UPDATE: Bay Wide Approach: Threshold effects of altered shorelines and other stressors on forage species in Chesapeake Bay

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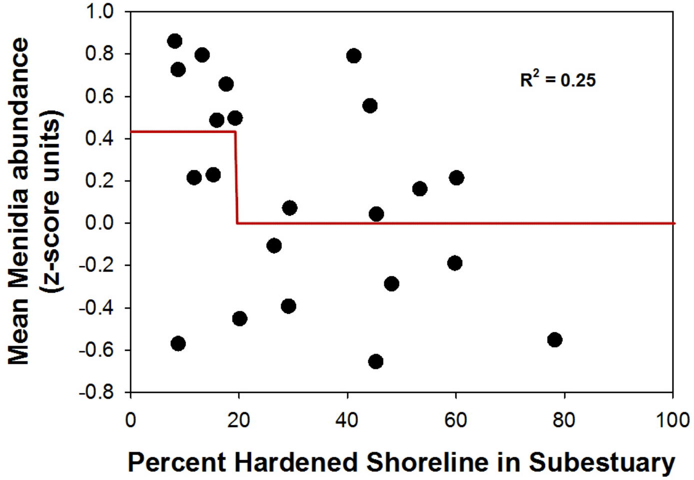
Bay-wide Approach: Methods

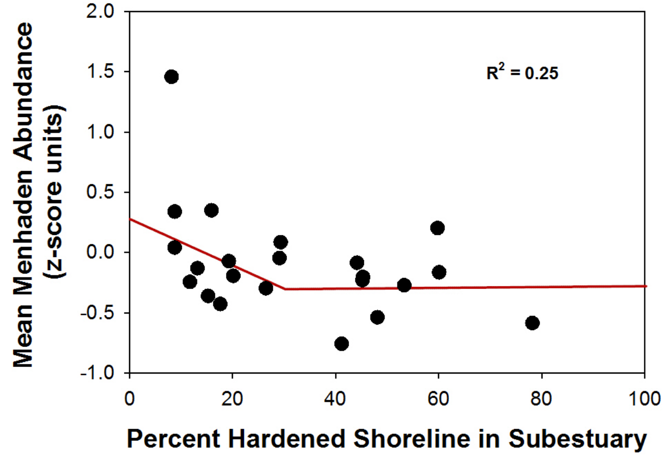
- Examine previously compiled Bay-wide data sets (588 sites Kornis et al. 2017) for threshold shoreline condition effects on important forage species (identified in Ihde et al. 2015 report)
- Graphical approach fitting non-linear curves (piecewise, sigmoidal)
- Examine new data sets (e.g., juvenile blue crab survey and Bay-wide blue crab dredge survey) for threshold shoreline condition effects for blue crabs

Results: Curves for thresholds - forage fish

***Menidia* sp.**
Sigmoidal

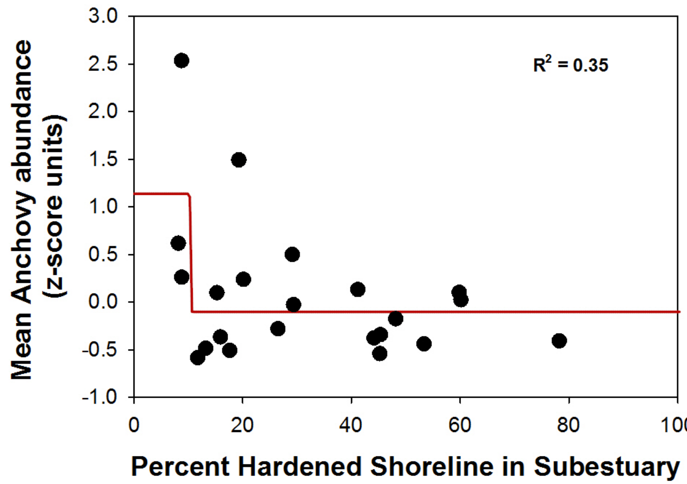


Atlantic Menhaden
Piecewise Regression

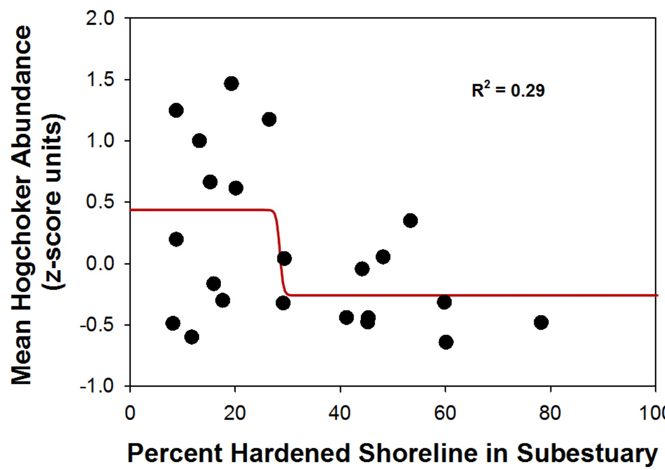


All improved over linear:
- *Menidia* R^2 0.25>0.16
- Anchovy R^2 0.35>0.13
- Menhaden R^2 0.25>0.18
- Hogchoker R^2 0.29>0.19

Bay Anchovy
Sigmoidal

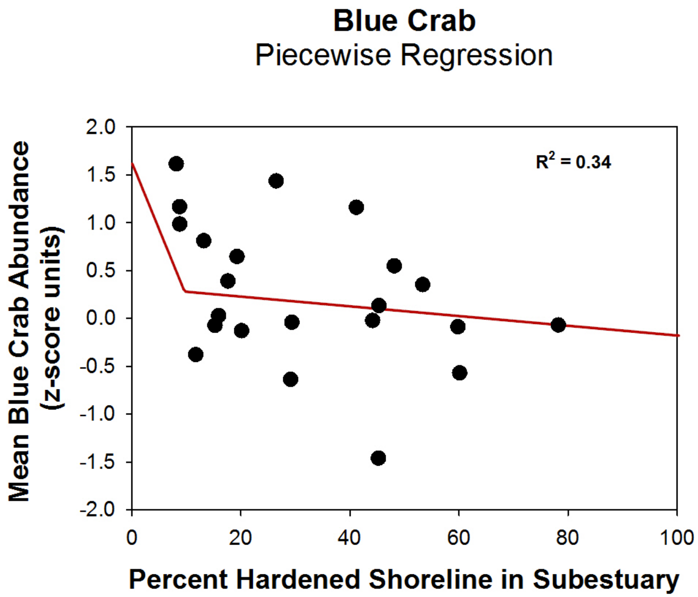


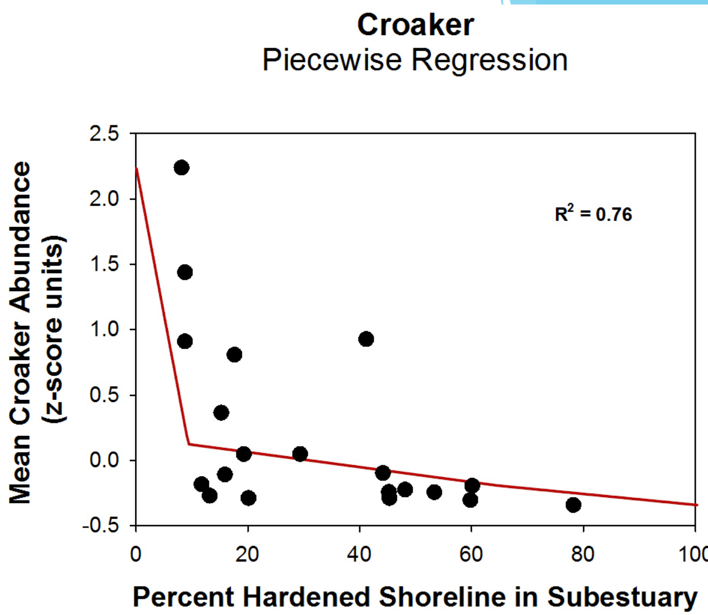
Hogchoker
Sigmoidal

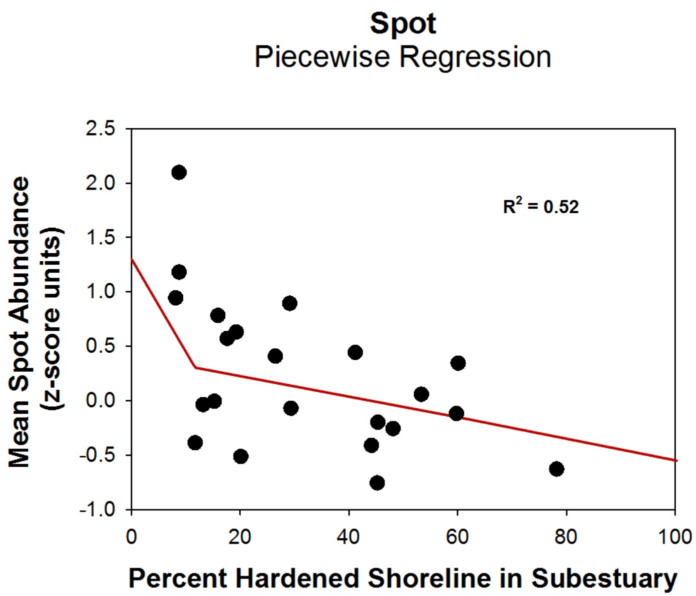


Threshold levels:
- *Menidia* 20%
- Anchovy 10%
- Menhaden 30%
- Hogchoker 30%

Results: Curves for thresholds - Crab, Spot, Croaker



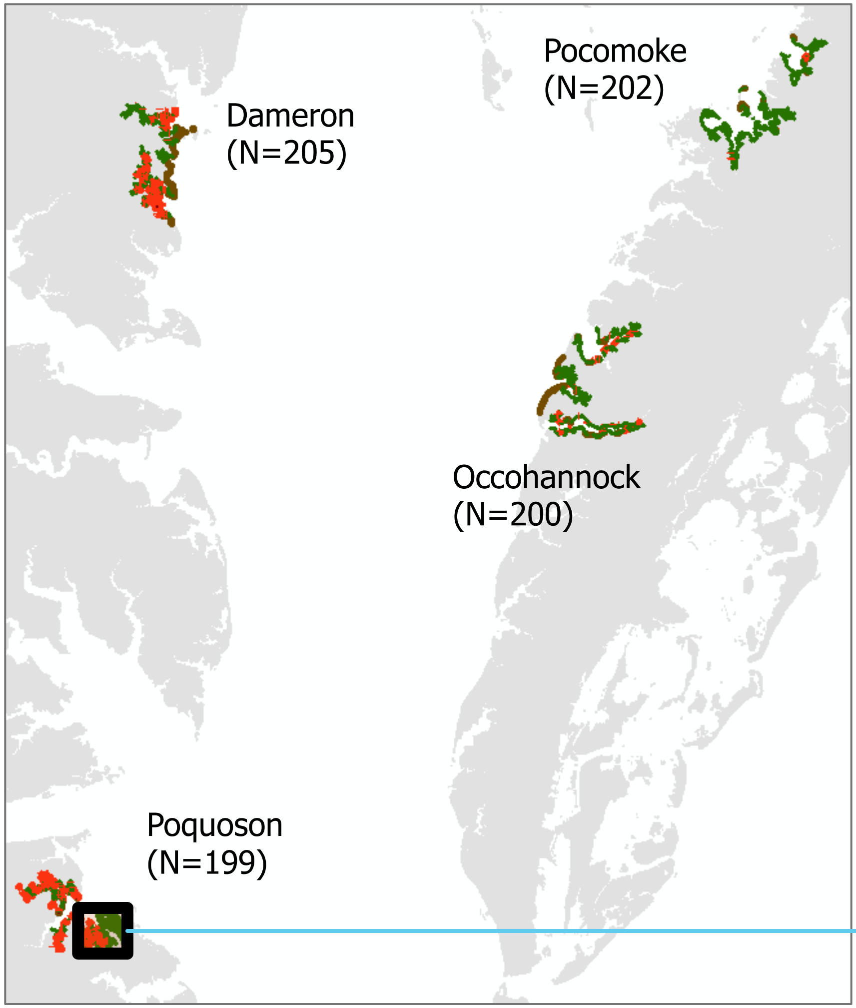


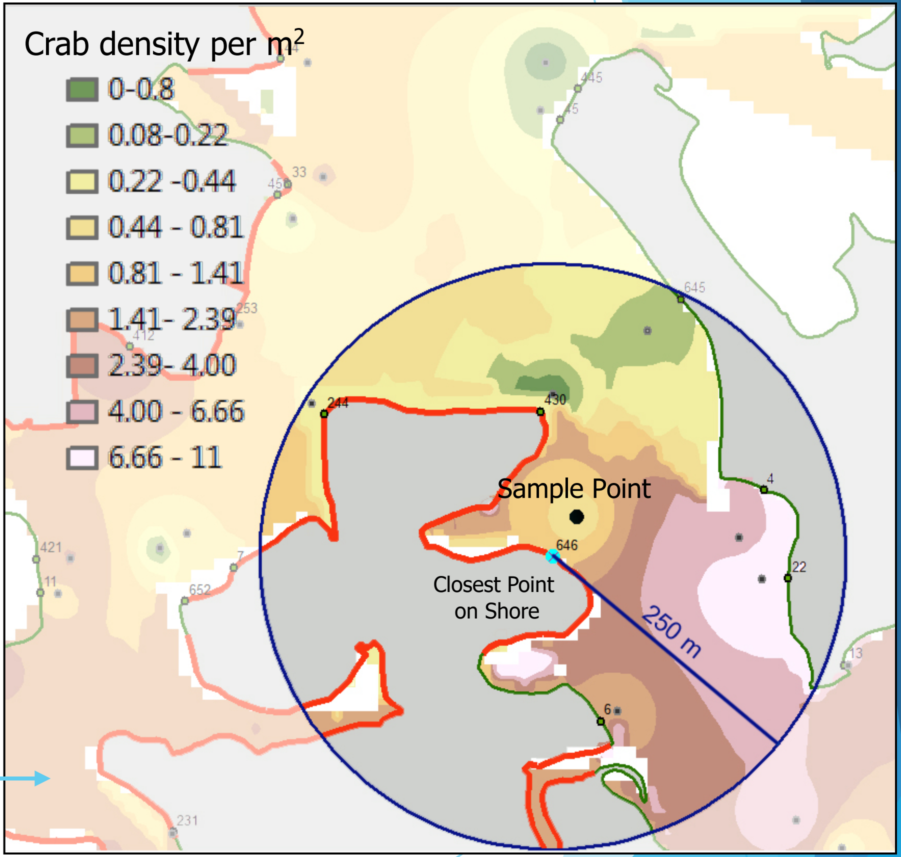


All improved over linear:
- Crab R^2 0.34>0.16
- Spot R^2 0.52>0.29
- Croaker R^2 0.76>0.29

Threshold levels:
- Crab 10%
- Spot 10%
- Croaker 10%

Juvenile Crab Survey
Methods: 4 locations – link crab sample to nearest shoreline



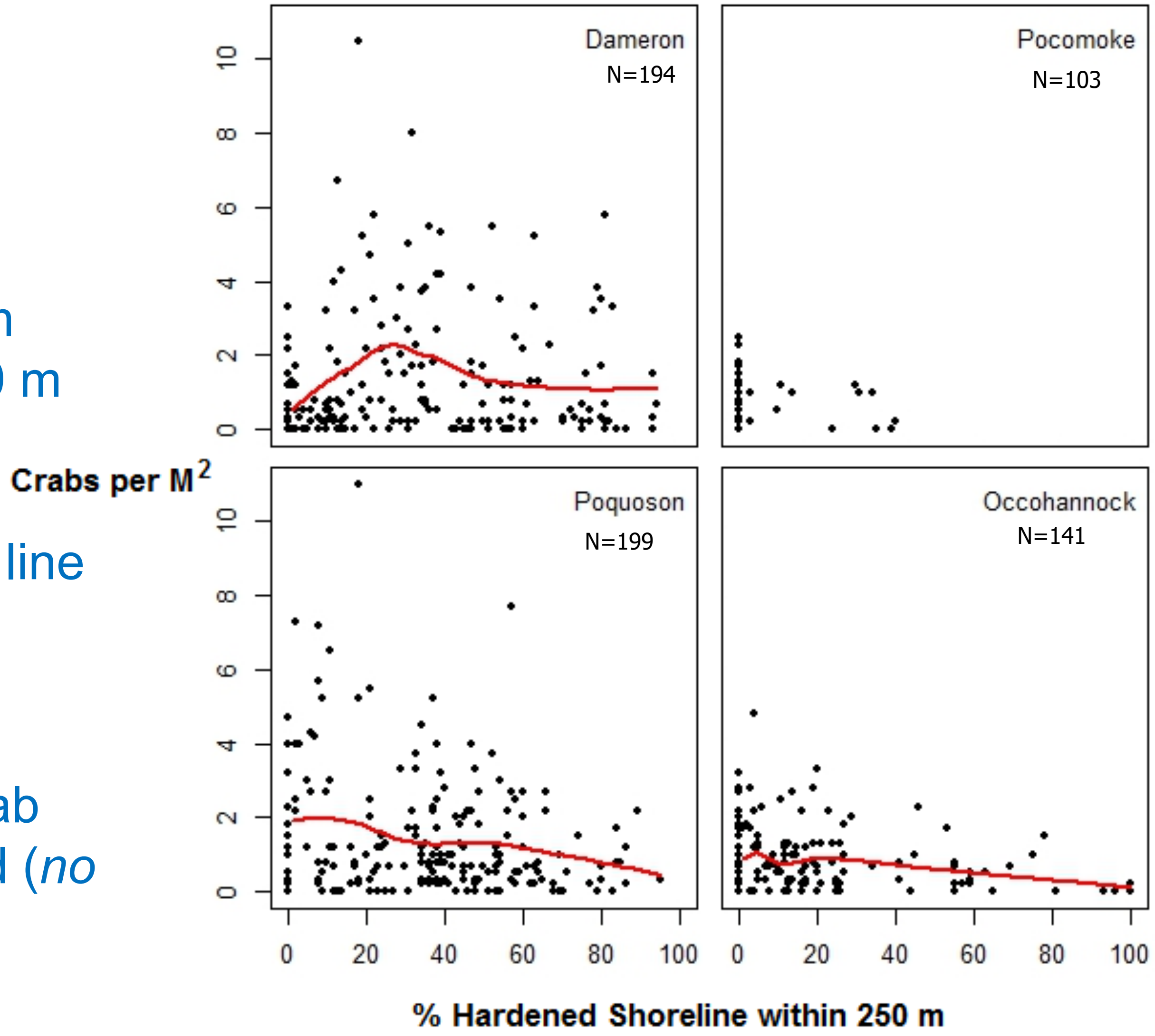


Shoreline Key
Red = developed
Green + Brown = natural

Used only points <250 m from shore
Calculated % developed within 250 m of that point

Juvenile blue crab survey: threshold with % hardened shore?

- Only points within 250 m from land and using 250 m shoreline buffer
- Red is Loess smoothed line through data
- Results: declining linear relationship between crab density and % hardened (*no threshold*)
- AIC used to compare influence of % hardened shore and upland use



Model	Variables (Estimate and SE)						
	Intercept	Area	Temperature (°C)	Salinity (psu)	Dissolved O_2 (mg/L)	Shoreline % Hardened	Upland Use % Developed
g_1	B_0	$B_1 - B_3$	B_4	B_5	B_6	B_7	B_8
g_2	B_0	$B_1 - B_3$		B_5		B_7	B_8
g_3	B_0	$B_1 - B_3$				B_7	B_8
g_4	B_0	$B_1 - B_3$					B_8
g_5	B_0	$B_1 - B_3$				B_7	
g_6	B_0	$B_1 - B_3$					
g_7	B_0						

Model	k	AIC	ΔAIC	w_i
g_1	10	2730.9	0.9	0.35
g_2	8	2730.0	0.0	0.56
g_3	7	2735.7	5.7	0.03
g_4	6	2738.3	8.3	0.01
g_5	6	2735.3	5.3	0.04
g_6	5	2738.0	8.0	0.01
g_7	2	2746.5	16.5	0.00

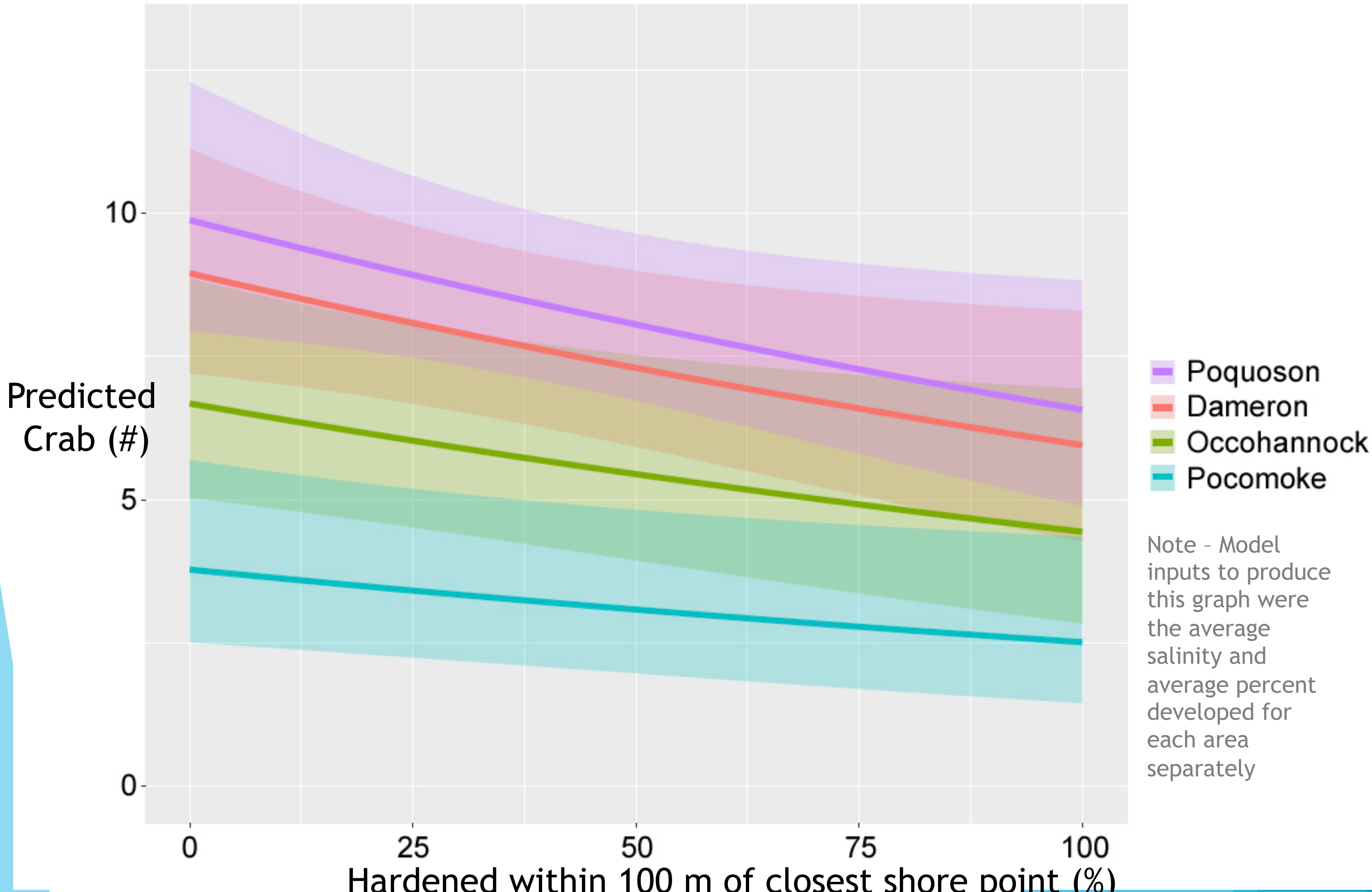
Coefficient		Estimate	SE	IRR
Intercept		0.8235	0.5434	2.279
AREA	Occohannock	-0.5318	0.1978	0.588
	Pocomoke	-1.1447	0.2583	0.318
	Poquoson	-0.2844	0.1903	0.752
Salinity		0.0894	0.0336	1.094
Shoreline % Hardened		-0.0041	0.0019	0.996
Upland Use % Developed		-0.0020	0.0032	0.998

Interpretation of the Incidence Rate Ratio (IRR) for significant variables

1. There are 41.2% fewer and 68.2% fewer crabs in Occohannock and Pocomoke compared to Dameron
2. For every 1 psu increase in salinity, there is a 9.6% increase in crabs
3. For every 1 % increase in hardened shoreline there is 0.4% decrease in crabs

Best Model (w_i= 0.56)

Crabs ~ Area + Salinity + Hardened Shoreline in 100 m + Developed in 500 m



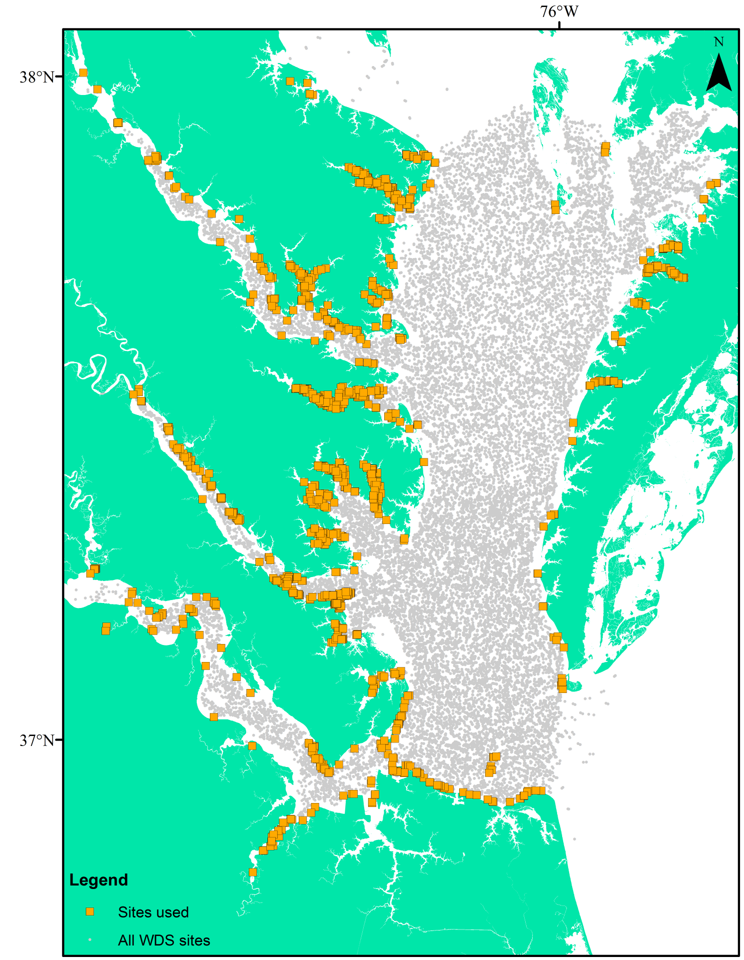
Note – Model inputs to produce this graph were the average salinity and average percent developed for each area separately

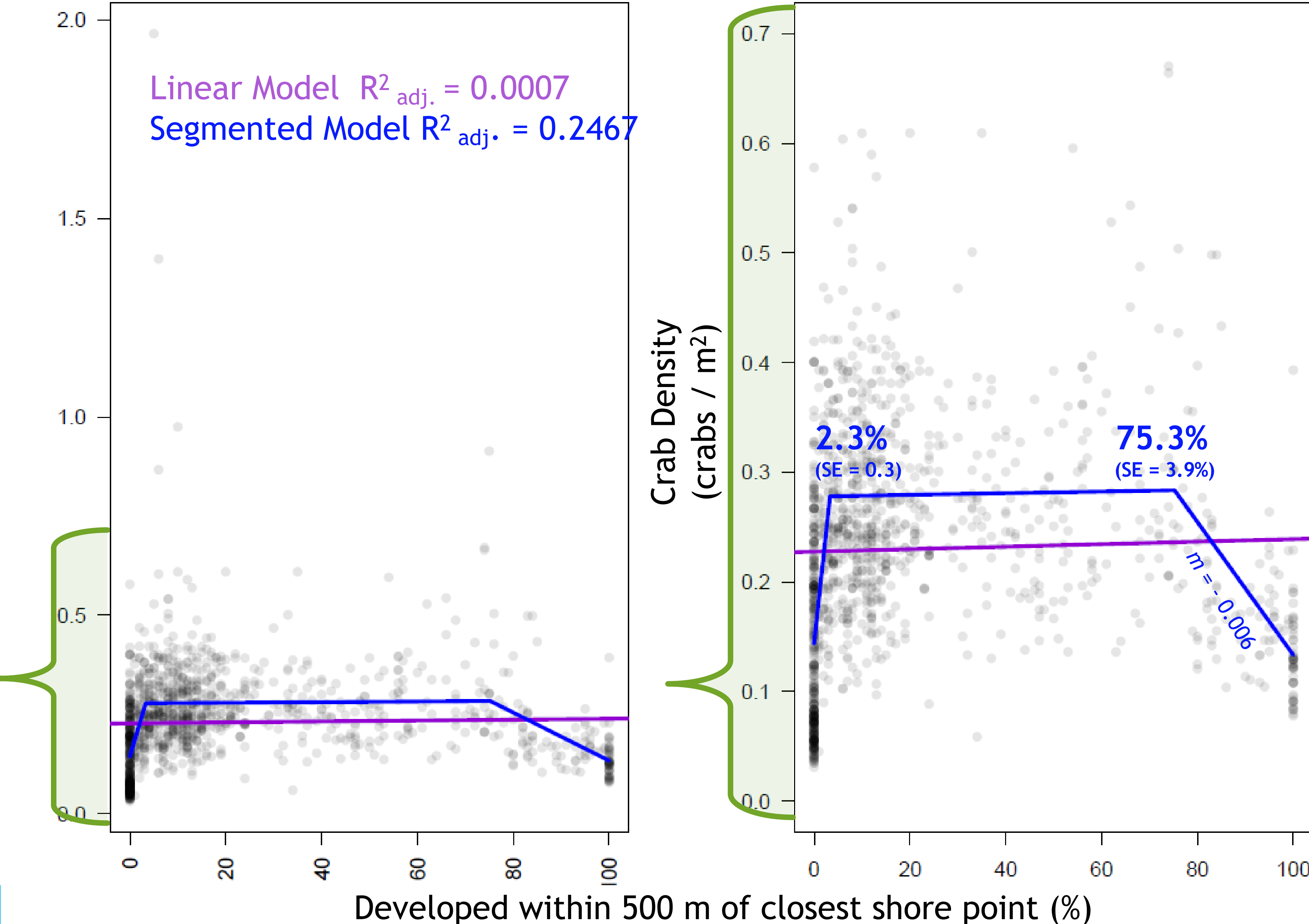
Blue Crab Winter Dredge Survey

LOESS line between % upland developed and crabs suggested a threshold, thus, we used a segmented model

Note- since only 1% of dredge points fell within 100 m of shore, % hardened shoreline was excluded from analyses, but Upland development examined

Used dredge survey sites within 500 m of shore (yellow)





2.0
1.5
1.0
0.5
0.0
Linear Model $R^2_{adj.}$ = 0.0007
Segmented Model $R^2_{adj.}$ = 0.2467
0
20
40
60
80
100
Crab Density
(crabs / m²)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.3%
(SE = 0.3)
75.3%
(SE = 3.9%)
m = - 0.006
0
20
40
60
80
100
Developed within 500 m of closest shore point (%)

Conclusions & Future Directions

- Continue analyses and explore curve-fitting for subset of upland use
- Comparison of Bay-wide and Subestuary-scale approach
- Coordination with CBT
- Propose a numerical threshold for shoreline hardening for some species but not others
  - Of the 7 species with thresholds, range was 10-30% shoreline development
  - Mean was 17%
- Juvenile blue crabs show general decline with shoreline development
  - For every 1% increase in hardened shoreline, there was a 0.4% decrease in crabs
- Development and upland-use decisions should consider reductions in forage species
- *We thank Chesapeake Bay Trust for funding*

CHESAPEAKE BAY TRUST

Organization Name: Virginia Institute of Marine Science
Project Leader: Rochelle D. Seitz
Project Title: Threshold effects of altered shorelines on forage species: Baywide approach and subestuary approach

Deliverables:

1) **"Develop a synthesis of shoreline impacts on forage species."**
We analyzed many datasets to synthesize impacts of shoreline development and other stressors on the important forage species identified in the STAC forage workshop (Ihde et al. 2015). For some species, shoreline impacts as well as upland development impacts were important, thus, multiple stressors must be taken into account (Kornis et al. 2017a) for informed management. In sum, when species showed a threshold, the threshold for many key forage species occurred at 10-30% shoreline development. There was an average threshold of 17% shoreline development across seven species (blue crabs, spot, croaker, *Menidia* sp., anchovies, menhaden, and hogchoker) that showed a threshold at all (other species showed no threshold). Caution is advised on using 17% as a definitive value for a forage-species threshold response to development, as the threshold among key species varied between 10 and 30% (if a threshold was found at all). However, for juvenile blue crabs in our shallow-water survey in the lower Chesapeake Bay, no threshold was present, but rather there was a 0.4% monotonic decrease in juvenile crab abundance for every 1% increase in hardened shoreline.

2) **"Propose a numerical threshold for shoreline hardening that could serve to inform local land-use decisions"**
Our statistical analyses tested for threshold responses of fauna to development, and these were evaluated Baywide. We re-analyzed data from fyke and seine net surveys compiled in an original meta-analysis that our group conducted (Kornis et al. 2017). In the present study, we used a graphical approach to examine patterns in forage fish abundances in comparison to shoreline development by using various non-linear curves fit to the data (e.g., sigmoidal, piece-wise regression). We determined whether there was improvement upon the linear trends displayed in the Kornis et al. (2017) paper with the new curves.

We determined that piecewise regression curves for crabs, spot, and croaker versus shoreline development had improved R^2 values compared to a linear relationship (with Crab $R^2 = 0.16$, Spot $R^2 = 0.29$, and Croaker $R^2 = 0.29$). These three curves showed a breakpoint (i.e., threshold) at ~10% shoreline development. Also, we determined that sigmoidal curves for *Menidia* sp., anchovies, menhaden, and hogchoker versus shoreline development had improved R^2 values compared to a linear relationship (with *Menidia* $R^2 = 0.16$, Anchovy $R^2 = 0.13$, Menhaden $R^2 = 0.18$, and Hogchoker $R^2 = 0.19$). The threshold levels of shoreline development for the latter four species were each different, with *Menidia* at 20%, Anchovies at 10%, Menhaden at 30%, and Hogchoker at 30%.

We assessed relationships of juvenile blue crab abundances in various lower bay tributaries (from our juvenile crab survey) with shoreline use within 250 m of the nearest point of land to our sample, and upland use within the vicinity. We concluded that both upland use and shoreline hardening had significant effects on juvenile abundances (See tables below, and note the importance of models g_1 and g_2 from the AIC analysis, which include both % of shoreline hardened and % development of upland – see tables for AIC weights, w_i, greater than 0.20, which indicates importance), and there were differences by location (i.e., "Area" in the AIC analysis). In addition, for every 1% increase in hardened shoreline, there was a 0.4% monotonic decrease (no threshold) in juvenile crab abundance, and a 0.2% monotonic decrease in crab abundance for every 1% increase in upland development.

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3) **“Participate in bi-monthly meetings.”** Though we initially posed bi-monthly meetings, in a discussion with Bruce Vogt, we determined that less-frequent meetings would be necessary. We met or discussed issues by conference call when necessary, and in person at various GIT meetings.

4) **“Present a project status update and/or initial project findings to the Sustainable Fisheries GIT…”** We have presented project updates at multiple meetings of the Sustainable Fisheries Goal Implementation Team and at a meeting and conference calls with the Forage Action Team. We have given presentations that included relevant graphs and results. We have also written reports, given presentations at national conferences, and have publications in preparation on this work.

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