# CHAPTER 1 TITLE HERE

## Introduction

The blue crab (Callinectes sapidus) is a highly ranked commercial and recreational fishery in South Carolina with 3.9 million lbs. landed, and a value of $5.1 million in 2018 (ACCSP Non-confidential Landings by Species (Blue Crab) 2020.).

To support management, it is important to understand recruitment dynamics of juvenile blue crab into the adult stage – the stage that is available to commercial and recreational fishers.

Models can be developed to assess recruitment dynamics, including testing of crab abundance in any given year and its relationship to crab abundance in preceding years.

If adult abundance in a year is predicted by juvenile abundance in the prior year (e.g., 1-yr lag), this may provide a more predictive understanding of the blue crab fishery.

The South Carolina Department of Natural Resources (SCDNR) monitors the status of juvenile and adult blue crab across a range of habitat types using multiple fisheries independent surveys. Past research has characterized blue crab life history in South Carolina using both fisheries independent and dependent data in various watershed systems. Fisheries independent data are collected by SCDNR through a suite of monitoring surveys which employ both passive and active fishing methods to collect blue crab at specific life stages. Fisheries independent data can also be used to determine an index of abundance in catch per unit effort.

## Methods

### Census Surveys

A suite of fisheries independent monitoring surveys employed by the South Carolina Department of Natural Resources (SCDNR) encounter the blue crab using varying gear types in varying habitats with varying sampling regimes (Table 1).

The South Carolina Department of Natural Resources (SCDNR) is charged with monitoring South Carolina blue crab populations and the blue crab fishery based on its collection of fisheries independent and dependent data. The SCDNR collects fisheries independent data on blue crab using a suite of coastwide, long-term sampling surveys. Fisheries dependent data from the South Carolina commercial blue crab fishery have been collected by mandatory reporting as per the commercial license issued by SCDNR since 2004. Prior to 2004, the National Marine Fisheries Service (NMFS) collected these fishery dependent data.

The several fisheries independent and dependent surveys used in this investigation occur in different microhabitats within, for example, the Charleston Harbor watershed with some overlap between surveys. For instance, the Harbor Trawl Survey (HTS) occurs in open water located longitudinally along a salinity gradient along the river continuum. Sites range from polyhaline, found lower in the harbor close to the ocean, to more mesohaline dominated sites in the Ashley River. Creek Trawl Survey (CTS) sites occur in tidal creeks (<100 meters wide) also located longitudinally along a salinity gradient along the river continuum. These sites also range from polyhaline to mesohaline, but these sites are located in marsh dominated tidal creek habitats as opposed to the main channel of the open water dominated HTS sites. The Trammel Net Survey (TNS) sites are open water sites along the same river continuum but are focused on the shallow intertidal areas of the marsh edges of the Charleston Harbor system. South Carolina Estuarine Assessment Program (SCECAP) sites are mixed habitat within the Charleston Harbor watershed, with sites split between open water and tidal creeks. While I will be using statewide data in my research, the Charleston Harbor Watershed has extensive sampling coverage by all surveys and will play an important role in my research. I will be using abundance and landings data from 2018 and prior for my research.

Fisheries independent monitoring surveys collect biotic (size, abundance and population) and abiotic (salinity and temperature) data. Some of these long-term surveys have changed methods, gear or time of deployment and our data will be corrected for this when applicable. Abundance numbers will be in catch per unit effort (CPUE) standardized by “unit”. Unit will typically be one deployment of one gear type (i.e. one pot, one bloc of pots, one trawl, etc.) but unit could also be the date of several gear deployments, i.e. mean catch of replicate crab pots within a bloc. Sample size and station, or sample location, will be uniform across the dates in cases when date will be the unit. For cases where the deployment of one gear type, CPUEs will be corrected for time of deployment. In the case of SCECAP data, some CPUEs of abundance are reported per area or volumetric measure.

These surveys employ varying active and passive fishing gear types, which may or may not target blue crab. Gear discrepancies do exist within the surveys. For example, in the HTS, nets of different mesh sizes have been used throughout the years the survey has been performed. Our data will be corrected to account for these changes where applicable. This could include exempting data from non-typical mesh sizes. I may establish a range of size exclusions by survey determining standard error of the mean from these data.

These surveys also employ mixed methodologies for site selection, including fixed stations, random stations and random stratified stations. For surveys employing a fixed station methodology, I will pare our data down to only stations that are continuously sampled. For surveys employing random or random stratified sampling methodologies, data from all sampling stations will be used. When using these data in our correlations and predictive models for individual watersheds, I will further cull the data to reflect those data from only sites within the watershed boundaries.

Fisheries dependent data are collected via daily or weekly trip tickets which are reported to SCDNR by licensed wholesale vendors as part of their licensing agreement. These fisheries dependent data consist of general abundance information by reporting area, typically eight to ten-digit watersheds (USGS hydrologic units), with binned size data. Although these data can be used for temporally-based, abundance information, they only reflect abundance of blue crab above the 127 mm size limit.

### Survey Data Wrangling (includes CPUE generation)

Fisheries dependent commercial landings and fisheries independent survey abundances were truncated from statewide data to Charleston Harbor watershed data.

Pre-processed fisheries independent data were received from the Inshore Fisheries Research Section (Trammel Net survey) and the Environmental Research Section (SCECAP Open Water and SCECAP Tidal Creek surveys)…

Raw fisheries independent data from the Harbor Trawl, Creek Trawl, and Ashley Potting surveys were exported from Microsoft Access databases, maintained by Crustacean Research and Monitoring Section (CRMS) of the South Carolina Department of Natural Resources’ Marine Resources Division. These raw data were standardized to gear and sampling time (Table ) and expressed in survey-specific catch per unit of effort (CPUE).

Monthly means across all stations were used to calculate mean annual abundances as catch-per-unit-effort (CPUE).

### Size and Sexual Maturity Explanatory Variables

A range of biotic data (size, sex, maturity) are recorded as part of several surveys (Table 1). The CRMS harbor and creek trawl surveys have data on size, sex and maturity. The CRMS Potting survey has data on size and not sexual maturity, as these data are recorded in terms of legal (>127 mm) and sublegal (<127 mm) categories. Gear employed as part of the potting survey (38mm mesh) is size selective, targeting legal-sized crab, and allows escape of juveniles who have a length to width ratio of about 1:2 (Tagatz 1968). Size data are recoded as part of the SCECAP suite of surveys, but this survey’s data are rounded to the nearest centimeter in contrast to all other survey size data which are expressed in millimeters. Sexual maturity data are not recorded as part of the SCECAP suite of surveys. The trammel net survey has no size, sex or maturity data - only total abundance data per net deployment.

Individual crabs were assigned to the following size and sexual maturity categories (Table 1): Size Classes - juvenile (<60mm), subadult (61mm - 126mm), sublegal (<127mm) and adult (>126mm); Sexual maturity classes - mature female, immature female, mature male, and immature male. Sex and maturity were determined by presence of morphological characteristics of the abdomen as observed in situ. Size was determined by measurement of the carapace width in situ, from tip to tip. The juvenile size class of crab (<60mm carapace width) is based-on a trophic level shift in diet occurring in crab >60 mm carapace width (Laughlin 1982; Pattillo et al. 1997). The adult size class used (>127 mm carapace width) represents the legal-size limit for entry into the fishery in South Carolina. All crab with carapace widths between juvenile and adult sizes were considered subadult. Sublegal, when used, includes all crab <127mm.

Mean monthly CPUEs for size and sexual maturity variables were calculated by creating a percentage of total catch for each sampling event (e.g., trawl, trammel set, or pot set). These percentages were then applied to the standardized total CPUE for the sampling event. Sexual maturity CPUE variables are conservative estimates because some individuals were categorized as unidentifiable.

### Analytical Methods

Adult CPUEs were compared to juvenile CPUEs 1 and 2 years prior to test the applicability of a juvenile index. Additional indices of adult CPUE and total CPUE were developed using single regression models (n=) for each life-stage specific category at 1-yr and 2-yr lags. Significant (α = 0.05) models were ranked by explanatory power (i.e., r2)

## Results

### Long-term Trends of Abundance

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

Time series of mean annual commercial landings (Fig. 1) and adult abundances from SCDNR fisheries independent surveys (fig. 2) show the high inter-annual variablility of legal-sized "adult" blue crab (>126mm). These figures both show crab >126mm, which is the minimum legal limit of blue crab in South Carolina.

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 (>2003) landings data have incorporated data from the Ashley River and Cooper River reporting areas. This could be due to not being actively fished for blue crab, underreported for these reporting areas or included in another reporting area (e.g. a line of crab pots beginning in the Ashley River and continuing into Charleston Harbor where landings are eventually reported). Adult abundances from some surveys (B-Creek Trawl, C-Ashley Potting and D-SCECAP Open-Water) show a slight decline in adult abundance shortly after 2000.

### Juvenile Index of Adult Abundance

*\*Test the applicability of a juvenile index, where juvenile abundance in one year predicts adult abundance in a subsequent years (e.g. 1-yr and 2-yr lag)\**

Mean annual juvenile CPUE is not significantly related to mean annual adult CPUE in subsequent years for any survey (Table 3).

\*\*Table 3:\*\* Insignificant and poorly correlated relationships of adult CPUEs by juvenile CPUEs

### Indices of Adult and Total Abundance

*\*Explore other indices of abundance for size class and sexual maturity categories as they relate to total or adult blue crab abundance in subsequent years (e.g. 1-yr and 2-yr lag)\**

The CRMS Creek Trawl is the only survey (see notes for Tables 5 & 6) with predictive relationships where size class and sexual maturity categories relate to total or adult abundance in succesive years (Table 4). Fifteen size class and sexual maturity variables with 1- and 2-yr lag explain total CPUE and explain adult CPUE. The highest ranked model total Creek Trawl CPUE explained by subadult CPUE with a 2-yr lag (\*p\*-value = <0.01, r^2^ = 0.24; Fig. 3).

### Commercial Landings Predictions

\*Explore predictive relationships between fisheries-independent size class and sexual maturity abundance categories and commercial landings\*

Nine total predictive models using several size class and sexual maturity categories with 1-yr lag to explain effort corrected landings were developed. No 2-yr lagged size class and sexual maturity categories predict effort corrected landings. Predictive relationships were only found using the CRMS Harbor Trawl (N = 3) and Creek Trawl (N = 6) surveys. The strongest relationships ranked by explanatory power (r^2^) use the Harbor Trawl subadults with a 1-yr lag (\*p\* = <0.01, r^2^ = 0.43) and the Creek Trawl immature males with a 1-yr lag (\*p\* = <0.01, r^2^ = 0.41; Table 7).

Total landings (not effort corrected) have only two predictive relationships were size classs and sexual maturity variables from any survey predict total annual lbs landed (Table 8). These two poorly correlated relationships use mature males with a 1-yr lag from the Harbor Trawl (\*p\* = <0.05, r^2^ = 0.10) and adults with a 2-yr lag from the Ashley Potting Survey (\*p\* = <0.05, r^2^ = 0.15) to predict total annual pounds landed. Total landings data are missing for the Ashley and Cooper Rivers prior to 2004.

\*\*Table 7:\*\* Objective 3 - All significant relationships of effort corrected Charleston Harbor watershed (Ashley, Cooper and Wando Rivers and Charleston Harbor) commercial Landings by size classs and sexual maturity variables from all surveys using OLS regression.

ACCSP Non-confidential Landings by Species (Blue Crab), generated by S. C. 2020. Atlantic Coastal Cooperative Statistics Program. Arlington, VA. https://safis.accsp.org:8443/accsp\_prod/f?p=1490:310:2664292005781::NO::P310\_GO\_FLAG:-1.

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