Predicting blue crab (*Callinectes sapidus*) fisheries independent survey abundances and commercial landings in Charleston Harbor, South Carolina

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Abstract

Marked high fluctuations in blue crab (*Callinectes sapidus*) seasonal and annual abundance, and commercial landings are typical, but data from both fisheries independent and dependent surveys have shown declines in populations in recent years in South Carolina. Despite several long-term fisheries independent surveys encountering blue crab, predictive models have not recently been developed in South Carolina to quantify variation in abundance and commercial landings. The goal of this study is to assess the current status of blue crab in SC and explore the potential for developing a more predictive understanding of commercial landings. This goal is me through the following objectives: 1) assess long-term trends in blue crab landings and fisheries-independent abundance, 2) test the applicability of a juvenile index, where juvenile abundance in one year predicts adult abundance in a following year, 3) explore predictive relationships between fisheries-independent abundance and commercial landings. Data from several long-term South Carolina Department of Natural Resources (SCDNR) fisheries independent blue crab surveys were standardized for each of six surveys and commercial landings data were compiled. Analyses testing the application of a juvenile index of abundance show that no juveniles collected in surveys explain variation in annual survey abundances. The Creek Trawl survey was the only survey with significant, but weak, correlative relationships between multiple lagged population structure variables and its own annual abundance. Significant relationships were found with effort-corrected commercial landings predicted by the previous year's abundance of male crabs. This relationship was significant for immature crabs collected in the Harbor Trawl survey, and for mature crabs collected in the Creek Trawl survey. These results suggest effective population sampling, but a potential influence on abundance of blue crab from outside factors such as fishing, habitat or environmental variables.

Methods

Data were put through a rigorous data wrangling process to standardize each survey relative to its own methods. Fisheries dependent commercial landings and fisheries independent survey abundances were truncated from statewide data to Charleston Harbor watershed data.

Surveys cover a range of habitats.

Table 1: Methods - SCDNR fisheries independent survey methodology. This table sums up some of the differences in methodology from each of the survey. I think it covers a range of of different methodology variables (temporal, spatial, gear, standardization, sample numbers, etc.).

	Gear		Sample			Data	
Survey	Gear Method	Gear Type	Sample Area	Sample Interval	Sample Method	N(events)	CPUE Standardization
CRMS							
Creek Trawl	Active	6m Trawl, 2.54cm stretch mesh	Ashley River, Wando River	Monthly, May-Sep	Fixed Stations	1827	Time
Harbor Trawl	Active	4.6m Trawl, 0.6cm D mesh	Ashley River, Charleston Harbor	Monthly	Fixed Stations	2956	Time, Gear
Ashley Fall Potting	Passive	0.6 x 0.6 x 0.46m Pot, 3.8 cm mesh	Ashley River	Monthly, Oct-Nov	Randomized Block w/in a Fixed Station	128	Time
ERS							
SCECAP Tidal Creeks	Active	5m trawl, 1.9cm bar mesh	Charleston Harbor Systemwide	Jun - Aug	Random Stratified	62	Volumetric
SCECAP Open Water	Active	5m trawl, 1.9cm bar mesh	Charleston Harbor Systemwide	Jun - Aug	Random Stratified	92	Volumetric
IFRS							
Trammel Net	Passive	183 x 2.1m trammel net	Charleston Harbor Systemwide	Monthly	Random Stratified	4736	None (Total)

Table 2: Lifestage data for blue crab by SCDNR fisheries independent survey. It should be mentioned in the methods what type of lifestage data is available from these surveys. The "legal" category is pretty redundant. "Legal" = "Adult, and"Sublegal" = "Juvenile" + "Subadult", although at shows the potting survey having some size data and sublegal can be considered a joint variable (juv + subadult).

		Size			Legal (Size)		Class (Sex/Maturity)			
Survey	Total CPUE	Juvenile	Subadult	Adult	Legal	Sublegal	Immature Female	Mature Female	Immature Male	Mature Male
CRMS										
Creek Trawl	X	X	X	X	X	X	X	X	X	X
Harbor Trawl	X	X	X	X	X	X	X	X	X	X
Ashley Fall Potting	X				X	X				
ERS										
SCECAP Tidal Creeks	X	X	X	X	X	X				
SCECAP Open Water	X	X	X	X	X	X				
IFRS										
Trammel Net	X									

Objective 1

Assess long-term trends in blue crab landings and fisheries-independent abundance

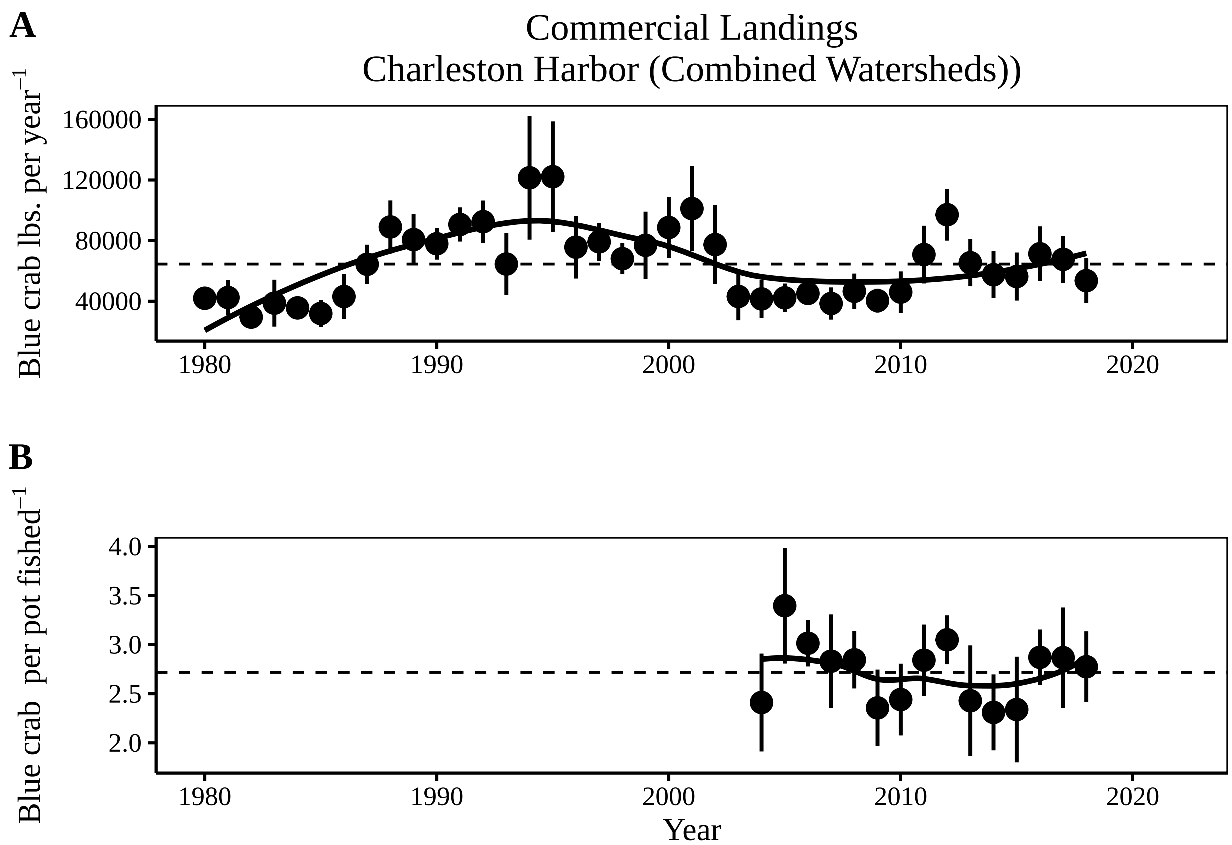

Figure 1: Objective 1 - This plot shows the point that there is high annual variability in blue crab catches and a potential decline in population starting around 2002. It should be mentioned that statewide initial analyses of the data have indicated a sharp decline but that when corrected for effort, and post implementation of proper reporting (2003-present), these data may not show the severe decline in populations that have been reported.

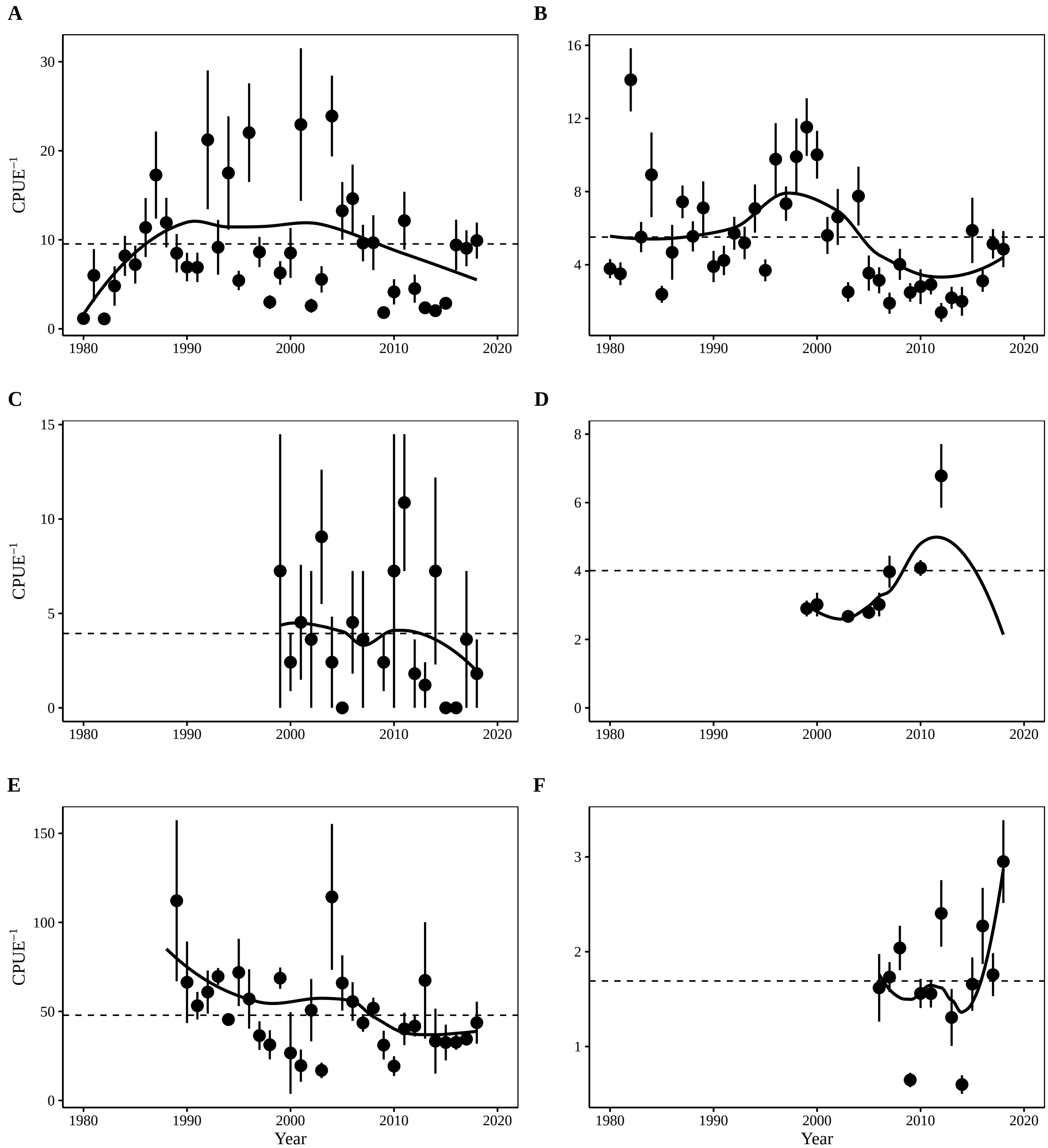

Figure 2: Objective 1 - . . . although this plot does show a decline in some of the more robust surveys (A, B, E), with disagreement from another robust survey (F) that is not long-term (>2005). The same high annual variabilty in the commercial landings are found in the fish-independent surveys. This plot could suggest different resiliency (? wrong word), and/or different responses of the population in different habitats. I'd love to add some sort of size/sex time series plot in

Methods

Discussion

Commercial landings (fig. 1) and survey abundance (fig. 2) time series show the high annual variablility of blue crab populations, but also may not agree totally on the decline in populations through the decade of the 2000's.

The total pounds landed in the combined Charleston Harbor watersheds shows a trending decline from 2003 - 2010, but when these same landings data are corrected for effort in terms of number of pots pulled that trend is not observed. The year 2003 marks the first year of "trip ticket" reporting, in which all commercial blue crab license holders are required to report their catch. This is the same time frame (>2003) the Ashley and Cooper Rivers are included in commercial landings, whether that is due to not being actively fished for blue crab, underreported, or included in another reporting area. Time series data from the abundance surveys (fig 2) show a more severe decline in surveys occuring in tidal creek areas (figs 2B and 2D) than in open water areas (figs 2A, 2C, 2E) with data from the SCDNR Trammel Net survey not showing a decline but no data available for comparison before 2006. This suggests influence of habitat or environmental conditions on blue crab populations in particular areas of the estuary.

Of note: for commercial landings (fig. 1), and the longer abundance surveys (figs 2A and 2B), variability is increased when CPUEs are above the long-term mean - could this indicate less 0-catch events and do we care?

Objective 2

Test the ability of a juvenile index, where juvenile abundance in one year predicts adult abundance in a following year

Table 3: Objective 2 - These are all relevant explanatory variables. Only one survey has explanatory relationships. No juveniles from any survey predict abundances in later years. Maybe the subadults with a 2-yr. lag show that juveniles in this survey could be used with a 3-yr lag, or that the survey simply does not catch juveinles effectively, or juveniles are not populating sampled micro-habitats. I do not think regression tables are needed for the mulitple OLS models as they do not improve the model or the relationship above an Rˆ2 of 0.299.

		Summary Statistics			
Dependent Variable	Explanatory Variable	p-value	r2	F-statistic	Degrees of Freedom
Total CPUE	Subadult (2-yr. lag)	0.001926	0.2432	11.250	35
Total CPUE	Mature Male (1-yr. lag)	0.002197	0.2321	10.880	36
Total CPUE	Immature Male (2-yr. lag)	0.004023	0.2131	9.481	35
Total CPUE	Sublegal (1-yr. lag)	0.004317	0.2102	9.316	35
Total CPUE	Total CPUE (2-yr lag)	0.004898	0.2050	9.024	35
Total CPUE	Subadult (1-yr. lag)	0.007774	0.1809	7.949	36
Total CPUE	Immature Female (2-yr. lag)	0.010380	0.1733	7.337	35
Total CPUE	Mature Female (2-yr lag)	0.019000	0.1473	6.048	35
Total CPUE	Total CPUE (1-yr lag)	0.019060	0.1434	6.027	36
Total CPUE	Sublegal (1-yr. lag)	0.025290	0.1314	5.448	36
Total CPUE	Mature Male (2-yr. lag)	0.030760	0.1265	5.067	35
Total CPUE	Adult (1-yr. lag)	0.031200	0.1225	5.028	36
Total CPUE	Legal (1-yr. lag)	0.031200	0.1225	5.028	36
Total CPUE	Immature Male (1-yr. lag)	0.048540	0.1038	4.169	36
Total CPUE	Immature Female (1-yr. lag)	0.050070	0.1025	4.111	36

Table 4: Objective 2 - This table shows the results of a dredge function run on the highest correlated variables (Figure 4), the total CPUEs (1-yr. lag) for the Harbor and Creek Trawl surveys (univariate corrs found Table 4). The multivariate model's Radjˆ2 was lower than the univariate models. The multivariate was not compared to univariate models. A delta <2.0 from another model's delta means the dredge sees no staistical difference outside of chance between the compared models. Population structure variables (Harbor Trawl mature males 1-yr lag, Creek Trawl immature males 1-yr lag) are statistically better models according to the dredge.

	Intercept	CPUE 1-yr. lag	CPUE 2-yr. lag	Immature Male 2-yr. lag	Mature Male 1-yr. lag	Subadult 2-yr. lag	Sublegal 1-yr. lag	df	logLik	AICc	delta	weight
delta Group 1												
1	3.619	NA	NA	NA	NA	NA	NA	2	-30.807	66.614	0.000	0.22907265
17	2.346	NA	NA	NA	NA	0.783	NA	3	-29.456	67.094	0.480	0.18020202
3	2.388	NA	0.349	NA	NA	NA	NA	3	-29.743	67.668	1.054	0.13523796
5	2.669	NA	NA	0.879	NA	NA	NA	3	-30.126	68.434	1.819	0.09223732
delta Group 2												
33	3.743	NA	NA	NA	NA	NA	-0.049	3	-30.797	69.776	3.162	0.04714406
9	3.651	NA	NA	NA	-0.032	NA	NA	3	-30.807	69.795	3.181	0.04670090
2	3.638	-0.005	NA	NA	NA	NA	NA	3	-30.807	69.796	3.181	0.04668150
19	2.523	NA	-0.494	NA	NA	1.749	NA	4	-29.315	70.630	4.015	0.03076570
21	2.457	NA	NA	-0.637	NA	1.138	NA	4	-29.350	70.700	4.085	0.02970492
25	2.180	NA	NA	NA	0.153	0.794	NA	4	-29.440	70.879	4.265	0.02715834
18	2.189	0.041	NA	NA	NA	0.792	NA	4	-29.441	70.883	4.268	0.02711077
49	2.430	NA	NA	NA	NA	0.782	-0.033	4	-29.451	70.902	4.287	0.02685151
11	2.168	NA	0.358	NA	0.194	NA	NA	4	-29.718	71.436	4.821	0.02056314
4	2.269	0.031	0.352	NA	NA	NA	NA	4	-29.735	71.470	4.856	0.02021224
35	2.494	NA	0.348	NA	NA	NA	-0.041	4	-29.735	71.470	4.856	0.02021142
7	2.404	NA	0.385	-0.135	NA	NA	NA	4	-29.738	71.477	4.862	0.02014555

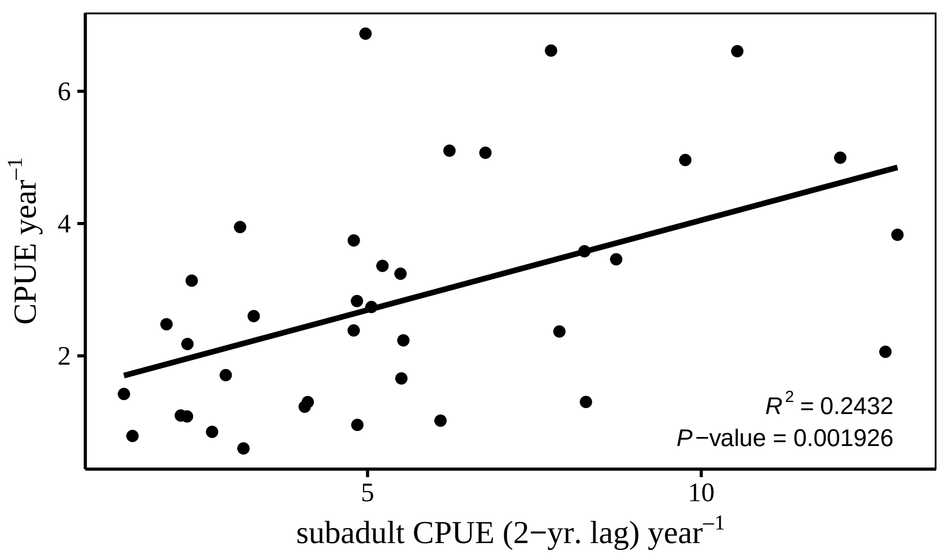

Figure 3: Objective 2 - Shows the potential to predict, but poor correlation. Prediction by subadult with a 2-yr lag suggests that either juveniles are underrepresented in sampling, or maybe they do not congregate until this size? THIS PLOT IS NOT NEEDED AND WOULD NEED CLEANUP

Discussion

OLS regression models using all lifestages from all surveys with a 1- and 2-yr lag to predict all survey's total CPUEs were constructed to find all explanatory relationships. The CRMS Creek Trawl survey is the most consistently responsive of the surveys when used in regression modeling. Fifteen significant relationships exist between total CPUEs from the Creek Trawl survey and several 1- and 2-yr.lagged lifestage variables (Table 3). The CRMS Harbor Trawl had one significant explanatory relationship with subadults from the same survey lagged 1-yr. The Trammel Net survey had one significant explanatory relatioship with mature females from the Harbor Trawl lagged 1-yr, which is the highest correlation (r2=0.36) of all the single regression models.

Although there were several significant regression models constructed using fisheries independent survey life stage abundance CPUEs, no relationships correlate strong enough to be effective models. Using OLS single regression modeling, the six SCDNR fisheries independent surveys used to monitor blue crab populations in the Charleston Harbor watershed are ineffective predictors of their own abundance CPUEs. When these single variables were used to populate multiple regression OLS models, the adjusted Rˆ2 values did not improve the correlations. Juvenile variables did not predict mean annual CPUEs.

Objective 3

Explore predictive relationships between fisheries-independent abundance and commercial landings.

Table 4: Objective 3 - All significant relatioships of effort corrected Charleston Harbor watershed (Ashley, Cooper and Wando Rivers and Charlesotn Harbor) commercial Landings by lifestage variables from all surveys using OLS regression. Only variables from the Harbor and Creek Trawl surveys were related to these corrected landings. Multiple variables with consistent correlations through both surveys seem to suggest the surveys are effectively measuring the population, but there may be some other driver (habitat, environmental, fishing) outside of stock/population (proper term?) variables that affect blue crab abundance.

		Summary Statistics			
Dependent Variable	Explanatory Variable	p-value	r2	F-statistic	Degrees of Freedom
Harbor Trawl (explanatory variable)					
Mean Landings CPUE	Mature Male (1-yr. lag)	0.007659	0.4330	9.928	13
Mean Landings CPUE	Subadult (1-yr. lag)	0.016680	0.3670	7.538	13
Mean Landings CPUE	Total CPUE (1-yr. lag)	0.027710	0.3208	6.140	13
Creek Trawl (explanatory variable)					
Mean Landings CPUE	Immature Male (1-yr. lag)	0.010420	0.4076	8.946	13
Mean Landings CPUE	Sublegal (1-yr. lag)	0.014850	0.3772	7.875	13
Mean Landings CPUE	Subadult (1-yr. lag)	0.019470	0.3532	7.100	13
Mean Landings CPUE	Total CPUE (1-yr. lag)	0.023880	0.3346	6.538	13
Mean Landings CPUE	Juvenile (1-yr. lag)	0.030140	0.3129	5.921	13
Mean Landings CPUE	Immature Female (1-yr. lag)	0.033210	0.3038	5.672	13

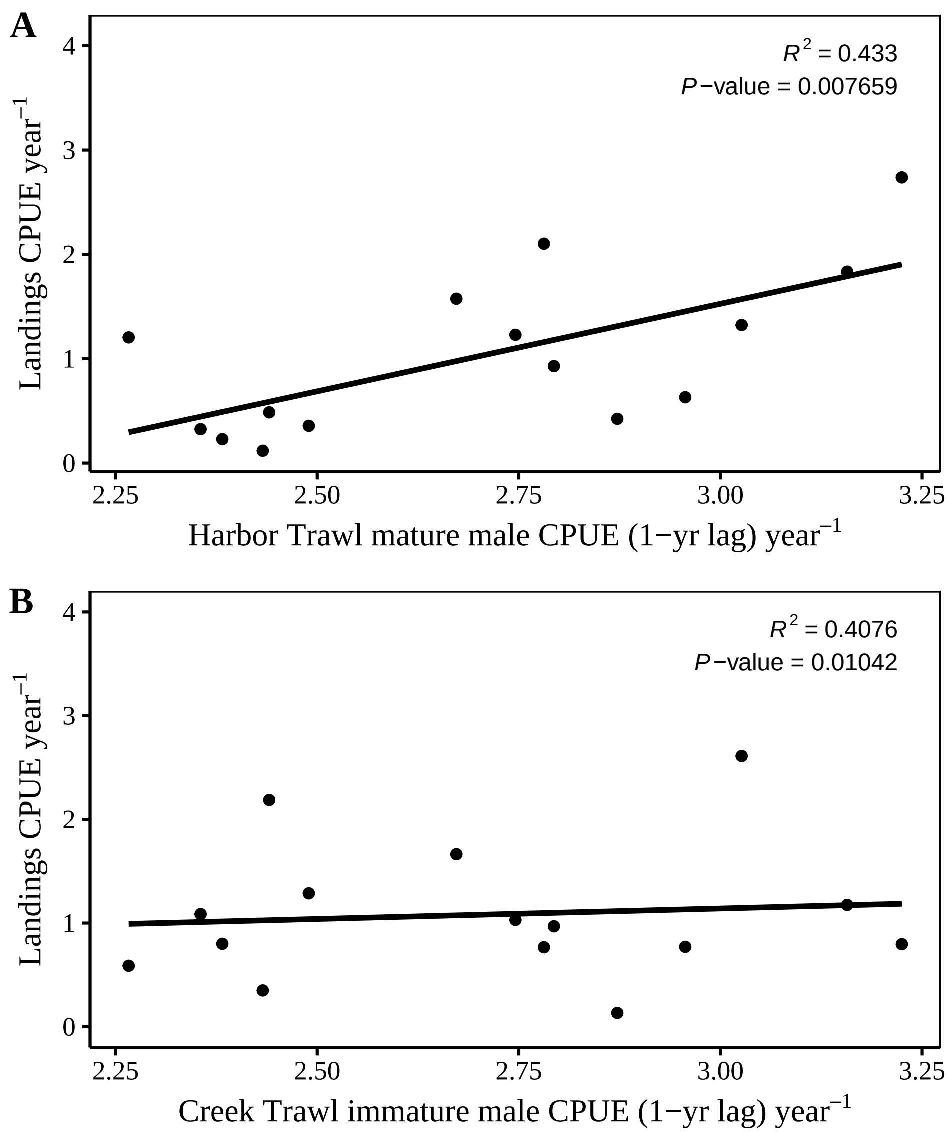

Figure 4: Ordinary Least Squares regression plots of select significant explanatory relatioships using lagged variables to Charleston Harbor watershed Landings CPUEs. Mean annual landings CPUE by Harbor Trawl mature males with a 1-yr lag (A), and mean annual landings CPUE by Creek Trawl immature males CPUE with a 1-yr. lag (B). Because the multiple regression relationships do not have as strong a correlation as some of the single, and are more illogical, I don't think the table with multiple regression models is needed since their is no improvement in correlation.

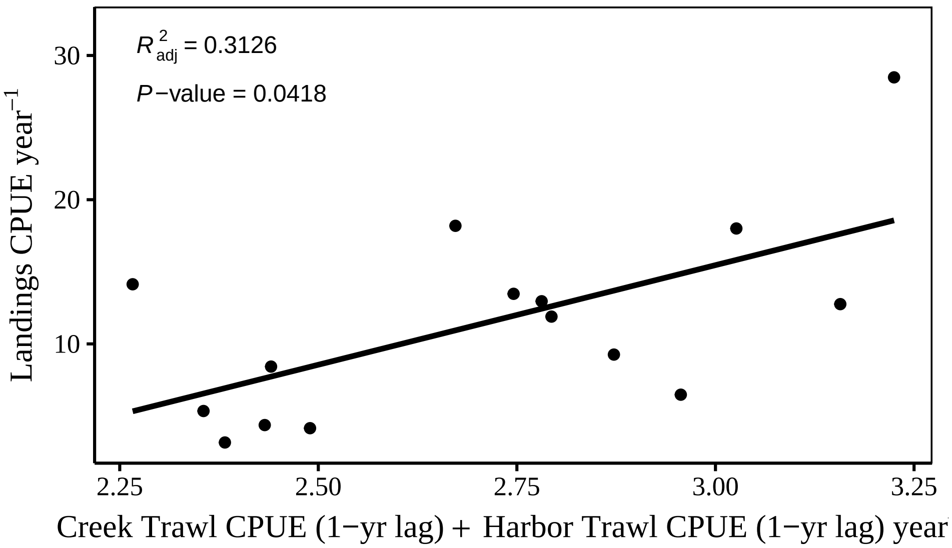

Figure 5: Objective 3 - This plot shows no model improvement if Total CPUEs are added together into a multiple regression model. The adj R^2 is not an improvement over the R^2 of the individual variables (See Table 4)

Table 5: Objective 3 - This table shows the results of a dredge function run on the highest correlated variables (Figure 4), the total CPUEs (1-yr. lag) for the Harbor and Creek Trawl surveys (univariate corrs found Table 4). The multivariate model's Radj^2 was lower than the univariate models. The multivariate and univariate models were scored using AICc for small samples. A delta <2.0 from another model's delta means the dredge sees no staistical difference outside of chance between the compared models. Mean annual population structure variables (Harbor Trawl mature males 1-yr lag, Creek Trawl immature males 1-yr lag) are statistically better models than mean annual total CPUE according to the dredge.

		lagged 1-yr.								
	Intercept	Harbor Trawl	Harbor Trawl mature male	Creek Trawl	Creek Trawl immature male	df	logLik	AICc	delta	weight
delta Group 1										
3	2.4398	NA	0.2580	NA	NA	3	1.3454	5.4911	0.0000	0.29635636
9	2.3683	NA	NA	NA	0.3252	3	1.0170	6.1478	0.6567	0.21340957
delta Group 2										
7	2.3559	NA	0.1905	0.0445	NA	4	2.0587	7.8827	2.3916	0.08963631
5	2.3943	NA	NA	0.0904	NA	3	0.1454	7.8910	2.4000	0.08926239
11	2.3664	NA	0.1605	NA	0.1675	4	1.9835	8.0331	2.5420	0.08314296
2	2.4541	0.0317	NA	NA	NA	3	-0.0088	8.1994	2.7083	0.07650819
4	2.4487	-0.0060	0.2955	NA	NA	4	1.3760	9.2481	3.7570	0.04528866
10	2.3601	0.0108	NA	NA	0.2509	4	1.2164	9.5671	4.0761	0.03861101
13	2.3527	NA	NA	0.0244	0.2592	4	1.1137	9.7725	4.2815	0.03484222
6	2.3517	0.0193	NA	0.0584	NA	4	1.0577	9.8847	4.3936	0.03294232

Discussion

OLS regression models using all lifestages from all surveys with a 1- and 2-yr lag to predict Charleston Harbor watershed (Ashley River, Cooper River, Wando River and Charleston Harbor) landings CPUEs were constructed to find all explanatory relationships. All significant relationships are displayed in the following tables. The CRMS Creek Trawl is the most consistently responsive of the surveys when used in regression modeling. Nine significant relationships exist between mean annual Landings CPUE and several 1- and 2-yr.lagged lifestage variables from the CRMS Harbor and Creek Trawl surveys (Table 4). The CRMS Harbor Trawl survey's mature males 1-yr. lag and the CRMS Creek Trawl survey's immature male 1-yr. lag are the only variables with a coefficient of determination (r-squared) > 0.40. Multiple regression OLS models populated with these variables did not improve correlation.

Only two fisheries independent life stage abundance CPUEs have significant relatioships with total landings (not effort corrected). The effects from these models have very small explanatory power over total landings. It should be mentioned that >2003 is when data from all 4 reporting areas (Ashley, Cooper, Wando Rivers and Charleston Harbor) and the effort-correction (pots pulled) begin.