Patrick Bayou Superfund Site

Risk Assessment Summary

Presented by
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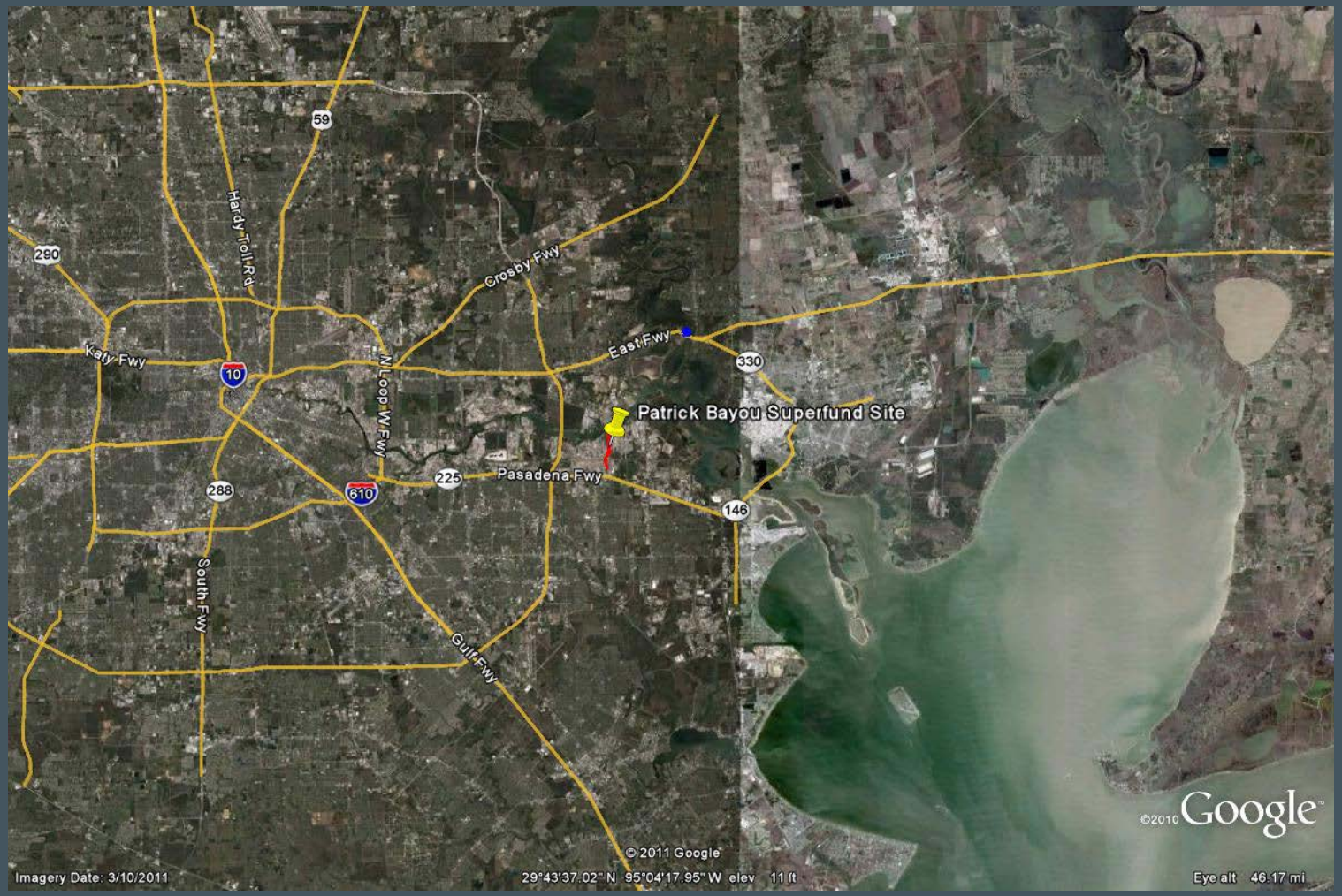
9418619

Site Location



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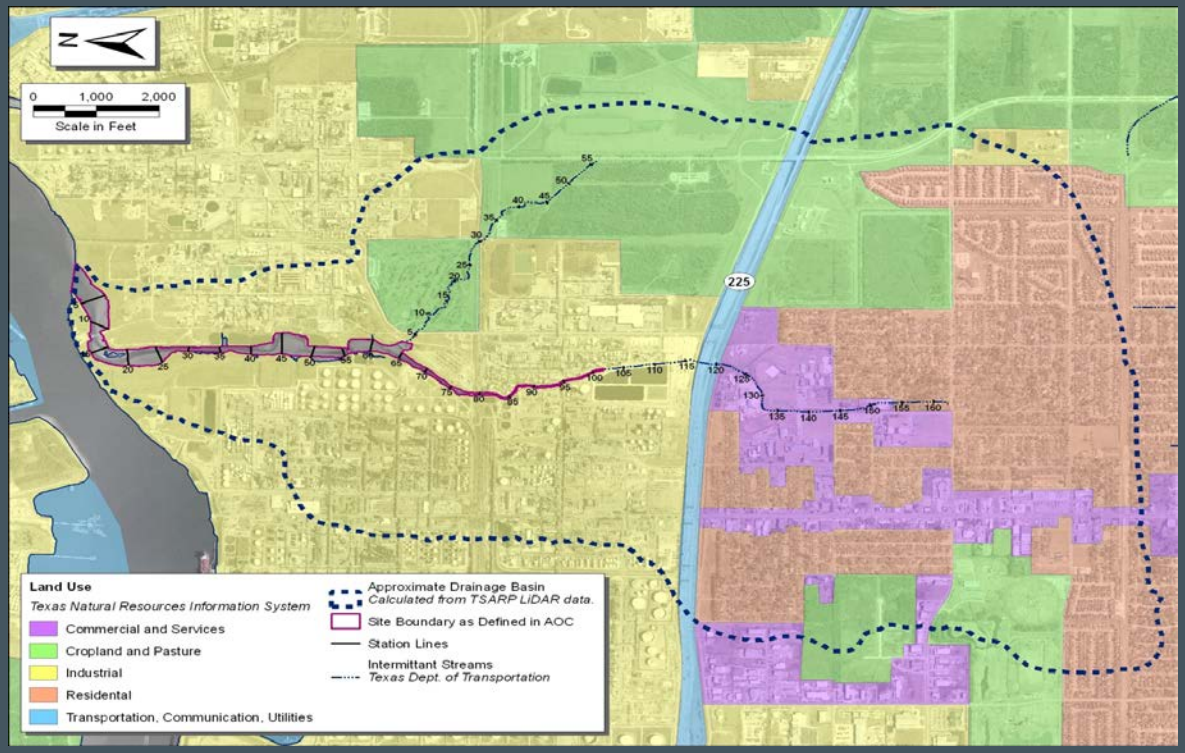
Land Use



- Upstream areas serve as primary storm water conveyance for City of Deer Park
- Downstream areas are bordered by industrial facilities

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Surface Hydrology

- Tidally influenced with typically low flow velocities
- Site is prone to flooding due to high volume runoff
- Silty to silty-sand bottom with shallow side slopes
- Upland areas are industrialized with some areas of riparian and tidal habitat

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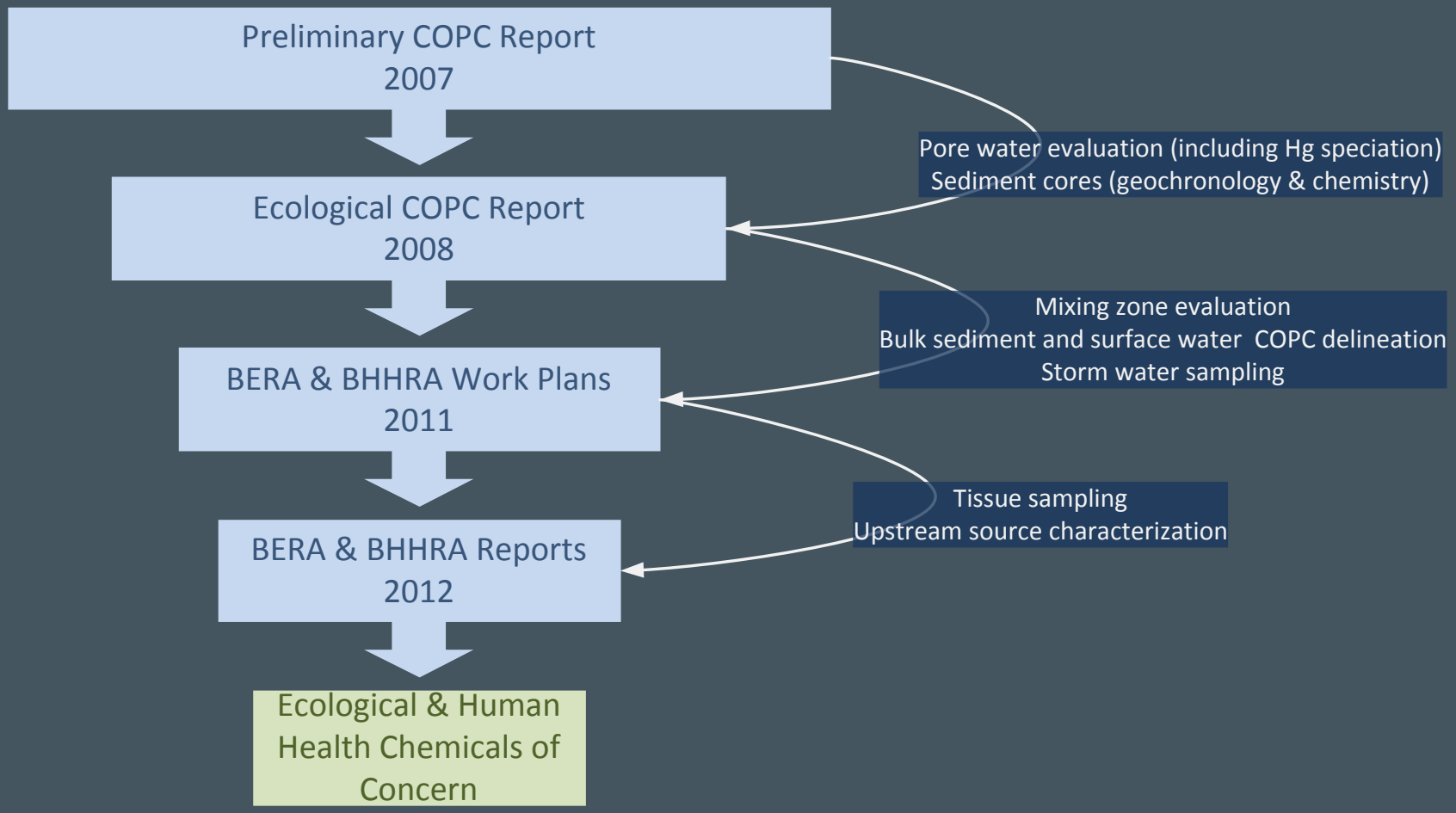
Risk Assessment Reports and Activities



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Remedial Investigations and Supporting Data

- 2006
  - 129 surface/subsurface sediment core samples from 16 stations (radioisotope data collected from 5 stations)
  - 5 surface sediment samples (0-2 cm) from 5 stations upstream of Site boundary
- 2007
  - 10 porewater samples from 10 stations (mercury speciation data also collected)
- 2007 – 2008
  - 11 sediment trap samples from 2 stations
- 2008
  - 49 surface/subsurface sediment samples (0-20 cm) from 10 stations (radioisotope data also collected)

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Remedial Investigations and Supporting Data
(continued)

- 2009
  - 46 surface sediment samples (0-2 cm and 0-10 cm) from 46 stations
  - 22 surface water samples (from near bottom and mid-depth of water column)
- 2011
  - 33 invertebrate samples (BERA)
  - 50 fish samples (BERA)
  - Sediment probing at 114 locations
  - 6 surface sediment samples (0-10 cm) from 6 stations
  - 5 surface/subsurface (0-10 cm and 0-90 cm) sediment samples from SH225 culverts
  - 4 surface water samples
  - 33 hardhead catfish samples (BHHRA)
  - 20 blue crab samples (BHHRA)

Remedial Investigations and Supporting Data
(continued)

- TMDL Data
  - 2000 – 2003
    - 51 samples from 19 stations with co-located sediment chemistry and toxicity test data
  - 2002 – 2004
    - 33 hardhead catfish samples (also from HSC)
    - 48 blue crab samples (also from HSC)
  - 2008 – 2009
    - 25 hardhead catfish samples (also from HSC)

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Site COPC†

COPC	Ecological	Human Health
Lead	X	
Mercury	X	
PAHs	X	X
PCBs	X	X*
Dioxins/Furans	X	X*
Hexachlorobenzene	X	X
Hexachlorobutadiene	X	
1,3-Dichlorobenzene	X	
1,4-Dichlorobenzene	X	
bis-(2ethylhexyl) phthalate	X	

* Fish ingestion pathway COPC

†Based on approved BERA and BHHRA Work Plans

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Human Health Risk Assessment

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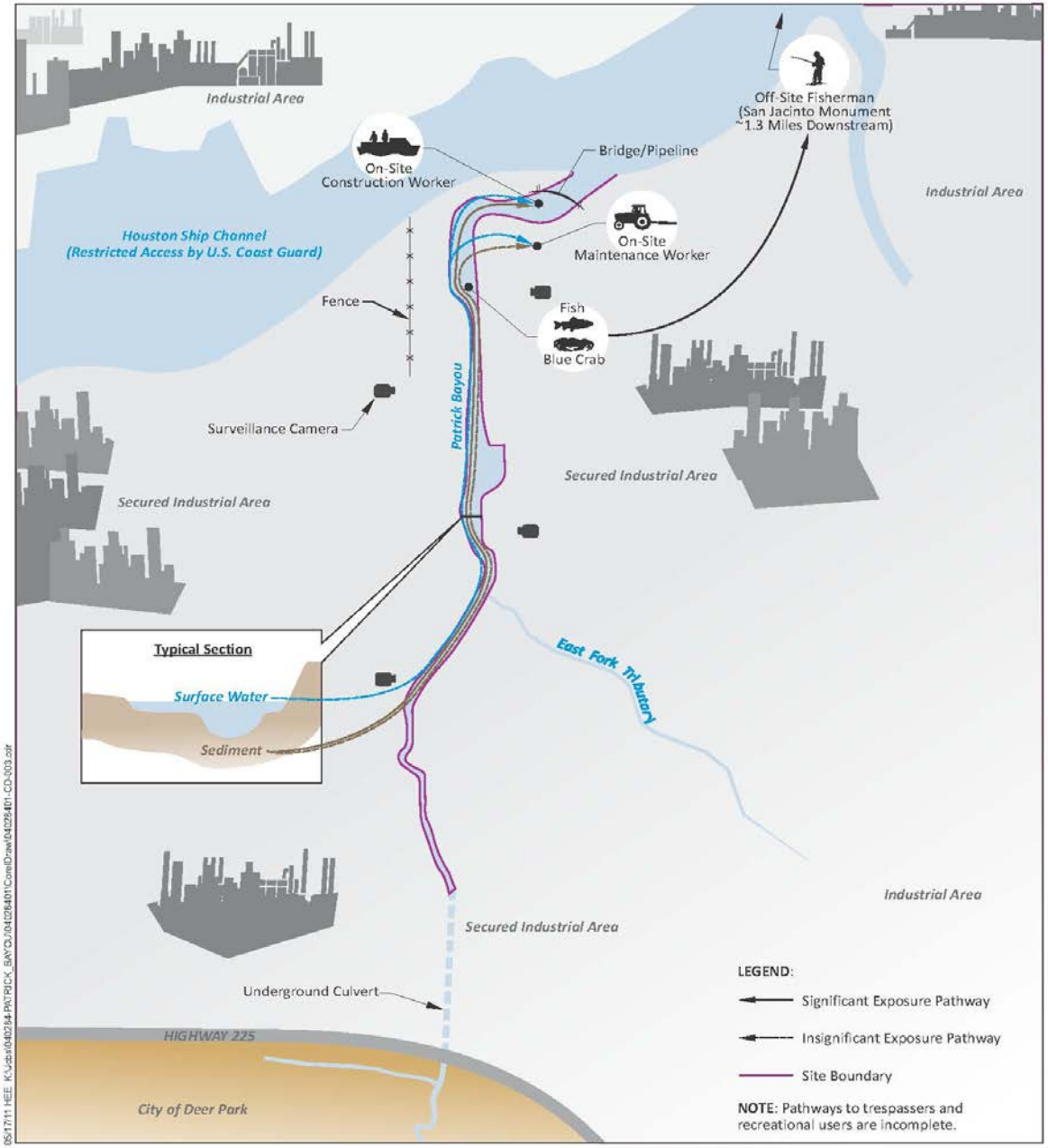

BHHRA Conceptual Exposure Model

BHHRA Work Plan – On Site Exposure Scenario

- Refined list of COPCs for direct contact scenarios:
  - Hexachlorobenzene, PCBs, Carcinogenic PAHs, Dioxin/furans
- Refined list of on-site scenarios to include utility/construction workers

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BHHRA Work Plan – Offsite Exposure Scenario

- Identified off-site fishermen COPCs
  - Point of exposure defined as San Jacinto Battleground State Historic Site
  - Compared available TMDL and seafood advisory data from SJM to screening levels to identify preliminary COPC
  - Further refined list using spatial analysis of data to determine if Patrick Bayou is acting as source for preliminary COPC
    - The initial list included, arsenic, mercury, Aroclor 1248, Aroclor 1260, alpha BHC, chlordane, dieldrin, heptachlor epoxide, hexachlorobenzene, Lindane, p'p'-DDD, p'p'-DDE, total PCB congener TEQ 2005 (mammal), total dioxin/furan TEQ, 2005 (mammal)
    - Excluded arsenic, mercury, and pesticides
    - Identified PCBs and dioxin/furans as COPC for BHHRA

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On-Site Construction Worker: Exposure Assumptions

- 20 days/year exposure
- 12.5 year total exposure time period
- Incidental ingestion of sediment at 100 mg/day
- Dermal exposure at 402 cm^2/day
- Exposure Point Concentration (EPC) based on concentrations in sediment from throughout PB (surface and subsurface sediments)
- For Reasonable Maximum Exposure (RME) EPC the upper 95UCL on the mean is used

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BHHRA Sediment Data Set

Utility/Construction Worker

Non-carcinogenic assessment (RME)

Chemical	RfDo	DAF	Sediment EPC (UCL95)	CDI_{Dermal}	$CDI_{Ingestion}$	CDI_{Total}	HQ	HI[1]
Hexachlorobenzene	8.00E-04	0.1	18.83	4.21E-08	1.47E-06	1.52E-06	**0.002**	**NA**
Total cPAH	NV	0.13	5.788	1.68E-08	4.53E-07	4.70E-07	--	--
Total Dioxin/Furan TEQ	7.00E-10	0.03	0.0003	2.03E-13	2.37E-11	2.39E-11	**0.04**	**NA**
Total PCB Congener TEQ	7.00E-10	0.03	0.000187	1.25E-13	1.46E-11	1.47E-11	**0.03**	**0.07**
Total PCB Congeners	2.00E-05	0.14	29.0	9.09E-08	2.27E-06	2.36E-06	**0.1**	**NA**

RfDo – Oral reference dose ($mg/kg_{bw}/day$)
DAF – Dermal absorption factor
EPC – Sediment exposure point concentration (mg/kg)
UCL95 – Upper confidence limit of the mean
CDI – Chronic daily intake ($mg/kg_{bw}/day$)
HQ – Hazard quotient
HI – Hazard index
NV – No value; carcinogenic effects only

Notes:

[1] Hazard index is for the sum of risks from total dioxin/furan TEQ and total PCB congener TEQ

* Table adapted from Table 7-1 of Draft BHHRA

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Utility/Construction Worker

Carcinogenic Risk

Chemical	SFo	DAF	Sediment EPC (UCL95)	CDI_{Dermal}	$CDI_{Ingestion}$	CDI_{Total}	ELCR	Total ELCR[1]
Hexachlorobenzene	1.6	0.1	18.83	7.51E-09	2.63E-07	2.71E-07	**4.33E-07**	NA
Total cPAH	7.3	0.13	5.788	3.00E-09	8.09E-08	8.39E-08	**6.13E-07**	NA
Total Dioxin/Furan TEQ	156000	0.03	0.0003	3.62E-14	4.23E-12	4.27E-12	**6.65E-07**	NA
Total PCB Congener TEQ	156000	0.03	0.000187	2.23E-14	2.61E-12	2.63E-12	**4.10E-07**	**1.08E-06**
Total PCB Congener	2	0.14	29.0	1.62E-08	4.06E-07	4.22E-07	**8.45E-07**	NA

Sfo – Oral slope factor $(mg/kg_{bw}/day)^{-1}$
DAF – Dermal absorption factor
EPC – Sediment exposure point concentration (mg/kg)
UCL95 – Upper confidence limit of the mean
CDI – Chronic daily intake $(mg/kg_{bw}/day)$
ELCR – Excess lifetime cancer risk

Notes:
[1] Total risk is for the sum of risks from total dioxin/furan TEQ and total PCB congener TEQ.
* Table adapted from Table 7-3 of Draft BHHRA

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Off-Site Fisherman: Incremental Exposure Analysis

- Compared distributions of dioxins/furans and PCBs in catfish from Patrick Bayou and from the HSC and its tributaries
  - HSC dataset includes ~ 68% hardhead catfish, 26% blue catfish, 6% from bullhead, channel and gafftopsail catfish
- Compared distributions of dioxins/furans and PCBs in blue crab from Patrick Bayou and from the HSC and its tributaries
- Spatial Analyses of dioxins/furans and PCBs in hardhead catfish and blue crab in the HSC and its tributaries

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Patrick Bayou Tissue Sampling Plan

- The goal was to collect fish and blue crabs at the size that humans would fish for
  - fish >30cm total length and blue crabs >13 cm wide at carapace
- Targeted four fish species along with blue crabs
  - Hardhead catfish, Blue catfish, Gafftopsail catfish, Channel catfish
  - Although not targeted, speckled seatrout and Atlantic croaker would have been collected if found

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PCBs and Dioxin/Furan Distribution in Tissue

- Patrick Bayou
  - Collected fish (30 samples – only hardhead catfish were caught) and shellfish (20 samples – blue crab) in 2011
- Houston Ship Channel
  - Fish samples collected for TMDL assessment in 2002/2004 (D/Fs), 2002/2003 (PCBs) and 2008/2009 (PCBs only)
  - Blue crab samples collected for TMDL assessment in 2002 (PCBs) and 2002/2004 (D/Fs)

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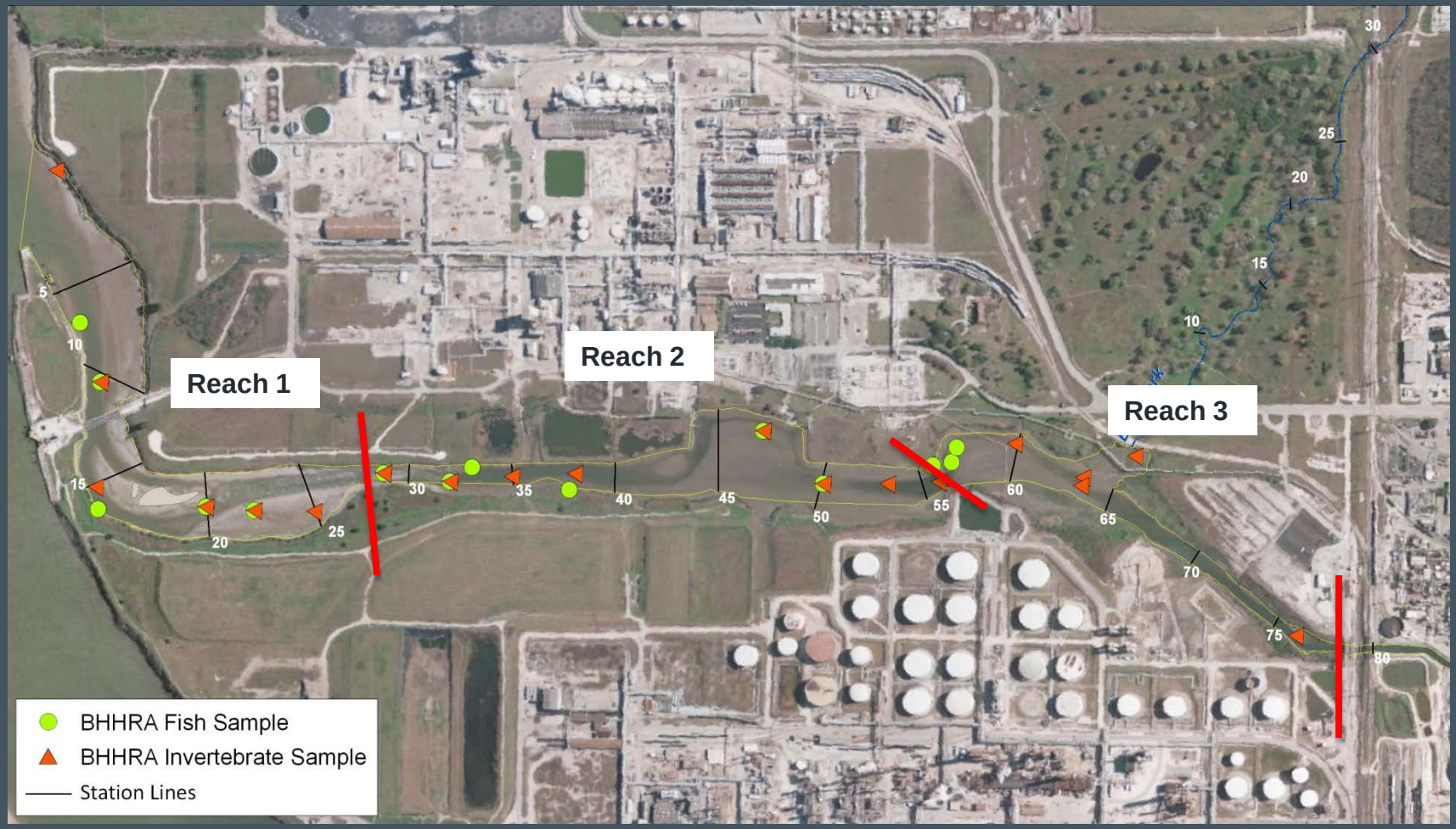
BHHRA Tissue Data Set



Some locations include multiple samples

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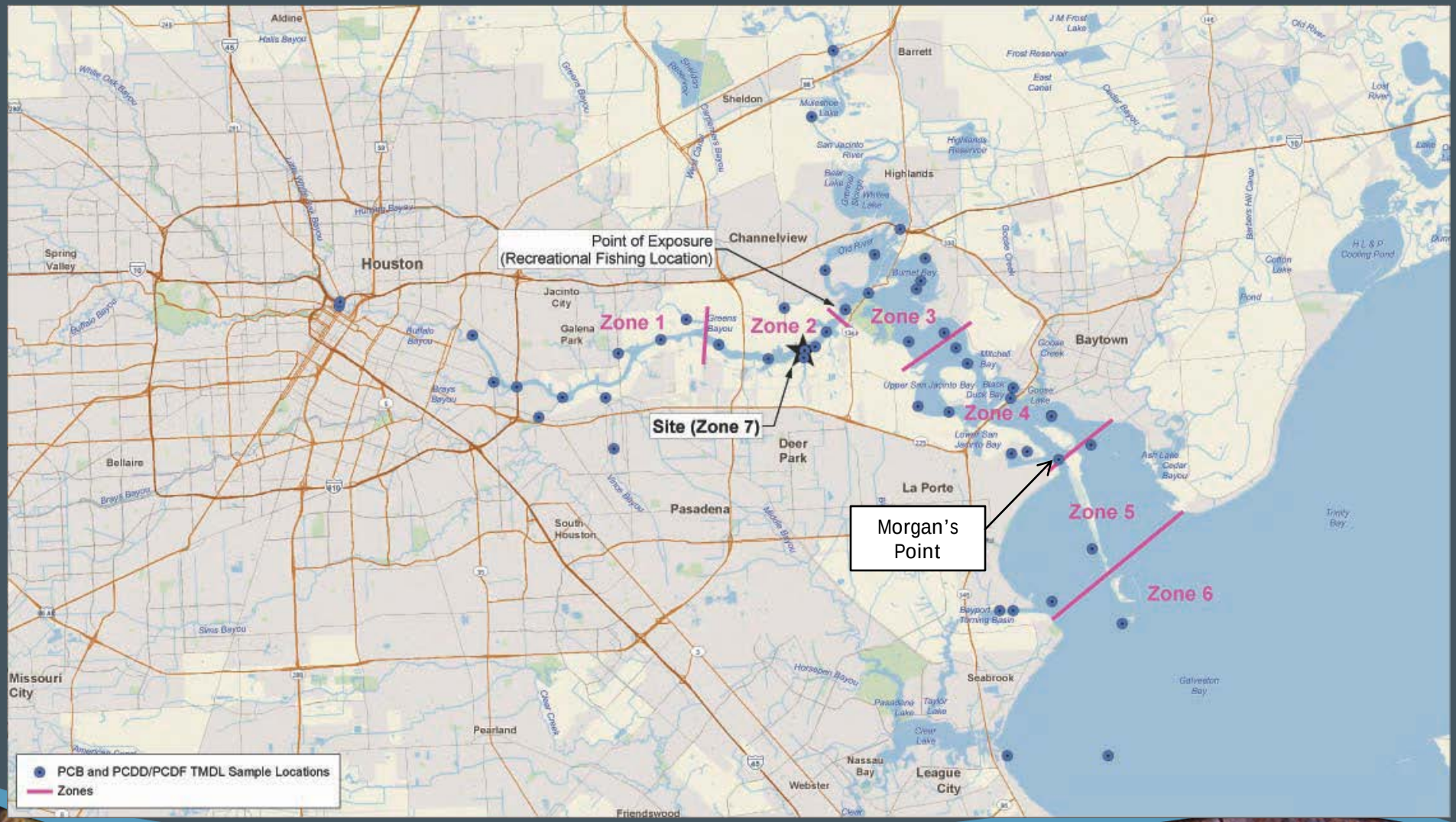
Data Assessed Spatially by River Mile Zones for PCBs and Dioxin/Furans



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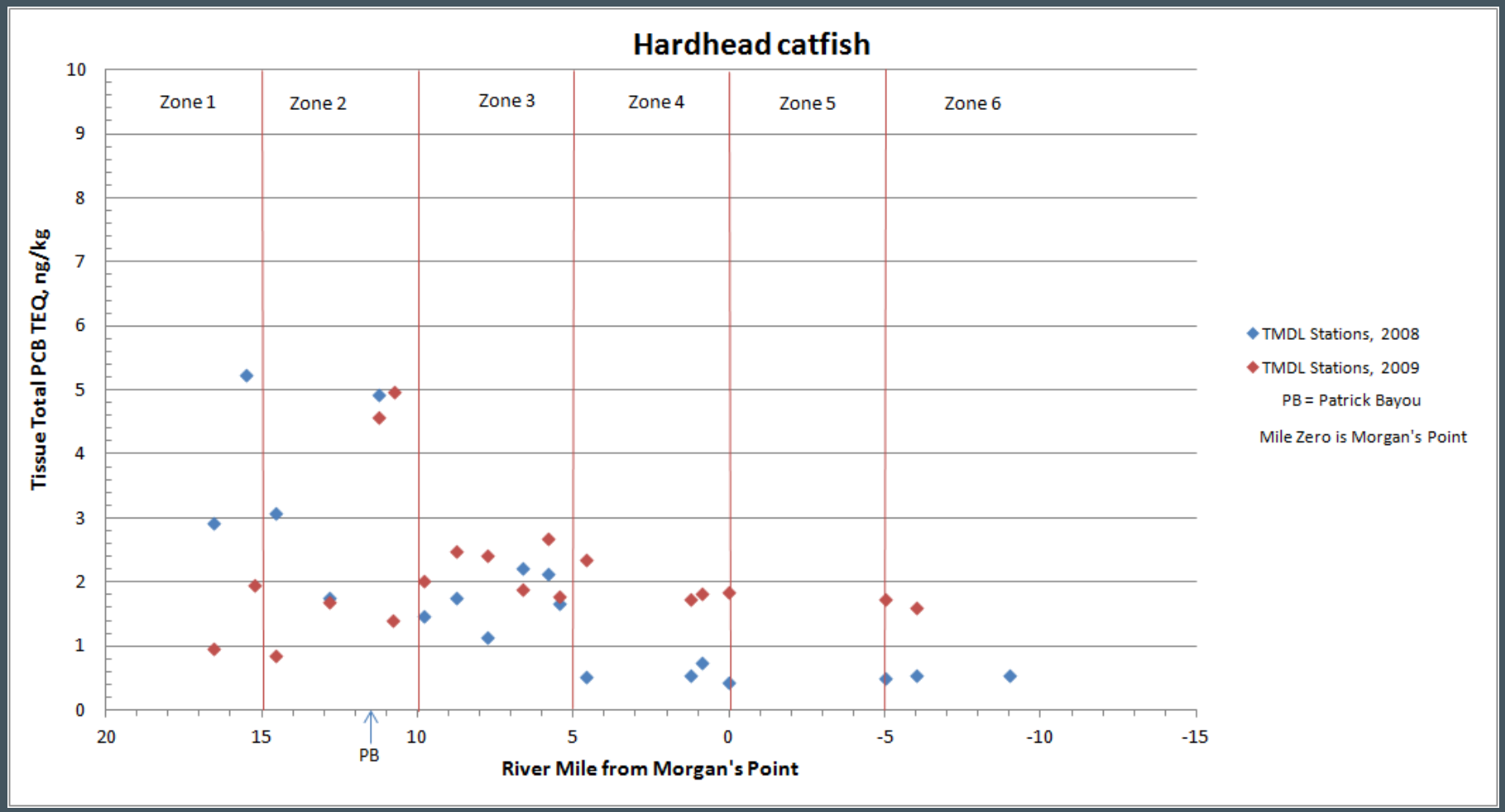
Total PCB TEQ Variation along HSC in Fish Tissue



ND's set at ½ DL

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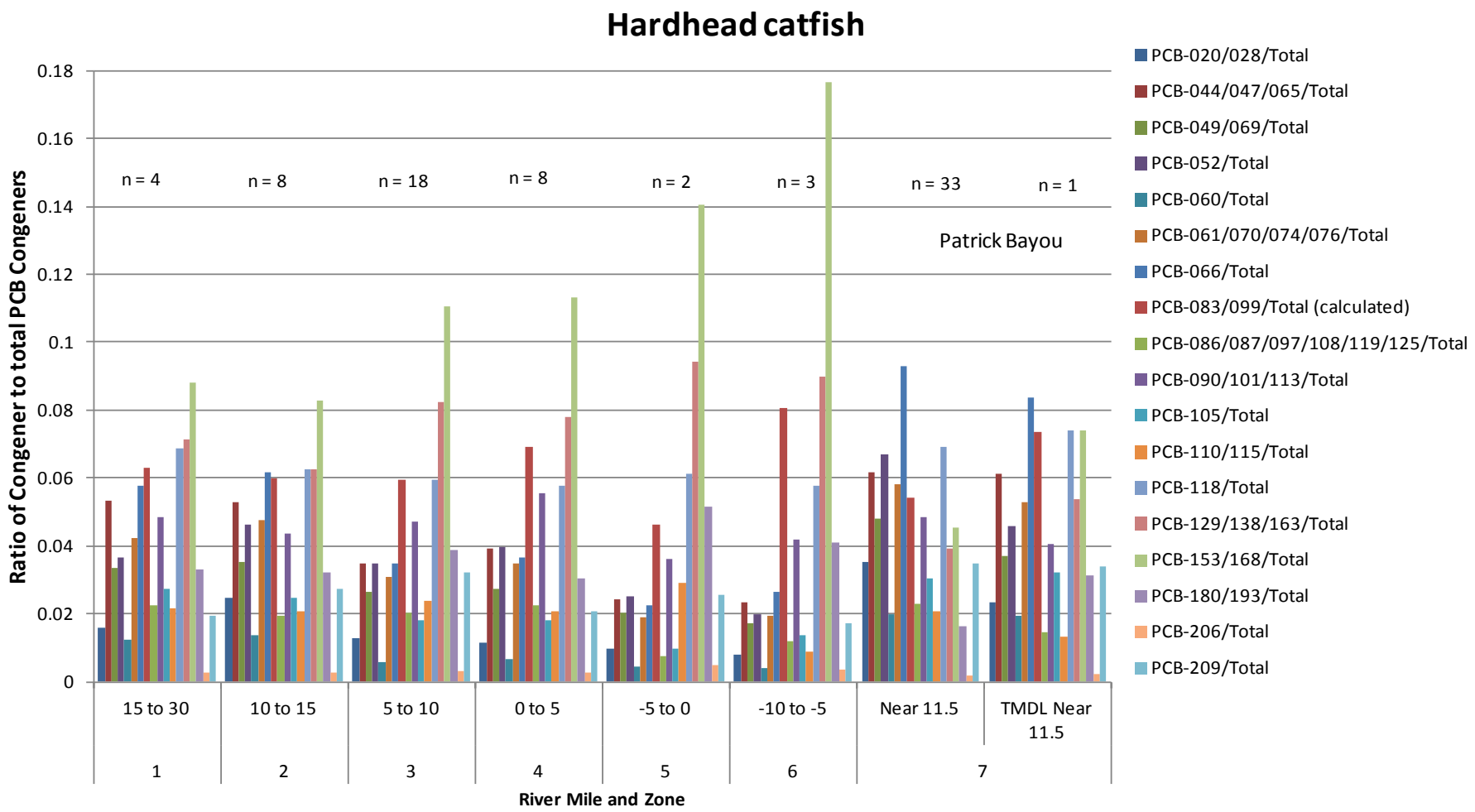
Fish Tissue PCB Congeners as Ratios to Total



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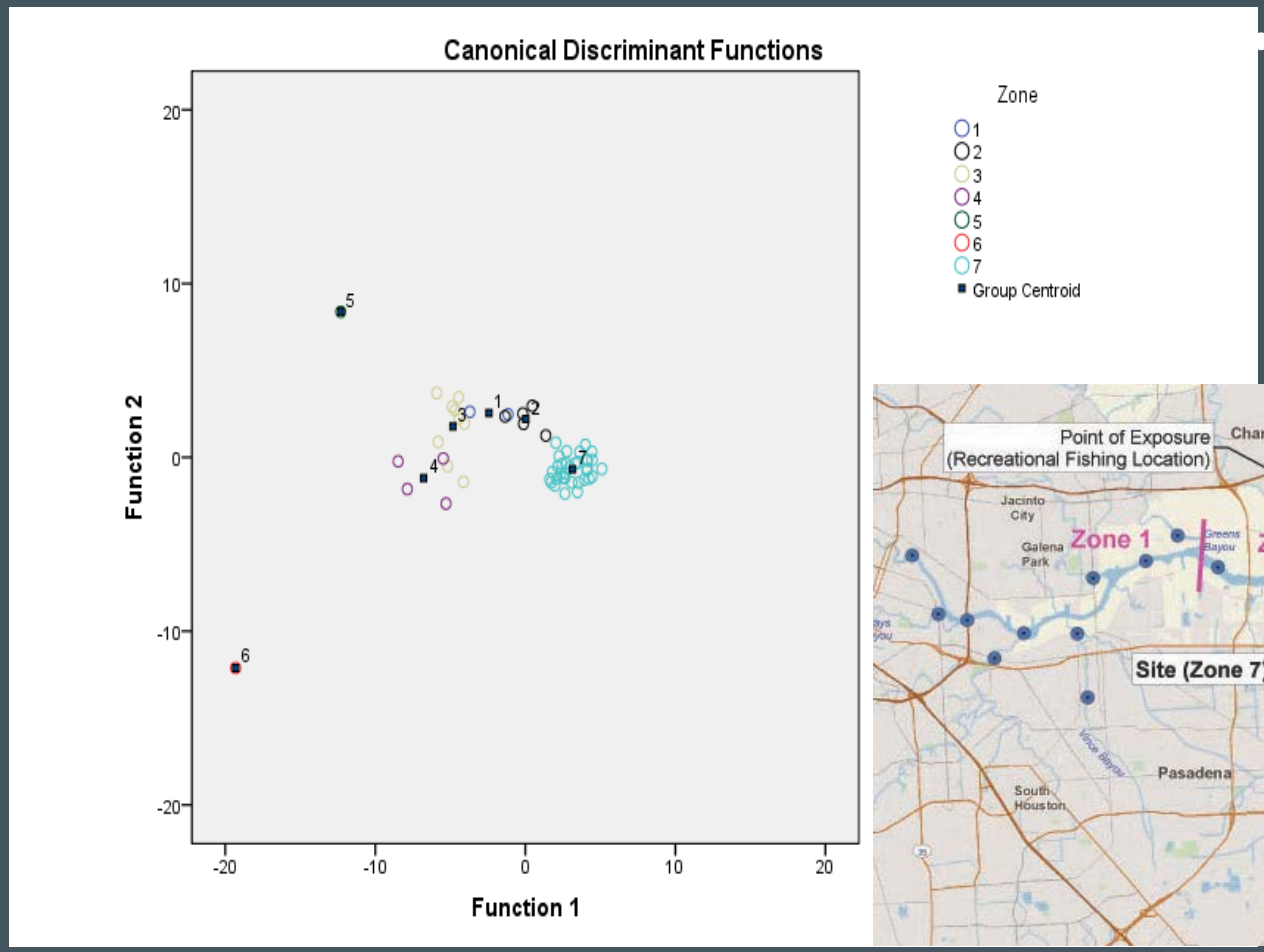
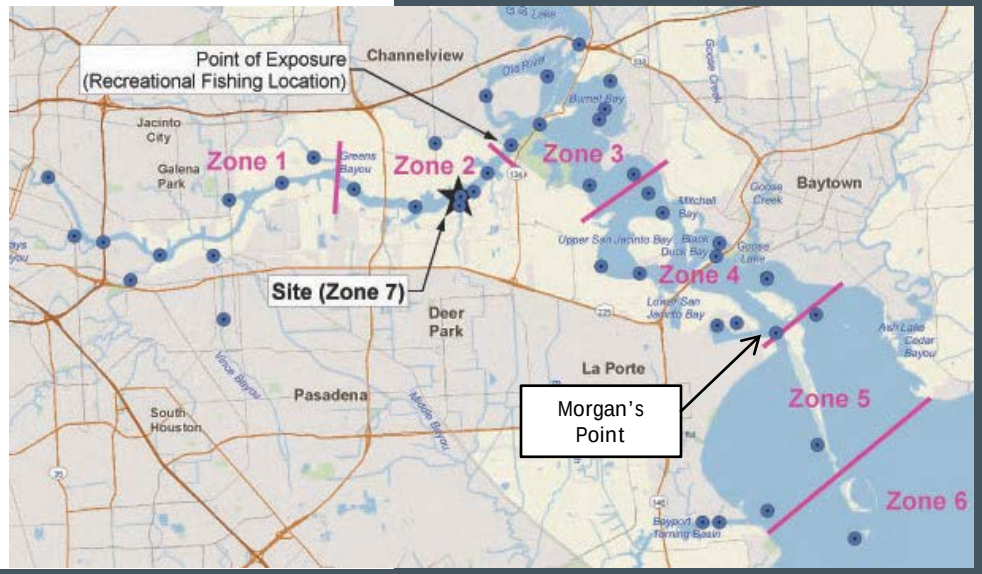
Discriminant Plot of PCB Congeners as Ratios to Total for Hardhead Catfish



- No HSC hardhead catfish are similar to Patrick Bayou hardhead catfish



Discriminant Analysis Classification Results

Hardhead Catfish - PCB Congeners

PCBs as Congeners, Classification Results[a,b]

	Zone	Predicted Group Membership by Zone							Total
		1	2	3	4	5	6	7 (Site)	
Count	1	2	0	0	0	0	0	0	2
	2	1	4	0	0	0	0	0	5
	3	0	0	9	0	0	0	0	9
	4	0	0	1	3	0	0	0	4
	5	0	0	0	0	1	0	0	1
	6	0	0	0	0	0	1	0	1
	7	0	1	0	0	0	0	33	34
%	1	100.0	--	--	--	--	--	--	100
	2	20.0	80.0	--	--	--	--	--	100
	3	--	--	100.0	--	--	--	--	100
	4	--	--	25.0	75.0	--	--	--	100
	5	--	--	--	--	100.0	--	--	100
	6	--	--	--	--	--	100.0	--	100
	7	--	2.9	--	--	--	--	97.1	100

Notes:

[a] 94.6% of original grouped cases correctly classified.

[b] Table from Table 5-6 of Draft BHHRA

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BHHRA Conclusions

- On-site
  - On-site construction worker risk below conservative thresholds (ELCR < 10^{-6}, HI < 1.0)
- Off-site
  - The Site has no apparent influence on tissue concentrations at the off-site POE
  - BHHRA concludes that exposure at off-site POE is equivalent to ambient conditions within the HSC
  - No incremental risk to human health associated with the Site at the off-site POE

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Baseline Ecological Risk Assessment

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BERA Work Plan

- Key elements
  - Refined COPC list based on comprehensive surface water & sediment sampling effort conducted in 2009
  - Identified wildlife receptors, exposure models, and effects data
  - Developed potential benthic toxicity model for sediment risk characterization
  - Developed a tissue sampling plan to assess fish and wildlife COPC to address gaps in the BERA dataset

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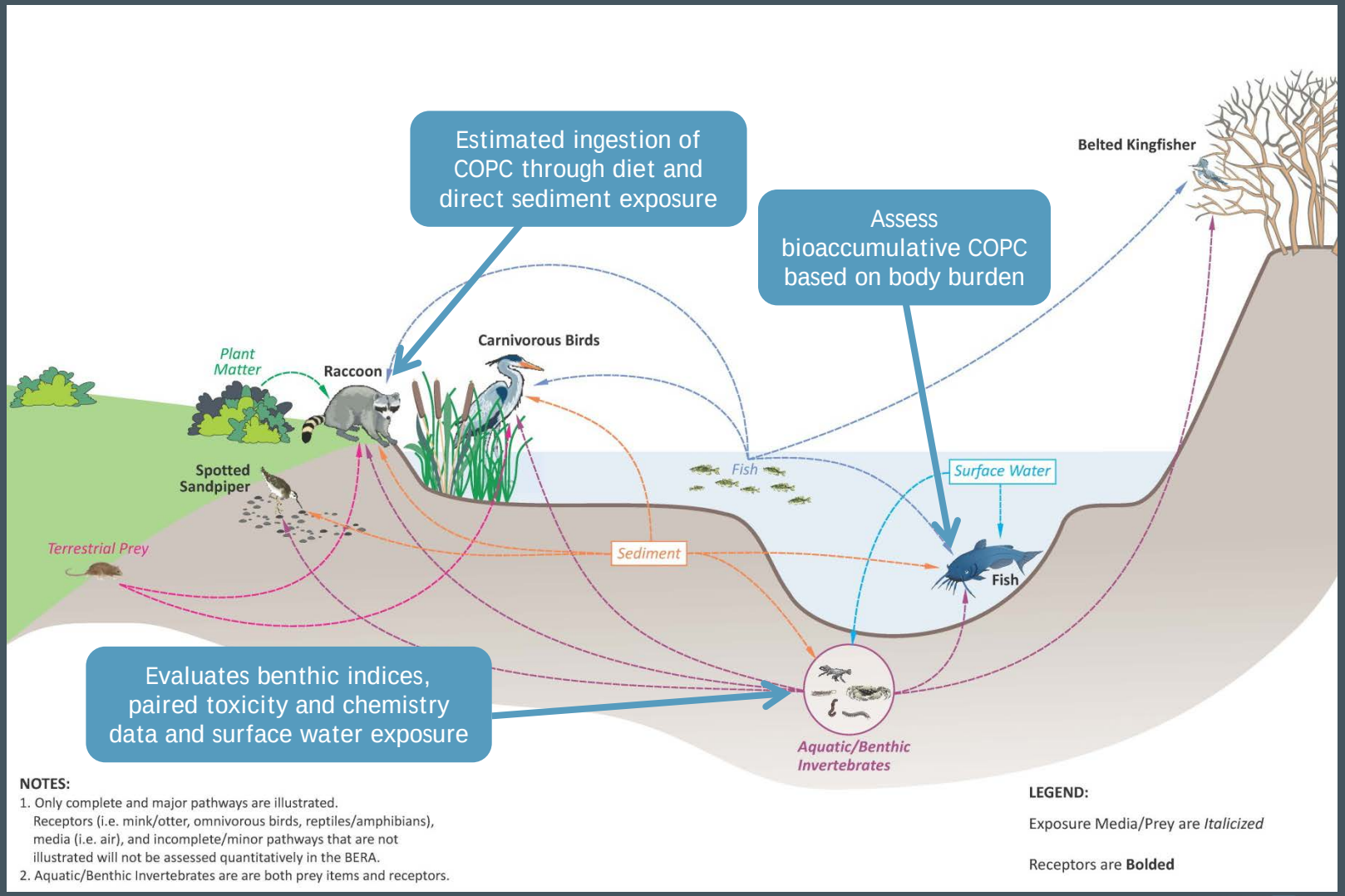
BERA Conceptual Exposure Model



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BERA Data Set

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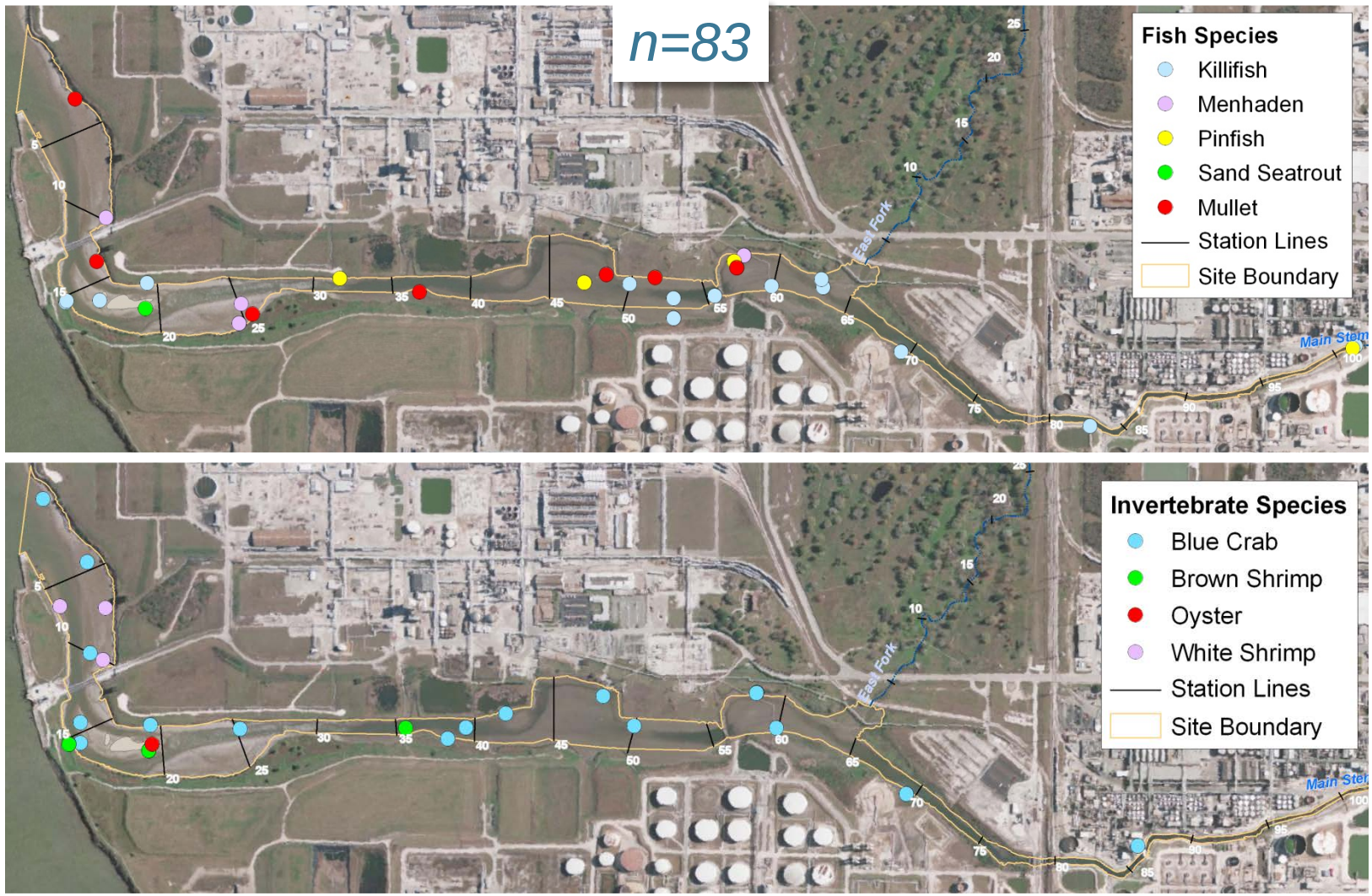
Tissue Sampling



Wildlife Risk Assessment

COPC	Receptor Group				
	Kingfisher	Spotted Sandpiper	Carnivorous Wading Bird	Fish	Raccoon
Mercury	X	X	X	X	X
Lead		X			
PAHs		X			
Total PCB Congeners	X	X	X	X	X
PCB Congeners TEQ	X	X	X		X
Dioxin/furan congener TEQ		X		X	
Hexachlorobenzene	X	X			
Hexachlorobutadiene		X			
1,3-Dichlorobenzene	X	X			
1,4-Dichlorobenzene		X			
2-Methylnaphthalene		X			

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Wildlife Risk Assessment

Analysis Plan

Exposure

RISK

$$HQ = \frac{[COPC]_{BIOTA} + [COPC]_{SEDIMENT}}{Toxicity\ Reference\ Value}$$

Effects

- Exposure to COPC is based on dietary ingestion of COPC in food and incidental ingestion of sediment
- Effects thresholds represent Lowest Observable Apparent Effects Level (LOAEL) from literature

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Wildlife Risk Assessment

Exposure Assessment

- Tissue ingestion
  - Upper-bound estimate of the mean (UCL95) of tissue concentrations based on prey groups identified in Work Plan
- Sediment ingestion
  - Surface weighted average (SWAC) of intertidal zone sediments
  - Segregated mercury exposure into methylated and inorganic forms based on bioavailability
- Identified area use factors (AUF) based on results of BERA Work Plan and additional analyses in BERA

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Wildlife Risk Assessment

Exposure Assessment

- Mercury bioavailability
  - Pore water sampling of methyl mercury indicated low rates of methylation due to excess sulfide
  - Assessed pore water and sediment data to evaluate proportion methyl mercury in sediments
    - Methyl mercury is 95% bioavailable to wildlife
    - Inorganic mercury is less than 15% bioavailable and is much less toxic than methylated form
    - Estimated proportion in sediment using equilibrium partitioning
  - Estimated using Equilibrium Partitioning
    - Proportion of methyl mercury to total mercury is less than 0.2% in all samples (n=11)
  - Conservatively assumed 1% of total mercury in methylated form for exposure assessment

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Wildlife Risk Assessment

Exposure Assessment

Area Use Factors

Receptor	75th Percentile of Home Range	Number of Studies	Size of Site	AUF
Spotted Sandpiper	7.3 (km)	8	2.5 (km)	0.34
Belted Kingfisher	3.6 (km)	7	2.5 (km)	0.69
Carnivorous Bird	6.9 (km)	12	2.5 (km)	0.36
Raccoon	1.5 (km^2)	2	0.03(km^2)	0.02

Note: Home ranges based on linear stream distance for avian receptors and on an area basis for raccoon

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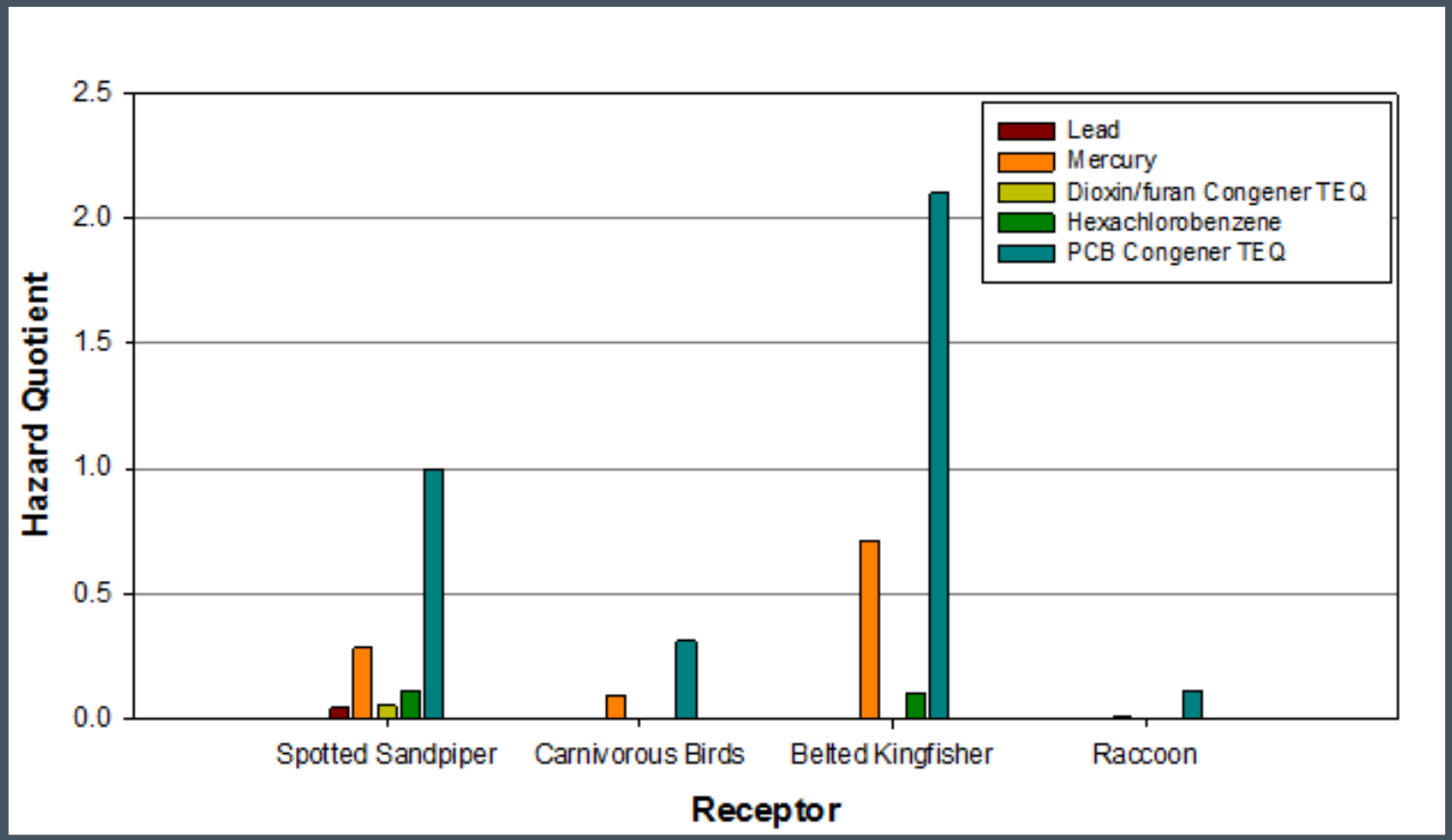
Wildlife Risk Assessment Results

Risks exceed HQ of 1.0 for PCBs only for spotted sandpiper and belted kingfisher.



Note: 1,3-dichlorobenzene; 1,4-dichlorobenzene; total PAH, and hexachlorobenzene not shown (HQ < 0.1)

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Summary - Wildlife Risk Assessment

- Risk Conclusions
  - Most receptor-COPC pairs had HQ < 1.0
    - Spotted sandpiper and belted kingfisher had HQ of 1.0 and 2.1, respectively

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Fish Risk Assessment

Analysis Plan

- Bioaccumulative COPC
  - Compared tissue body burden to tissue-based TRVs using a HQ approach
    - Tissue concentration represents exposure from all media and pathways for bioaccumulative COPC
    - Upper limit of the mean (UCL95) assumed as EPC
    - Literature derived TRV based on whole body concentration

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Fish Risk Assessment

Tissue Residue Risk

COPC	HQ GKF	HQ GM	HQ (GM, STM, PNF, SAS)	HQ (GKF, STM, PNF, SAS)	HQ All Fish
Mercury (Methyl)	-	0.038	-	0.015	0.024
PCB Congener TEQ (Fish)	0.0081	-	0.0033	-	0.0059
Selenium	-	-	-	-	0.82

Notes:

COPC - chemical of potential concern

GKF - Gulf killifish

GM - Gulf menhaden

STM - Striped mullet

PNF - Pinfish

SAS - Sand seatrout

PCB - polychlorinated biphenyl

TEQ - toxic equivalent

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Summary - Fish Risk Assessment

- Risk Conclusions
  - No risks to fish from bioaccumulative COPC

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Benthic Risk Assessment

Lines of Evidence

- Three lines of evidence:
  1. Benthic indices were calculated to describe the condition of the benthic community at the Site and compared to other similar sites
     a) Engle & Summers Benthic Index (1999)
     b) GOM Benthic Index of Biological Integrity (TetraTech 2011)
  2. Assessment of paired sediment toxicity and chemistry datasets from the Site (e.g. benthic model)
  3. Surface water exposure pathway risk assessment - chemical concentrations in water are compared to TRVs derived for the protection of aquatic organisms

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Benthic Risk Assessment

Benthic Community Assessment

- Benthic Habitat
  - Environmental conditions are limiting factors
    - The Site is located in a highly developed watershed and historical channel modifications result in strong temporal salinity gradients and high velocity runoff events
      - Most benthic community in top 2 cm
    - Periods of low DO (24 hr avg < 2.0 mg/L) are frequent in upstream areas
  - Environmental stressors prevent benthic communities in Patrick Bayou from reaching apex successional stages

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Benthic Risk Assessment

Benthic Community Assessment

- Benthic Index Evaluation
  - Calculated index values for samples collected in Patrick Bayou
  - Calculated index values for nearby comparison sites identified by Dobberstine (2007)
    - Evaluated candidate reference sites for Patrick Bayou
      - Exhibit similar physical conditions (salinity, grain size, etc.) as Patrick Bayou
      - Have low levels of sediment contaminants and observed toxicity

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Benthic Risk Assessment

Benthic Community Assessment

Site sample locations

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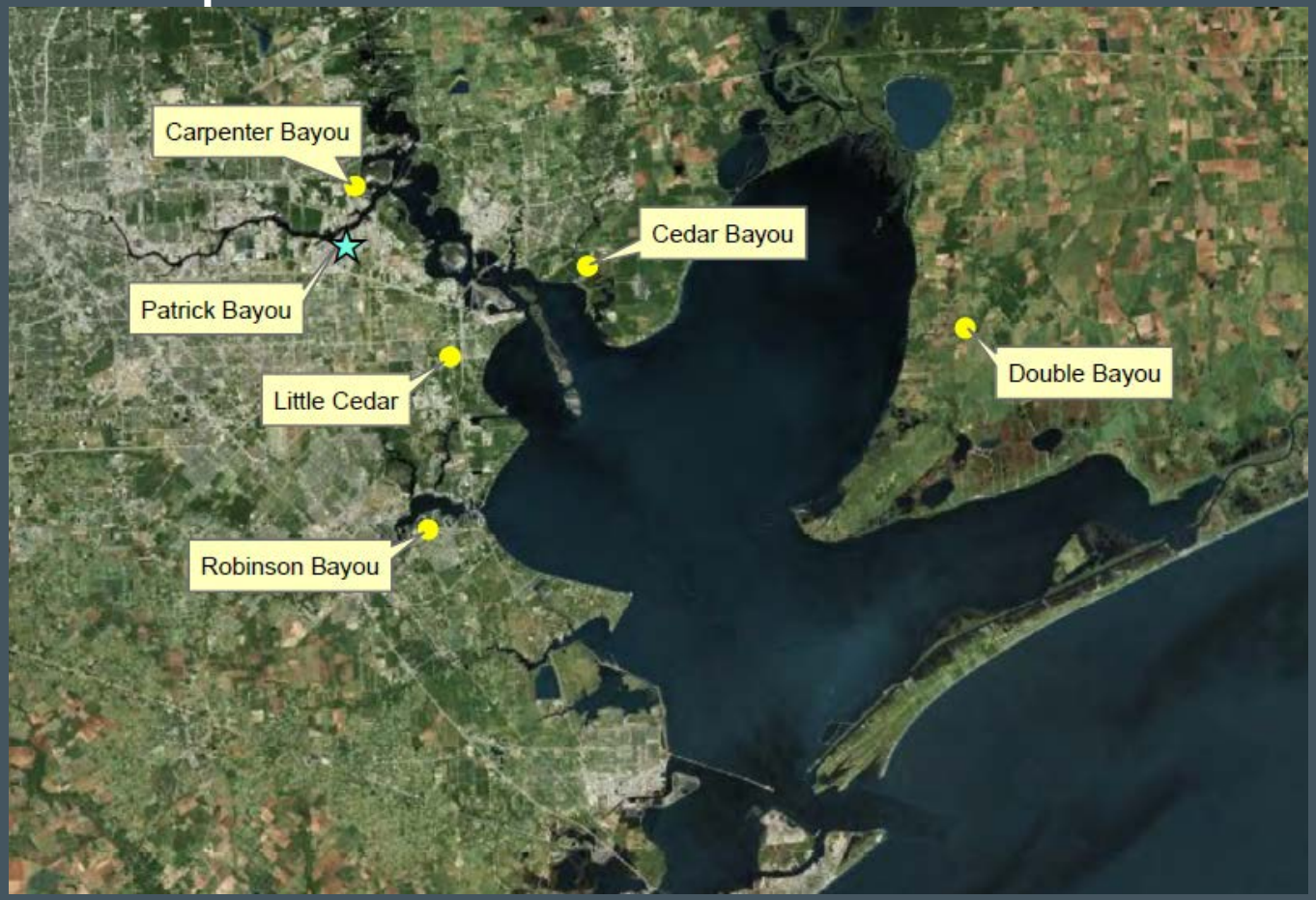
Benthic Risk Assessment

Benthic Community Assessment

Comparison Sites



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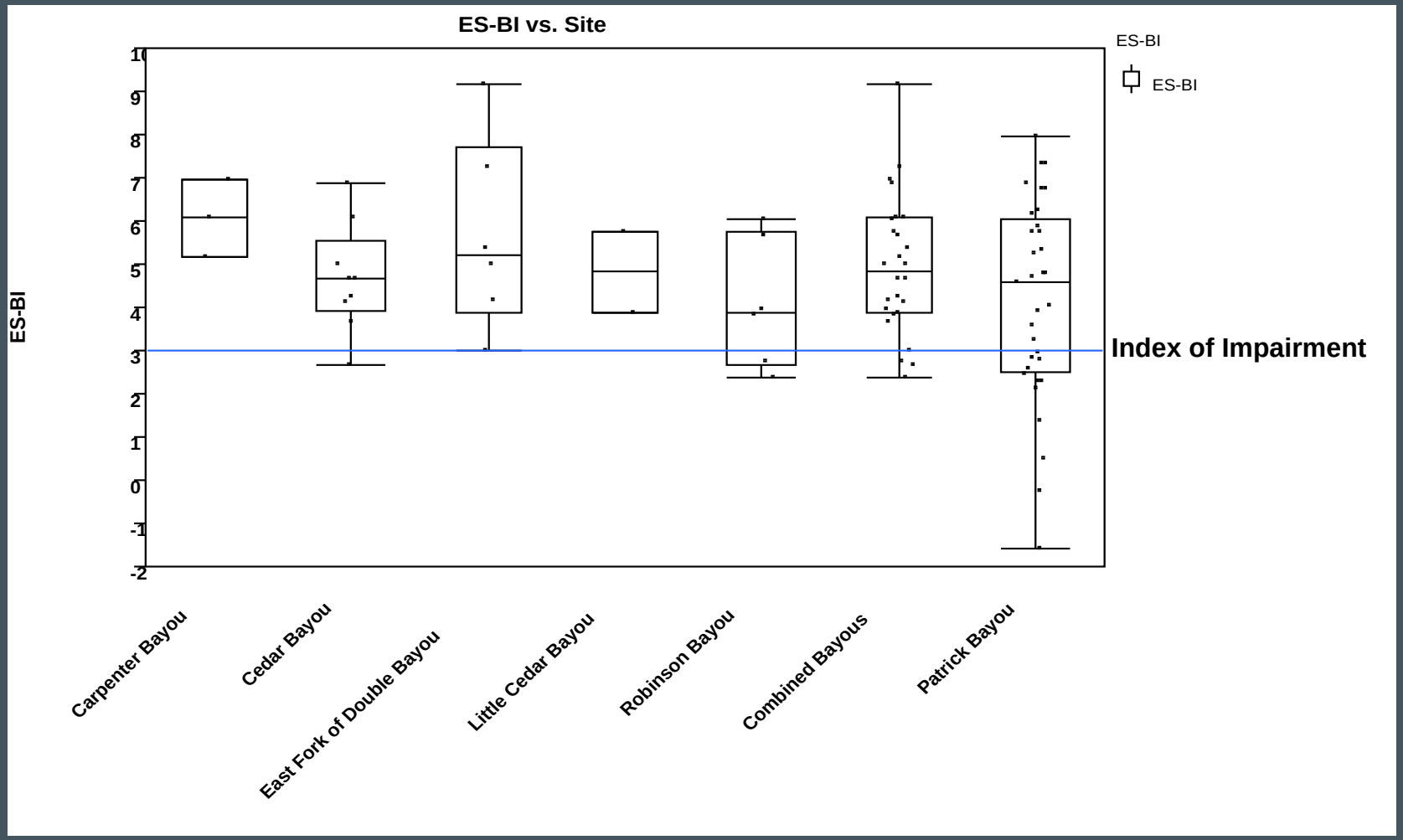
Benthic Risk Assessment

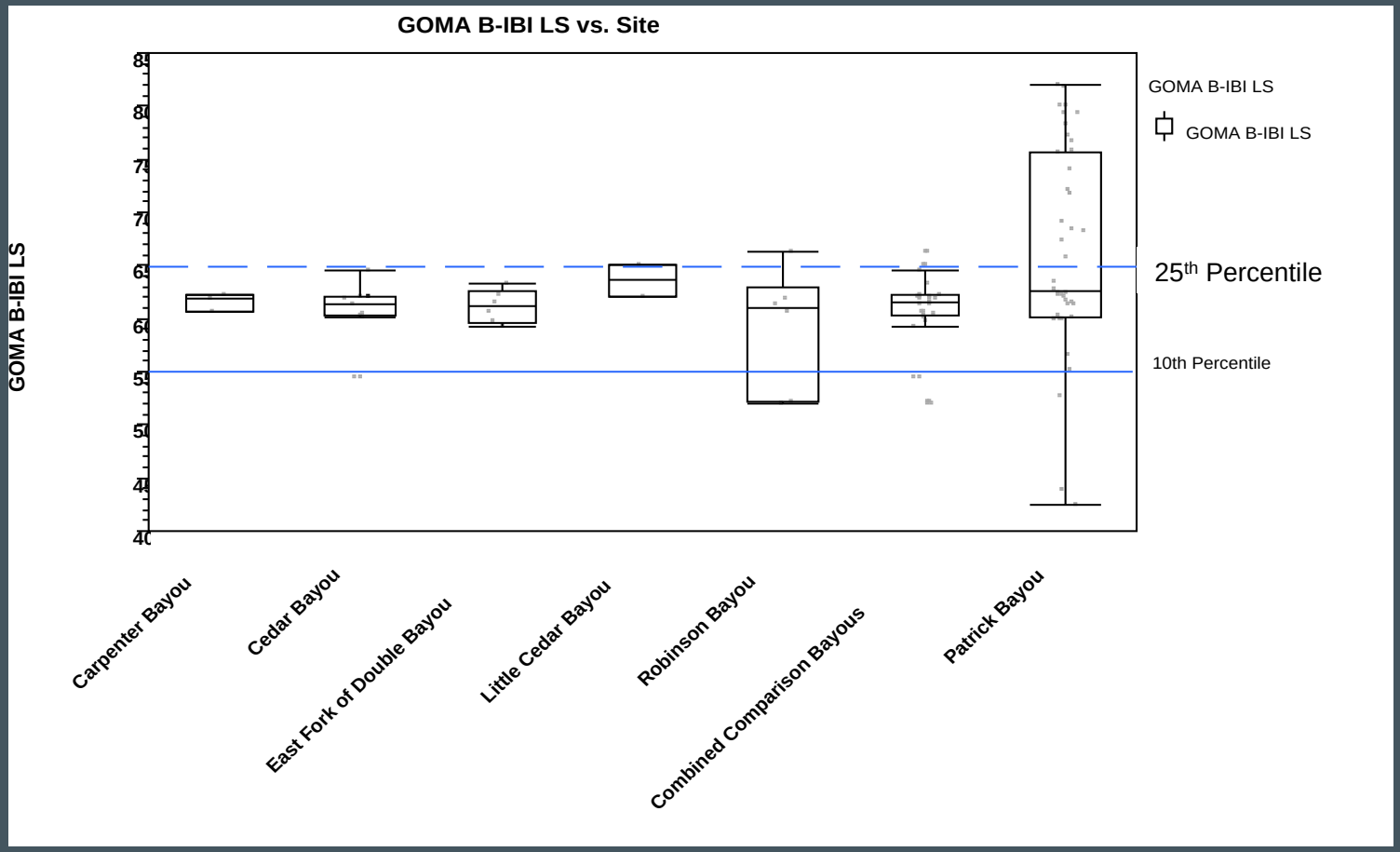
Benthic Community Assessment



Index values less than 3 are considered impaired based on *a priori* definitions provided by Engle & Summers (1999)

Benthic Risk Assessment

Benthic Community Assessment



25th and 10th percentiles of the *a priori* reference dataset index distribution. These threshold are associated with a discriminant efficiency of 86 and 30%, respectively.

Benthic Risk Assessment

Predictive Toxicity Model

Benthic model development process:

1. Compile site-specific toxicity & chemistry database from existing data
2. Identify candidate models to predict toxicity in sediments with a mixture of COPC
3. Apply models to sediment chemistry data for samples in the database
4. Compare model prediction to actual observed toxicity in each sample

   Predicted toxicity = observed toxicity?
5. Perform model optimization steps and uncertainty assessment

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Benthic Risk Assessment

Predictive Toxicity Model

- Model Results
  - Few models met acceptability criteria
    - PEC-Q and PEL-Q
  - Inconsistent responses and varied sensitivity among species tested
  - Only most sensitive species, *Leptocheirus plumulosus*, demonstrated a response to some COPC (total PAHs, total PCBs, lead, and BEHP)
  - No dose-response relationships observed between concentration and percent survival

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Benthic Risk Assessment

Predictive Toxicity Model

- Model utility and relevance
  - Amphipods are not representative of in situ benthic community
    - Amphipods represent less than 1 percent of benthic community in comparison sites
  - Amphipod bioassays are poor predictors of benthic community conditions in GOM estuaries (Brown et al. 2000)
- Thus, translation of effects on sensitive indicators such as amphipods in bioassay tests
  1) Is not an ecologically relevant endpoint for the Site and,
  2) Result in significant uncertainty and overestimation of risks

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Benthic Risk Assessment

Surface Water Exposure

- USEPA WQC is based on mammalian endpoint and is not ecologically relevant for benthic invertebrates.
- *Fuchsman et al*. (2006) addressed this issue by developing a benthic invertebrate final chronic value from the literature using WQC guidelines
  - 540 ng/l total PCB threshold identified

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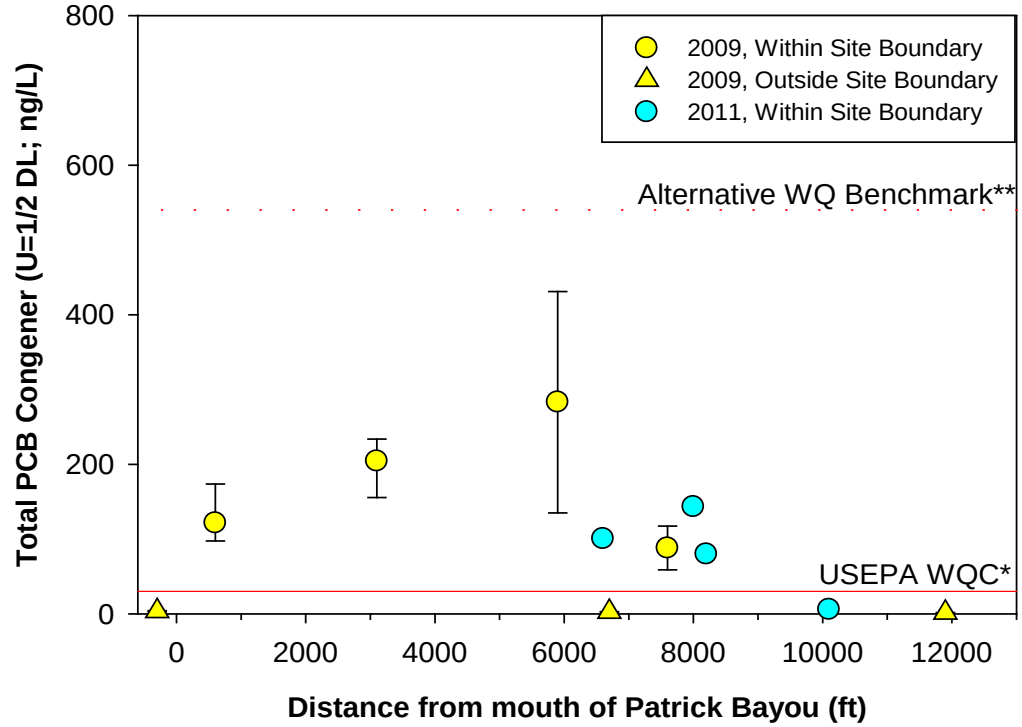
Benthic Risk Assessment

Surface Water Exposure

FCV of 540 ng/L for benthic invert used as WQ benchmark:

$HQ_{ALT} = 0.4$

$HQ_{AWQC} = 6.4$



*USEPA Water Quality Criteria for total PCB congeners is 30 ng/L

** Alternative WQ Benchmark (Fuchsman, et al. 2006) is 540 ng/L

Summary - Benthic Risk Assessment

- Risk Conclusions
  1. The available Site information and measurement endpoints indicate that the condition of the benthic community is related to non-chemical stressors and is unrelated to sediment contamination.
     - Indices are not significantly different than comparison sites
  2. Benthic toxicity predictive models are uncertain and result in overestimation of risk to benthic community – no risk conclusions or COC were identified using this LOE.
  3. Risk to benthic invertebrates from PCBs in surface water was determined to be negligible and no surface water COC were identified using this LOE.

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BERA Summary

1. Most receptor-COPC pairs had HQ < 1.0
   a) Spotted sandpiper and belted kingfisher had HQ of 1.0 and 2.1, respectively
2. Bioaccumulative COPC for fish all have HQ < 1.0
3. Benthic community is similar to nearby comparison sites that reflect reference conditions
4. Results of benthic toxicity modeling do not provide for a relevant LOE to assess benthic risk

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