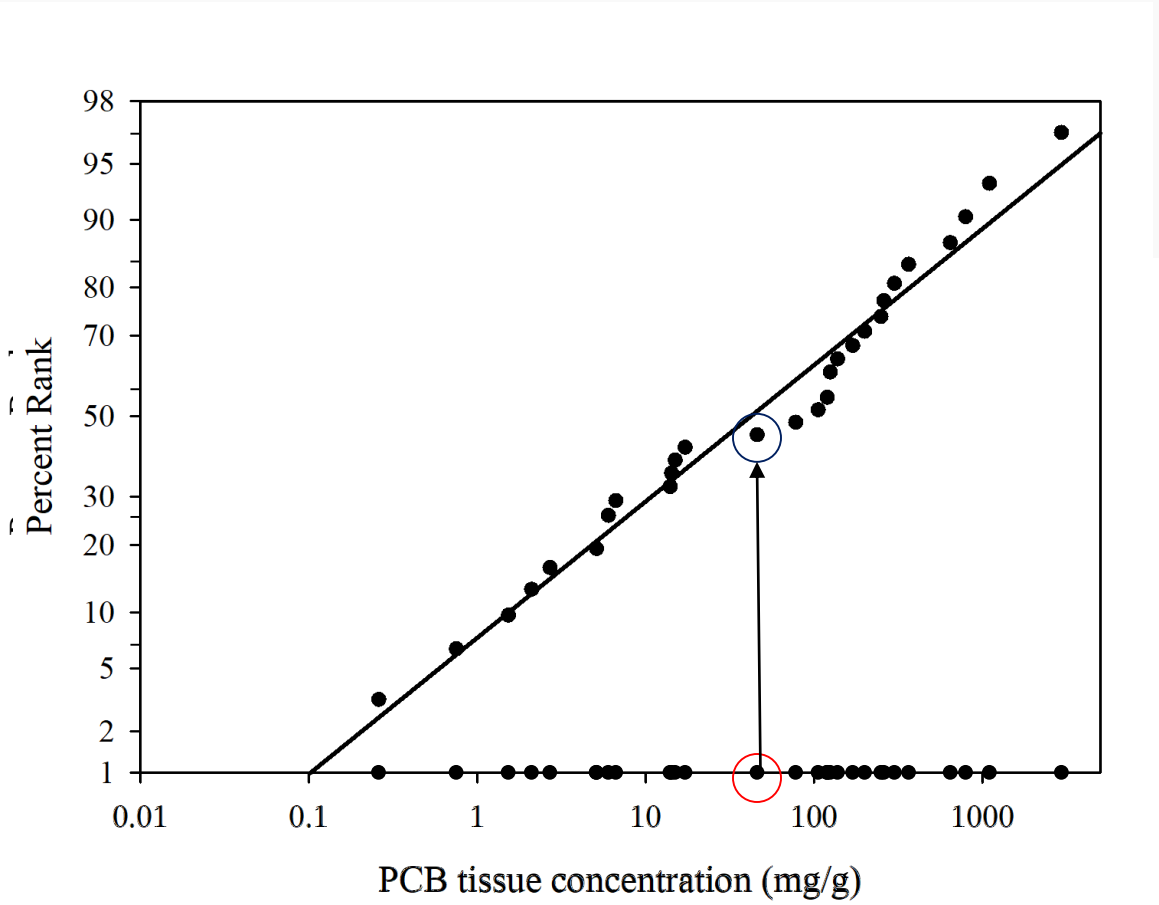
Results

- 31 Lab-based studies met criteria
- 55 total data points
- 16 PCB mixtures
- 22 species of fish

		Mortality	Growth	Reproduction
Data Inclusion	Studies	22	15	7
	Data Points	29	17	8
	PCB mixes	10	10	7
	Fish species	16	11	6
Life History Parameters	warm/cold water	22/7	11/6	7/1
	fresh/salt water	16/13	12/5	7/1
	adult/early life stage	9/20	5/12	8/0

MGR Probabilistic Sensitivity Distributions

Conc µg/g	Rank Probability
0.26	3.2
0.75	6.5
1.53	9.7
2.1	12.9
2.7	16.1
5.1	19.4
5.1	19.4
6	25.8
6.65	29.0
14	32.3
14.25	35.5
15	38.7
17.2	41.9
46	45.2
77.9	48.4
106	51.6
120	54.8
120	54.8
125	61.3
138	64.5
170	67.7
200	71.0
250	74.2
260	77.4
300	80.6
365	83.9
645	87.1
795	90.3
1100	93.5
2950	96.8



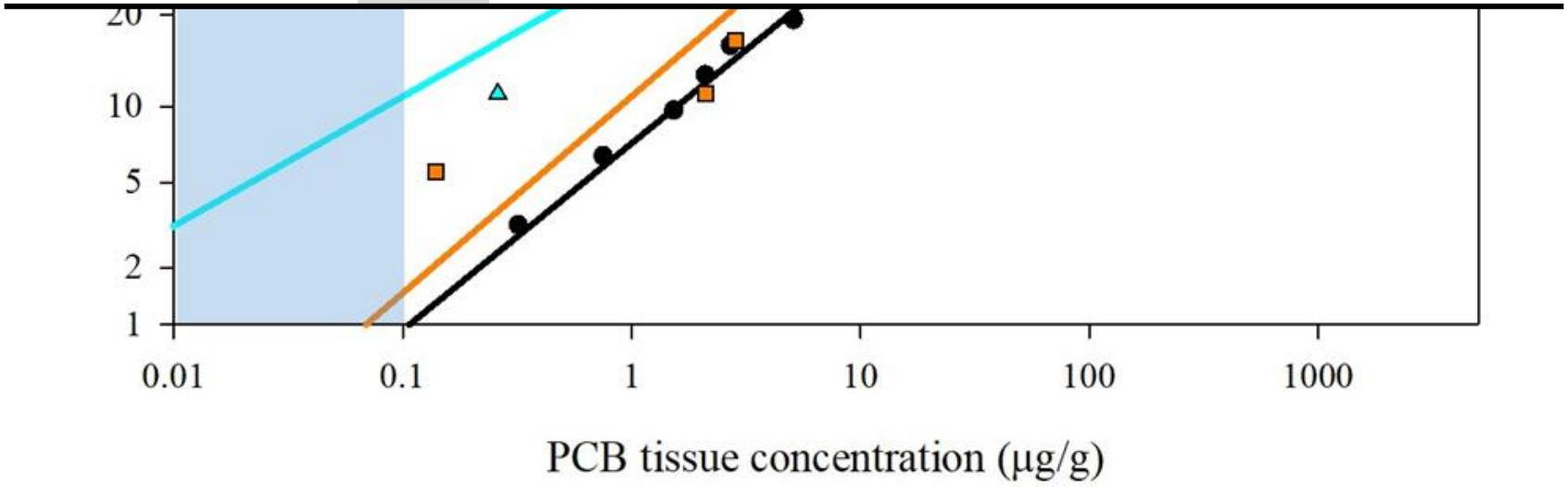
MGR Probabilistic Sensitivity Distributions

Predicted Percent Fish Species (%) expected to have significant adverse effects at specified PCB tissue concentration (µg/g)

	0.1	0.5	1	5	10	50	100	500	1000
Mortality	0.9%	4.2%	7.3%	20.3%	28.7%	52.5%	63.0%	83.1%	89.0%
Growth	1.5%	6.5%	10.9%	28.3%	38.6%	64.4%	74.3%	90.5%	94.5%
Reproduction	10.9%	21.2%	27.0%	42.8%	50.2%	67.0%	73.4%	85.5%	89.4%

Predicted PCB tissue concentrations (µg/g) associated with specified Percent Effects

	10%	20%	30%	40%	50%	60%	70%	80%	90%
Mortality	1.6	4.9	11.0	22.1	42.5	81.5	164	370	1148
Growth	0.9	2.6	5.6	10.9	20.3	37.6	72.9	158	463
Reproduction	0.08	0.43	1.4	3.8	9.8	25.1	68.7	223	1143

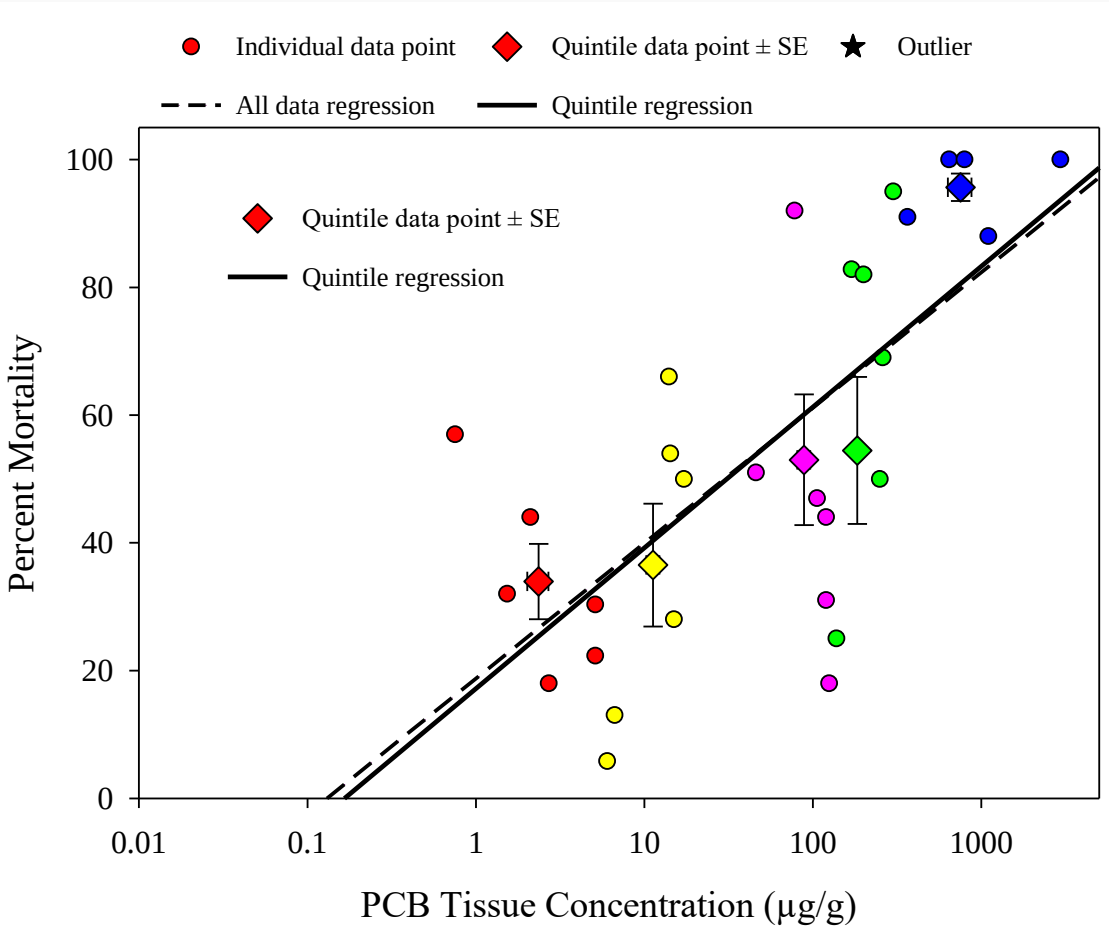


What about the degree of effect?

- Sensitivity distributions can estimate at what concentrations significant effects would occur
- Need to estimate the degree of effect.
  - Use percent effect (quantified degree of effect)
- Use percent effect and paired PCB tissue concentration to generate linear regressions
- Regression provides estimate of degree of effect across entire range of concentrations

PCB-related Mortality in Fish

Conc µg/g	Effect %	Quint	Quint Conc	Quint % Eff
0.26	92%	*		
0.75	57%	Q1	2.4 ± 0.3	33.9 ±5.9%
1.53	32%	Q1		
2.1	44%	Q1		
2.7	18%	Q1		
5.1	22.%	Q1		
5.1	30%	Q1		
6	5.8%	Q2	11.3 ± 1.0	36.1 ±9.9%
6.65	13%	Q2		
14	66%	Q2		
14.25	54%	Q2		
15	28%	Q2		
17.2	50%	Q2		
46	51%	Q3	88.6 ± 7.8	53.0 ±10.2%
77.9	92%	Q3		
106	47%	Q3		
120	44%	Q3		
120	31%	Q3		
125	18%	Q4	183 ± 10.8	54.5 ±10.9%
138	25%	Q4		
170	83%	Q4		
200	82%	Q4		
250	50%	Q4		
260	69%	Q4		
300	95%	Q5	753 ± 120	95.7 ±2.1%
365	91%	Q5		
645	100%	Q5		
795	100%	Q5		
1100	88%	Q5		
2950	100%	Q5		



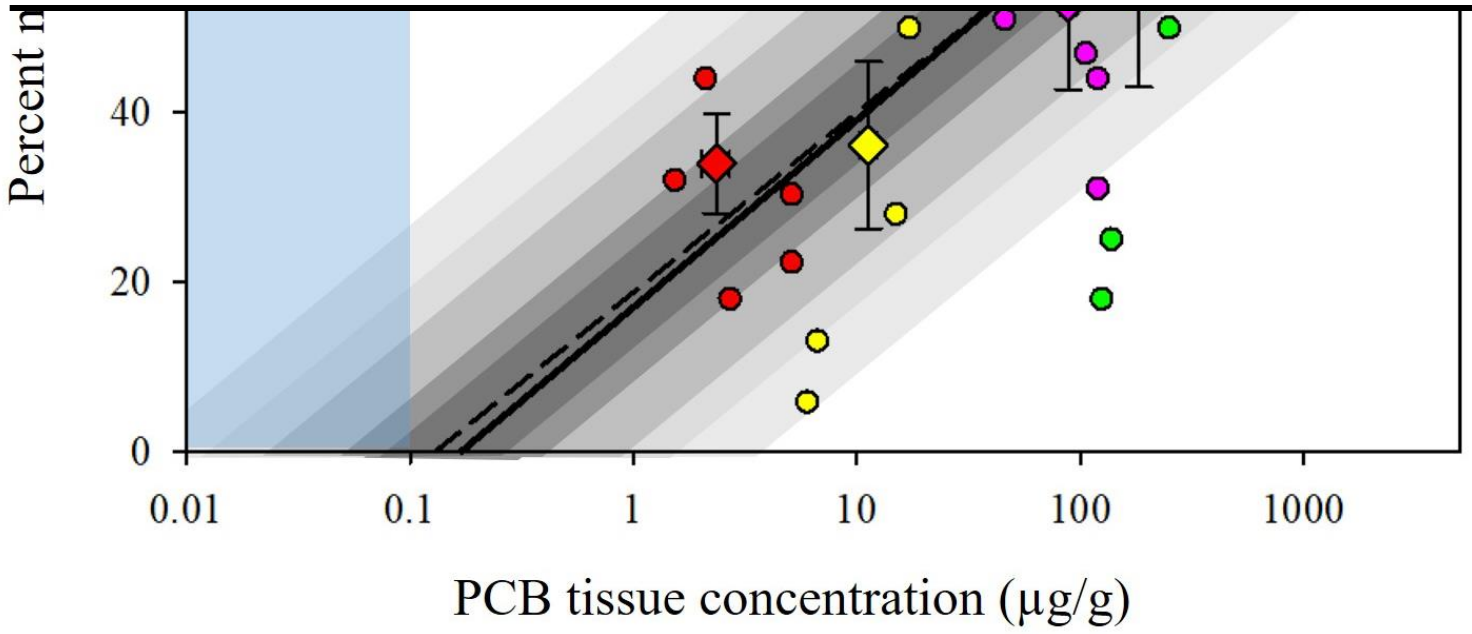
PCB-related Mortality in Fish

Predicted Percent Effect (%) associated with specified PCB tissue concentration (µg/g)

		0.1	0.5	1	5	10	50	100	500	1000
Mortality	#	12.6%	18.9%	33.7%	40.1%	54.9%	61.2%	76.0%	82.4%
Quintile Mortality	#	10.4%	17.0%	32.5%	39.1%	54.6%	61.2%	76.7%	83.3%

Predicted PCB tissue concentrations (µg/g) associated with specified Percent Effects

	10%	20%	30%	40%	50%	60%	70%	80%	90%
Mortality	0.38	1.12	3.33	9.90	29.4	87.4	260	771	2290
Quintile Mortality	0.49	1.43	4.13	11.9	34.5	99.9	289	836	2420



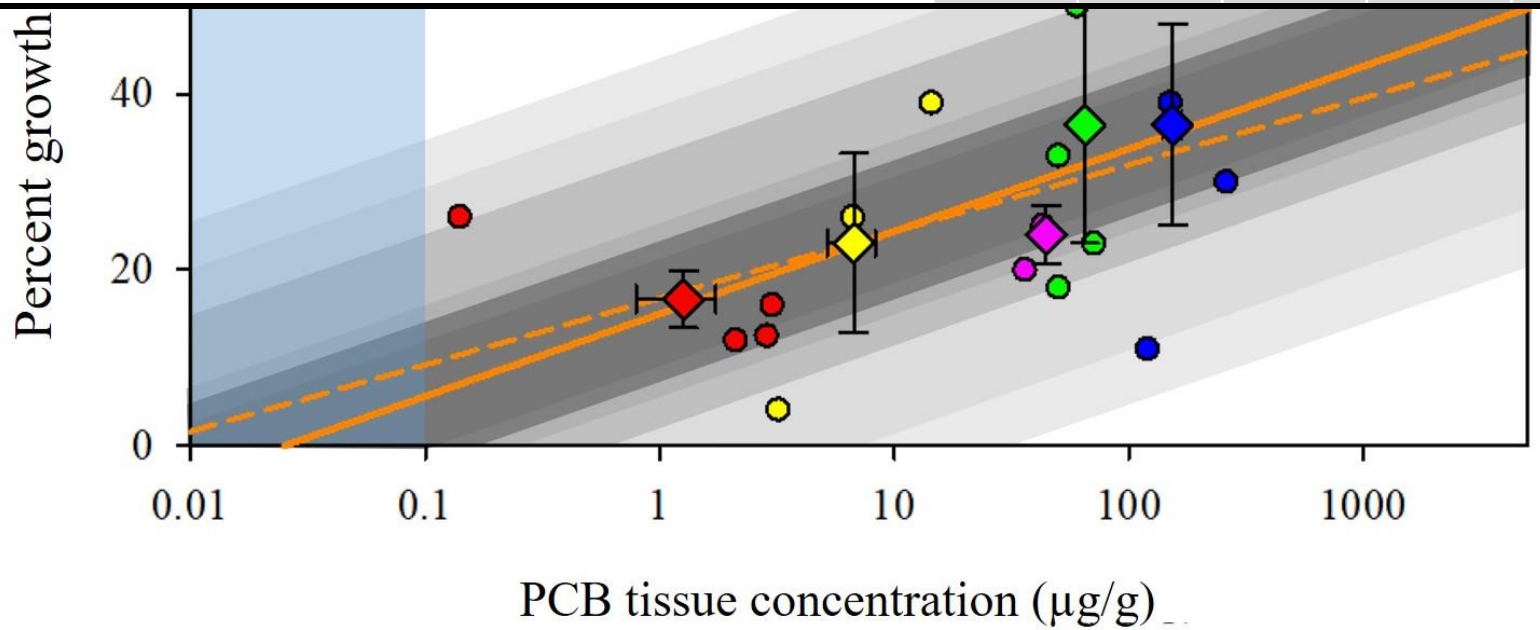
PCB-related growth inhibition in Fish

Predicted Percent Effect (%) associated with specified PCB tissue concentration (µg/g)

	0.1	0.5	1	5	10	50	100	500	1000
Growth	9.2%	14.5%	16.8%	22.1%	24.3%	29.6%	31.9%	37.2%	39.5%
Quintile Growth	5.6%	12.2%	15.0%	21.6%	24.4%	30.9%	33.8%	40.3%	43.1%

Predicted PCB tissue concentrations (µg/g) associated with specified Percent Effects

	10%	20%	30%	40%	50%	60%	70%	80%	90%
Growth	0.13	2.68	55.7	1161	*	*	*	*	*
Quintile Growth	0.29	3.42	39.8	464	5406	*	*	*	*



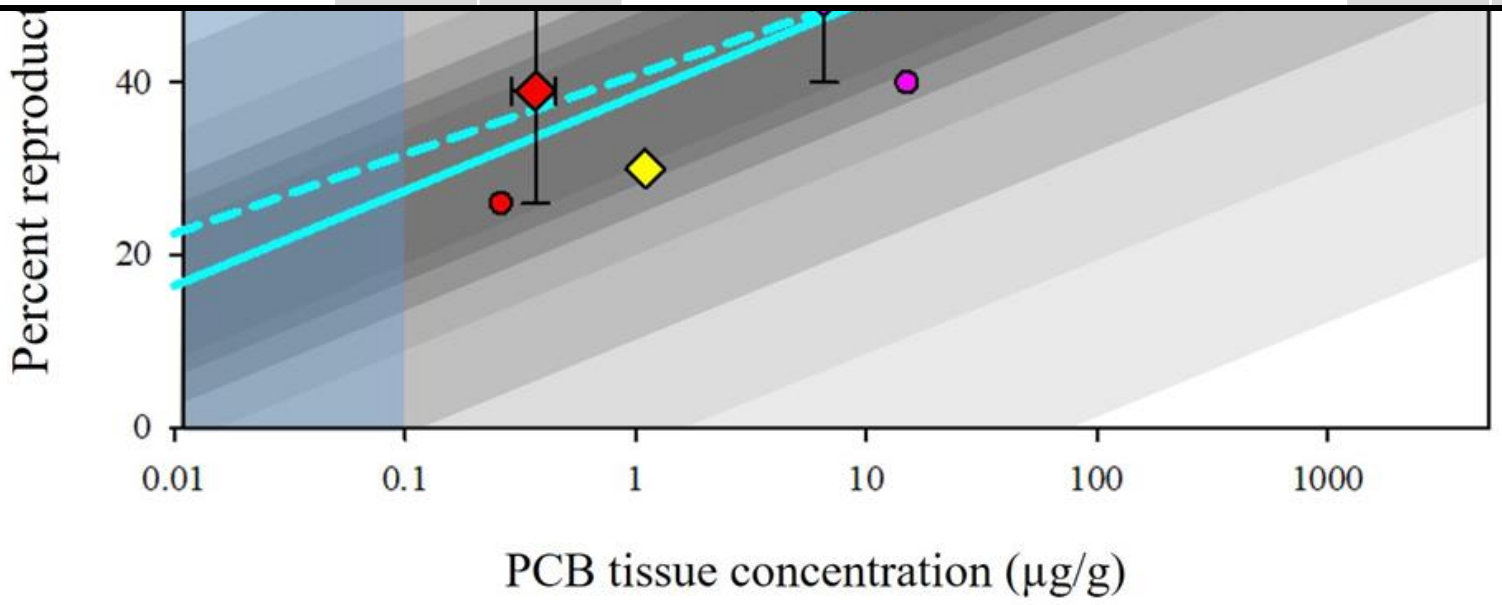
PCB-related reproduction inhibition in fish

Predicted Percent Effect (%) associated with specified PCB tissue concentration (µg/g)

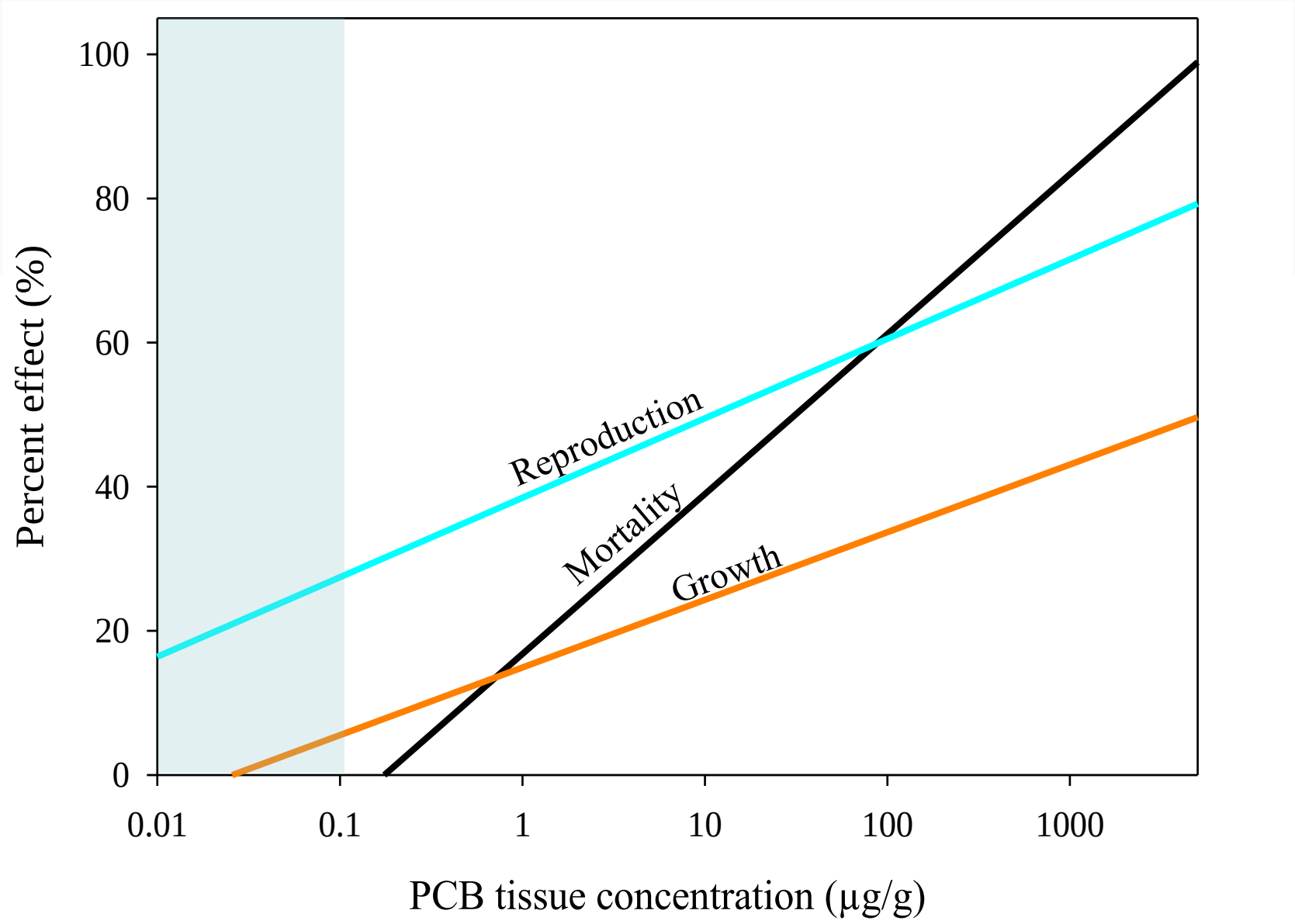
	0.1	0.5	1	5	10	50	100	500	1000
Reproduction	31.7%	38.1%	40.9%	47.3%	50.1%	56.5%	59.3%	65.7%	68.5%
Quintile Repro	27.4%	35.2%	38.5%	46.2%	49.5%	57.2%	60.5%	68.2%	71.6%

Predicted PCB tissue concentrations (µg/g) associated with specified Percent Effects

	10%	20%	30%	40%	50%	60%	70%	80%	90%
Reproduction	0.0004	0.01	0.07	0.8	9.8	119	1458	*	*
Quintile Repro	0.003	0.02	0.17	1.4	11.1	89.5	722	5825	*



Mortality, Growth, Reproduction Quintile Regressions

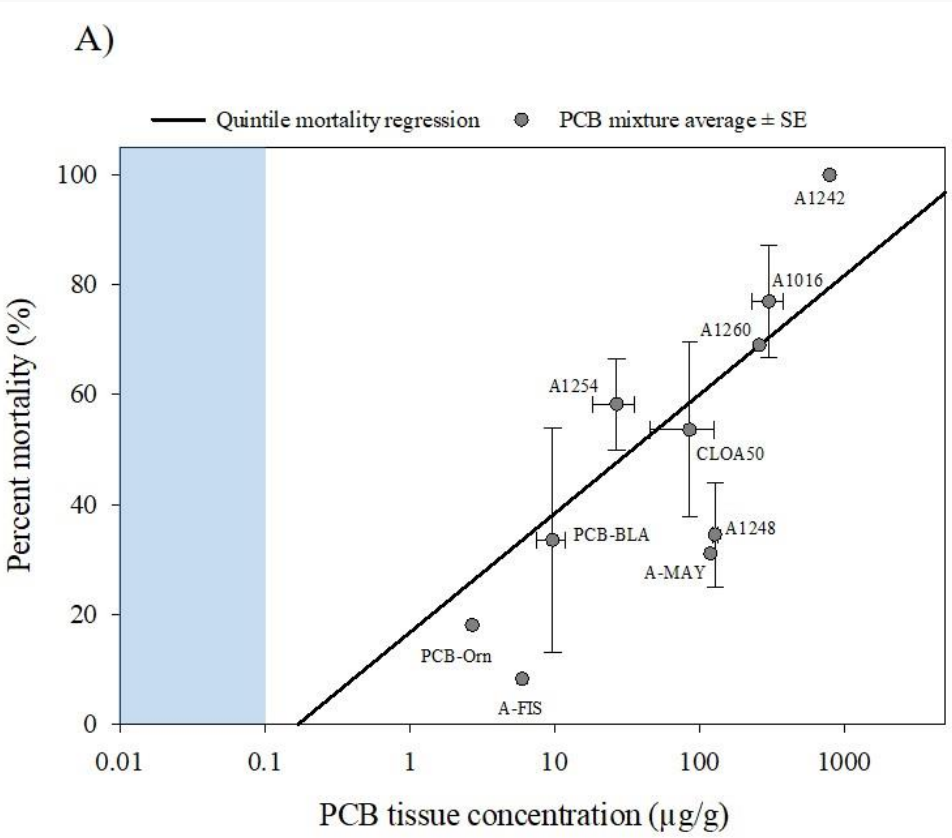


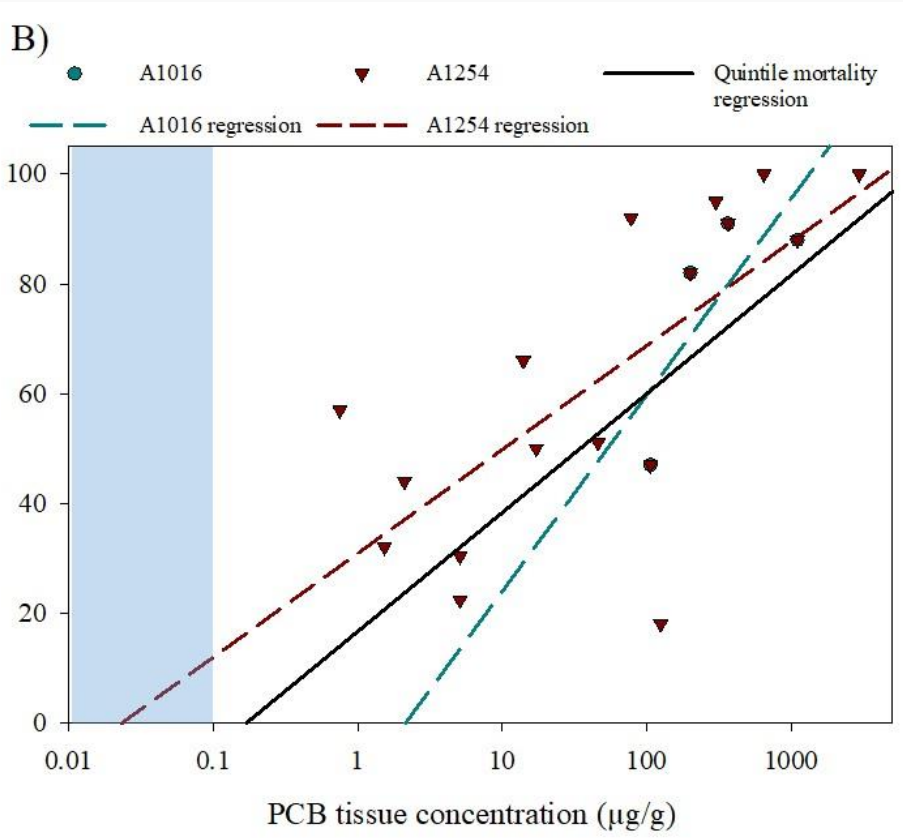
What about variables?

- PCB mixtures have different potencies
- Fish species have different sensitivities
- Other variables?
  - Life stage: adult vs. early life stage
  - Temperature: warm water vs cold water
  - Salinity: salt water vs. freshwater
- Do any specific variables drive the data?
- Do any of these variable preclude our data inclusive approach.

PCB-related Mortality in Fish: variables

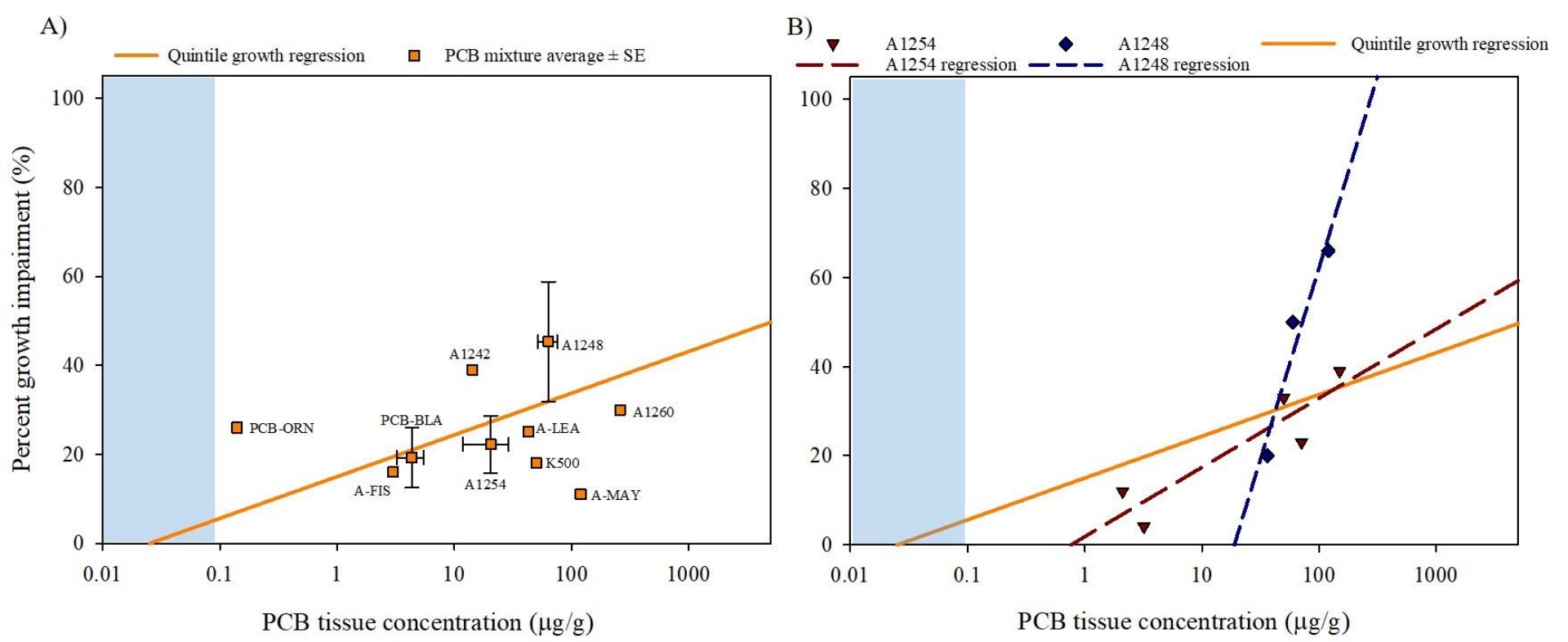
PCB-mortality response parameter comparisons : PCB Mixtures





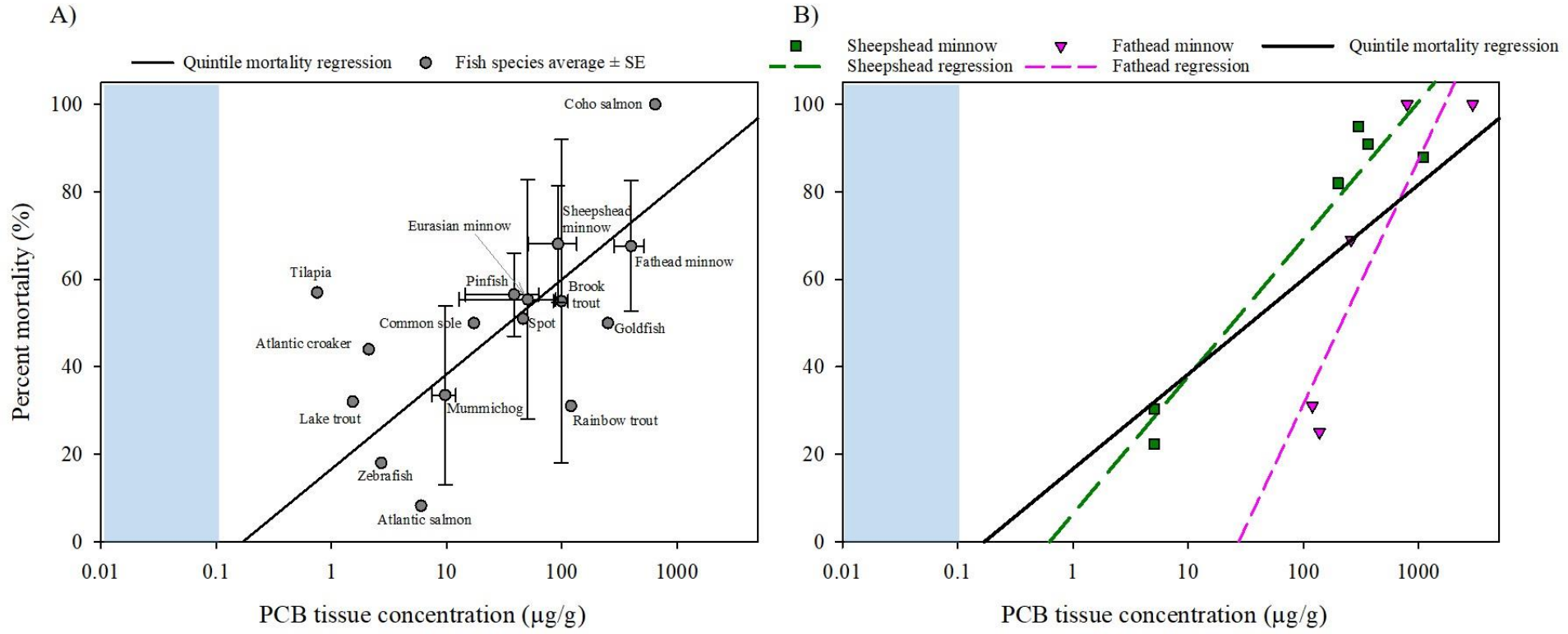
PCB-related growth inhibition in Fish: variables

PCB-growth response parameter comparisons :



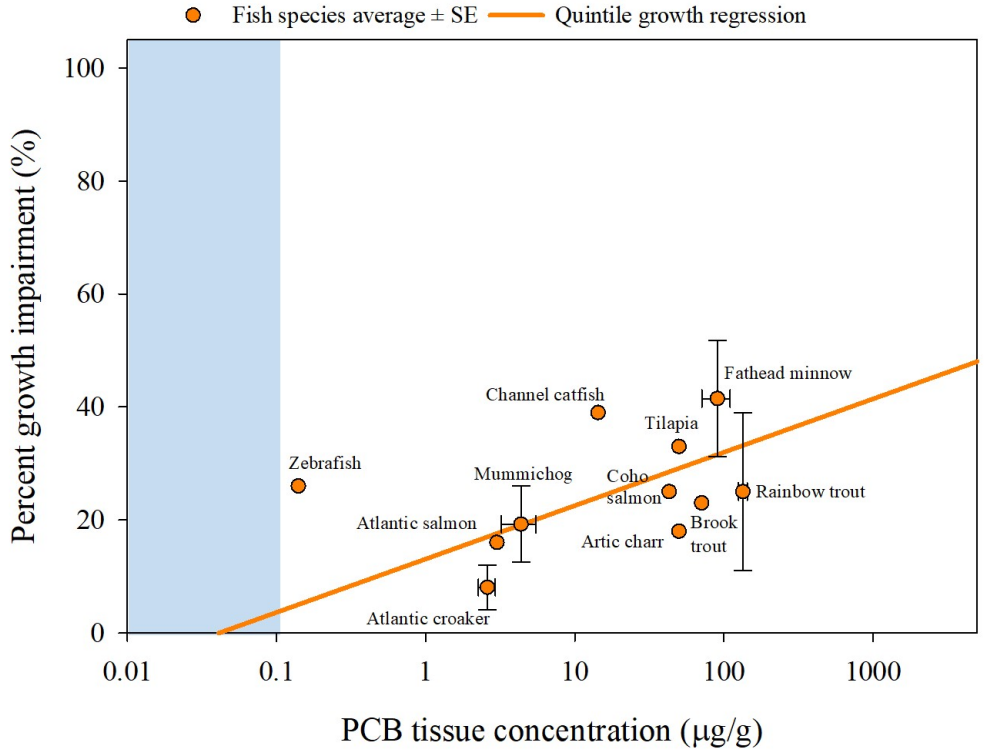
PCB-related Mortality in Fish: variables

PCB-mortality response parameter comparisons: Fish Species

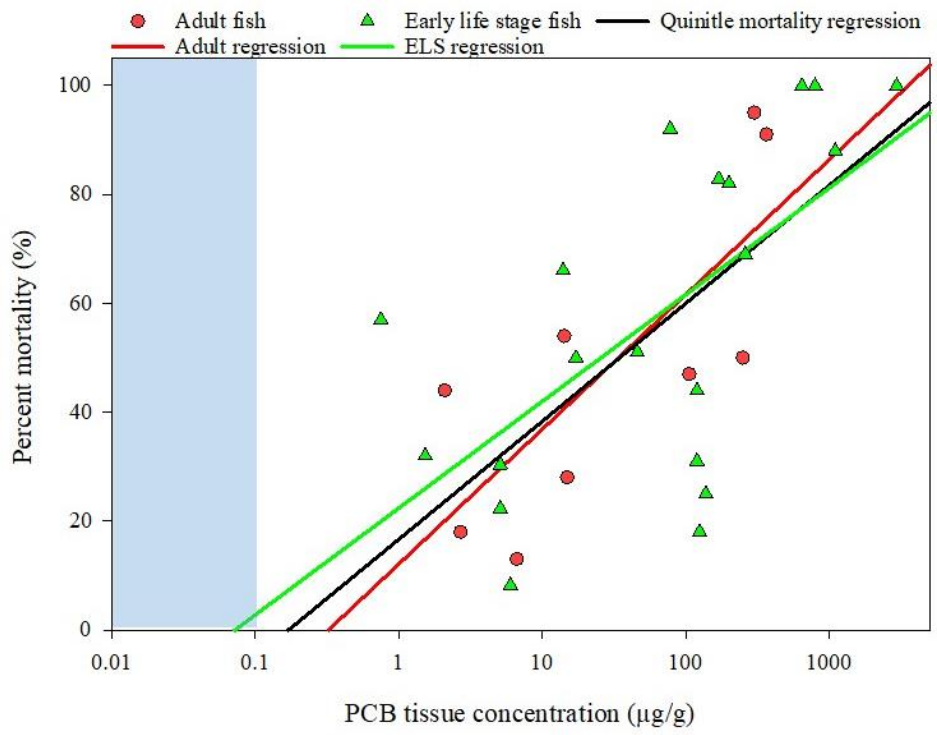


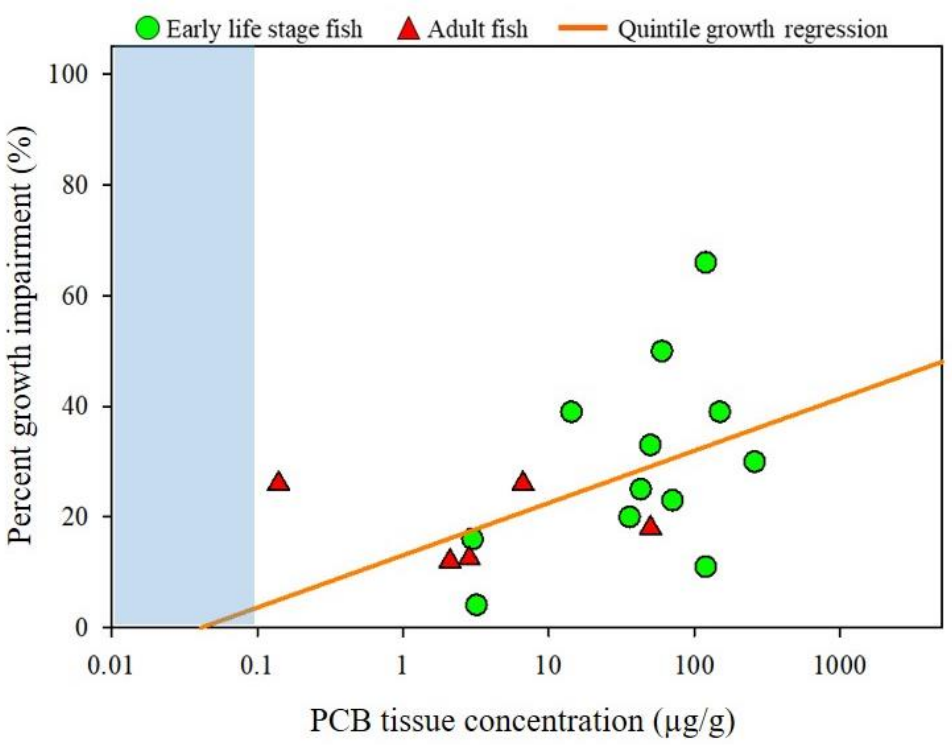
PCB-related growth inhibition in Fish: variables

PCB-mortality response parameter comparisons: Fish Species

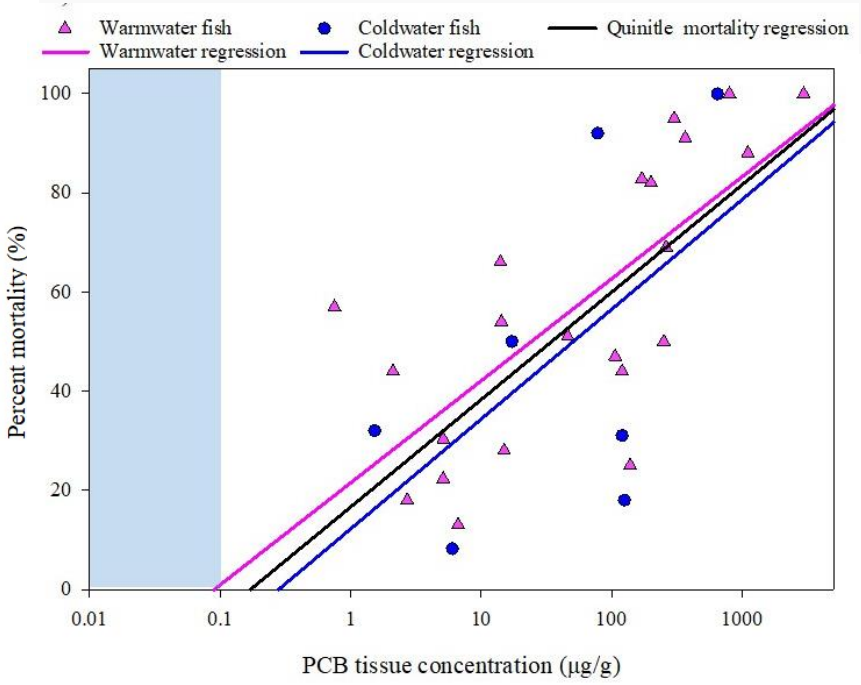


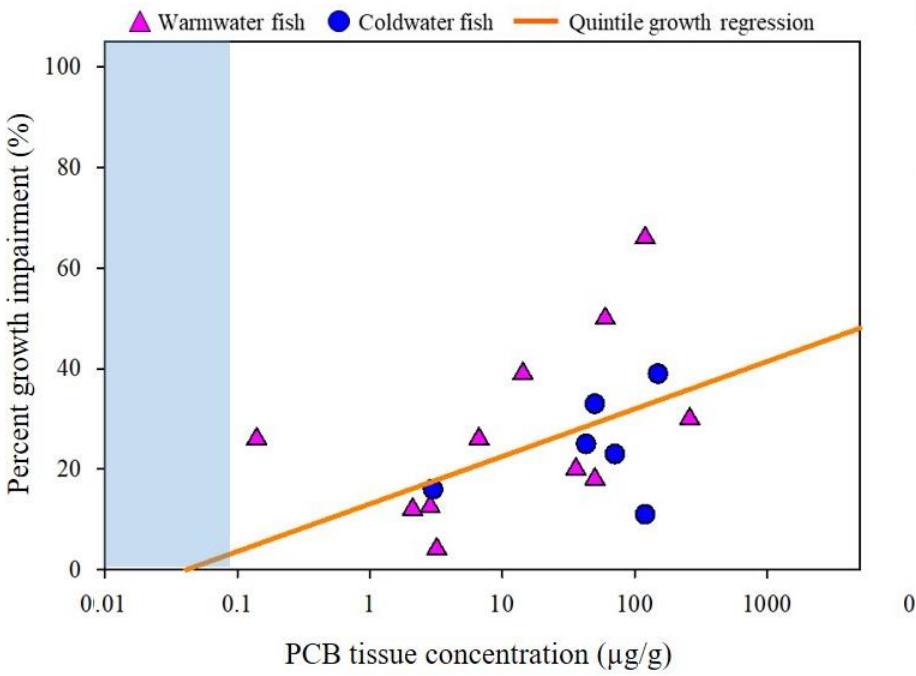
PCB-effect response parameter comparisons : Life Stage



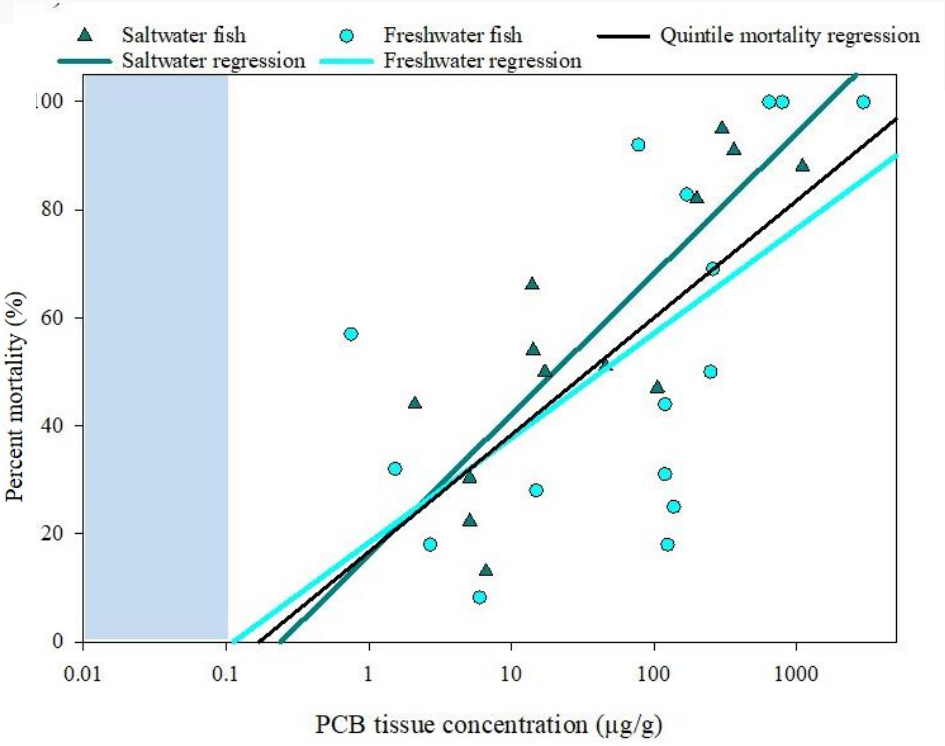


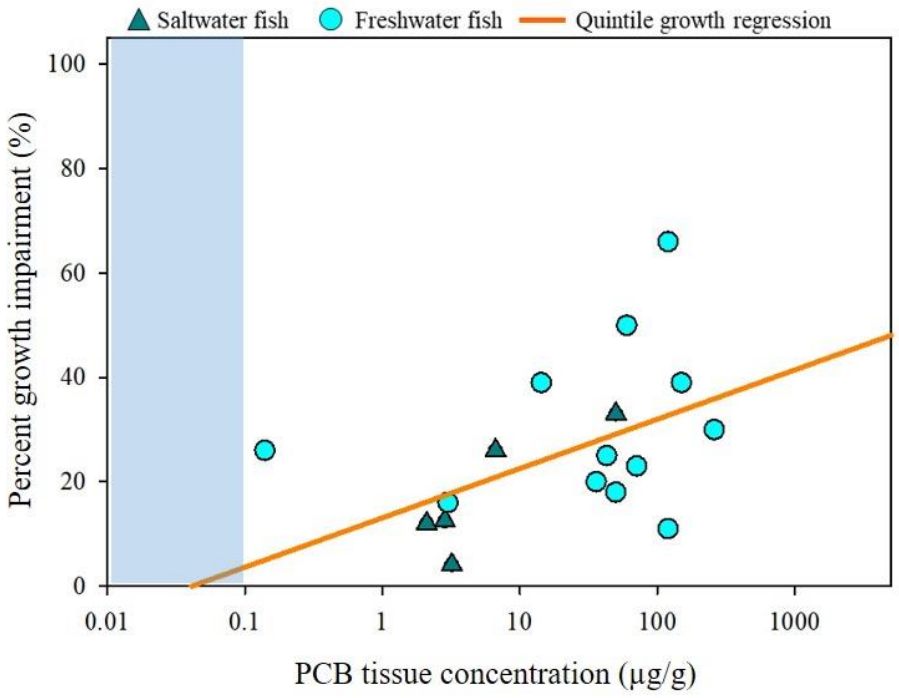
PCB-mortality response parameter comparisons : Temperature





PCB-mortality response parameter comparisons : Salinity

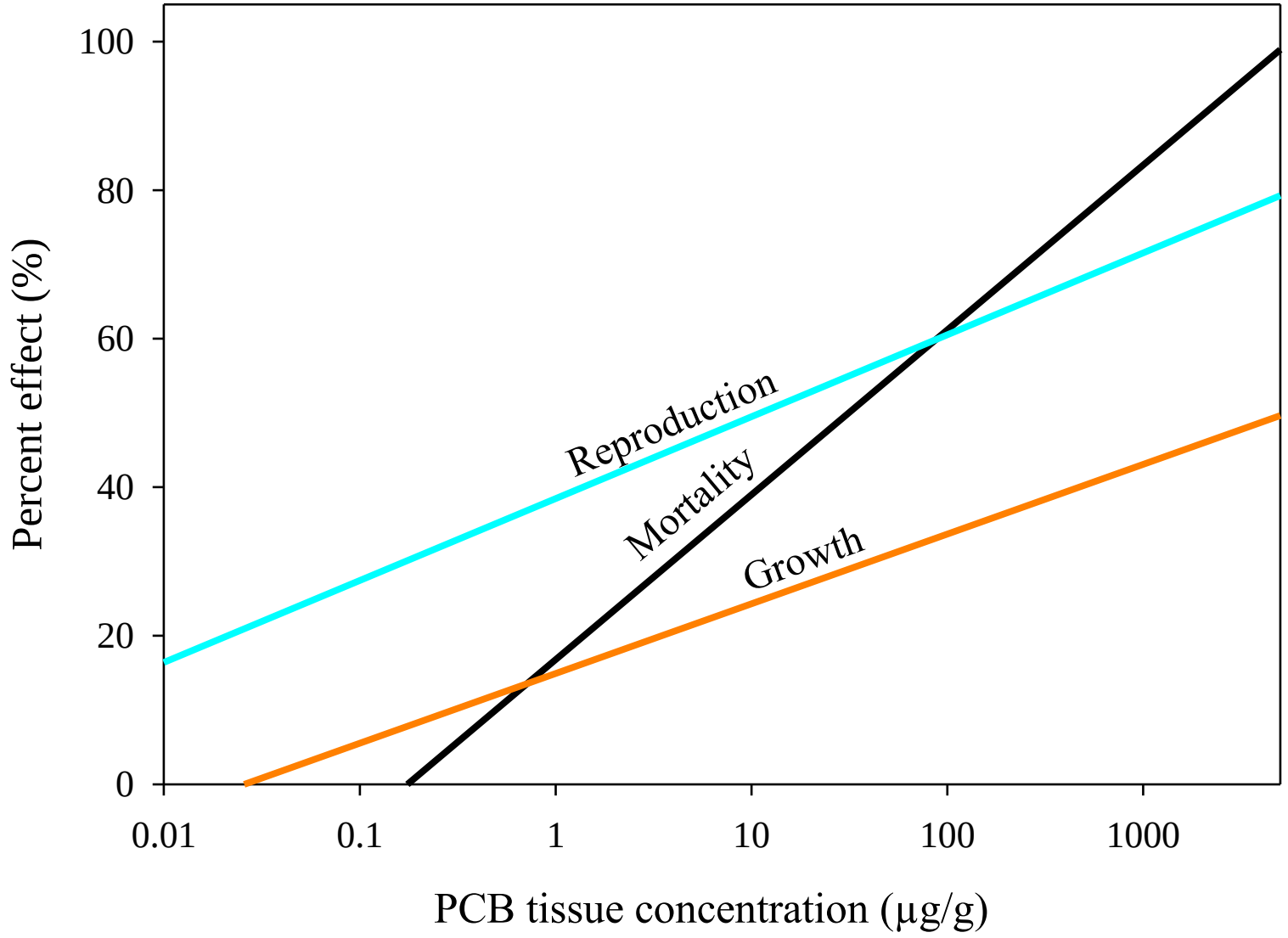




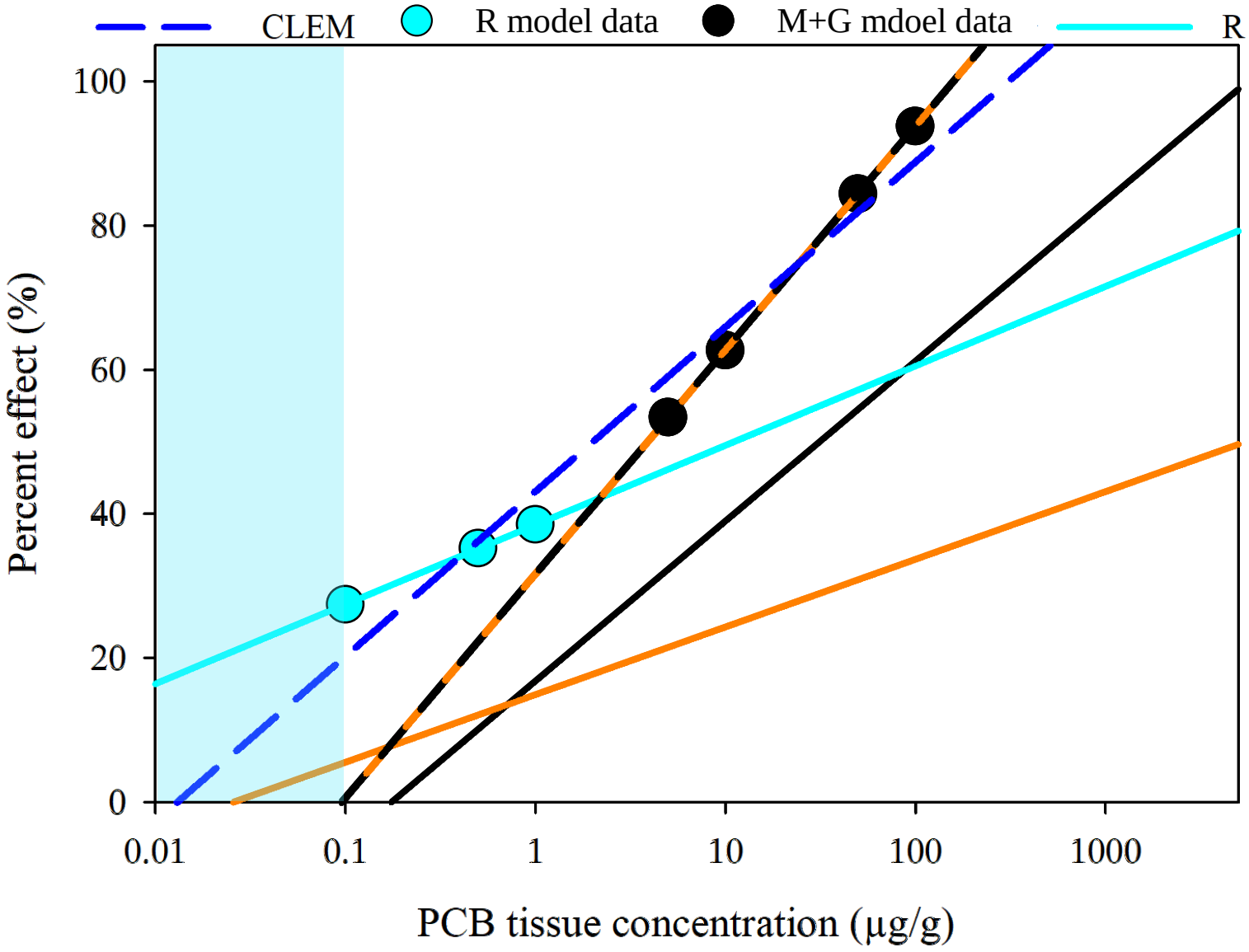
What about the variables?

- Yes, fish and PCB mixtures have different sensitivities/potencies
- Variables do not occur independently.
- Limited available data.
- Differences in life history variables are not great enough to support separation.
- Interactions and limited amounts of data preclude meaningful analysis separately

How do we address cumulative effect?



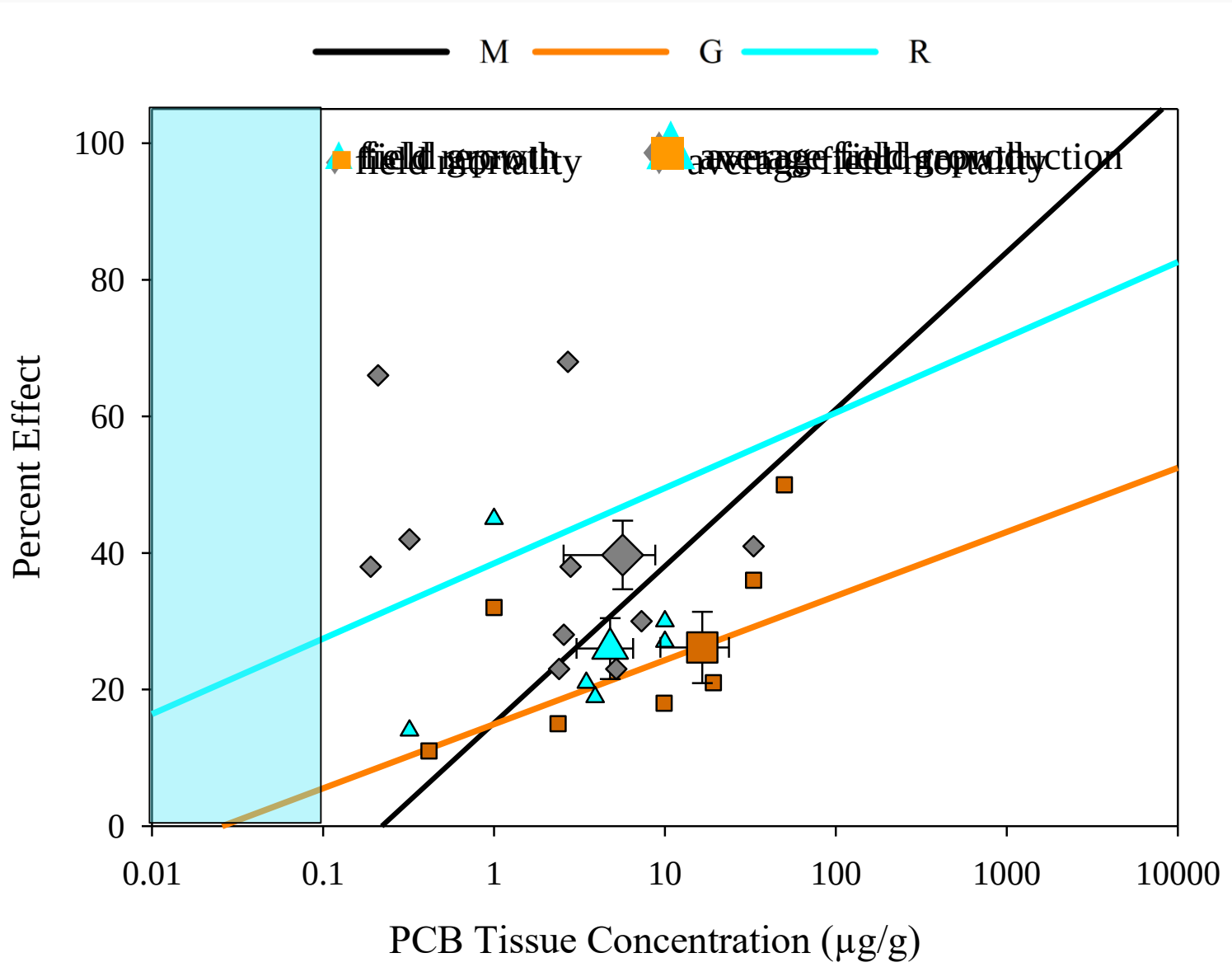
Cumulative Largest Effect Model (CLEM)



Does laboratory PCB exposure translate to the field?

- Do PCBs have the same effects in the lab and field
  - Are lab responses a valid measure of effects in the field?
- Do field responses corroborate lab responses
  - Concentration – response?

Field Validation of Laboratory Responses to PCBs



Discussion

- Available data limited but sufficient
- Transparency in data selection, conversion, analysis
- Use of percent effect and measured PCB tissue concentrations allowed for LOAER to be quantifiable
- Inherent uncertainties exist based on the nature of the data

Discussion

- MGR sensitivity distributions provide a screening tool.
- MGR concentration-effect regressions provide estimate of degree of effect across range of tissue concentrations.
- Cumulative effects can be estimated

Discussion

- Sufficiently robust to be useful for injury assessment
- Framework to utilize the entire array of available data
- Provides practitioners tools for assessment.
  - Data/approach is available and able to be modified to fit specific needs of practitioners

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