NCCOS | NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE

NCCOS Research Focusing on PCBs in Coastal Environments

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Ecotoxicology Branch

National Centers for Coastal Ocean Science

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NETS Mini-Series

NOS/NCCOS/HML

NCCOS LOCATIONS:

Silver Spring, MD (HQ)
Beaufort, NC
Charleston, SC
Oxford, MD
Seldovia, AK

Our **mission**: Deliver ecosystem science solutions for stewardship of the nation's ocean and coastal resources in direct support of National Ocean Service (NOS) priorities, offices, and customers to sustain thriving coastal communities and economies.

https://coastalscience.noaa.gov/

Ecotoxicology

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Current Research

- Develop new methods for quantification of legacy and emerging environmental chemical pollutants
  - ❖ Silicone Bands as passive samplers for chemicals in estuarine waters
- Contribute to chemical risk assessments
  - ❖ Characterize toxicity of PFAS in estuarine fish and invertebrates
  - ❖ Characterize toxicity of compounds proposed for AFFF replacement
  - ❖ Characterize chemical transport and fate for PFAS
- Support national and regional chemical contaminant assessments
  - ❖ Mussel Watch Program, SC Estuarine and Coastal Assessment Program
  - ❖ Develop biomarkers of chemical exposure and effects for estuarine fish and invertebrates
- Provide science to support NOAA's mandate for spill response and restoration
  - ❖ Develop oiled marsh replanting methods
  - ❖ Develop chemical and toxicity monitoring tools

Capabilities

- **Laboratory**
  - Toxicity Testing
    - Acute and chronic
    - Aqueous, sediment
    - Static renewal, effluent, flow-through, life-cycle, multi-stressor
    - Cellular & molecular biomarkers
  - Analytical Chemistry
    - Inorganic and organic
    - Water, sediment, tissues
    - Uptake and depuration
    - Legacy chemicals and CECs
    - ICP-MS, GC/MS, LC/MS

Capabilities, cont.

- **Mesocosm**
  - Greenhouse
  - Modular estuarine systems
  - Replicated
  - Tidal flux
  - Chemical fate and effects
  - Technology testing
  - Ecosystem level testing

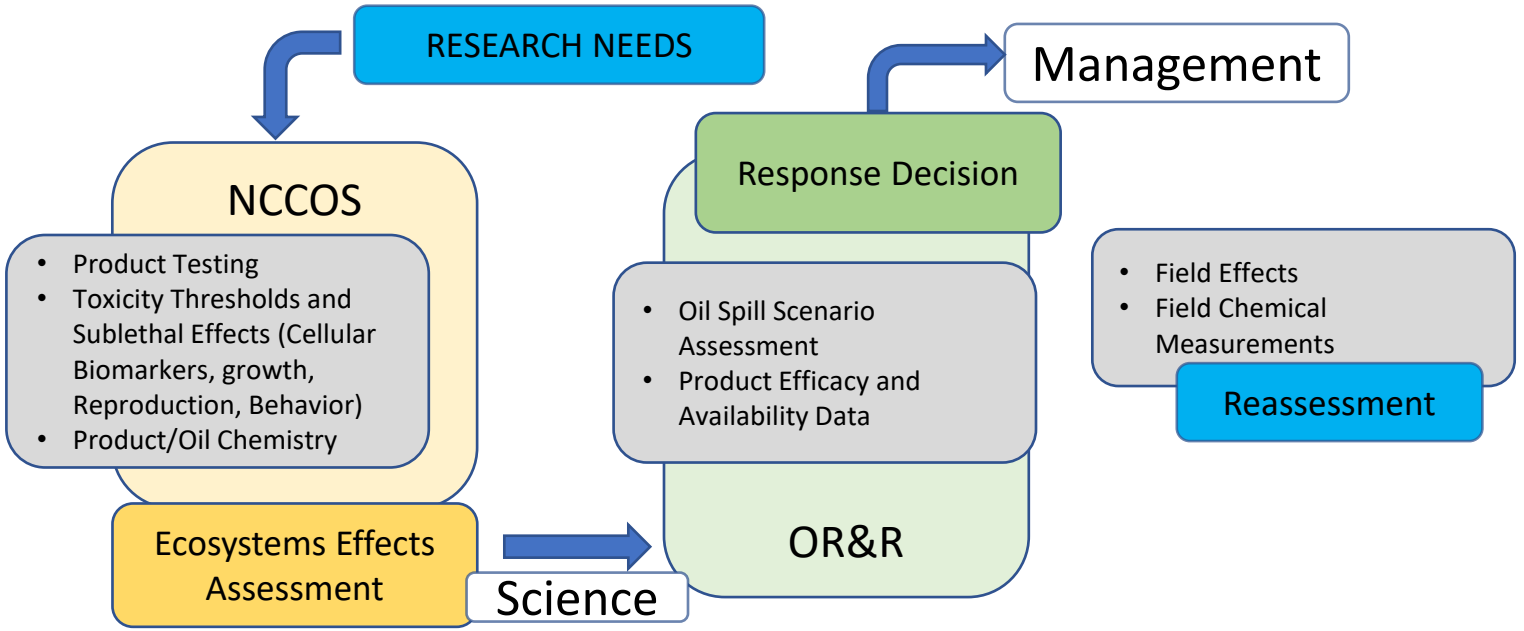
- **Field**
  - Deployed animals
  - Monitoring
  - Water quality measures
  - Sample collection
  - Datasondes, trucks, small boats

Partnerships

- NOAA OR&R
- SC DNR
- NIST
- US ACE
- SCCWRP
- EPA
- College of Charleston
- Clemson University
- University of South Carolina
- Texas A&M
- Florida A&M
- University of Florida

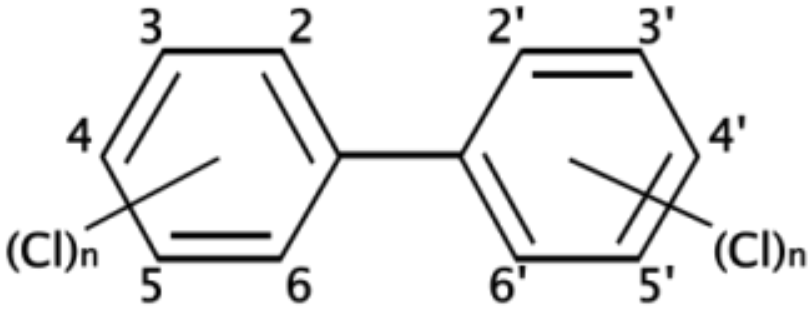
Science to Support Management

Delivering chemistry and toxicology data to inform oil spill damage assessment and mitigation in direct support of NOAA's Office of Response and Restoration



What are PCBs?

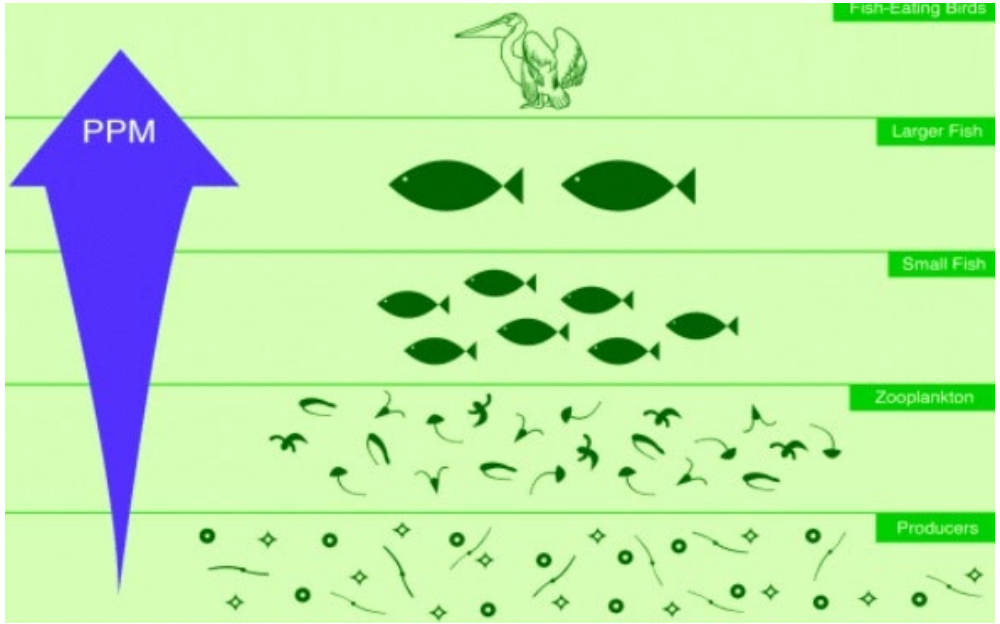
- Chemical used for industrial / electrical insulation processes
- 209 possible congeners
- Produced in the U.S. from 1929 to 1977
- Aroclors distinguished by percent chlorination
- Extremely stable with long half life
- Increasing chlorination generally associated increasing hydrophobicity and half life



- PCBs *bioaccumulate* in organisms and *biomagnify* across higher trophic levels

- Environmental analysis is complex as homologues (even congeners) have slightly different degradation patterns that make pattern analysis difficult

- Changes in analytical capabilities adds to complexity
  - Total PCB by Aroclors
  - NOAA18
  - ERL/ERM
  - HR GCMS availability



https://programs.wcs.org/india/Newsroom/Blog/ID/15443/Biomagnification-An-Ever-growing-Threat

Are PCBs still a relevant environmental issue?

Country	Start of production		End of production		Amount (1,000 t)	
	Earliest estimate	Latest estimate	Earliest estimate	Latest estimate	Lowest estimate	Highest estimate
Korea (DPR)	1960s	1960s	2006	>2006	25	30
Soviet Union/ Russian Federation	1938	1939	1993	1993	180	180
Spain	1930	1955	1984	1986	25	29
Czechoslovakia	1959	1959	1984	1984	21	21
West Germany	1930	1950	1983	1983	59	300
Italy	1958	1958	1983	1983	24	31
France	1930	1930	1980	1984	102	135
Poland	1966	1966	1977	1977	2	2
USA	1929	1930	1975	1977	476	700
China	1960	1965	1974	1983	7	10
Japan	1952	1954	1972	1972	59	59
United Kingdom of Great Britain and Northern Ireland	1951	1954	1965	1977	66	67
Total					**1,046**	**1,512**

- While U.S. production ended in 1977; *UN Envirnoment programme* notes international production data
- Still a relevant environmental issue

(Searched 1/29/24) https://www.unep.org/explore-topics/chemicals-waste/what-we-do/persistent-organic-pollutants/pcbs-forgotten-legacy

PCBs in context at NOAA

- National Status and Trends (mid-1980s)
  - Nation-wide assessment of 'background' concentrations
  - Focused on legacy pollutants (PCBs included)
- Technology was beginning to address congener specific data

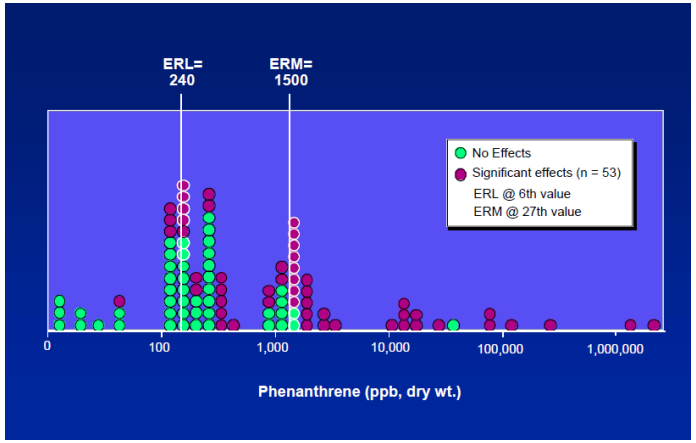
- NOAA defined a list of 18 congeners

  (di- thru deca- chlorination homologs)

  - 8 | 18 28 | 44 52 66 | 101 105 118 | 128 138 153 | 170 180 187 | 195 | 206 | 209
  - Total PCB estimated (modeled) by ΣPCB_18*2

(ng/g wet)	NOAA 18_PCB	TOTAL_PCB
Maui Composite 1	0.458	0.688
Maui Composite 2	0.899	1.778
Maui Composite 3	0.249	0.360
Maui Composite 4	11.6	18.1
Maui Composite 5	0.454	0.721
Maui Composite 6	0.066	0.066
Maui Composite 7	0.165	0.176
Maui Composite 8	0.232	0.280
Maui Composite 9	0.086	0.086

PCBs in context at NOAA



- Mid 1990's –
  - Researchers developed a series of sediment quality guidelines
  - Estimated the potential impacts or effects on benthic communicates at a given Total PCB concentration (Long et al. 1990 and 1995)

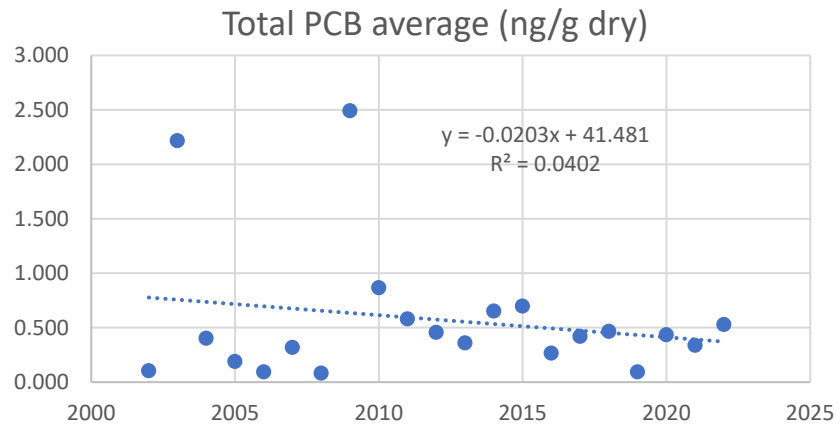
    - **NOT** a criteria and **NOT** a threshold

    - EFFECTS RANGE LOW (ERL) – estimates of the concentrations below which toxicity is least likely (effectively a concentration of ranked tests where toxicity is not recorded in more than 10% of studies)

    - EFFECTS RANGE MEDIAN (ERM) - estimates of the concentrations above which toxicity is likely (effectively a concentration from ranked tests where toxicity likely reported in ~50% of tests)

    - Total PCB: (ERL) 22.7 ng/g dry mass (ERM) 180 ng/g dry mass

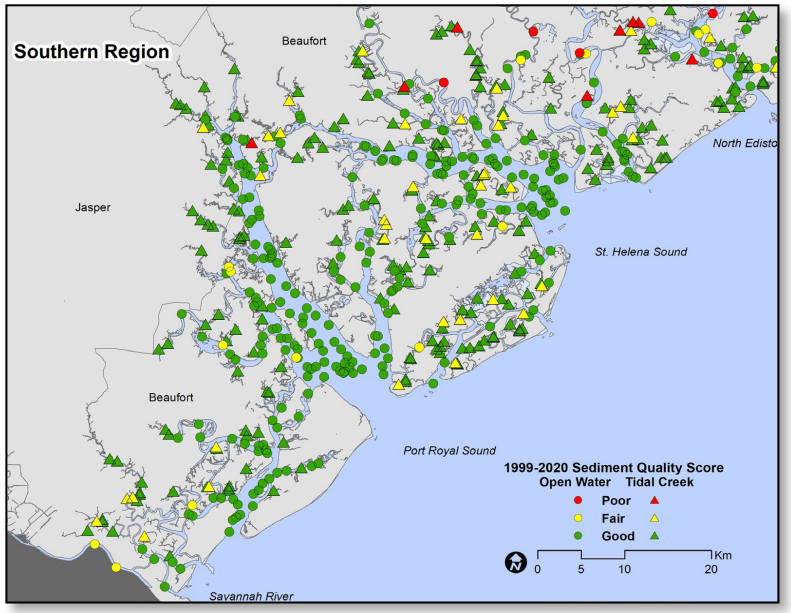
Monitoring Efforts (for example: SCECAP; A. Tweel, SC DNR)

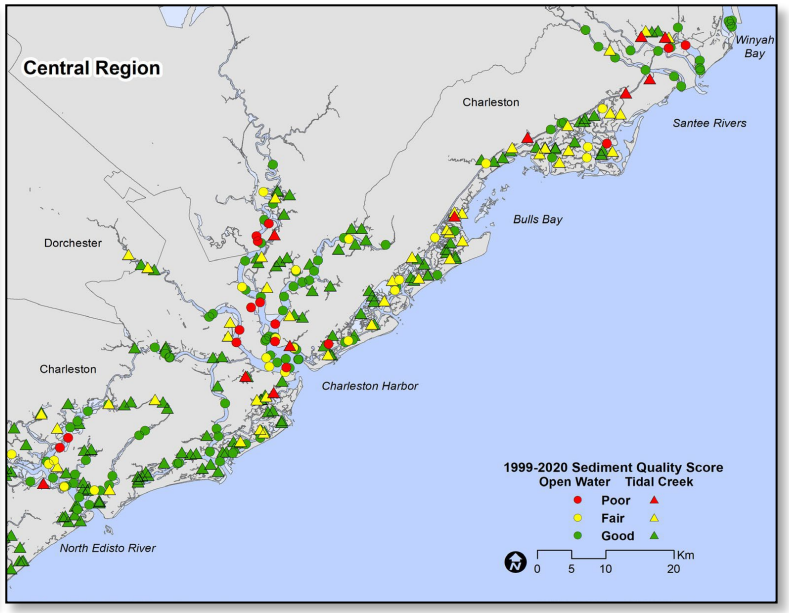


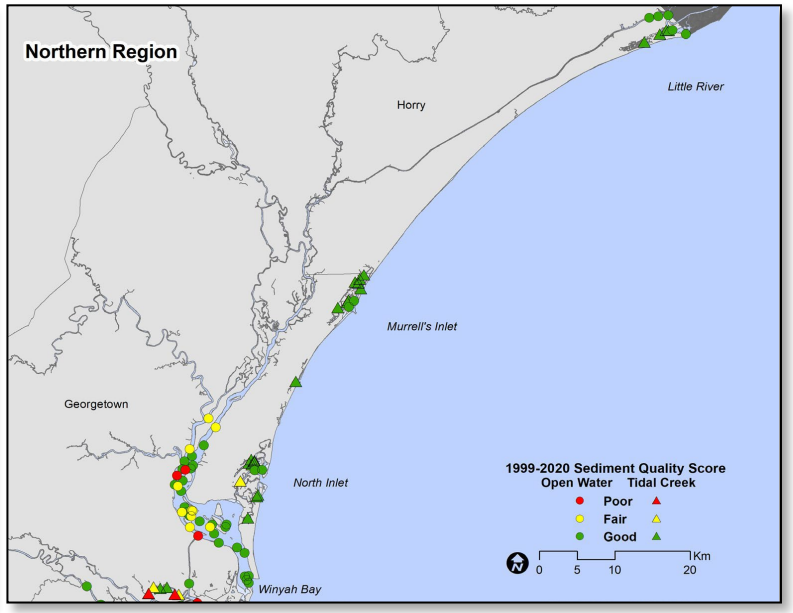
- Total PCBs monitored in SC annually since ~1999
- Annual averages are generally <2 ng/g dry
- Total PCB is a factor in sediment quality assessment

(using ERL/ERM values as a predictor of possible impact)

- Can help identify areas or chemicals of concern







Supporting Office of Response and Restoration

- Evaluate damage from oil and chemical spills in the environment

- Two science efforts
  - 1) Emergency Response
  - 2) Assessment and Restoration

  - Validated benthic injury models that estimate impact from PCB contamination

https://www.flickr.com/photos/noaa_response_restoration/1_9128873685/

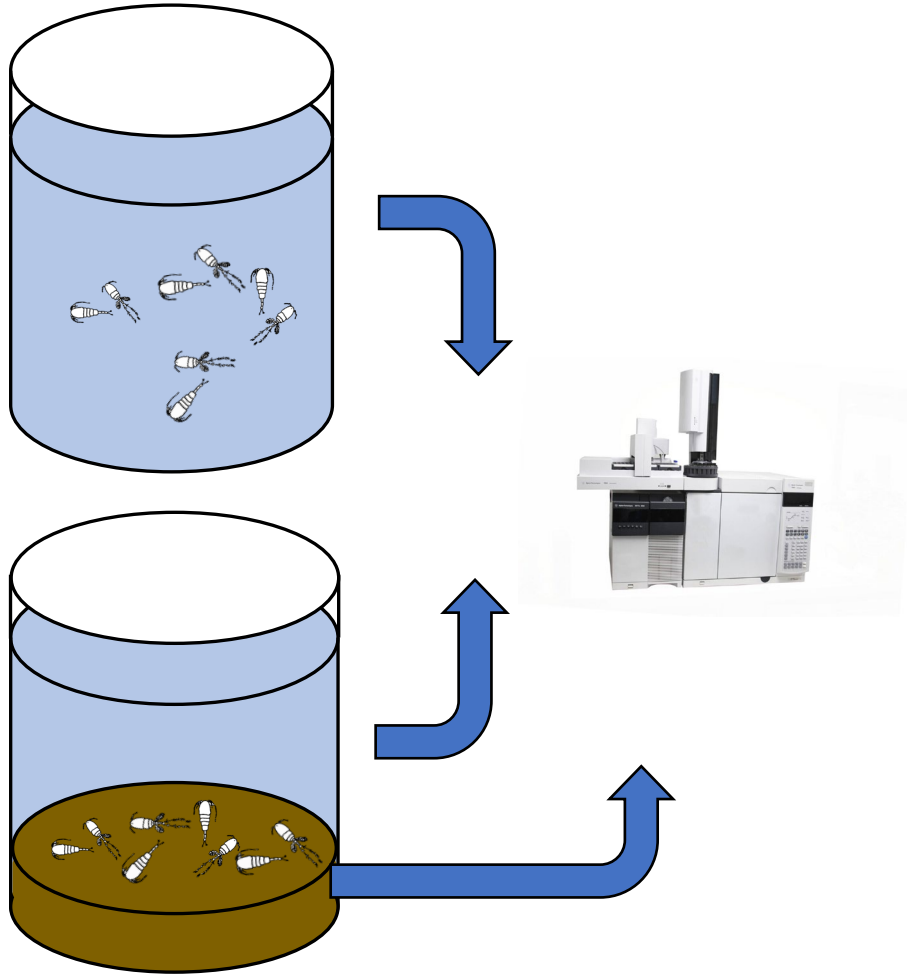
2019 Benthic Injury Verification (Finkelstein et al., 2020)

Objectives

- Create experimental data that validates the proposed dose-response model with MEASURED PCB chemistry and impacts on benthic taxa
  - Mortality in aqueous exposure
  - Effect of organic carbon on sediment toxicity

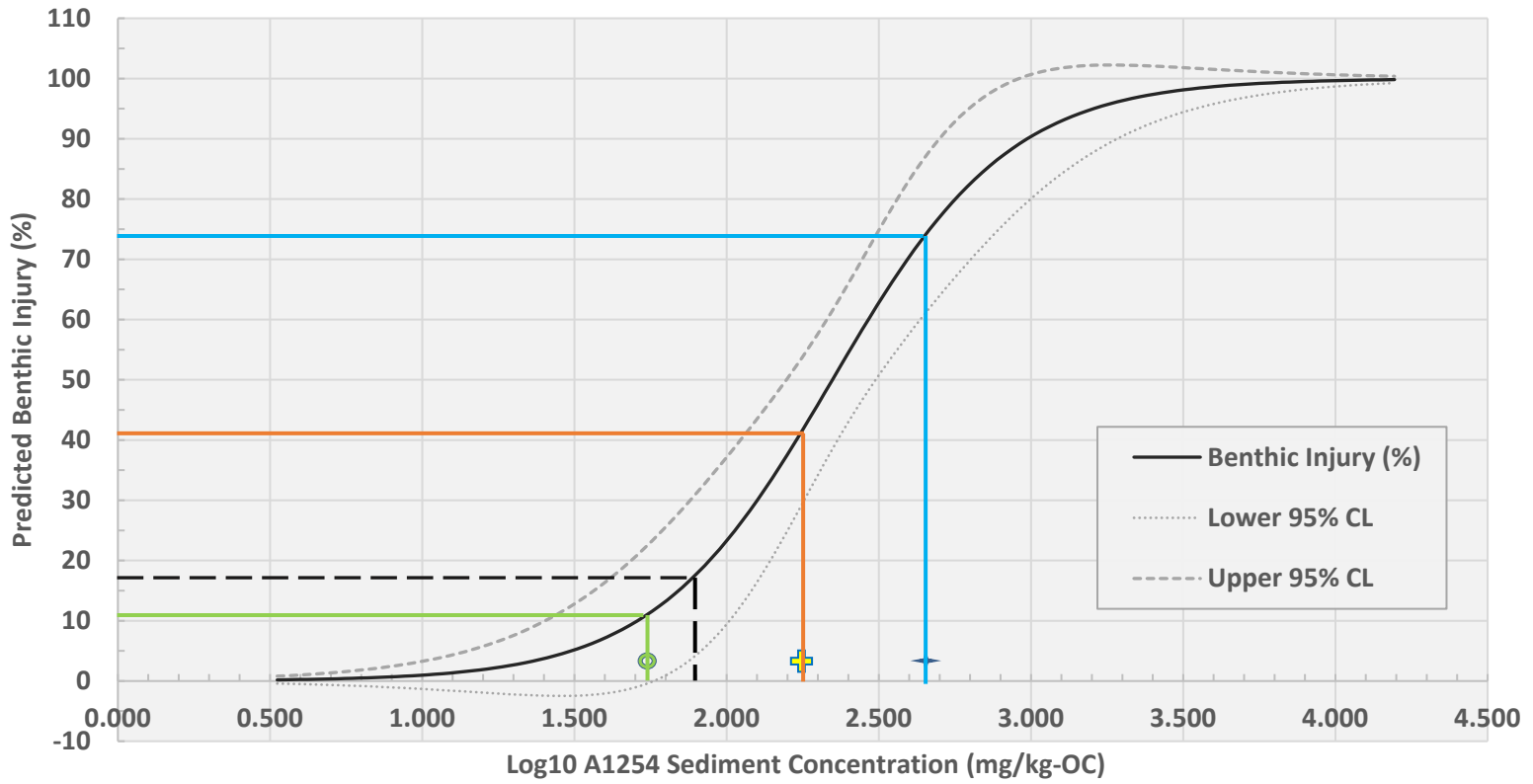
$$\%\_Injury = 100 / (1+10^{(logEC50-log\ [A1254]*slope)})$$

- Model and look-up tables based on literature values that often date to publications in the 1970s
- Very Conservative Koc used



Predictive Benthic Injury Model

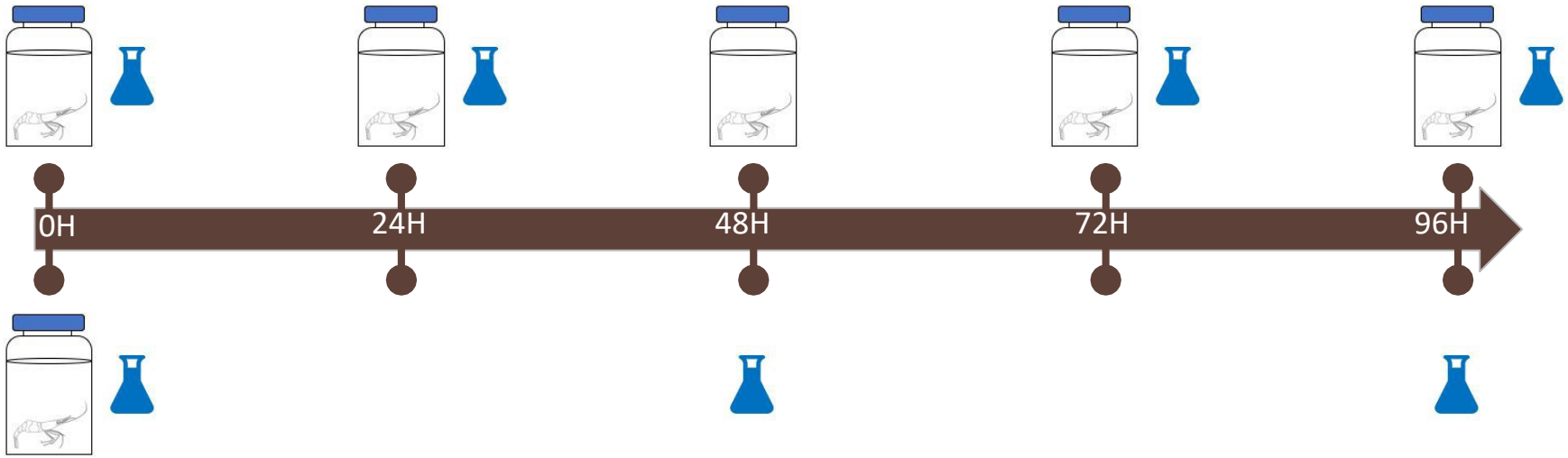
Predicted Benthic Injury	Predicted Log A1254	Lower 95%	Upper 95%
1%	1.00929	0.96141	1.05437
2%	1.21410	1.17256	1.25326
3%	1.33517	1.29730	1.37092
4%	1.42197	1.38667	1.45532
5%	1.49000	1.45669	1.52151
6%	1.54618	1.51447	1.57619
7%	1.59418	1.56383	1.62295
8%	1.63622	1.60702	1.66391
9%	1.67370	1.64552	1.70046
10%	1.70760	1.68033	1.73353
15%	1.84232	1.81844	1.86515
20%	1.94376	1.92216	1.96451
25%	2.02754	2.00759	2.04681
30%	2.10072	2.08200	2.11893
35%	2.16720	2.14937	2.18464
40%	2.22939	2.21219	2.24634
45%	2.28903	2.27222	2.30572
50%	2.34747	2.33083	2.36411
55%	2.40591	2.38922	2.42272
60%	2.46555	2.44860	2.48274
65%	2.52774	2.51030	2.54557
70%	2.59422	2.57602	2.61294
75%	2.66740	2.64814	2.68734
80%	2.75118	2.73044	2.77277
85%	2.85262	2.82980	2.87649



Relationship between Aroclor 1254 sediment concentration and the predicted benthic injury from Finkelstein et al., 2017). Using 1% OC, the green, black, yellow and blue lines respectively represent ***benthic injury of about 12% at a concentration of approximately 0.60 µg/g , about 20% at 1.0 µg/g , about 43% at approximately 1.80 µg/g and about 74% at approximately 4.5 µg/g***

Acute Toxicity Tests

Static Renewal Tests (*P. pugio, L. plumulosus, A. bahia*)



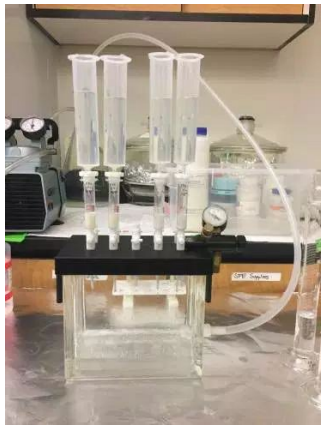
Static Test (*A. bahia*)

Chemical Analysis

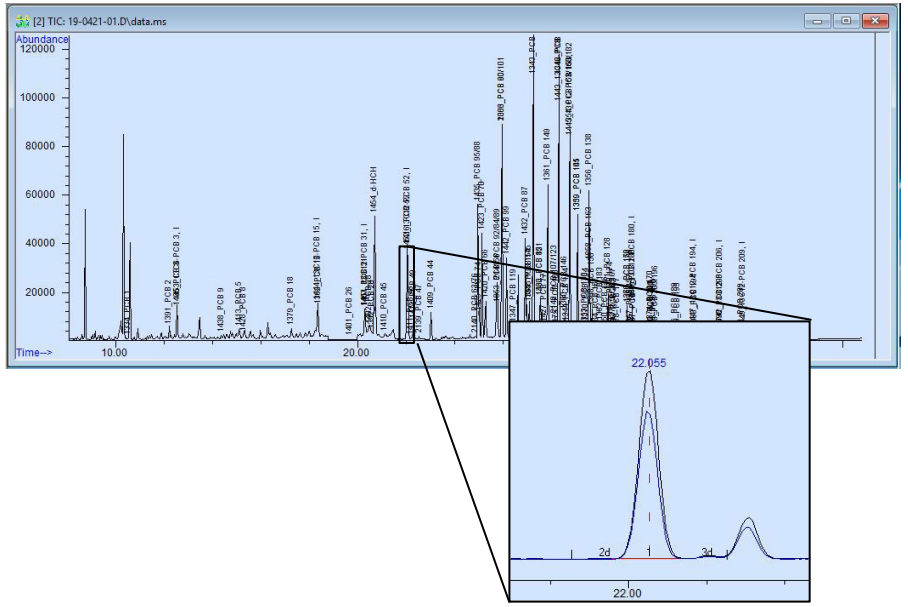
PCB Isolation

GC-MS Analysis

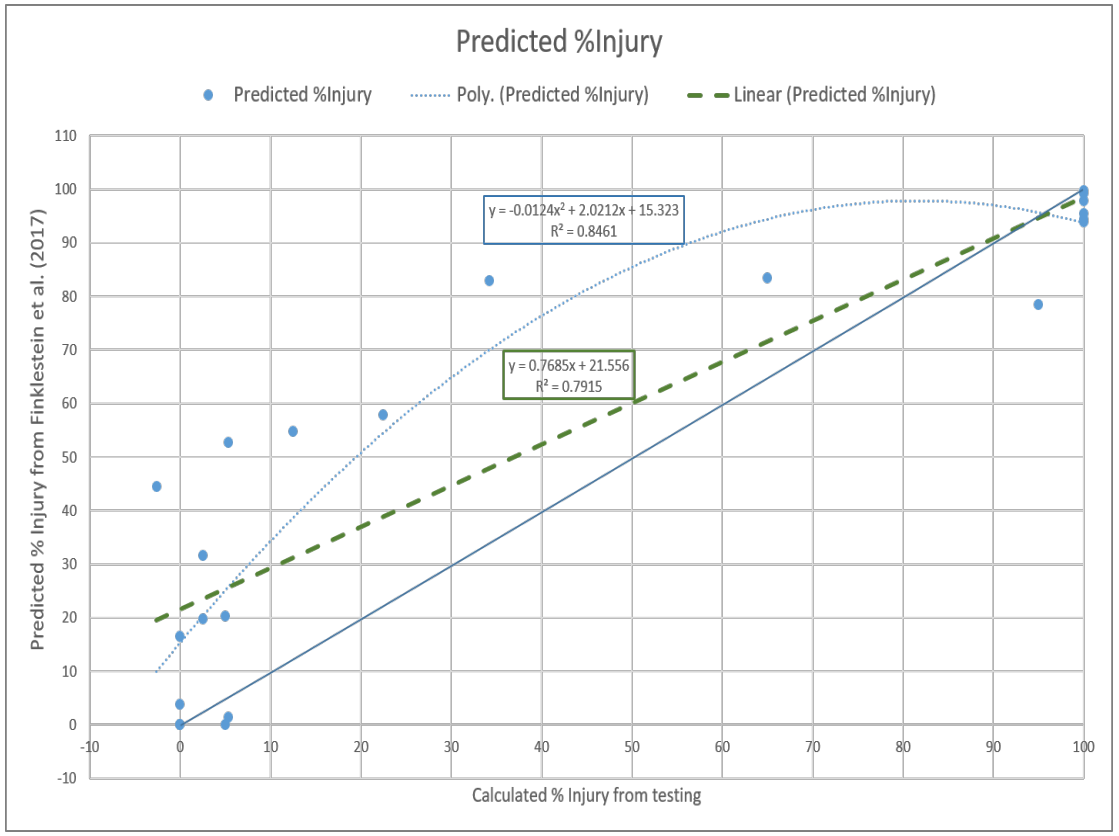
- Solid-phase extraction (SPE)



SPE apparatus



Benthic Injury Model validation



- Provide the user a chronic and acute PCB concentration to estimate benthic injury in PCB contaminated sediment
- User must review the primary literature before making decisions on site specific toxicity
- Generally a good agreement between the predicted and measured benthic injury (r^2>0.75) but the predicted injury generally over estimates the response

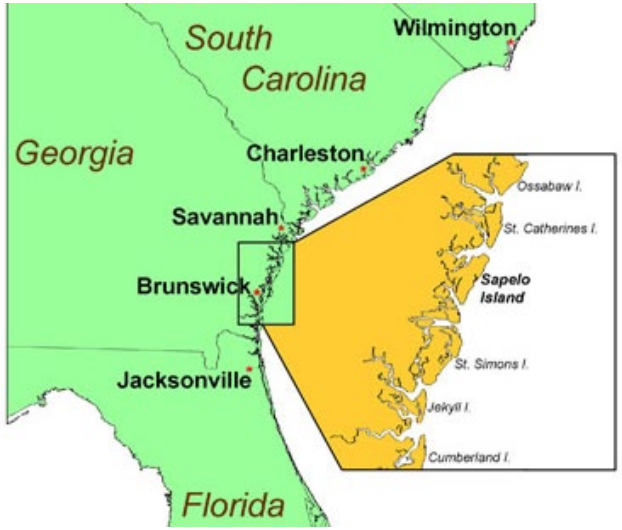
Characterization of PCBs in fish from Sapelo Island and Brunswick, GA

Broad Project overview and goals

- Spatial assessment of the “environmental condition” of the Sapelo Island NERR
- Endpoints included water quality, benthic community assessment, and *contaminants in sediment and tissues*
- Additionally, designed to also help address the potential for trophic contaminant transport to sentinel species via prey within the NERR

What we did

- Sampled 30 stations (sediment, benthos, water quality) within the SI NERRs in a stratified random design.
- Fish were collected from 9 of the 30 stations from the SI NERR.
- In the greater Brunswick area, fish were caught or provided by GA DNR
- Targeted fish species included: striped mullet, spotted sea trout, red drum, flounder, croaker, whiting, silver perch
- Contaminants in filets were analyzed for a total of 51 fish (22 from SI and 29 from BR)
- Contaminants were also measured in the carcasses of 9 fish from each estuary to allow for the estimation of whole body contaminant concentrations.



Explanation of fillet and carcass model

- All fish were filleted and depending on size, either one or two fillets were homogenized for chemical analysis.
- After filleting the fish, carcasses from 3 sea trout (SI) and 6 mullet (3 from SI and 3 from BR) were also homogenized and prepared for chemical analysis. *
- Results from these matched samples were used to calculate weighted estimated of whole body chemical concentrations.

Numbers of Fish from each estuary analyzed for PCBs

•Total n= 51

Species	Sapelo	Brunswick
Mullet*	10	9
Sea trout*	3	1
Flounder	1	0
Red Drum	2	0
Croaker	2	8
Whiting	1	1
Silver Perch	3	4
Spot	0	6

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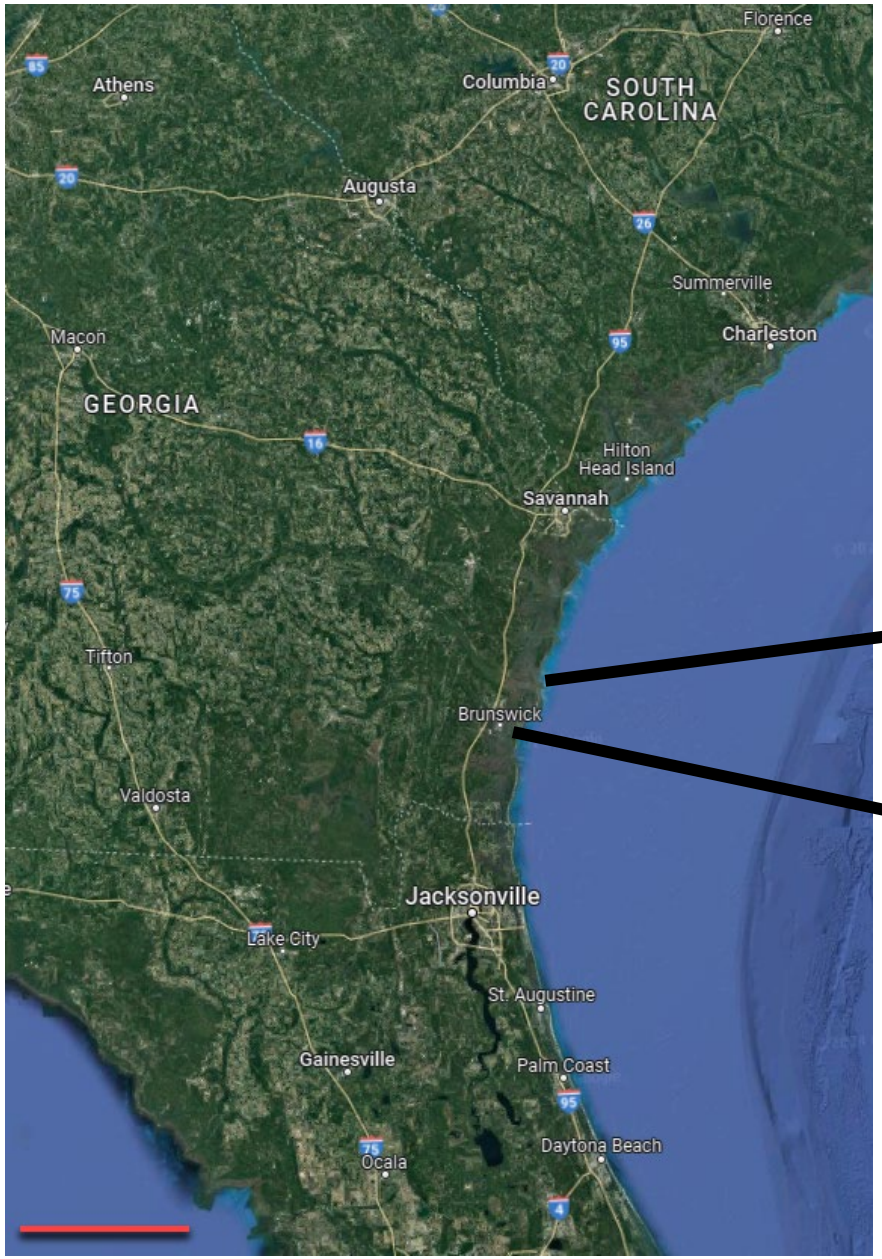
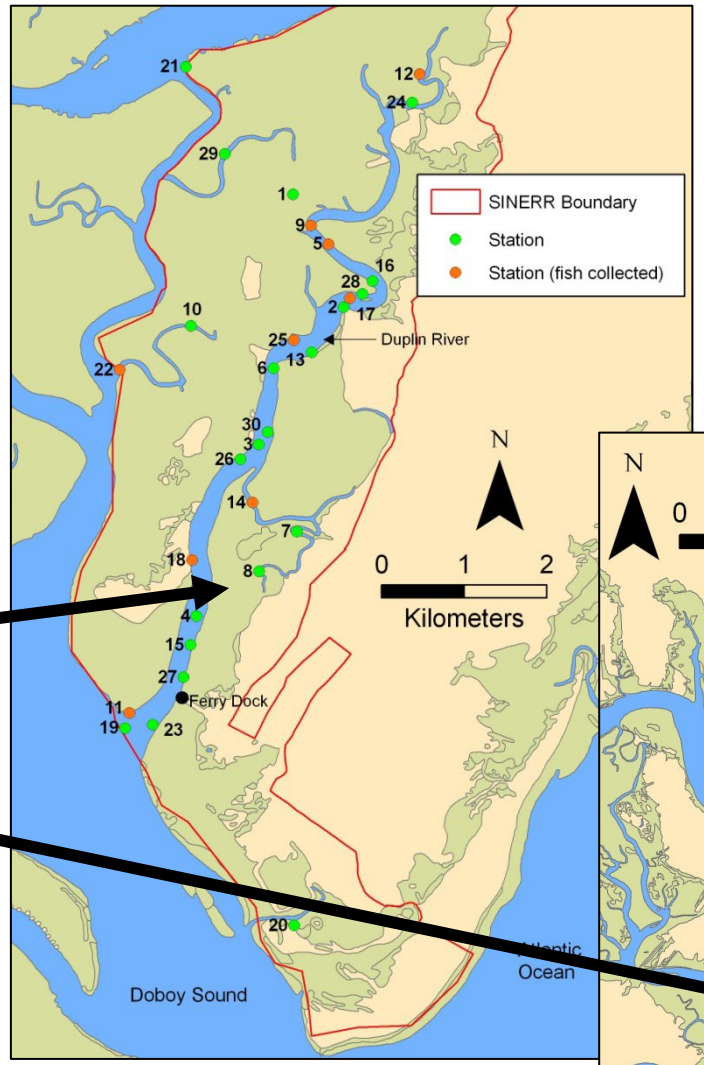
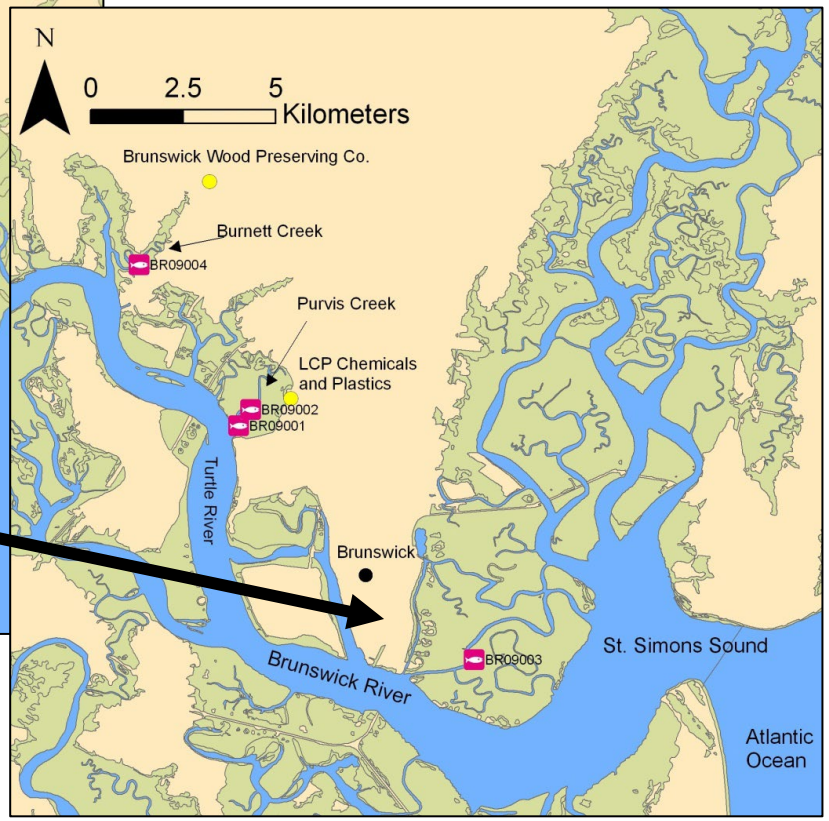
Sampling Stations







SCIENCE SERVING COASTAL COMMUNITIES

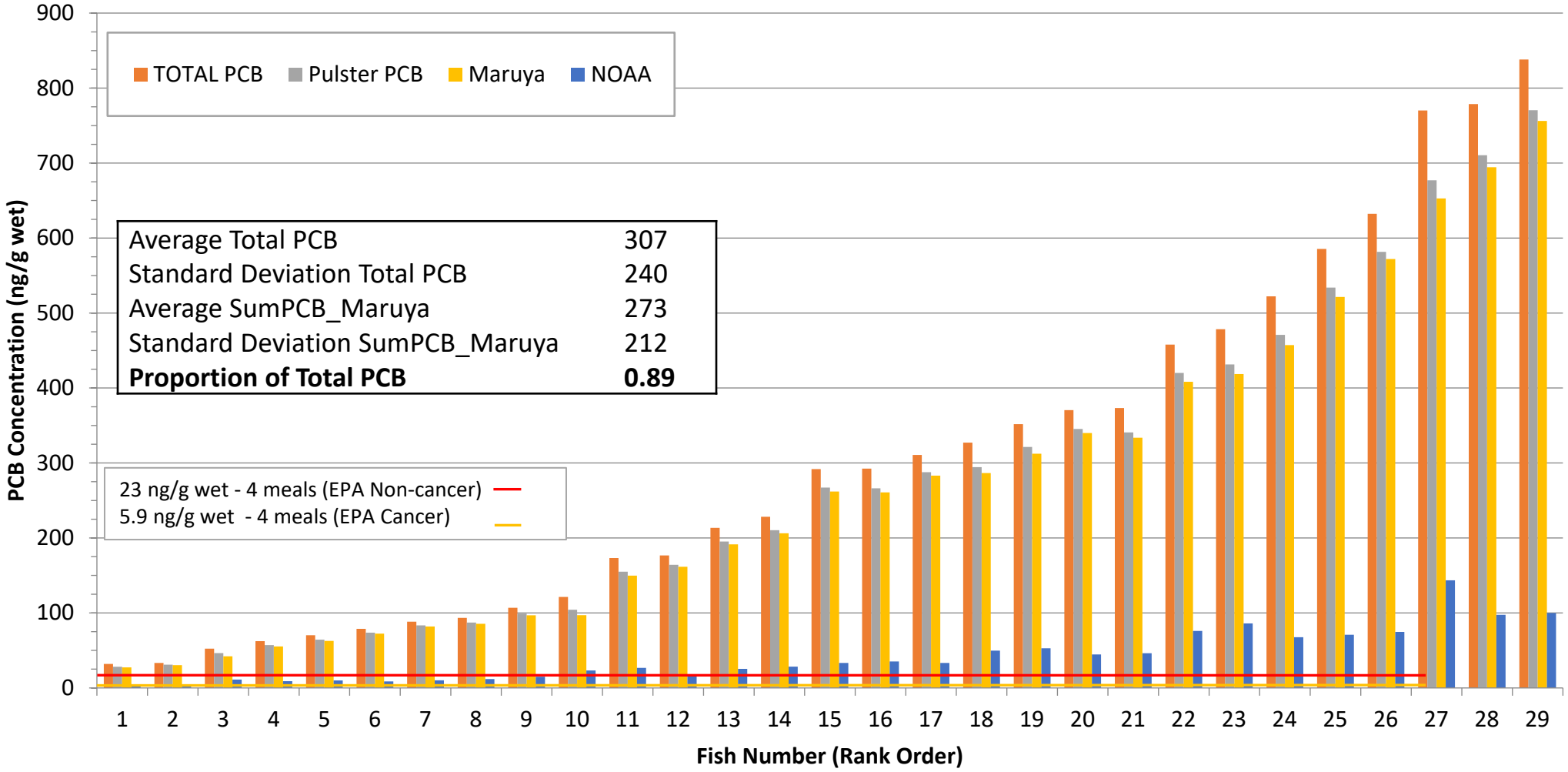
Multiple PCB Congener lists and how to compare – particularly looking at Aroclor 1268

- NOAA NS&T list (n=18 congener peaks)
- Maruya 1998 (n=12)
- Pulster 2005 (n=18)
- Pulster 2008 (n=17)
- Pulster 2009 (n=41 but unidentified)
- This study (n=81)

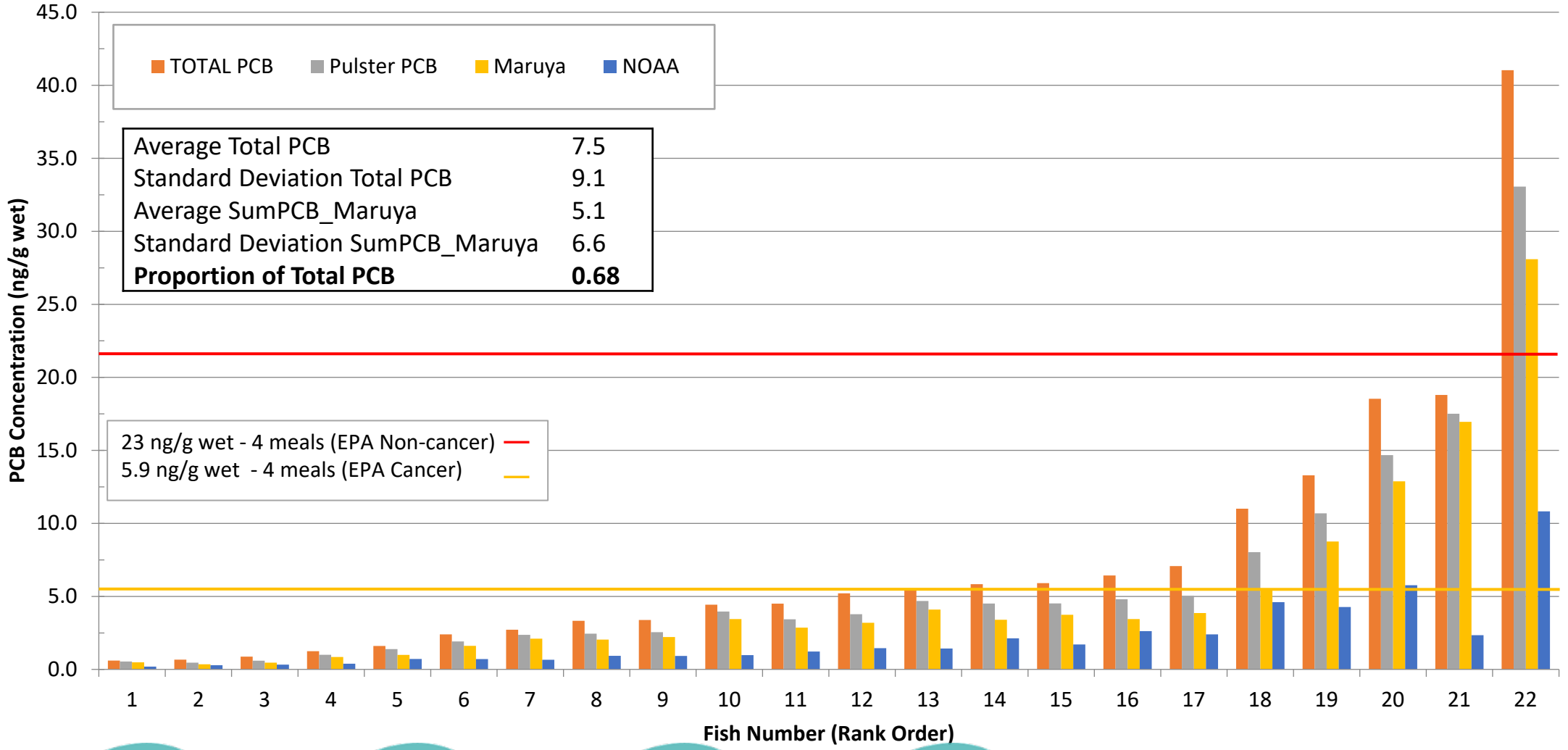
Maruya and Lee 1999	Pulster et al 2005	Pulster et al 2008	NOAA NS&T
187	118	188/118	*101/90*
199	153	153	*105*
200	105/CL6	105	118/106
180	138	138	*126*
201	187	187	*128/167*
196	202	202	153
207	201/204	201	164/163/138
208	180	180	*169*
202	170	170	170/190
194	199	199	*18*
206	196	196	180
209	208	208	187
	207	207	*28*
	194	194	*44*
	206	206	*52*
	209	209	*66*
			77
			8/5

PCB Congener suites identified in A1268 / LCP associated publications

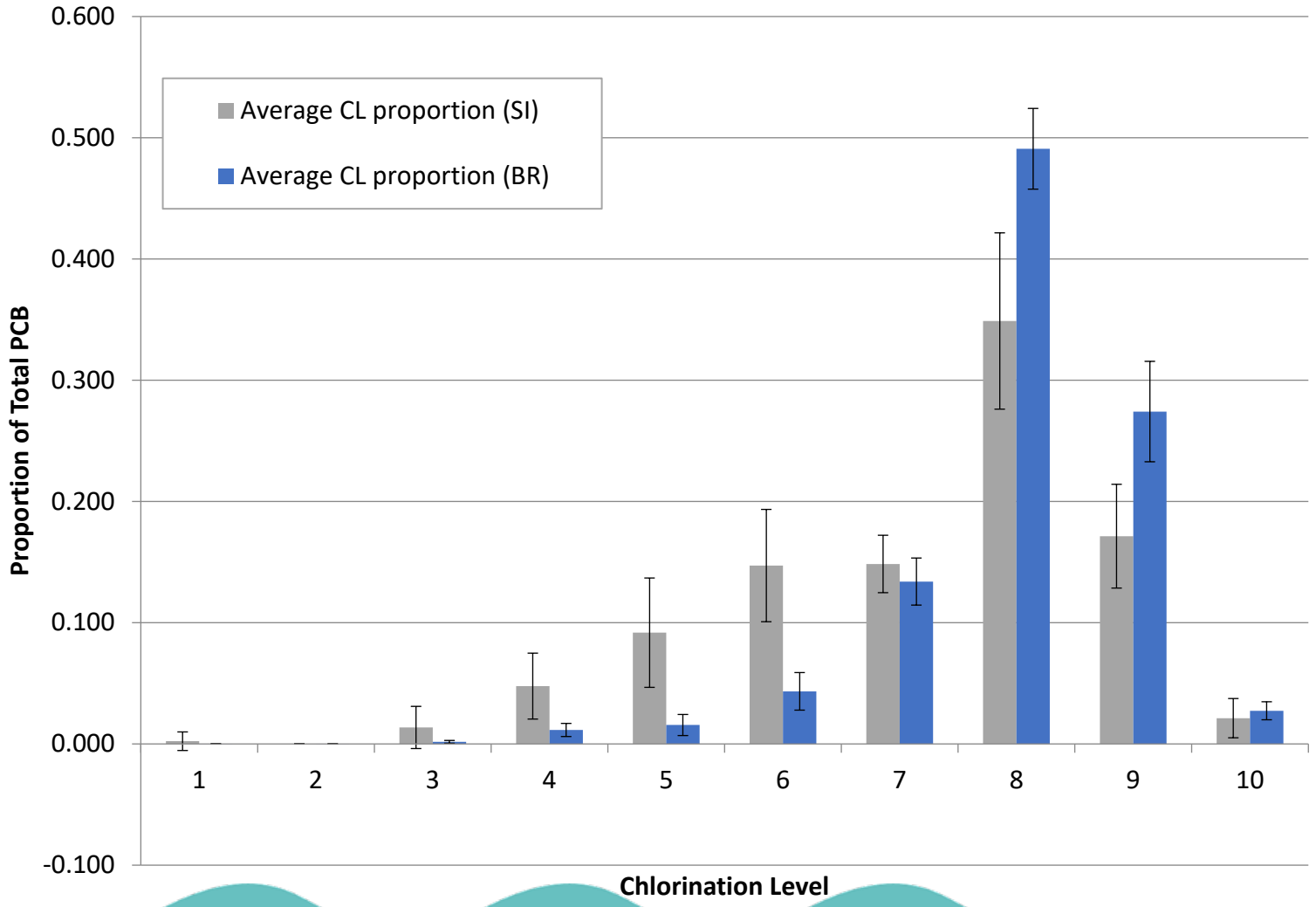
Distribution of PCBs in Fillets from Brunswick collection overlayed with EPA cancer and non-caner consumption guidelines (4 meals per month)



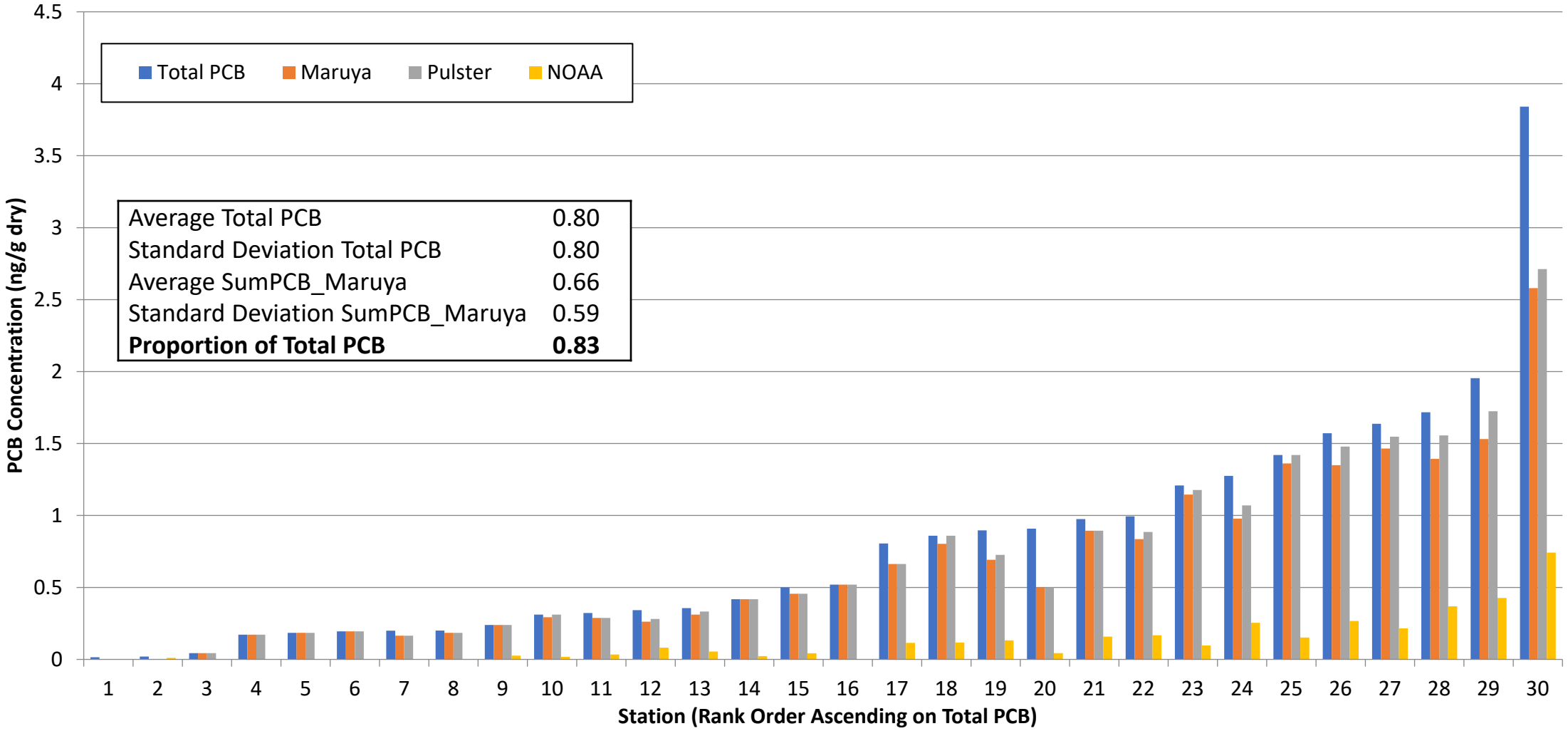
Distribution of PCBs in Fillets from Sapelo Island collection overlayed with EPA cancer and non-caner consumption guidelines (4 meals per month)



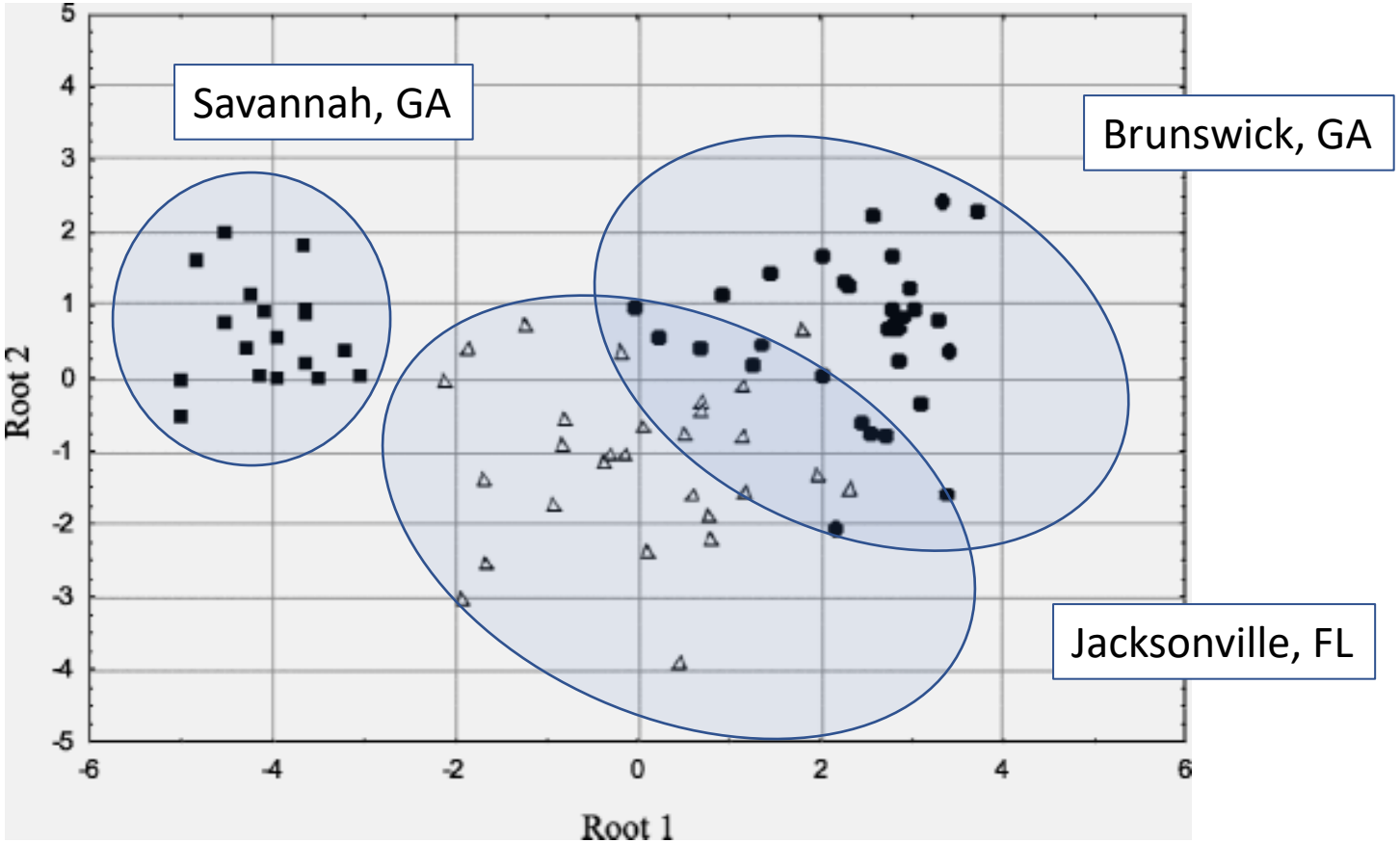
Proportion of Total PCB displayed for each chlorination level in tissues (average proportion with st dev)



PCB Sediment Concentrations from 30 Stations within the SI NERR

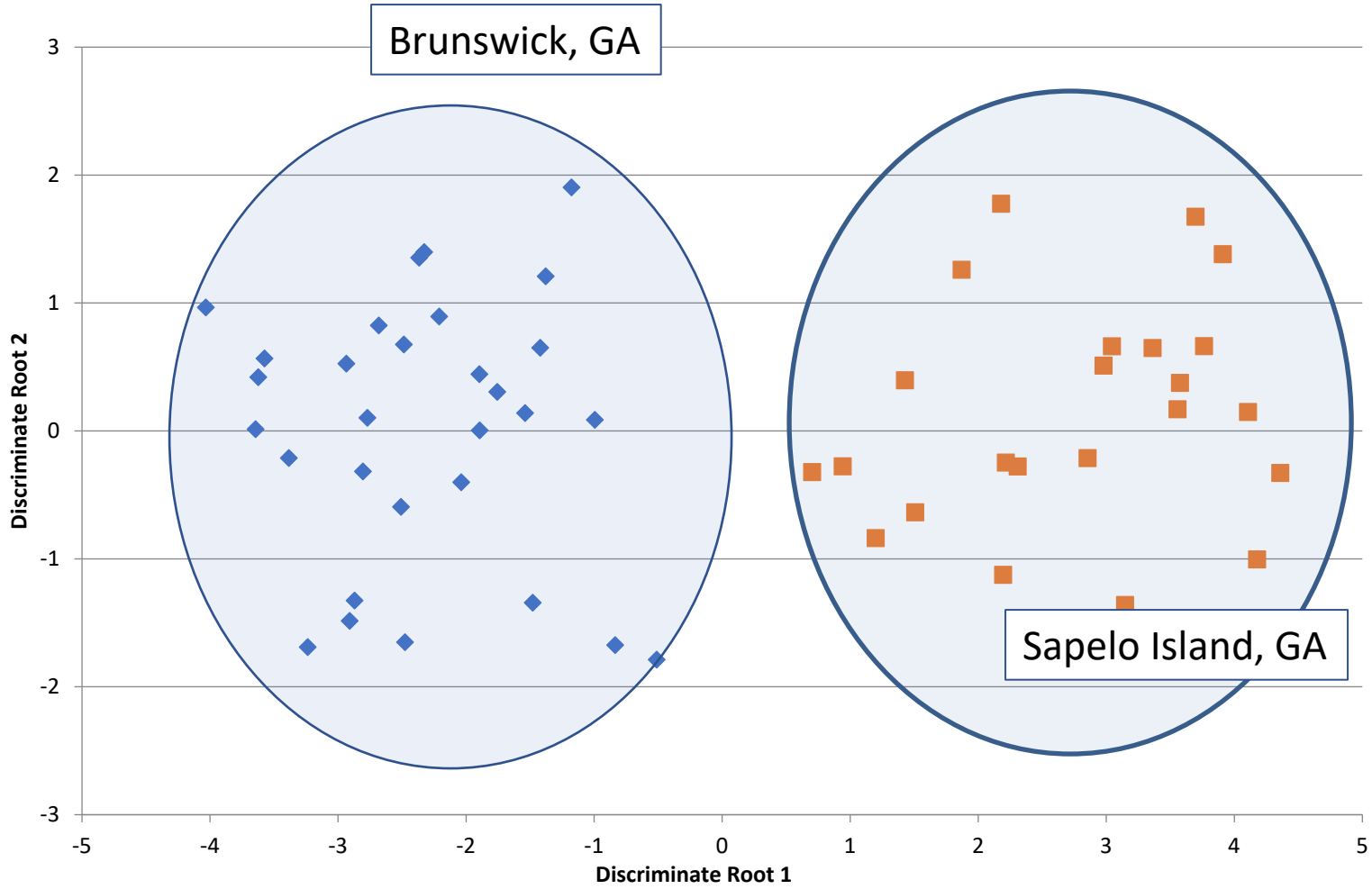


Published regional assessment and PCB contamination in prey from coastal GA



Canonical plot (discriminant analysis) of mean polychlorinated biphenyl congener abundance by estuary (all species; n = 77). Root 1 explained 90% of the variability. (Pulster et al , 2005, Environmental Toxicology and Chemistry 24:3128-3136)

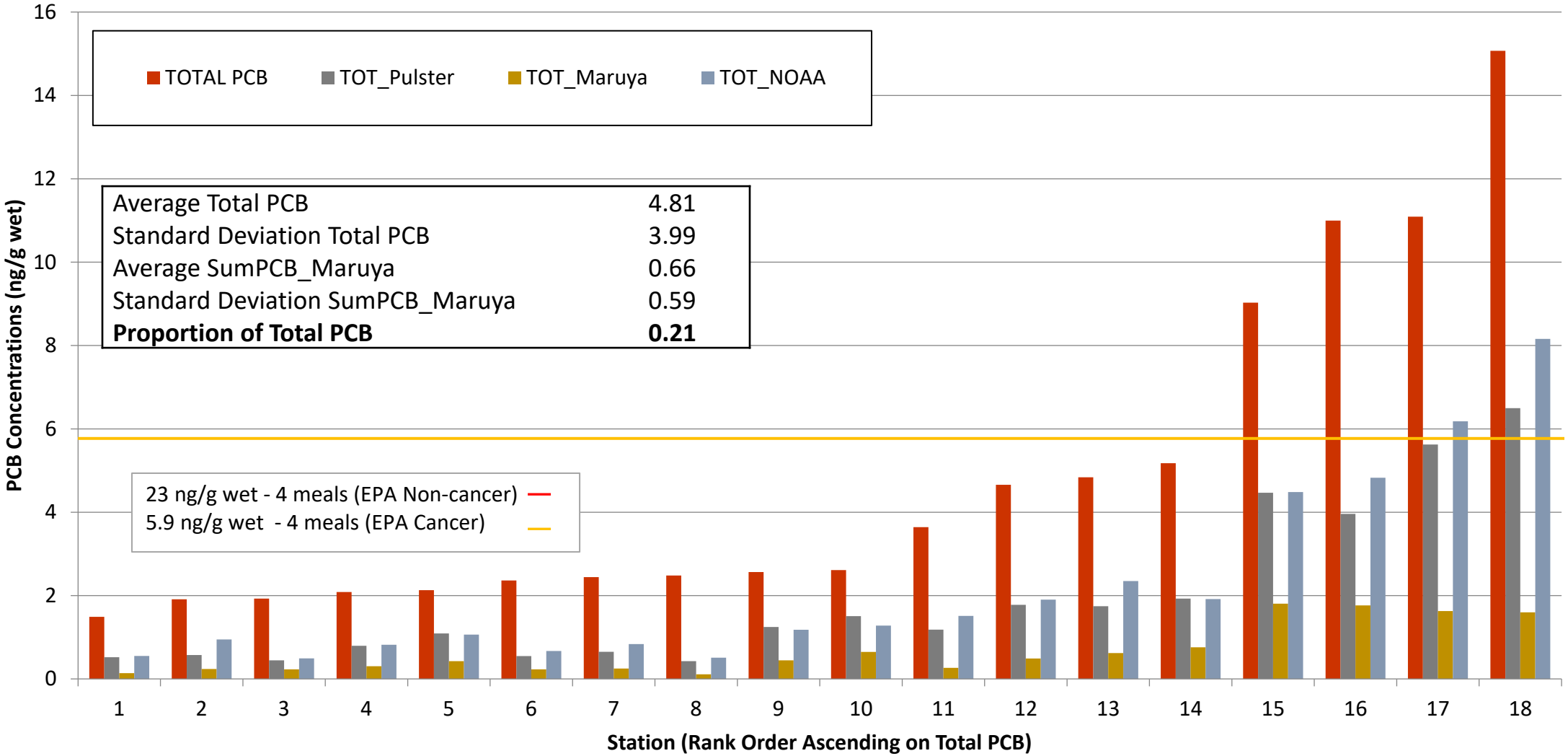
Discriminate Analysis Plot for Tissues from SI NERRs and BR



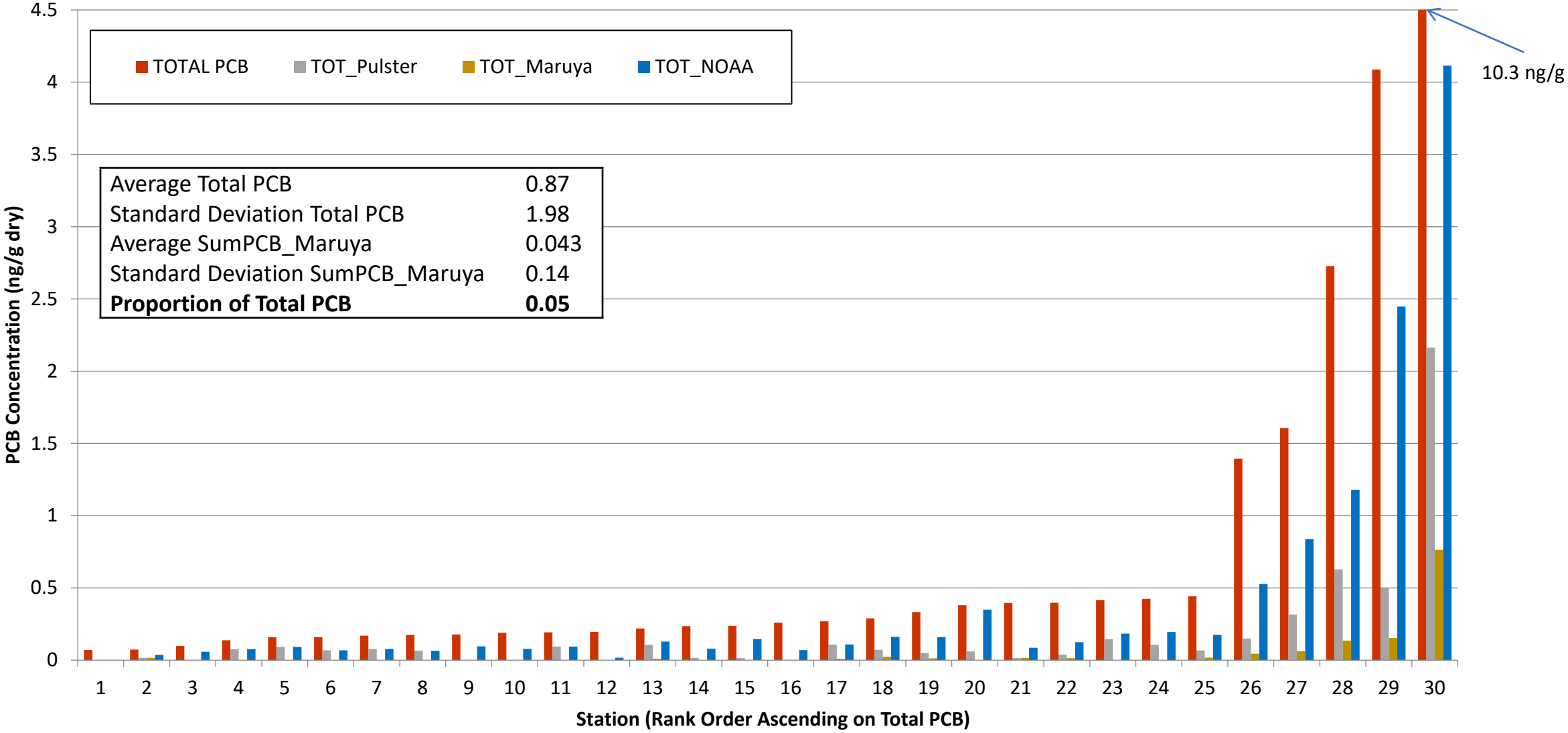
Future Directions

- Increase the number of data sets regionally to better evaluate Aroclor 1268 signature transport
- Currently collecting selected species of fish from SC NERRs (North Inlet and ACE Basin) to be able to compare PCB profiles in fish from protected areas to the north of the SI NERRs
- When the proportion of Aroclor 1268 congeners to Total PCBs is compared to similar data (preliminary) from coastal SC, the signal looks very different (Maruya suite/Total PCB):
  - Sediment_SC (0.05) versus Sediment_SI (0.83)
  - Tissues_SC (0.21) versus Tissues_SI (.68) or Tissues_BR (0.89)
- Published environmental status of SI NERRs and regional status of marine protected areas along the southeast coast of the U.S.

Preliminary PCB Tissue Concentrations from Coastal SC (2010)



Preliminary PCB Sediment Concentrations from Coastal SC (2010)

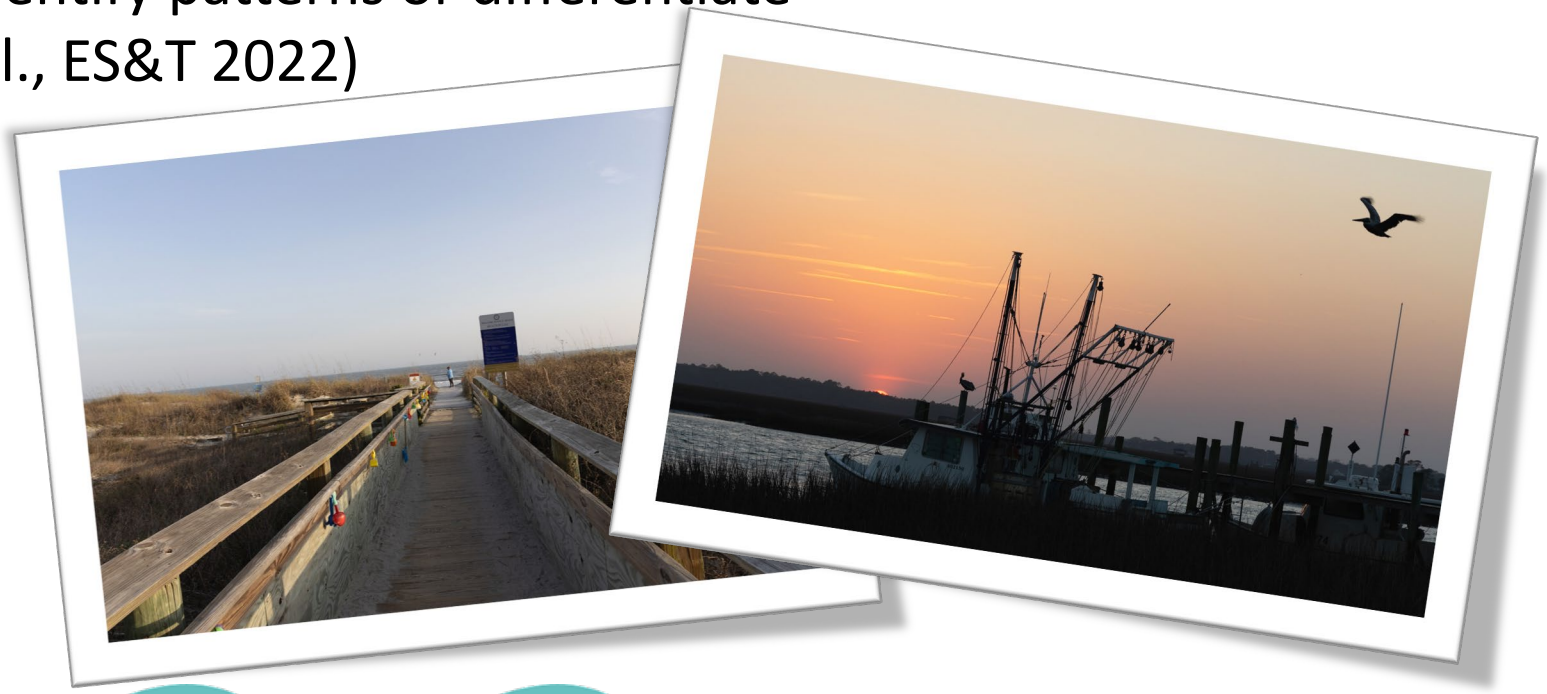


Summary of Project Conclusions

- PCB concentrations in fish from Brunswick are consistently orders of magnitude greater than those found in fish collected from Sapelo (as would be expected), although Aroclor 1268 congeners AND patterns are easily distinguishable in SI fish
- All fish from BR exceeded the EPA Consumption guidelines, BUT 7 (of 22) fish from SI also exceeded the guidelines (1 non-cancer and 6 cancer)
- Large decrease in PCB contamination within the SI region relative to Brunswick but there still seems to be a significant Aroclor 1268 signal within the SI NERR (sediment and fish); predation is likely a source for trophic transfer within the SI NERR but it is unclear as to the magnitude of this vector.

Overall Wrap-up

- Environmental PCBs still a relevant environmental hazard
- New processes to help understand hazard and risk are important
  - Machine Learning to identify patterns or differentiate sources (Mahynski et al., ES&T 2022)



Questions?

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