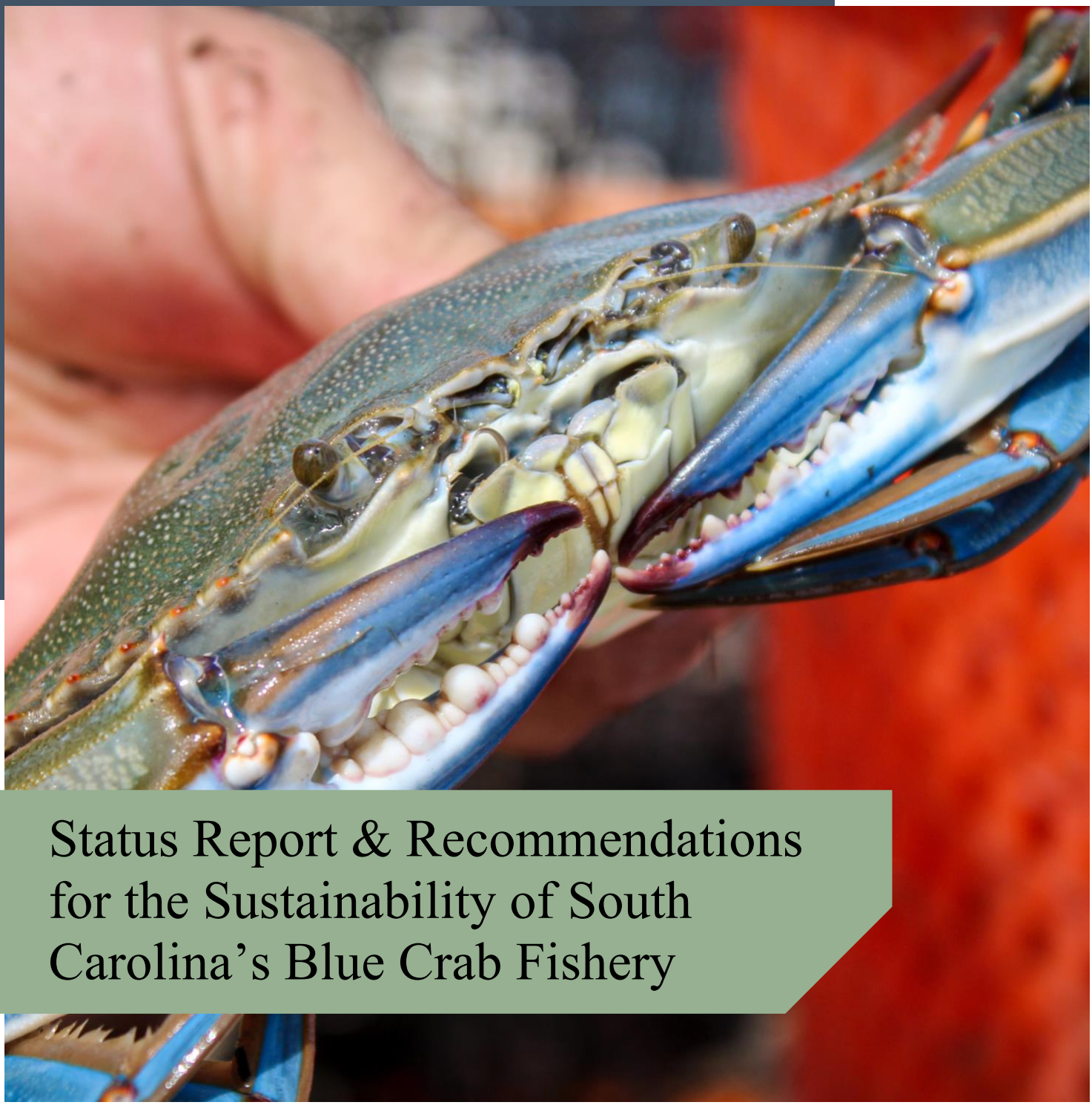

Status Report & Recommendations for the Sustainability of South Carolina's Blue Crab Fishery

South Carolina Department of Natural Resources

January 2023
Compiled by the Marine Resources Division
Charleston, South Carolina

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EXECUTIVE SUMMARY

Blue crabs are a vital species in South Carolina's waterways and shared coastal heritage. Archeological evidence shows that the first human inhabitants of the southeastern United States caught and ate blue crabs, and they've served as an important food source ever since. Today, blue crabs support one of the state's oldest and largest fisheries, with landings valued at over $6 million annually. They also form a critical link in the coastal food web, eating plants and small animals while serving as prey for larger animals such as fish, dolphins and sea turtles.

In recent years, both commercial and recreational crabbers have voiced concerns over the health of South Carolina's blue crab population. In 2021, South Carolina Department of Natural Resources (SCDNR) biologists and fisheries managers began taking a closer look at the factors that impact South Carolina's blue crab population, the history of regulations governing our fisheries and the status and perceptions of crabbers. A state budget proviso subsequently directed the Department to "produce a report on sustainability of the blue crab fishery and prepare recommendations for seasons, closed zones and catch limits" by January 10, 2023. This report provides an overview of the state's blue crab research and monitoring efforts, commercial and recreational crab fisheries, public perceptions of these fisheries and preliminary management recommendations. Here are key takeaways from each section:

SCIENCE & RESEARCH

Blue crabs have a complex life cycle with abundances that can fluctuate greatly from year to year in a large part due to responses to their environment, which is changing.

Since the late 1970s, SCDNR crustacean biologists have monitored the health of the blue crab population in South Carolina to manage the species for future generations. The team currently operates multiple surveys to study the blue crab's status across the state.

Data from these multiple surveys show that, beginning with a severe drought around 2000, blue crabs have experienced two decades of decline. Some numbers have begun to increase again, but concerning signals in the data remain, including continued declines in crab abundance during the fall, the season when most crabs are harvested commercially.

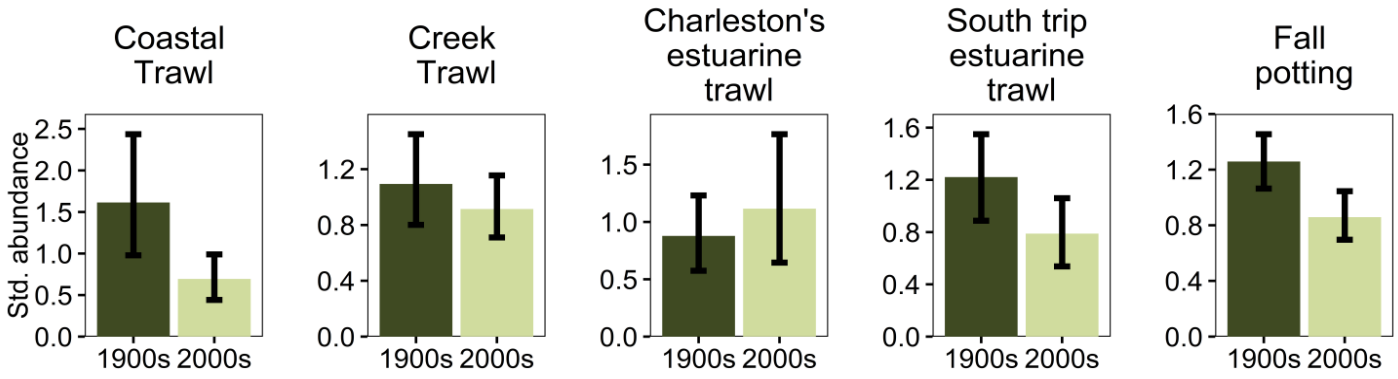

Figure 1. Comparison of mean standardized blue crab abundances (± confidence limits) from five SCDNR fisheries-independent surveys between samples collected through 1999 and since 2000.

COMMERCIAL & RECREATIONAL FISHERIES

The vast majority of South Carolina's crab harvest is commercial. Recreational crabbers are believed to represent a relatively small fraction of harvest pressure in South Carolina.

Economic and environmental pressures elsewhere along the east coast of the United States strongly impact South Carolina's commercial blue crab fishery. Shortages of crabs in the mid-Atlantic United States, for example, have driven prices high coast-wide, subsequently increasing harvest pressure in South Carolina. Landings have declined in recent years, reaching a 50-year low in 2021. At the same time, because of soaring prices nationally, the total value of landings is near record levels (Figure 1).

South Carolina has not passed new regulations related to blue crabs in decades. The fishery is underregulated and likely overcapitalized compared with neighboring states.

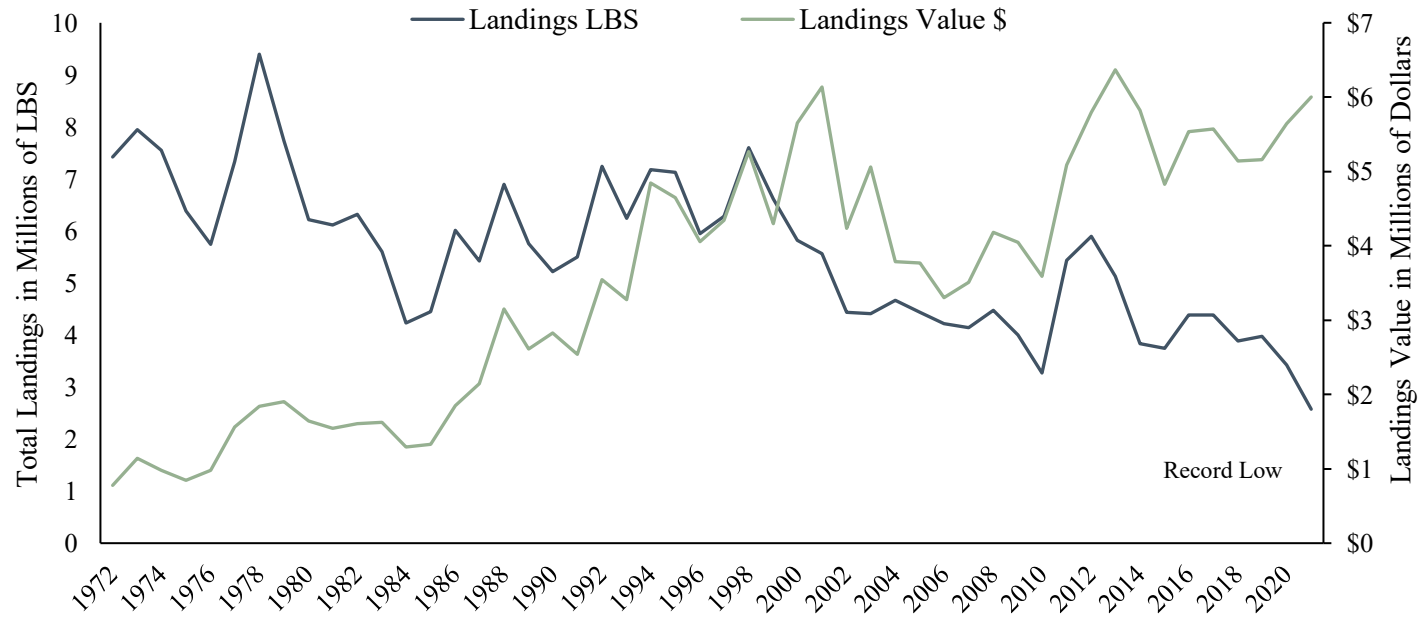

Figure 2. Annual commercial blue crab landings and wholesale value in South Carolina.

PUBLIC PERCEPTIONS

In summer 2022, SCDNR Marine Resources Division staff surveyed both recreational and commercial crabbers on their fishing practices and perceptions of South Carolina's blue crab fishery. The majority of both recreational and commercial crabbers perceive that blue crabs are less numerous than they used to be. Both recreational and commercial crabbers provided support at varying levels for potential management options. Recreational catch limits and commercial pot limits were fairly well supported, as was limiting the number of licenses. Commercial crabbers expressed particular concern over the peeler fishery.

RECOMMENDATIONS FOR A MORE SUSTAINABLE FISHERY

The following suite of recommendations includes both data collection and management measures, as well as adjustments to existing Code and operations. The data collection and management measures are intended to prevent the potential for overharvesting and to gradually reduce fishing pressure. The adjustments to code and operations are intended to clarify and augment existing measures to help prevent overexploitation and to strengthen enforcement capabilities.

1. Set a cap of 100 commercial crabbing licenses in the blue crab fishery.
2. Set the maximum number of crab pots allowed per commercial license at 200.
3. Establish a recreational blue crab daily catch limit of 1/2 bushel per person per day and a daily boat limit of 1 bushel per day.
4. Authorize the Department to respond in a timely manner to ensure sustainability of the fishery through management actions such as closures on an as-needed basis in response to resource conditions or trends, environmental or biological factors related to blue crab population health, and emerging threats.
5. Establish an annual two-week period (January 16-January 29) when all crab pots must be removed from the water to allow for the identification and removal of abandoned and derelict pots.
6. Reduce latent capacity in the fishery by (a) creating an "enhanced recreational crab pot fishery endorsement" for individuals who hold a valid saltwater recreational fishing license that wish to fish up to 10 pots (which is expected to reduce the number of licensed commercial crabbers), (b) adjusting the current fee structure for commercial crab trap/pot licensing to allow for desired effort and (c) clarifying language in existing South Carolina Code of Law Sections regarding the operation of licensed commercial blue crab pots by others than the licensee.
7. Codify the description of a legal blue crab pot/trap, including a requirement for escape rings/vents (to allow for the escape of undersized crabs) for both recreational and commercial pots.
8. Establish a certification process for all Peeler (soft-shell crab) Dealers to certify that such dealers have bona fide peeler crab shedding facilities.
9. Increase funding to support expanded and new, essential blue crab-focused biological, population and fishery data collection and monitoring efforts.

A BRIEF HISTORY OF BLUE CRAB PROTECTIONS IN SOUTH CAROLINA

See Appendix A for a more complete history.

1906	The South Carolina Board of Fisheries is established.
1924	A $5 annual blue crab fishing license is required by the General Assembly.
1935	The Legislature authorizes the Board of Fisheries authority to manage blue crabs.
1938	The General Assembly makes it illegal to harvest or possess sponge (egg-bearing) crabs.
1939	The fee for a crabbing license is reduced from $5 to $1.50 to encourage more crabbers to buy a license and thus help the state better quantify total effort and catch.
1941	A minimum size width of 5 inches for blue crabs is passed.
1953	Crab trawls towed by shrimp trawlers in sounds and bays become legal.
1950s	Crab pots and/or strings of crab pots must be licensed.
1979	The first comprehensive peeler crab industry law is enacted.
1984	It becomes lawful to import small crabs as peelers with a permit.
1986	All trawling in sounds and bays is outlawed.
1989	Act 170 outlaws the use of crab pots/traps in the legally defined freshwaters of the state.
1990	Act 541 allows crab trawling by permit from Dec. 1 to Mar. 29. Act 536 (Code 50-17-716) requires that all crab pot floats must be of solid construction.
1996	A committee of commercial crabbers and Marine Resources Division staff convenes to recommend improvements in blue crab laws.
1997	The General Assembly approves legislation requiring escape rings in commercial crab pots and identification numbers on commercial crab boats.
2002	The Marine Resources Division establishes another citizen's committee to make recommendations in response to reports of poor catch rates of blue crab.
2005	Final recommendations go to the SCDNR Board but are strongly contested by a small number of commercial crabbers and ultimately do not pass to the legislature.
2008 & 2018	Various parties express renewed interest in improving blue crab regulations that ultimately do not proceed.
2022	Crabbing in the General Trawl Zone is outlawed when shrimp season is open.
2022	Legislature requests a comprehensive report on the sustainability of South Carolina's blue crab fishery, including recommendations to improve the fishery.

I. SCIENCE & RESEARCH

KEY MESSAGES

- Blue crabs have a complex life cycle and require access to high quality habitat in the open ocean, salt marshes and estuaries to reach maturity.
- SCDNR biologists look at many sources of data when determining the health of a population. For blue crabs, those sources include seven SCDNR research surveys that have been conducted in South Carolina waters, some for several decades.
- SCDNR data show blue crab abundances that are lower in the 2000s than in the 1900s. North Carolina and Georgia have seen similar declines in blue crabs since 2000.
- Data show that South Carolina's estuaries have become saltier and warmer, shifts that appear to be influencing blue crab abundance.

BIOLOGY AND ECOLOGY OF BLUE CRABS

Understanding the biology and ecology of Atlantic blue crabs (*Callinectes sapidus*) is critical to making effective management decisions. This is especially true when there are indications of declines since intrinsic biology and organismal interactions with their environment affect population dynamics. For a species that is heavily targeted for both commercial and recreational harvest, understanding how the environment affects the population is an important component of ensuring the effectiveness of fisheries management strategies.

Blue crabs make use of oceanic and estuarine habitats at different points in their life cycle (Figure 1-1). Oceanic habitats are especially important for the early developmental stages of blue crabs, whereas estuaries provide critical habitat for juvenile, subadult, and adult blue crabs. Estuaries also provide abundant food resources and refuge from predation. Because blue crabs are generalists both in terms of their predatory feeding strategies and their environmental requirements (Hines, 2007), they can thrive in a variety of habitats across their geographic range.

Estuarine systems in South Carolina are very different from those in the Chesapeake Bay and along much of the North Carolina coast, where most research on blue crabs has historically been conducted. In those areas, expansive bay systems are dominated by submerged aquatic vegetation, whereas in South Carolina, as well as in Georgia and the southern North Carolina coast, submerged aquatic vegetation is not available to blue crabs (Posey *et al*., 2005). Rather, these coastlines are dominated by extensive salt marsh systems characterized by dense stands of smooth cordgrass (*Spartina alterniflora*) and intertidal oyster (*Crassostrea virginica*) reefs, both of which provide important habitat for blue crabs. These estuaries also experience substantial semi-diurnal tidal ranges of up to eight feet that generally result in marshes being inundated twice daily.

Photo 1-1. A crab megalopa (Photo: SCDNR)

The early life stages of blue crabs are spent primarily in high-salinity oceanic waters (Epifanio, 2019). After eggs hatch near the mouth of estuaries or in the open ocean, larvae are swept out to sea and develop through seven to eight planktonic stages known as zoea (Costlow, 1965), a process that takes approximately 31-49 days. During this time, they feed primarily on small zooplankton. Zoea then molt into megalopae, the earliest stage to possess claws (chelae) (Photo 1-1). At the megalopal stage, crabs begin their migration into the estuary (Olmi, 1986), rising in the water column to catch

flooding tides and settling to the bottom as the tide becomes slack before it ebbs (Forward *et al*., 2003). This system of navigation allows crabs to make use of currents for ingress into estuaries. The length of time that blue crabs remain in the megalopal stage depends on many factors but generally ranges from 20-40 days along the mid-Atlantic coast (Sulkin & Van Heukelem, 1986; Lipcius *et al*., 1990; Forward *et al*., 1994). Megalopae then molt into the first juvenile crab stage, at about 2.5 mm in width, and take on the recognizable crab shape that they will retain for the rest of their lives.

Juvenile blue crabs disperse throughout the estuary, but they are more often found in lower salinity (brackish) areas (Mense & Wenner, 1989; Bishop *et al*., 2010; Posey *et al*., 2005). Sampling in South Carolina has demonstrated that blue crabs of all sizes use subtidal habitats in open water and tidal creeks (Mense & Wenner, 1989; Archambault *et al*., 1990). Recent research in South Carolina has also demonstrated that juvenile crabs use the marsh surface when it is inundated (Julien *et al*., 2020), as has been documented in other regions in the South Atlantic Bight (Fitz & Weigert, 1991; Johnson & Eggleston, 2010). Although it has generally been thought that blue crabs leave the marsh to inhabit subtidal areas within tidal creeks during low tide, there is increasing evidence that many crabs will remain on the marsh surface (Johnson & Eggleston, 2010; Johnson, 2022). Due to their value for refuge from predation and abundant food resources, salt marsh and oyster reef habitats are particularly valuable for juvenile crabs in South Carolina.

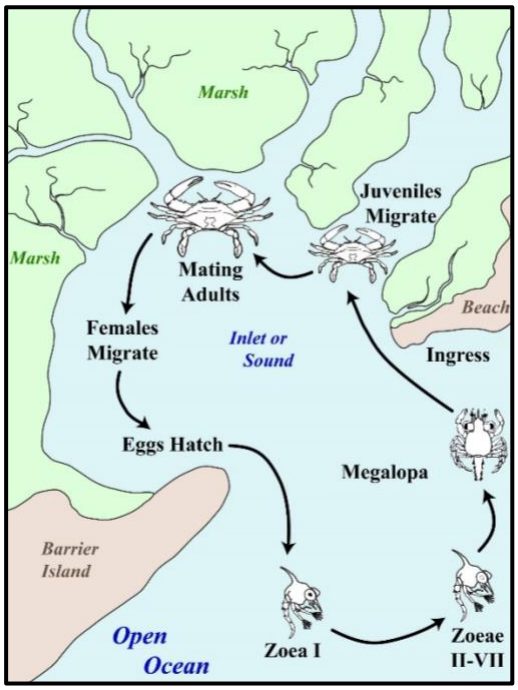

Figure 1-1. The blue crab life cycle

Adult blue crabs are known to migrate throughout the estuary in response to seasonal temperature changes and seek optimal conditions for offspring development (Whitaker *et al.*, 1998). Adult blue crabs may seek out warmer open and offshore water habitats during colder parts of the winter (Fischler & Walburg 1962), but crabs typically migrate back into the estuary with warming spring temperatures (Powers *et al*., 2009), after which female crabs again migrate seaward (Archambault *et al*., 1990). The migratory patterns of adult blue crabs are also associated with reproduction. Mating of blue crabs in South Carolina, for instance, is thought to occur primarily in upper estuary waters from March through September (Eldridge & Waltz, 1977), with peaks reproductive activity occurring in May-June and August-October (Mense & Wenner, 1989). Mating occurs when female crabs transition from immature to mature form. Prior to molting into mature crabs, immature female crabs (referred to as sallies) will actively seek out mature male crabs (referred to as jimmies). Following the female's molt, and while her shell is still soft, the male crab will transfer spermatophores to the female's seminal receptacle. A mature male crab will protect a mated female during this molt period. Once the female's shell has hardened, the newly mature female is not expected to mate again and thus this is the female's terminal molt. The female will use the same set of spermatophores to fertilize multiple broods of eggs over the course of several months.

After mating, mature females (referred to as sooks) migrate seaward using ebb-tide transport (Forward *et al*., 2003) to the mouths of estuaries or into coastal waters to spawn and release their eggs (Fischler & Walburg, 1962). As they approach the mouth of the estuary, the female extrudes her fertilized eggs that then adhere to her underside. It takes about two weeks for the eggs to hatch. On the average, female blue crabs produce ~2 million eggs (Milliken & Williams, 1984, Prager et al., 1990), although it has been suggested that only one out of every million survives to adulthood (van Engel, 1958). Due to their reproductive migration seaward, sponge crabs (those carrying eggs, also termed ovigerous or in-berry) are generally restricted to higher salinity (>15 psu) areas (Archambault *et al*., 1990).

The timing of spawning is important for determining when young crabs will enter the commercial fishery. Research in South Carolina has demonstrated that the peak in ingress of megalopae occurs in late summer and fall (*i.e.*, late August-October; Olmi & Sandifer, 1986; Mense & Wenner, 1989; Boylan & Wenner, 1993), further supporting the conclusion that blue crab spawning activity has historically been greatest in late summer. Mense & Wenner (1989) found additional pulses of larval ingress in the spring. Archambault *et al.* (1990) suggested that juvenile crabs grow very little during the winter months, since crabs do not grow or molt below 9°C (Smith & Chang, 2007). These authors concluded that it takes as many as 20 months for female crabs to reach sexual maturity. Crabs that were spawned in early spring are present in the estuary throughout the summer and fall, when growth rates are highest, and become peelers the following spring, thus forming the next year's spawning stock. Crabs that were spawned in mid- to late-summer typically enter the fishery the following fall and winter.

Photo 1-2. SCDNR crustacean biologists Kristin Hamilton (former staff) and Jeff Brunson take the measurements of a mature female blue crab aboard the Department's monthly estuarine trawl survey in Charleston Harbor aboard the R/V *Silver Crescent*. (Photo: Erin Weeks/SCDNR)

SCDNR MONITORING EFFORTS & DATA

SCDNR biologists make use of many different data sources to track population trends of commercially and recreationally important species, including the blue crab. These sources include information directly from the fisheries themselves (*i.e.*, commercial landings data) but also include surveys that are conducted separately from the fishery, termed fishery-independent data sources. These fishery-independent data sources include standardized surveys that are designed to collect a wide range of information to help guide management decisions, including information on individual specimens (*i.e.*, size, sex, life stage, maturity status) and the total numbers of each type of specimen collected. These data can be used to track changes in total abundance (*e.g.*,

the number per sampling effort) and occurrence (*i.e.*, presence or absence), as well as trends in abundance, occurrence, phenology and size for specific sexes and/or life stages.

Fisheries-Independent Data Collection

SCDNR's Marine Resources Division staff track blue crabs in seven standardized monitoring surveys:

1) The *estuarine trawl survey* (1979-present) is conducted at fixed stations throughout the state with monthly sampling in the Charleston Harbor estuary and additional sampling in March, April, August and December south of Charleston Harbor to the Georgia border. Since 2002, this survey's gear has been standardized to one 6-m headrope otter trawl net with 2.54-cm stretch mesh and a 9-mm tickler chain towed from a stern-rigged trawler near low tide for 15 minutes at ~2 knots.

2) The *creek trawl survey* (1979-present) is conducted monthly from May to August at seven fixed stations in tidal creeks of the Ashley River and Wando River watersheds of the Charleston Harbor estuary. A 3-m head rope length otter trawl net with 6.4-mm heavy delta mesh is towed for 5 minutes behind a small (17-ft) outboard vessel towards the mouth of the creek near low tide. This survey recently expanded to a year-round, monthly sampling regime.

3) The *fall pot survey* (1988-present) is conducted in October and November across six estuaries using a 61-cm x 61-cm x 61-cm crab pot with 3.8-cm black, vinyl coated mesh. Each pot is baited with one menhaden (*Brevoortia tyrannus*). Within each estuary, 3 blocks are randomly selected from 5 possible blocks, with each block consisting of 5 baited pots set 100 m apart and soaked for 4 hours.

4) The *coastal trawl survey* (1986-present) samples nearshore trawlable habitat (mostly sandy and muddy bottom) in state and federal waters from central North Carolina to central Florida. The survey samples at depths from 15 to 30 feet. Samples are collected aboard the *R/V Lady Lisa* by towing a pair of 75-ft mongoose-type Falcon Trawls for 20 minutes. SEAMAP-SA Coastal Trawl Survey cruises are conducted each year in spring (mid-April to the end of May), summer (mid-July to mid-August), and fall (late September to mid-November).

5) The *South Carolina Estuarine and Coastal Assessment Program* (SCECAP; 1999-present) collects trawl samples as one part of the biological sampling component of a broader statewide habitat assessment monitoring survey. The SCECAP survey dataset is an aggregate of two trawl surveys ("Open Water" and "Tidal Creek"). The trawl surveys collectively sampled 50 to 60 stations annually in the summer months (July to August) from 1999-2006, until switching to a 30-sites-per-year sampling regime from 2007-present. Half of the annual stations are designated as open water stations (>100 m marsh bank to marsh bank) and half are designated as tidal creek stations (<100 m to >10 m marsh bank to marsh bank). New stations are chosen annually using a stratified random sampling design. Two replicate samples are collected using a 5.5-m head rope length trawl towed within three hours of low tide.

6) The *trammel net survey* (2006-present) employs a random stratified survey design with up to 12 monthly sites randomly sampled from each stratum. The 18-m x 2.1-m monofilament trammel net uses a 63.5-mm stretch inner panel set between two 355.6-mm outer panels with a floating head rope and a weighted (22.7 kg) bottom line. The net is deployed in <2 m water depth parallel to the shore during an ebb tide (Arnott, 2014).

7) The *Cooperative Atlantic States Shark Pupping and Nursery* survey (COASTPAN; 2011-present) conducts gillnet sampling from April through October, with most effort occurring between May and September. The survey uses an anchored gillnet constructed of #177 monofilament twine with a

stretched mesh of 10.3 cm. This net is approximately 230 m in length and 3 m deep and is set in <4 m of water adjacent to shorelines and inspected for catch at approximately 20-minute intervals to reduce mortality during the ~5-hour gear soak time. Although smaller juvenile blue crabs are collected, primarily when associated with submerged macroalgae, only larger juvenile and mature crabs are counted, and neither sex nor size of crabs is currently recorded. Given the short timeframe of available data, trends for this survey are not included in this report.

SCDNR biologists evaluate data from these monitoring surveys annually to understand trends and changes in South Carolina's blue crab population. The estuarine trawl survey can be used to help highlight blue crab life history (Figure 1-2) showing seasonal patterns of abundance for juvenile, subadult and adult crabs. The seasons of highest abundance for juvenile crabs are generally winter and early spring, for subadult crabs are spring and early summer, and for adult crabs is summer.

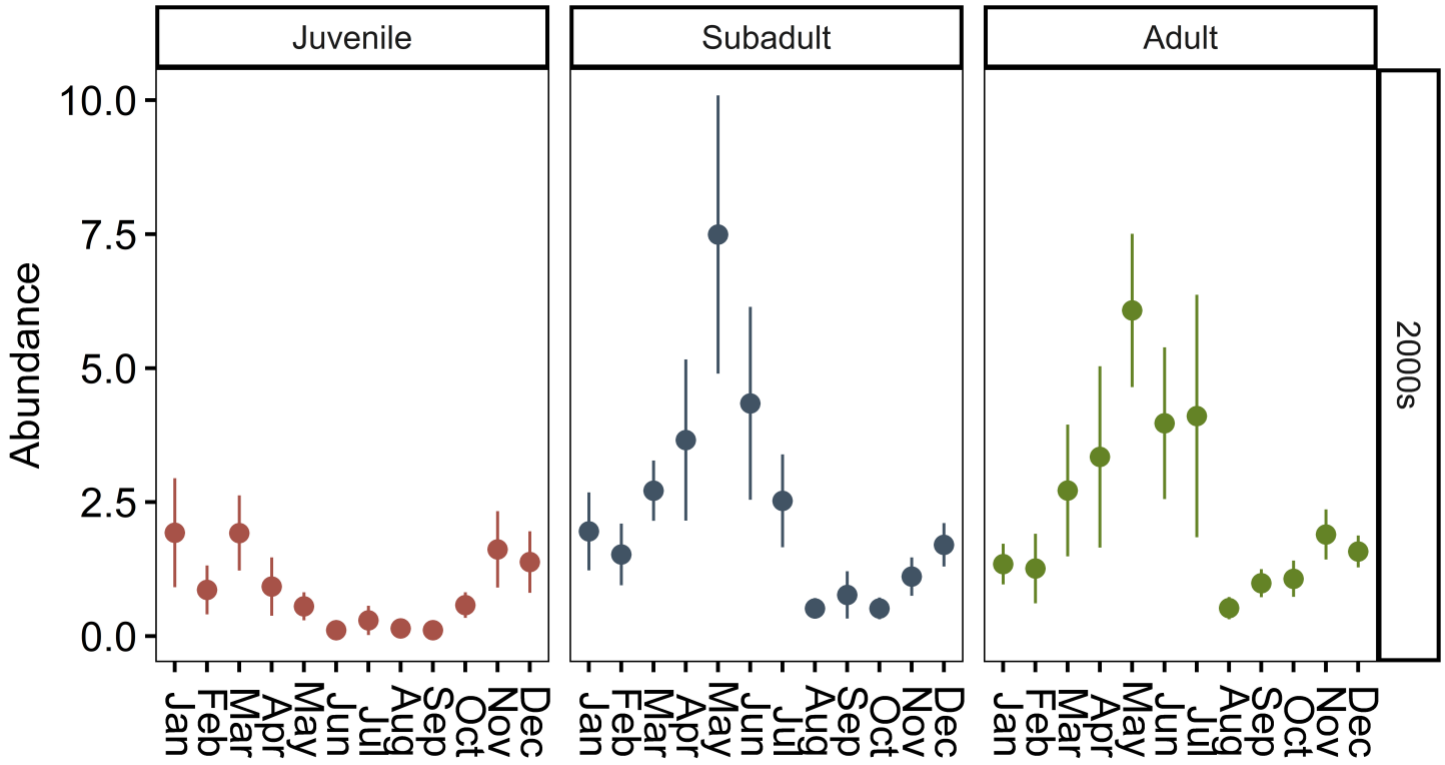

Figure 1-2. Monthly mean (with standard error) crab abundances from the estuarine trawl survey highlight the seasonal patterns of abundance for each of three life stages of blue crabs.

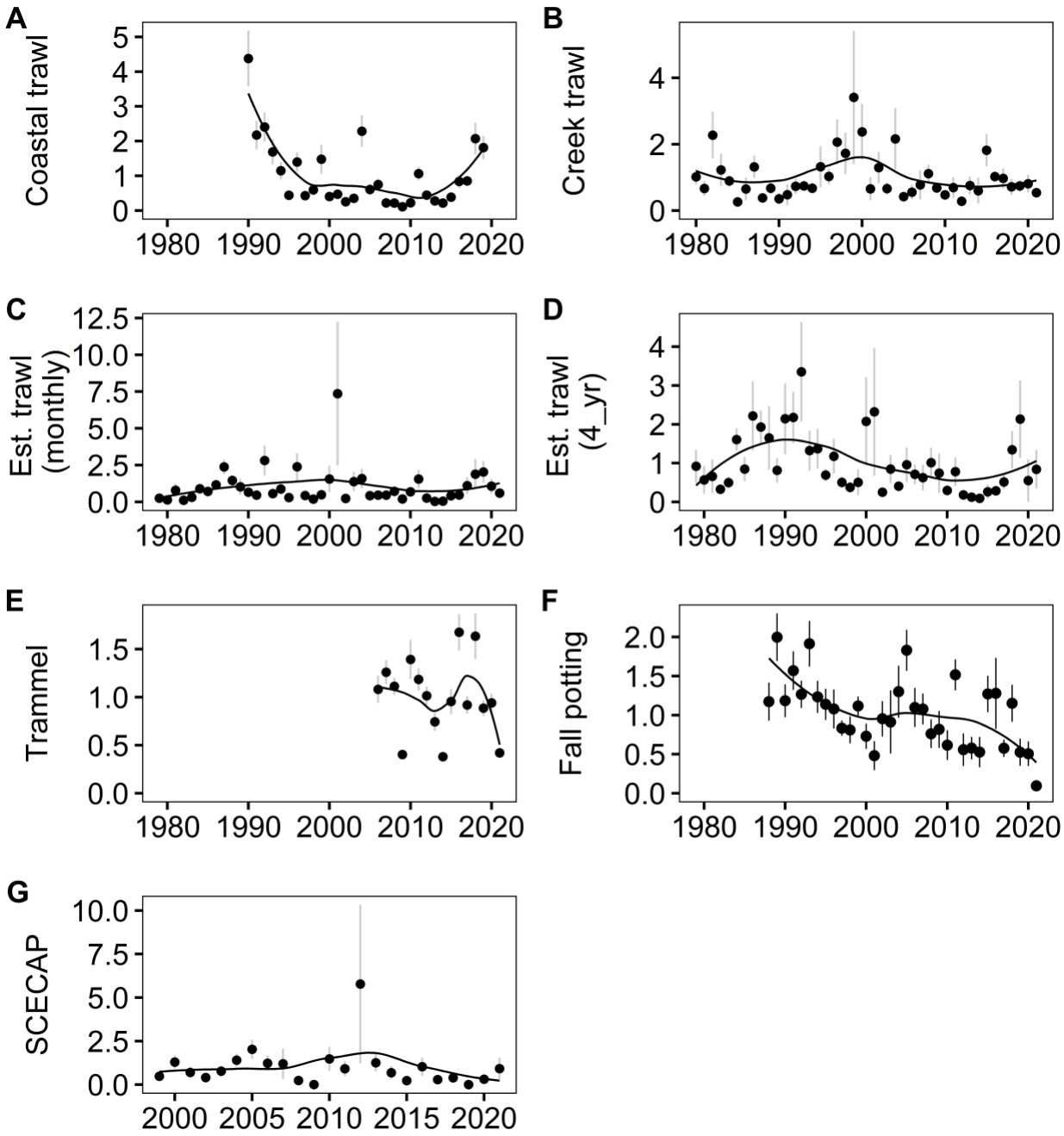

Figure 1-3. Annual standardized abundances (with standard error) of blue crabs for six surveys (data for the estuarine (Est.) trawl survey are separated into monthly and 4x/year sampling) conducted by SCDNR that encounter this species. Data from COASTPAN survey not shown due to limited time series.

Trends in annual abundance of legal-sized blue crabs from each of the seven surveys were variable (Figure 1-3) but generally show abundance patterns in recent years that are near-average for each survey and within historic levels. Some of the surveys show reduced blue crab abundance through the 2000s, but some recovery appears to have occurred since ~2017. The important exception is the continued decline of blue crab abundance in the fall potting survey, which shows a gradual decline since its inception in 1989 (Figure 1-3F). The patterns in South Carolina broadly mirror fisheries-independent data trends of abundances from both Georgia and North Carolina (Figure 1-4), which show somewhat higher abundances of blue crabs in the 1980s and/or 1990s but reduced abundances after 2000.

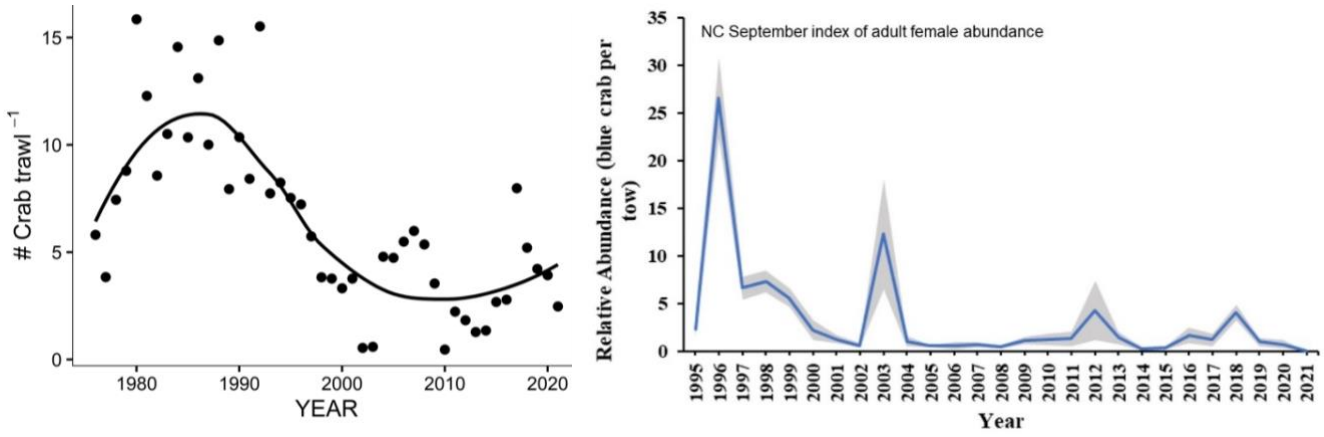

Figure 1-4. Blue crab abundances for fisheries-independent surveys conducted by the Georgia Department of Natural Resources (GADNR, left) and the North Carolina Division of Marine Fisheries (NCDMR 2022, right). GADNR's ecological monitoring trawl survey collects monthly samples across a statewide survey, while the NCDMF data show an index of adult female abundance for samples collected in September.

The difference in abundances between the 1900s and the 2000s is clearer when explicitly comparing standardized abundances across the broader time periods, with abundances for the coastal trawl survey and fall potting survey showing significantly reduced abundances in the 2000s (Figure 1-5). Two surveys (the estuarine trawl survey's south trip and the fall crab pot survey) can be used to assess spatial variability in these patterns (Figure 1-6). For both the estuarine trawl survey and fall pot survey, average legal-sized crab abundance was greater during the 1900s than during the 2000s, but the pattern did not differ across estuaries, nor was there an interaction between estuary and time period.

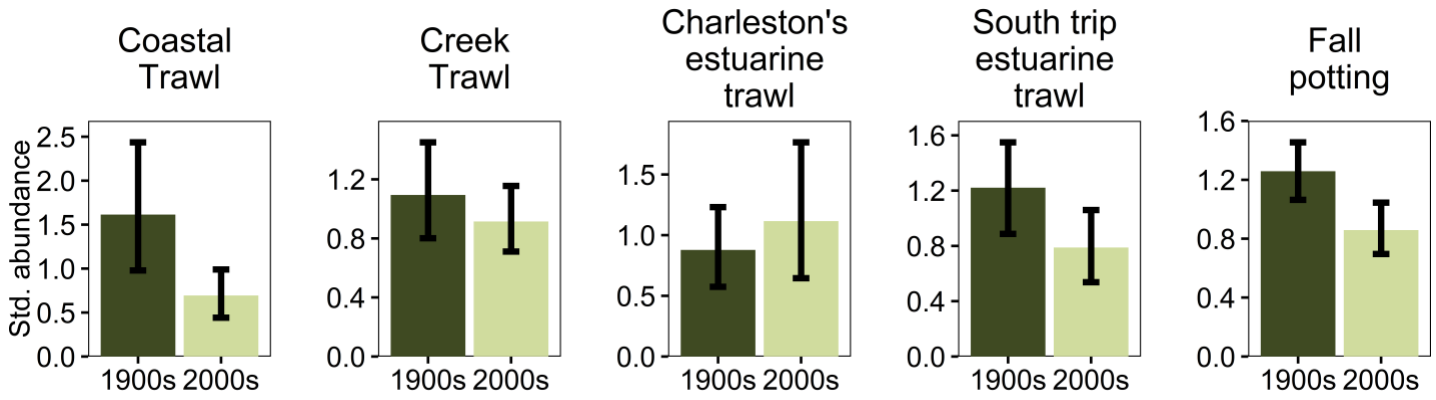

Figure 1-5. Comparison of mean standardized blue crab abundances (± confidence limits) from multiple fisheries-independent surveys between samples collected through 1999 (i.e., 1900s) and samples collected since 2000 (i.e., 2000s). Some surveys (i.e., trammel, SCECAP, and COASTSPAN) are not shown due to the lack of available data over these time periods.

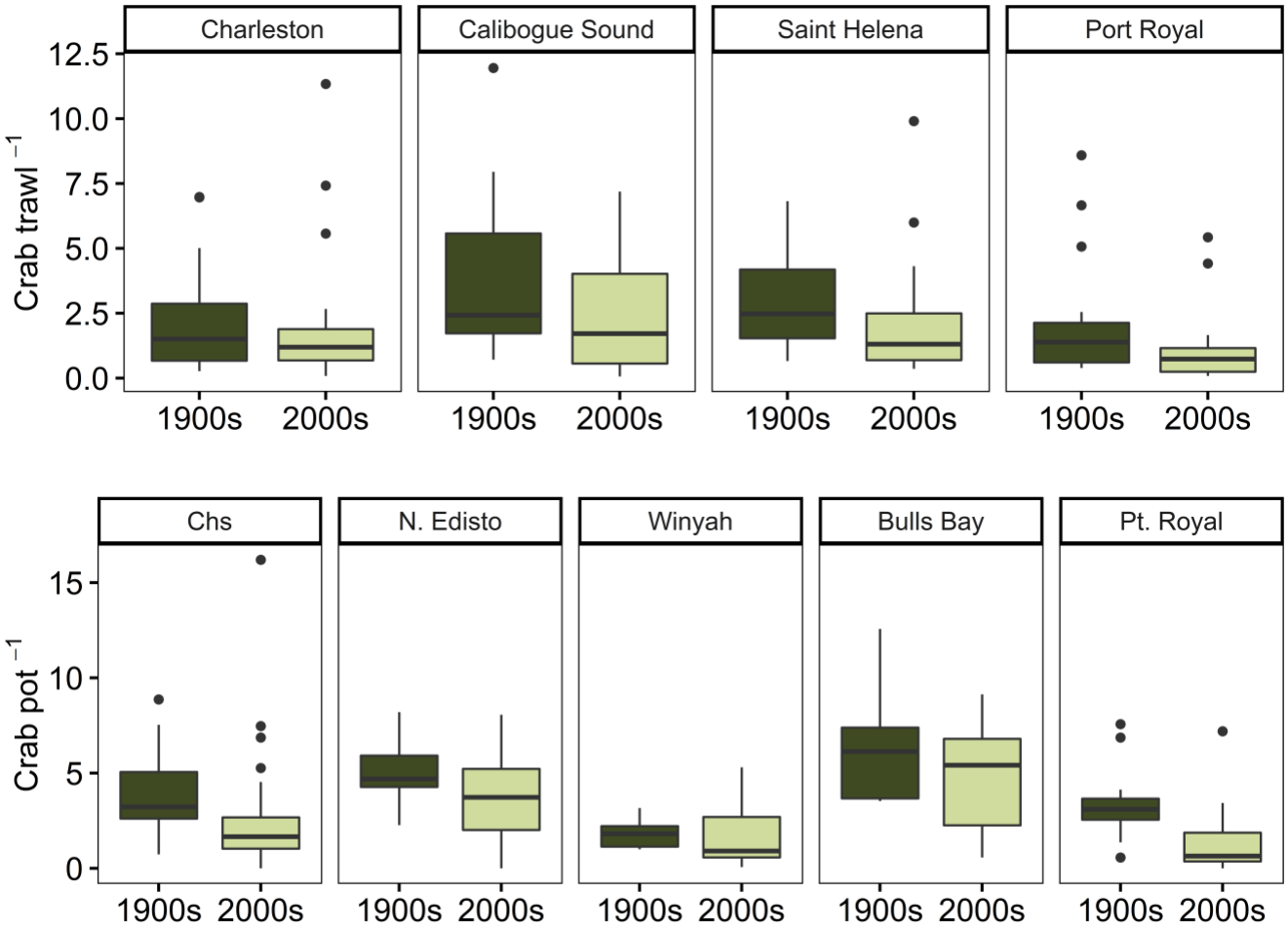

Figure 1-6. Estuary-specific comparison of blue crab abundances from the estuarine trawl survey (top) and fall pot survey (bottom) between samples collected through 1999 and samples collected since 2000. Chs = Charleston.

A similar pattern is seen across other crab life stages for the creek trawl and estuarine trawl surveys (Figure 1-7), for which abundances of these life stages were generally greater in the 1900s compared to the 2000s, and especially for the juvenile life stage. Abundance of subadult crabs was higher during the 1900s in the creek trawl survey, but not in the estuarine trawl survey. For sampling locations in the Charleston Harbor estuary, legal crab abundance was not different between these time periods for the estuarine trawl survey, nor the creek trawl survey.

In comparing seasonal patterns of adult blue crab abundance using the estuarine trawl survey's Charleston Harbor estuary data, fall is the only season when average abundances in the 2000s were lower than abundances in the 1900s (Figure 1-8). Spring and winter tended to show variable abundances with more recent upticks in catches during the late 2010s. Summer and fall catches peaked in the 1990s and early 2000s but have remained low in recent years.

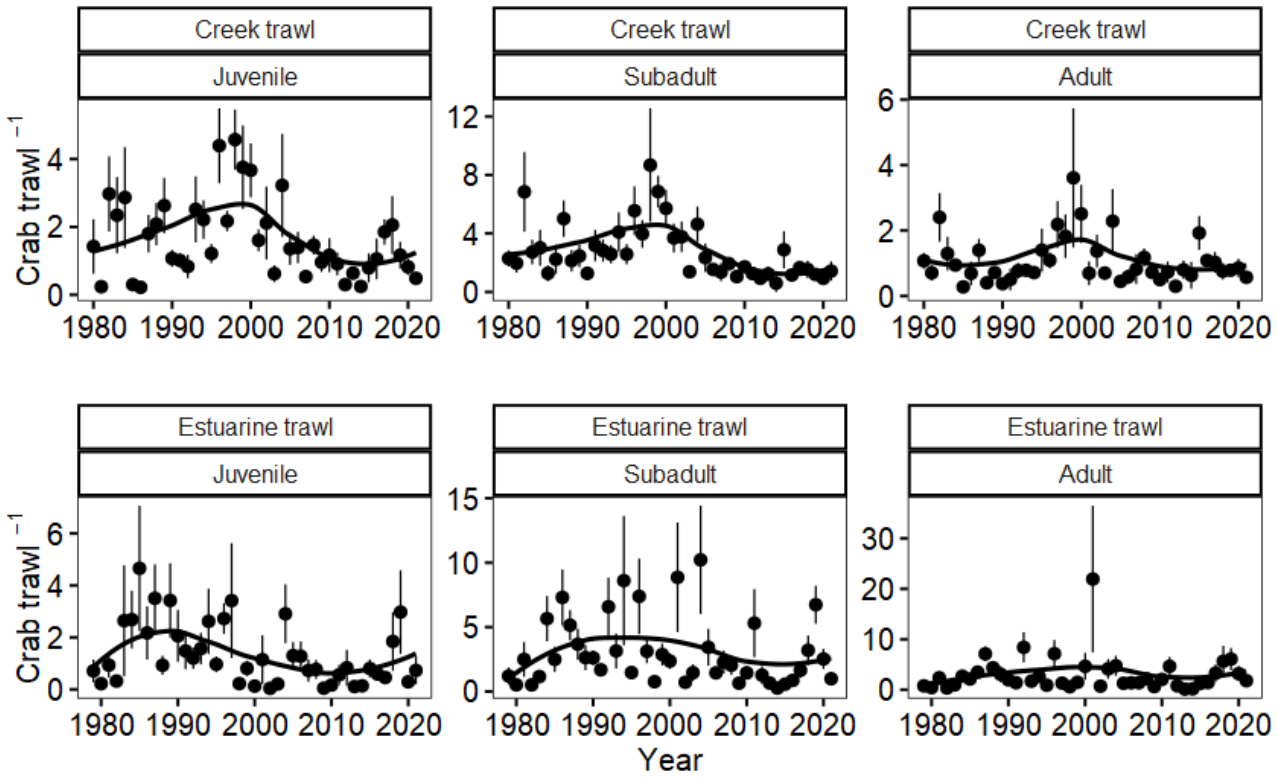

Figure 1-7. Time-series trends of life-stage-specific blue crab abundance trends for the creek trawl survey (top) and the estuarine trawl survey (bottom).

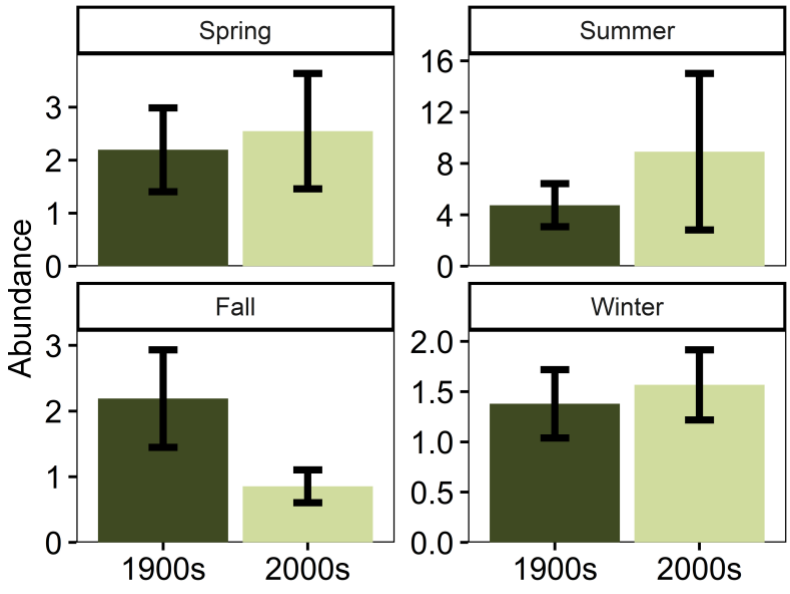

Figure 1-8. Seasonal trends in adult blue crab abundance for Charleston-based sampling as part of the estuarine trawl survey.

An evaluation of long-term patterns in blue crab size (Figure 1-9) demonstrates seasonal changes in the mean size of mature male and female crabs throughout the year. Seasonal patterns of female blue crab size appear to be driven largely by the presence of relatively small mature female crabs during the late spring and winter, followed by the absence of these smaller mature crabs in the fall. When comparing the 1900s with the 2000s, apparent increases in the average size of mature female crabs are evident for September, October and December. The pattern appears to be due to a reduced number of relatively small mature female crabs collected in these months in the 2000s and is reinforced by the finding that larger individual mature female crabs were collected in September and October of the 1900s as compared with the 2000s (data not shown). Crabs that are hatched from eggs at different times of the year (e.g., spring vs. fall), and thus experience different environmental (e.g., temperature) and ecological (e.g., population density) conditions as they grow, may help explain these patterns of crab size.

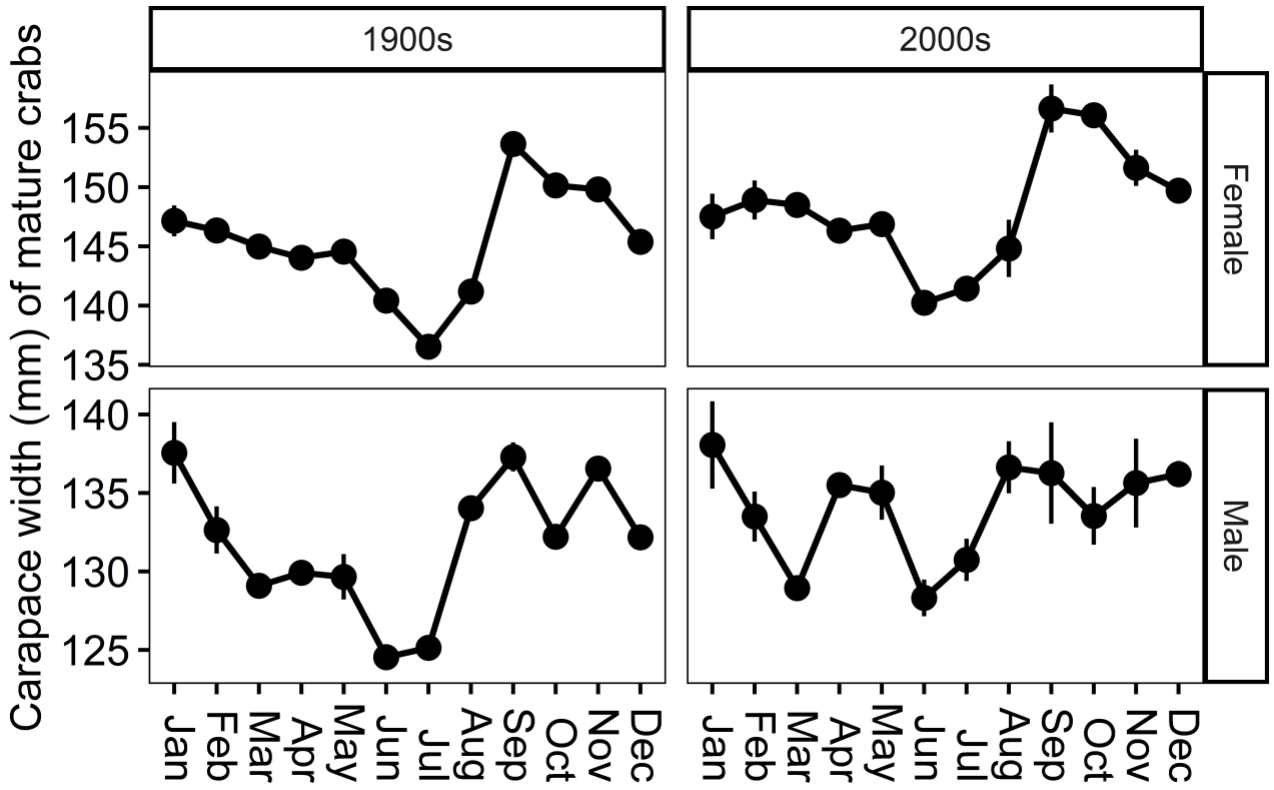

Figure 1-9. Monthly sizes of mature female (top) and mature male (bottom) blue crabs from the estuarine trawl survey, as compared between sampling conducted through 1999 (left) and since 2000 (right).

Trends in ovigerous (*i.e.,* egg-bearing) crab abundances demonstrate a slight shift in the timing and duration of spawning, with an apparent reduction in the number of ovigerous crabs in the fall, but an increase in the abundance of ovigerous crabs in the spring (Figure 1-10). The percent of ovigerous crabs in samples appears to be slightly higher in the 2000s as compared with the 1900s. The timing of onset of crab spawning is highly variable (Figure 1-11) from year to year, occurring, on average, on March 23. In 2019 and 2020, ovigerous crabs were recorded in February for the first time. A large proportion of the variability in the timing of the onset of spawning is attributed to winter water temperature, which accounts for 37% of interannual variability in the date of first appearance of an ovigerous crab in a given calendar year (Figure 1-11).

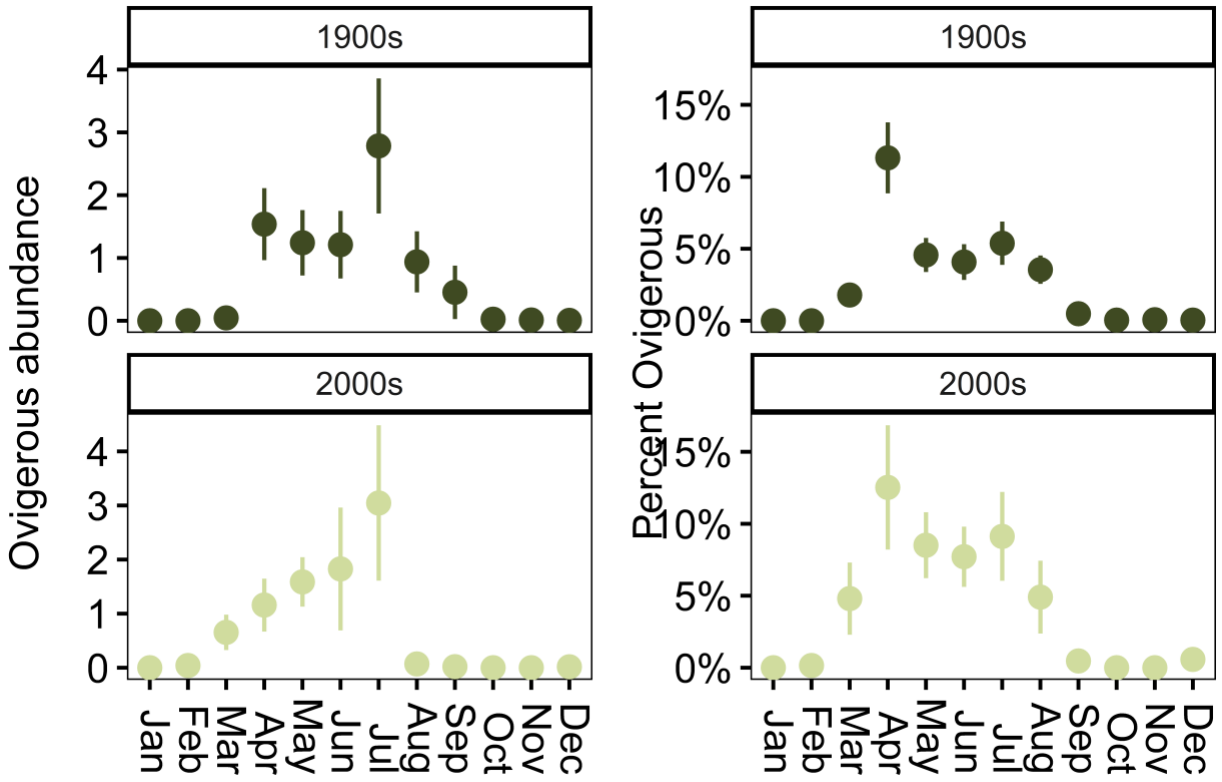

Figure 1-10. For ovigerous crabs (*i.e.*, egg-bearing or sponge crabs), mean (with standard error) monthly abundance values for ovigerous crabs (left) and mean (with standard error) percent of female crabs that are ovigerous (right).

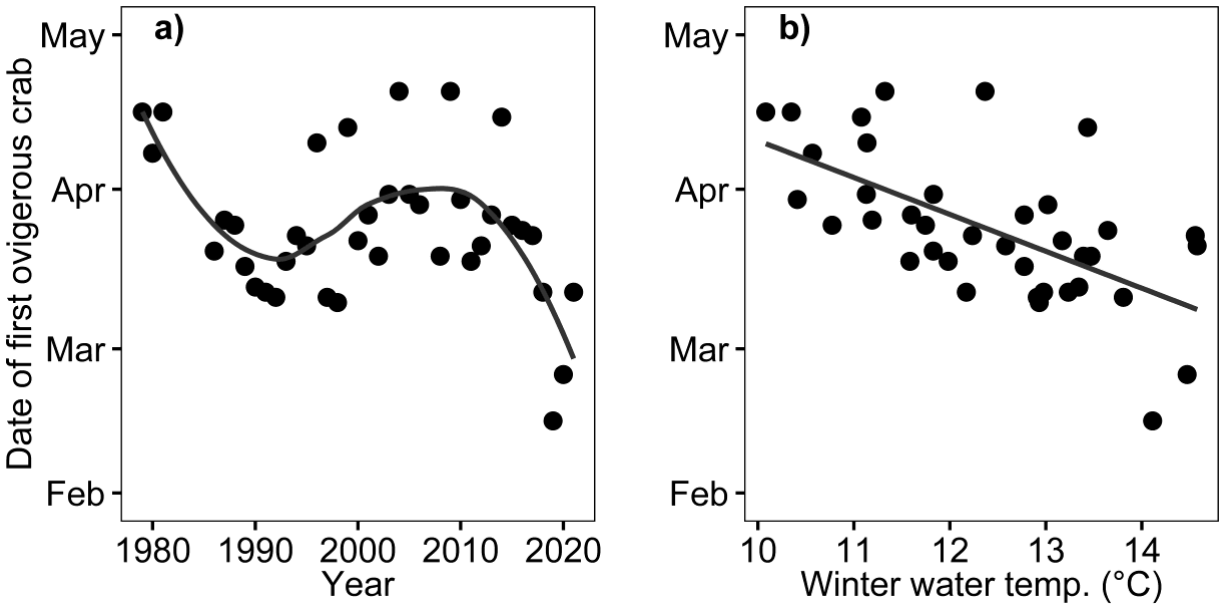

Figure 1-11. (a) The first date for which an ovigerous crab is observed (black circles) with a smoothed trend (black line) for every calendar year and (b) the relationship between this date and average winter water temperature in the Charleston Harbor.

Results from a short-term (2016-2021) crab potting project investigating the distribution of crabs along a transect from low to high salinity in the Charleston Harbor estuary highlight the presence of mature male crabs in low-salinity waters throughout the summer and early fall. Mature male crabs also show a clear size distribution along the low-high salinity continuum. The largest of the mature males are generally found in low-salinity habitats (Figure 1-12) where reduced fishing and predation pressures may afford some protection to these animals. This protection of large males in low salinity waters lessens concerns that sperm limitation is influencing population trends. An analysis of seasonal patterns of mature and immature male crabs across a gradient from low salinity (~2.1 psu) to mid-salinity (~12.2 psu), to high salinity (~21.3 psu) shows that mature male crabs are most abundant at higher salinities in July, August and September (Figure 1-13). Mature males are least abundant at low salinities in winter and appear rare at mid and higher salinities in March and when females are apparently male-limited (data not shown), setting the stage for the effective use of male-baited peeler pots during the spring.

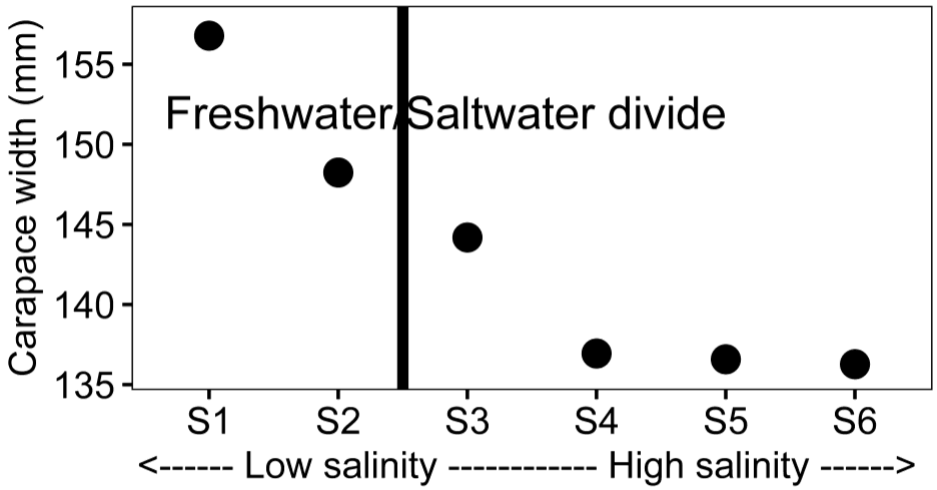

Figure 1-12. Mean carapace width of mature male crabs as collected from the salinity transect crabbing study showing spatial variation in male crab size from a low-salinity site (S1, mean salinity = 1.2 psu) to a higher-salinity site (S6, mean salinity = 21.7 psu) in the Charleston Harbor estuary.

Environmental conditions, particularly temperature and salinity, are important drivers of patterns of blue crab abundance. Winter water temperatures in Charleston Harbor are increasing. In the 2000s, water temperatures fell below the critical 9°C threshold (Figure 1-14), below which blue crab growth is arrested (Smith & Chang, 2007), in only 45% of winters. During the late 1900s, 80% of winters had water temperatures below 9°C. Temperatures are also increasing during the fall months (data not shown). Additionally, a significant drought also occurred in South Carolina beginning in 2001 and extending through 2012, resulting in a decrease in the number of years with statewide runoff above the long-term median value (Figure 1-14). The drought resulted in a shift in the salinity regime of the state's estuaries.

Juvenile crab abundance, calculated as the index of recruitment to late fall, winter and early spring abundances, was negatively related to winter water temperatures in the 2000s, with more individuals being found following cold winters; however, a similar relationship was not significant in the 1900s. When all data are combined, juvenile crab abundance is significantly greater in years following colder winters (Figure 1-15). Adult crab abundance showed no clear relationships with winter temperatures.

Adult crab abundance was significantly and positively related to an index of prior years' runoff for the 2000s (Figure 1-15); for the 1900s, this relationship was weaker but still significant and in the negative direction. When all data are combined, no significant relationship was documented for adult crab abundance in years

following greater runoff, (*i.e.*, fresher conditions and lower salinity). Juvenile crab abundance showed no clear relationships with runoff.

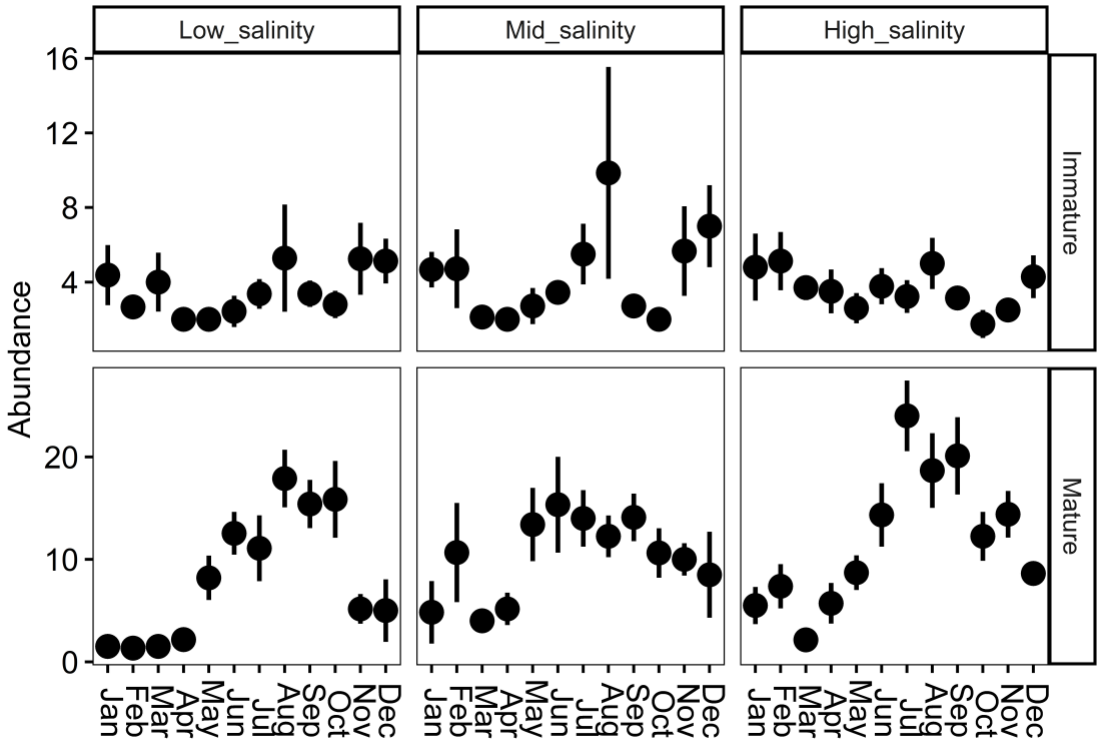

Figure 1-13. Monthly male blue crab abundances for immature and mature crabs for samples collected as part of the salinity transect crabbing study in Charleston Harbor.

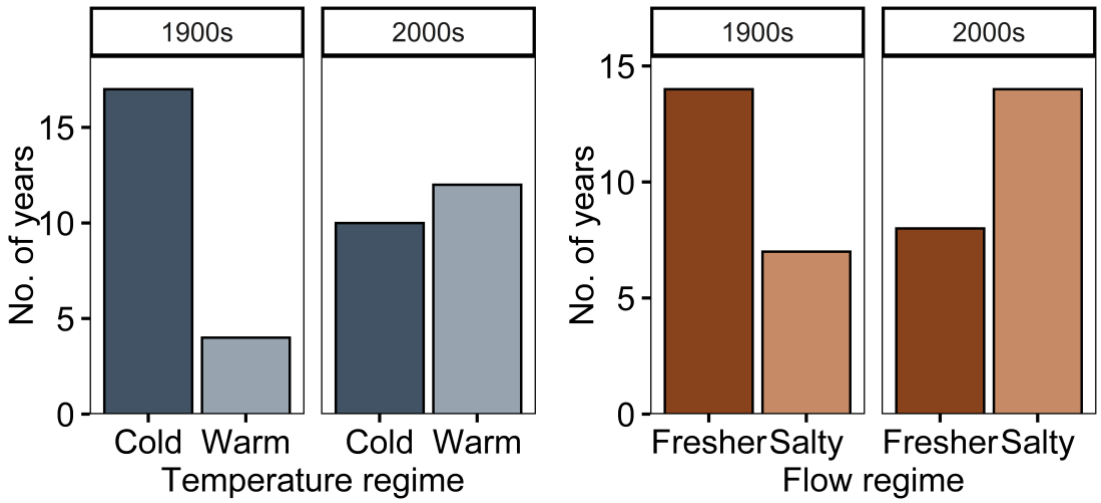

Figure 1-14. Count of the number of years falling into cold or warm categories (left) as defined by winter water conditions in the Charleston Harbor or fresher or salty conditions (right), as defined from statewide estimates of river runoff.

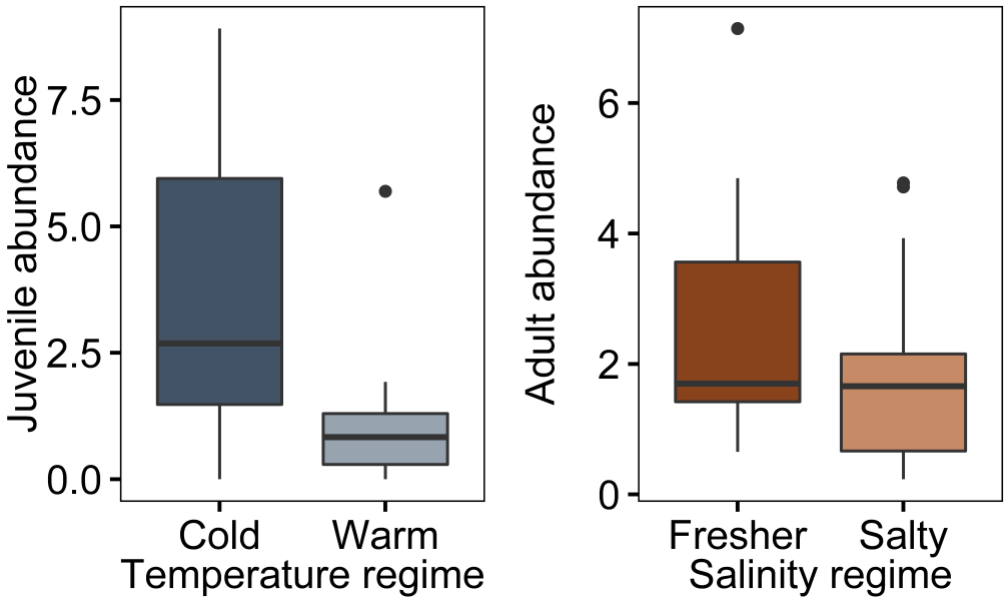

Figure 1-15. Comparison of juvenile abundance with temperature regime (left) and adult abundance with salinity regime (right) as compiled from environmental data and crab abundances from the Charleston Harbor as part of the estuarine trawl survey.

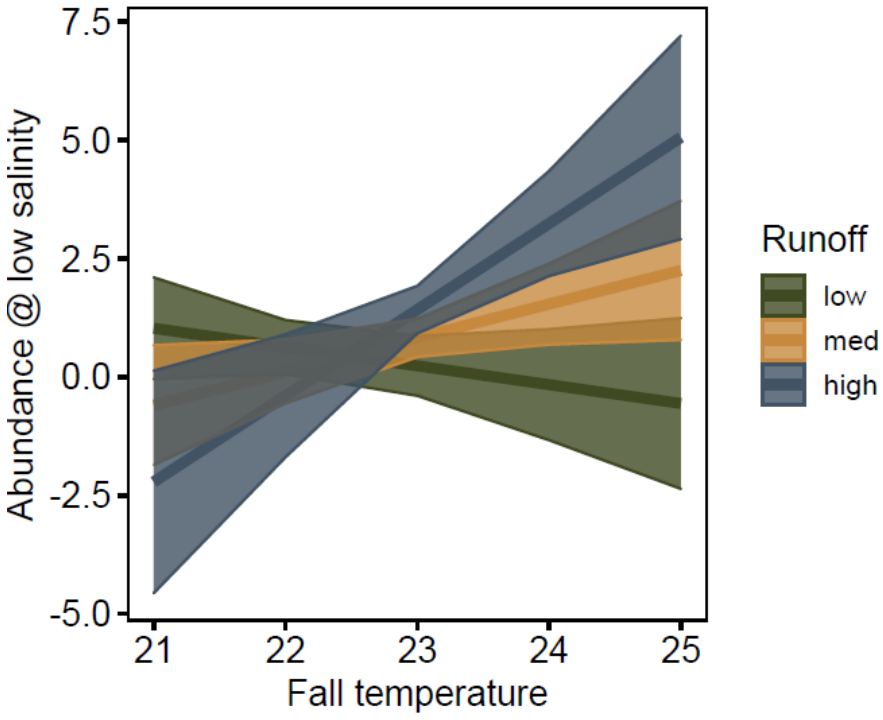

Figure 1-16. Results of multiple regression analysis showing both runoff and fall temperature are important predictors of blue crab abundance in low-salinity habitats of the Charleston Harbor estuary.

The combined effects of runoff and winter water temperature were needed to explain patterns of blue crab abundance, which showed one temperature response during periods of low runoff but a different temperature response during periods of high runoff. A similar model applied to the 1900s was not significant. Similarly, to explain patterns of abundance of blue crabs during the fall months at a lower-salinity site in the Ashley River, a tributary of Charleston Harbor, the previous years' runoff and the previous fall's water temperatures combined to explain blue crab abundance (Figure 1-16). During periods of high runoff, there was a positive relationship between fall temperature and the abundance of blue crabs in lower salinity waters. Together, these data indicate that both temperature and salinity are important factors affecting blue crab abundance.

TARGETED RESEARCH PROJECTS

SCDNR's Marine Resources Research Institute has a long history of blue crab-focused research projects intended to complement the long-term fisheries-independent surveys previously described.

SCDNR research staff published a study in 2017 that provides baseline genetic characterization of blue crab in Charleston Harbor, South Carolina (Cushman & Darden, 2017). This study found that genetic diversity was relatively high and the extent of inbreeding was fairly low. Effective population size estimates were on the order of several hundred to several thousand individuals. The results of the study exhibit positive indications for the overall genetic "health" of the Charleston Harbor blue crab population and provide valuable information that can be incorporated into management plans to aid in the conservation of blue crab in South Carolina. It may, however, be advantageous to periodically reexamine genetic diversity and effective population size in state waters, as decreases in population size affect genetic diversity.

In 2019, an undergraduate student conducted an experiment to investigate the effect of salinity on growth rates in juvenile male and female blue crabs. Results from the five-week experiment suggested that male crabs grew faster at low salinity (5 psu) than in at high salinity (25 psu) and that males grew faster than females at low salinity. These experimental results highlight that the differences in how male and female crabs interact with their environment occur very early in their life cycle. This type of research allows for the development of increasingly effective management strategies.

From 2021-2022, SCDNR biologists conducted a project to assess the use of different habitat types by juvenile blue crab and to test for relationships between blue crab and red drum abundance. The project surveyed subtidal creek bottom, marsh edge and interior marsh habitats in Charleston Harbor and Bulls Bay, finding no clear habitat preference. Analyses of long-term fisheries-independent data on both blue crab and red drum, however, revealed a positive relationship between subadult blue crab abundance from the estuarine trawl survey and red drum abundance from the trammel net survey, likely indicating that when conditions support high blue crab abundance, those same conditions also support higher red drum abundance.

To improve our understanding of patterns of early-stage juvenile blue crabs, a study is underway (2021-present) to use molecular techniques to help distinguish very small Atlantic blue crabs from similar species (*e.g.*, lesser blue crab, *Callinectes similis*). The project will allow for a greater understanding of how blue crabs interact with closely related species, including those that are not native to South Carolina waters, in the estuarine environment.

A Master's thesis is currently underway (2020-present) to understand spatial and temporal patterns in female blue crab size, with preliminary results indicating that little spatial variability exists in blue crab size within South Carolina, but that significant variability in the size of mature female blue crabs occurs in offshore waters across the southeastern United States. Furthermore, there is no evidence for a systematic decline in the size of mature female crabs since the 1970s, which is a potential indication that overfishing is not occurring.

Another project is currently underway (2021-present) to assess the effects of disease and parasites on blue crab population status. The project includes an assessment of *Hematodinium* infections (a parasitic dinoflagellate) in the hemolymph and the presence of other parasites in organ tissues. To investigate the role of disease as a factor in determining inter-annual variability in blue crab abundance, monthly sampling of open water and tidal creek habitats of the Charleston Harbor watershed were conducted. Trematode, haplosporidian, and nematode parasites were found infecting blue crabs, none of which appear to pose a direct threat to human health.

SCDNR staff also use combined survey and fisheries data to understand interactions and trends in the blue crab fishery. For instance, both pounds landed and value of blue crab harvest have changed substantially since the late 1970s (Figure 1-17). Changes in the seasonal timing of commercial harvests have also been documented. For the fall hard-shell fishery, peak harvest used to occur in October but now occurs in November (Figure 1-18). Similarly, spring soft-shell harvest used to peak in April/June and now peaks in March/April (Figure 1-18). Shifts in the timing of commercial activity could have implications for the effectiveness of management strategies.

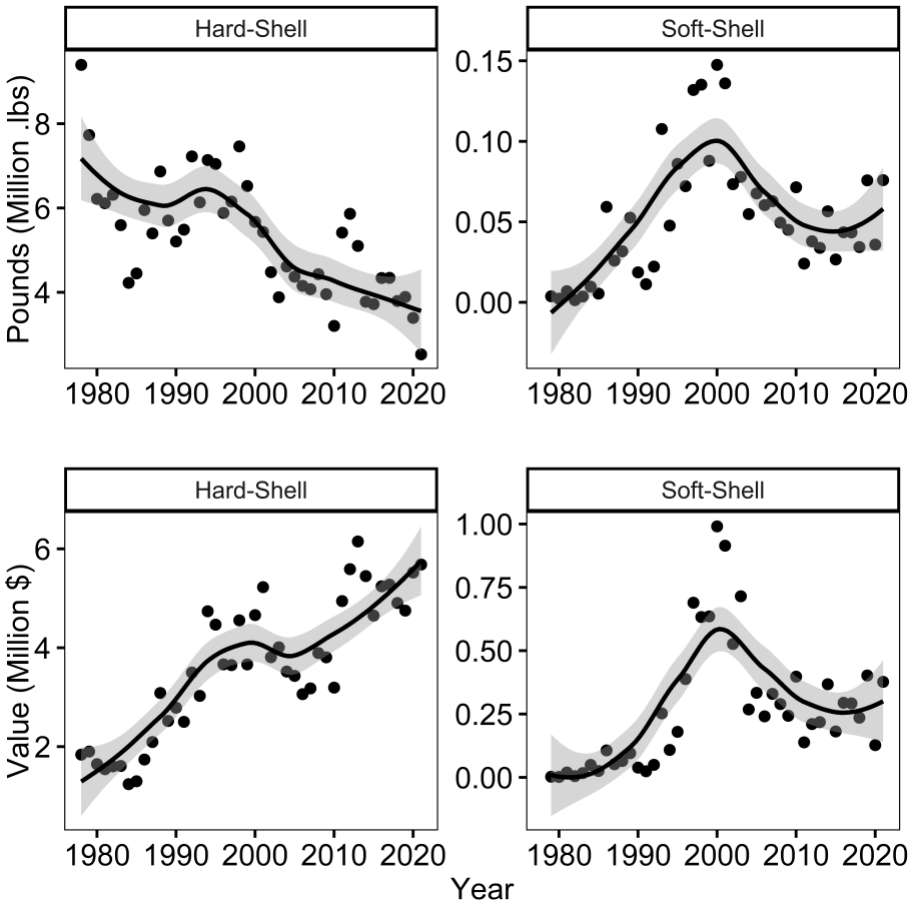

Figure 1-17. Annual values (black circles) for commercial landings (top) and value (bottom) for hard-shell crabs (left) and soft-shell crabs (right) in South Carolina. Black lines and grey shading represent smoothed trend lines and associated error, respectively.

To understand these trends, staff evaluated the relationship between adult crab abundance as measured in our fisheries-independent survey and commercial landings data. For soft-shell landings, no significant relationship between abundance and landings in the 1900s was detected. A significant positive relationship was documented for the 2000s (but largely driven by two data points). When comparing a given year's abundance to the previous year's soft-shell landings, there was no significant relationship. For hard-shell landings, adult abundance is not related to landings in the same year nor the previous year. Juvenile crab abundance recruitment index is also not related to soft-shell landings.

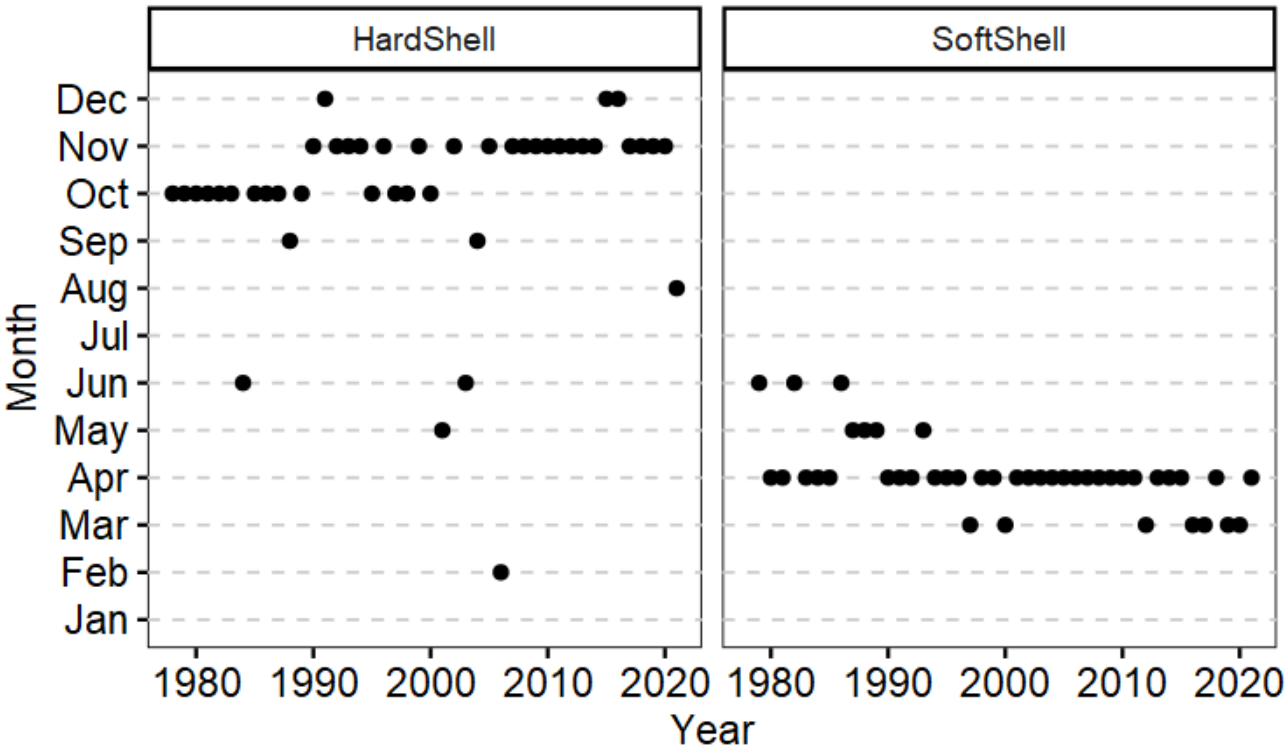

Figure 1-18. The month of peak commercial landings for hard-shell (left) and soft-shell (right) blue crabs for each year of available data.

SYNTHESIS OF RESEARCH FINDINGS

- Forty-three years of monitoring data provide a strong foundation for understanding the life history of blue crab in South Carolina and the influences of environmental conditions.
- Abundances were generally greater during the 1900s than in the 2000s, a pattern mirrored in North Carolina and Georgia, with declines mainly occurring in the fall.
- Shifting climate regimes from cold/wet conditions to warm/dry conditions have impacted blue crab abundance, with warming winters also leading to earlier spawning.

The monitoring of blue crabs by SCDNR staff over the past 43 years provides a strong foundation for understanding the intrinsic biology of this species, as well as its interactions with environmental conditions. Recent sampling as part of the estuarine trawl survey, for instance, reveals clear seasonal patterns of each blue crab life stage in South Carolina's estuaries that are consistent with previous studies (Mense & Wenner, 1989; Archambault *et al.*, 1990), including a higher abundance of juvenile life stages from fall through early spring (October-March) that is slightly later than work from the Chesapeake Bay (Orth & Van Montfrans, 1987), Florida (Tagatz, 1968) and the Gulf of Mexico (Williams *et al.*, 1990), where peak juvenile abundance occurs in September. Higher abundances of subadult crabs in the spring and adult crabs in the summer are also largely consistent with previous work (Hines, 2007).

Trends in abundance of adult blue crabs show significant variability throughout the time series, but the general pattern indicates that abundances were greater during the 1900s than in the 2000s. Annual trends in blue crab abundance in South Carolina are broadly similar to the trends observed in Georgia and North Carolina, where peak abundances also occurred during the 1980s and 1990s and declined in the late 1990s and early 2000s.

While trends in abundance for blue crab in South Carolina generally mirror long-term patterns of blue crab abundances in neighboring state, representing regional patterns of population synchrony (Colton *et al.*, 2014), increases and decreases in blue crab population abundances do appear to be synchronous across the entire Atlantic coastal range (Rogers & Munch, 2020).

Within South Carolina, temporal patterns across estuaries are similar, with generally reduced numbers of adult crabs being caught in the 2000s compared with the 1900s; however, estuary-specific patterns are apparent, with Charleston Harbor showing the most similar catches before and after 2000. For the fall pot survey, Charleston Harbor showed similar declines in abundance as compared with other estuaries. Estuary-specific patterns of blue crab abundance are known to be affected by factors such as habitat availability (Ruiz & Posey, 1993), recruitment (Heck & Coen, 1995) and predation (Heck *et al.*, 2001).

In comparing patterns of annual abundance between the estuarine trawl survey (*i.e.*, sampling open water habitats) with the creek trawl survey (*i.e.*, sampling tidal creek habitats), broadly similar patterns of abundance are observed. Some differences, however, are noticeable, especially in the abundance of blue crabs in the late 1990s, when a higher abundance of blue crabs in tidal creek habitats (especially those of the upper Wando River; data not shown) compared with the open water habitats was observed. It is unclear what is driving these patterns, but it may be related to a combination of effects from both temperature and salinity regimes. Regardless of the cause, the pattern appears to apply to all three life stages (*i.e.*, juvenile, subadult and adult). When looking seasonally at the data for the estuarine trawl survey, spring and winter abundance values are more variable and show little systematic trend. Abundance data in the fall (including August) show clear declines in the 1990s with no indication of recovery thereafter.

SCDNR data illustrate both seasonal changes and long-term trends in the size of mature female crabs. The smallest average size of mature crabs is found in the summer, which coincides with peak adult crab abundance. The increasing size of mature female crabs from the summer to the fall (*i.e.*, July-September) is also coincident with the decline in crab abundance in trawl surveys, suggesting that density dependence may be playing a role in seasonal patterns of the size of mature female crabs. Furthermore, an increase in mean size of mature female crabs is evident for the fall but does not appear to be the case for other months, again suggesting a possible role for density dependence. Mean size should be interpreted with caution, as it could represent an increase in the number of larger crabs but could also occur in response to the presence of fewer small crabs.

The timing of spawning events is known to be influenced, in part, by temperature, with clear latitudinal gradients in the timing of spawning having been observed across the eastern U.S. seaboard (Hines, 2007). Blue crab spawning in South Carolina is known to occur mainly from March to July, which is slightly earlier than the timing of spawning in the Chesapeake Bay (McConougha *et al.*, 1983) and begins slightly later than the timing in Florida (Tagatz, 1968). A single peak in egg-bearing blue crab abundance is similar to the single peak observed in the mid and upper portions of the Chesapeake Bay but differs from the lower Chesapeake Bay, where spawning peaks occurs in both spring and fall (Hines, 2007). Once females are inseminated, sperm can be stored for at least one year (Hines *et al.*, 2003), thus the connection between when the majority of females mate and when spawning occurs may be decoupled. There is some indication that most females mate in the summer and spawn their first batch of eggs the following spring/summer (van Engel, 1958; Hines *et al.*, 2003).

The results presented in our report show that interannual variability in winter temperatures influences the timing of spawning activities, with warming winters leading to earlier spawning activity. These results are consistent with work on other crustaceans (*i.e.*, penaeid shrimp), for which warmer winters are related to earlier spawning (DeLancey *et al.*, 2005). These results highlight the importance of warming temperatures, and especially warming winter temperatures, on blue crab populations.

Adult male crabs tend to occur in fresher waters than adult female crabs (Hines, 2007) and are thought to have less tendency for directional migration than their female counterparts (Judy & Dudley, 1970). Our results reinforce the tendency for males to be found in lower salinity waters (Archambault *et al.*, 1996), but also highlight a clear size gradient in male crabs coinciding with salinity suggesting that size-specific migration patterns may be occurring, with larger male crabs tending to migrate further upriver to the lowest salinity waters.

Sperm limitation of female crabs has been observed in Chesapeake (Jivoff, 2003) and the Gulf of Mexico (Olmi-Graham & Darnell, 2022) and has been proposed as an issue affecting other blue crab populations (Ogburn, 2019). Since male blue crabs in South Carolina appear to spend some of their life cycle in low-salinity areas that are generally protected from commercial harvest, the negative effects of sperm-limitation in females in South Carolina may be mitigated, except for the short time period during early spring when male abundances appear to be relatively low.

While male blue crabs appear particularly abundant in upper estuary waters during spring and summer, abundances of male crabs in these habitats appear to decline markedly in November and through the winter. One hypothesis is that these crabs migrate out of lower salinity waters and into open estuarine waters, where they are concentrated and readily available for harvest as part of the fall blue crab fishery.

The crab population is apparently male-limited in early spring, which allows for the use of live male crabs as ‘bait’ to effectively capture immature female crabs seeking a mate and supporting what is known as the peeler crab industry. Relative male scarcity in early spring could be due to continued fishing pressure on legal-sized crabs during the winter, a period of low growth and thus few 'new' crabs maturing into the fishery. Alternatively, male scarcity could be driven by a continued offshore migration of male crabs in response to continuously cooling temperatures from December to February. New data on seasonal movement patterns of blue crab may shed some light on the drivers of these patterns.

The conditions of South Carolina’s estuaries, as demonstrated by data from Charleston Harbor, have changed substantially over the 40+ years of survey records and have likely impacted patterns of blue crab abundance. These changes have led to a shift in our estuaries from cold/wet conditions to warm/dry conditions. Data show that abundance of juvenile crabs is greater when temperatures are colder, and after the onset of the drought in the early 2000s, adult crabs are more abundant in fresher conditions. Very high salinity can increase risk of *Hematodinium* infection, a parasite that can lead to mortality in crabs and occurs mainly in the fall months (Parmenter *et al.*, 2013) and may contribute to the reduced abundance of adult crabs following periods of reduced river flow. Results of disease survey work is early and ongoing but highlights multiple parasites that infect blue crabs with potential mechanisms that may contribute to recent declines in their abundances. The combined effect of temperature and river flow/salinity on adult crabs ultimately explains a high percentage (~>50%) of interannual variability in adult blue crab abundances.

Positive relationships between red drum and blue crab indicate that when blue crabs are more abundant, so are red drum. A strong positive relationship suggests that red drum are unlikely to be having a strong top-down impact on the abundance of blue crab in this region. More likely, the environmental conditions that contribute to higher abundance of blue crab (*e.g.*, non-drought conditions) also support strong recruitment of red drum. Invasive blue catfish (*Ictalurus furcatus*) are another important predator of blue crab that may be impacting blue crab populations, especially in the Chesapeake Bay (Schmitt *et al.*, 2019; Fabrizio, 2021). It is currently unclear whether blue catfish are impacting blue crab populations in South Carolina.

Only weak relationships were found when comparing blue crab landings with blue crab abundance, and these relationships showed different directionality when compared across the 1900s and 2000s. The complex and

multi-year life cycle of blue crabs obscures direct relationships between harvest levels and population abundances, suggesting that a more complex stock assessment is warranted for better understanding the relationship between population size and landings of blue crabs.

STOCK ASSESSMENT OPTIONS FOR BLUE CRABS IN SOUTH CAROLINA

Due to the limited ability to determine the age of blue crabs, stock assessments based on complex models, such as statistical catch-at-age models, as are often implemented for finfish, are not appropriate for use with blue crab. Alternative stock assessment approaches include surplus production models and catch-survey analysis. In the surplus production model, target species are modeled as a single stock, with the effects of recruitment, growth and mortality pooled for the analysis. Surplus production models make the following assumptions: 1) The population responds instantaneously to changes in biomass (*i.e.,* there is no delay between reproduction and recruitment); 2) total catch is known without error – a potential problem for recreational catch data; 3) no age structure exists (*i.e.,* all individuals experience the same growth and natural mortality rate); and 4) the carrying capacity of the system is stable. To conduct a surplus production stock assessment, data on total commercial landings (fishing mortality) and an index (or indices) of abundance within a time series are needed. Stock assessments of blue crabs using the surplus production modeling approach have been conducted in several states, including Texas, Florida and North Carolina. This method was also used to conduct a blue crab stock assessment in South Carolina in 2002. One of the limitations in surplus production modeling approaches for blue crabs is that fluctuations in recruitment may be a stronger driver of population dynamics than harvest pressure.

The catch-survey analysis is thought to be a more robust approach to stock assessment of blue crabs since assumptions of surplus production models are often violated. Several stock assessments have been conducted along the east coast of the United States using a catch-survey analysis (Eggleston *et al*., 2004; Murphy *et al*., 2007; Wong, 2010; Miller *et al*., 2011; VanderKooy, 2013). In this approach, the population is divided into two stages, generally a recruit (or pre-recruit) stage and a fully recruited stage. The model describes the population in terms of the number of recruits and fully recruited male and female crabs. How the stages are specifically distinguished depends on the data that are available. In a sex-specific, two-stage catch-survey analysis completed in North Carolina in 2018, for example, recruits were defined as those crabs with a carapace width < 5 in and a fully recruited stage defined as those with ≥ 5-in carapace width.

SCDNR researchers recently investigated options for conducting a meaningful stock assessment of blue crabs in South Carolina and determined that, given time constraints, the most effective way would be to utilize a robust model structure that had already been developed within the southeastern United States. Stock assessment scientists in North Carolina shared their modeling methods, including model code, and data input requirements. After an investigation of the available data, however, it was determined that sex-specific commercial landings data were not consistently available, making the catch-survey analysis approach currently unusable in South Carolina. Enhanced data collections would facilitate the use of this approach in the future.

II. THE BLUE CRAB FISHERY

KEY MESSAGES

- The majority of South Carolina's crab harvest is commercial. Recreational crabbers appear to represent a relatively small fraction of harvest pressure in South Carolina.
- Economic and environmental pressures elsewhere in the region strongly impact South Carolina's blue crab fishery. Shortages of crabs in the mid-Atlantic United States have driven prices high coast-wide, subsequently increasing harvest pressure in South Carolina.
- Landings have declined in recent years, reaching a 50-year low in 2021. At the same time, because of soaring prices nationally, the total value of landings is near record levels.
- South Carolina has not passed new regulations related to blue crabs in decades. The fishery is underregulated and likely overcapitalized compared with neighboring states.

THE COMMERCIAL FISHERY

The commercial blue crab fishery in South Carolina has historically ranked as the third-highest commercial fishery (in ex-vessel value) by landings behind penaeid shrimp and finfish (Figure 2-1). In 2021, the crab fishery represented almost 23% of all commercial landings in the state. The value of the crab fishery has been increasing in recent years due to higher market demand and prices paid for blue crab along the Atlantic coast of the United States.

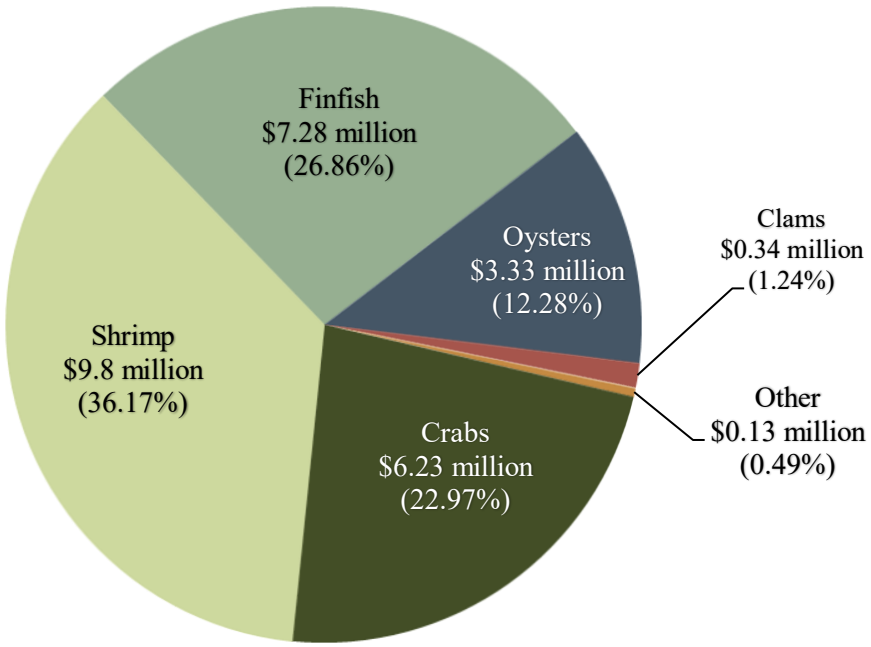

Figure 2-1. The 2021 South Carolina commercial seafood ex-vessel value: $27 million.

In recent years (2015-2022) the number of commercial crab licenses sold has ranged from 358-389 per fiscal year. In 2021 (fiscal year) there were 389 licensed crab harvesters with a total number of 36,242 licensed pots/traps. The number of pots per license holder ranged from 50 (the minimum) to 800, although the majority of commercial harvesters (93%) fished 200 pots or fewer. Additionally, there were 35 licensed Peeler (soft-shell) Dealers and a single crab trawl permit issued in 2021.

South Carolina's commercial crab fishery is significantly less regulated than other Atlantic and southeastern states. Where other states have measures in place, South Carolina has no cap on the number of commercial licenses, no cap on the number of pots per license, no harvest limits, no closed periods and minimal closed or gear-limited areas. In comparison, several states have a license cap (VA and GA), pot limits (VA, NC, GA, FL), closed seasons (VA, NC, FL), and closed areas (VA, NC, FL) (Table 2-1).

Table 2-1. Commercial blue crab regulations by state across the Atlantic coast.

State	License Cap	Pot/Trap Limit	Bag Limit	Seasonal Closures	Area Closures
VA	Yes	Yes	Yes	Yes	Yes
NC	No	Yes	No	Yes	Yes
SC	No	No	No	No	No
GA	Yes	Yes	No	No	No
FL	No	Yes	No	Yes	Yes

Commercial blue crab fisheries across the Atlantic states have experienced a general declining trend since the late 1990s (Figure 2-2). Prior to 1999, commercial landings across the Atlantic coast, while variable, were relatively stable, but since 1999 have showed a steady decline across all states.

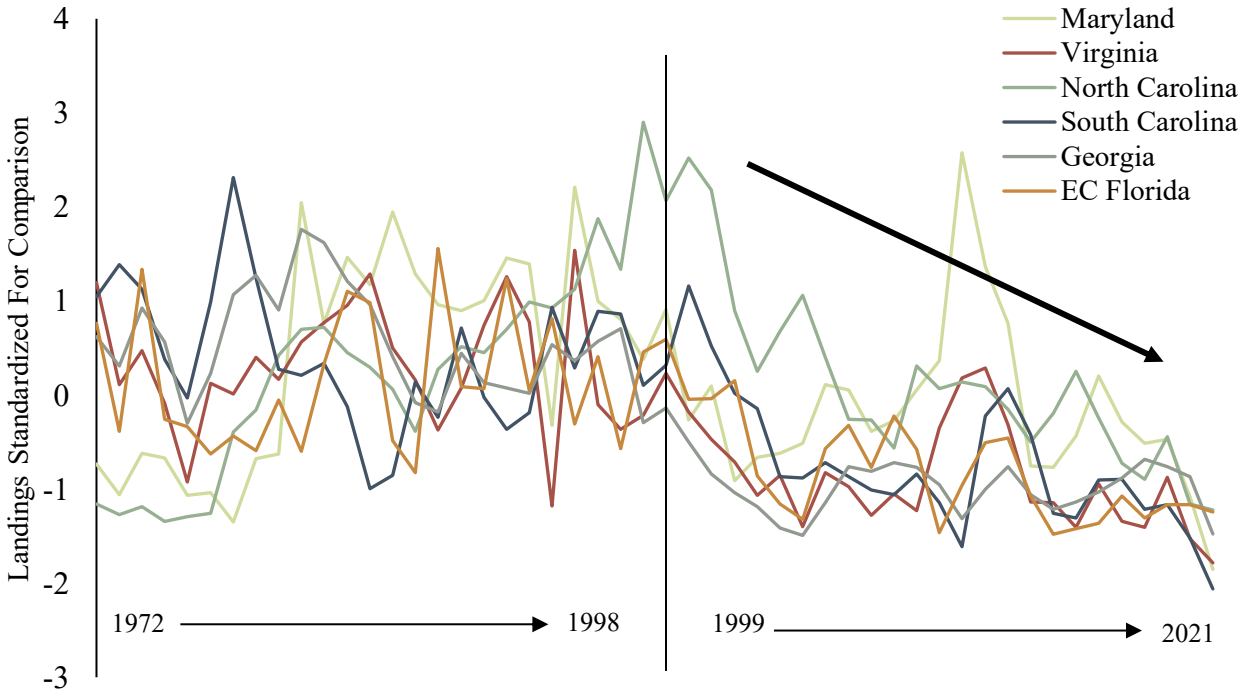

Figure 2-2. Annual commercial landings (standardized units for comparison) for blue crab by state (EC Florida = East Coast Florida).

For just the southeastern states (North Carolina to Florida), the same trend is even more evident with a stronger decline in commercial landings (Figure 2-3).

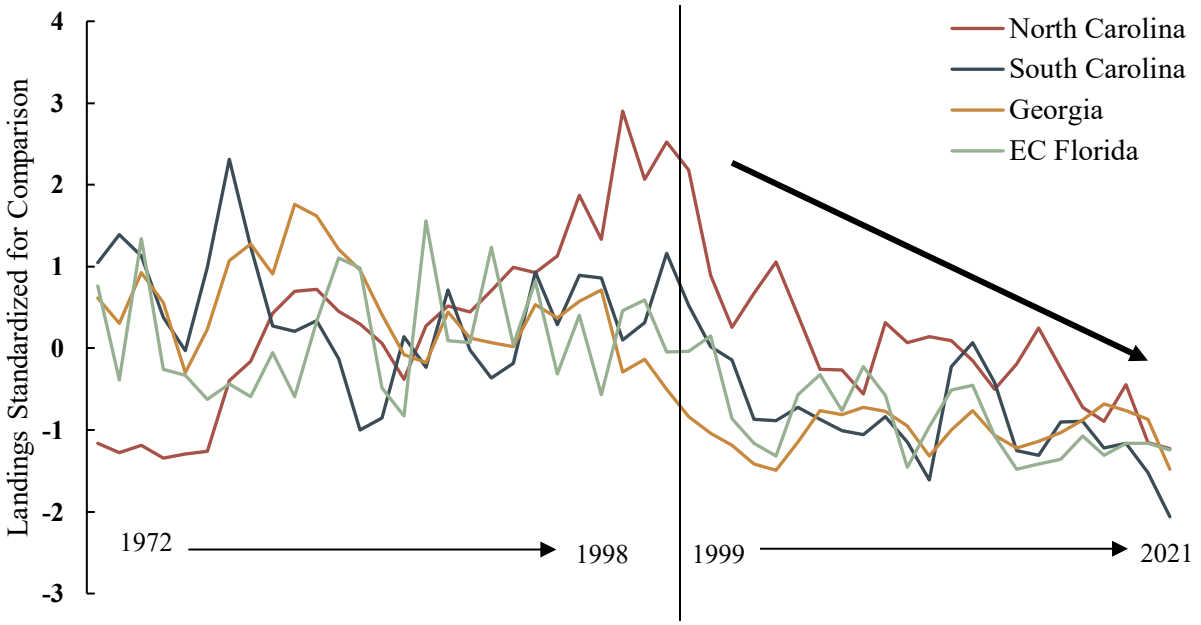

Figure 2-3. Annual commercial blue crab landings (standardized units for comparison) for the Southeast by state.

In South Carolina, commercial landings have consistently declined over time, while landings value has steadily increased (Figure 2-4). The lowest total landings and third-highest landings value in the entire time series (50 years) occurred in 2021.

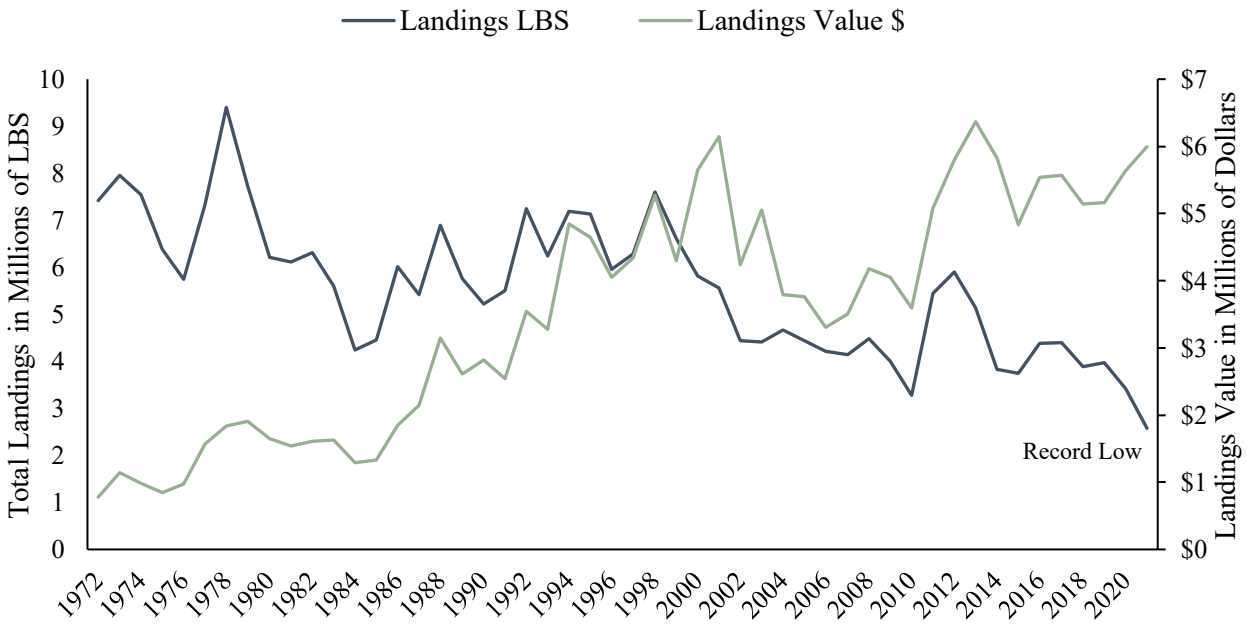

Figure 2-4. Annual commercial blue crab landings and wholesale value in South Carolina.

Higher market prices mean that overall harvest value is increasing even in the face of decreased landings, providing incentive for commercial crabbers to maintain or increase effort. South Carolina, Georgia and Florida are relatively small players in the Atlantic coast blue crab market (Figure 2-5). While landings in North Carolina, Virginia and Maryland have ranged from 20-60 million lbs annually, landings in South Carolina typically are less than 5 million lbs per year.

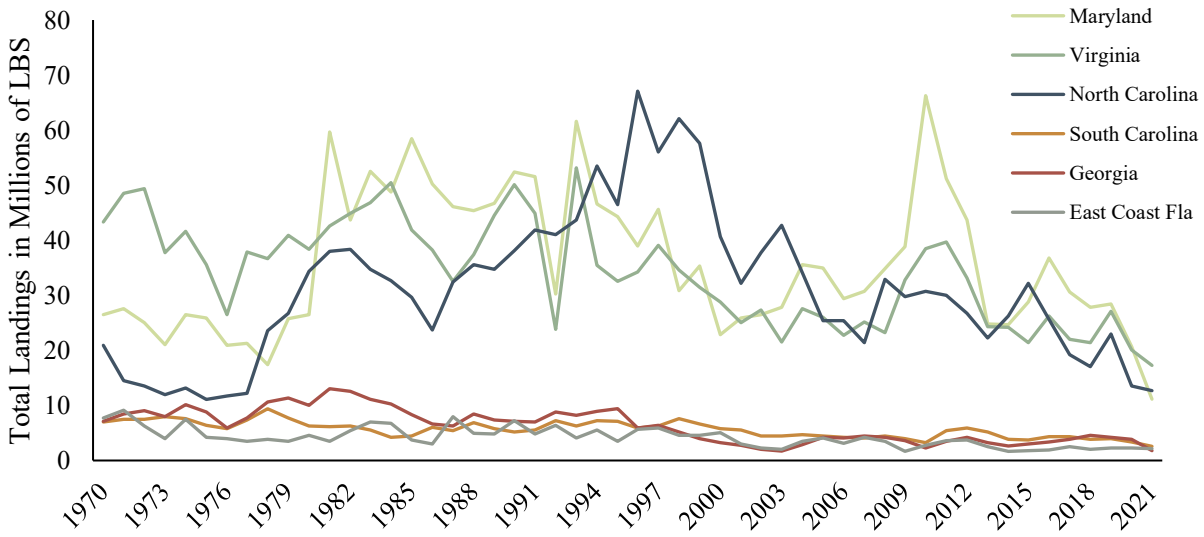

Figure 2-5. Annual total landings by state for the Atlantic coast of the United States.

Low availability of blue crabs in the mid-Atlantic coupled with a willingness to pay a much higher price for them places a greater demand on South Carolina's blue crab fishery and the overall resource. The low barrier to entry and more lenient regulatory framework in South Carolina leave the state open to potentially unsustainable exploitation due to market forces outside of South Carolina.

THE RECREATIONAL FISHERY

South Carolina's recreational blue crab fishery is far smaller, in terms of landings, than the commercial fishery. However, recreational crabbing is a time-honored tradition practiced by its citizens throughout its long history. There are many different types of gear utilized to catch blue crabs recreationally (*e.g.,* drop nets, trot lines, pots, etc.) but the most popular gear type is the standard crab pot. While individuals 16 and younger do not need a recreational fishing license to crab from a private dock or with different types of drop net gear, adults and children older than 16 are required to obtain a saltwater fishing license in order to use crab pots in South Carolina.

Licensees are allowed to use up to two pots, which is the only limit on gear used for recreational crabbing. There are no recreational harvest or boat limits, no escape ring requirement as required on commercial crab pots, no closed time periods to harvest, no limit on the number of licenses and no limit on gear (other than the two pots per person). Some of the other southeastern states allow a higher number of recreationally fished pots (North Carolina and Georgia each allow six, while Florida allows five). In South Carolina, an individual with a commercial fishing license can fish an unlimited number of pots for recreational purposes. While South Carolina has no recreational or boat limit for recreational crabbing, all other southeastern states have a daily bag limit (Virginia: one bushel per person per day; North Carolina: 50 crabs per person per day; and Florida: 10-gallon container per person per day). Additionally, South Carolina and Georgia are the only two states with no closed time period where pots are not allowed in the water. These closed time periods usually occur during slow times of the year to remove abandoned and derelict pots and protect spawning adults.

The number of recreational saltwater fishing licenses sold annually in South Carolina has ranged from 221,356 to 257,163, with an average of 236,881 (2010-2021). A recent survey of recreational license holders found that 16% of these anglers participate in recreational crabbing. At a potential of two pots each, this represents another

possible 75,800 pots that could be utilized during some portion of the year and is approximately twice the number of pots licensed for commercial use. Estimated recreational harvest based on survey responses was approximately 677,000 crabs (270,800 lbs) per year, representing additional pressure on a potentially declining crab population.

An additional important factor is the continued increase in the human population of coastal South Carolina in recent decades. This increase in population combined with interest in saltwater recreational fishing activities, and the relative ease and low expense of participating in a very simple fishery like crabbing, provide the basis for increased pressure placed on blue crab resources along the coast.

III. PUBLIC PERCEPTIONS

KEY MESSAGES

- SCDNR staff surveyed both recreational and commercial crabbers on their fishing practices and perceptions of South Carolina's blue crab fishery.
- The majority of both recreational and commercial crabbers perceive that blue crabs are less numerous than they used to be, regardless of how long they have crabbed.
- Both recreational and commercial crabbers supported potential management options to varying degree. Commercial pot and license limits were fairly well supported, as was a recreational catch limit.
- Commercial crabbers expressed particular concern over the peeler fishery.
- Survey responses also indicated that there could be significant amount of commercial harvest that is not being reported.

In late summer 2022, SCDNR staff developed and implemented surveys for both commercial and recreational crabbers to gather information on harvest effort, perceptions of the fishery and opinions toward potential management options. The surveys covered similar topics but were tailored specifically to each audience.

COMMERCIAL CRABBER SURVEY

The survey of commercial crabbers in South Carolina was conducted online and distributed via email to those licensed commercial crabbers for which an email address was available. Of the 361 individuals licensed in 2021, 263 had valid email addresses on file and 38 individuals responded to the survey (14%). Survey analysis focused on two specific groups within the respondents: 1) licensed individuals with a history of reported landings; and 2) licensed individuals with no reported landings. The latter group comprises roughly half of commercially licensed crabbers, and little is known about their level of fishing effort or how much they contribute to the overall crab harvest.

Respondents reflected all levels of commercial crabbing experience and fished throughout coastal South Carolina, with the highest concentrations in Charleston and Beaufort Counties. Survey participants were asked a series of questions to determine their level of effort and motivation for crabbing, including:

1. How many days do you crab?
2. How many pots do you fish?
3. What is your primary reason for purchasing a commercial crabbing license?

As expected, those commercially licensed crabbers with a documented history of landings indicated that they crabbed most days, typically fished more than 50 pots at a time and that commercial crabbing is their primary source of income. For the group with no history of landings, around half indicated that they fish fewer than 20 days a year, often with 10 or fewer pots in an effort to harvest crabs for themselves, family and friends. Some respondents, however, indicated that they fish more than half the year, use over 100 pots, and purchase a license specifically as a primary or secondary source of income (Figure 3-1). As commercial sales are legally required to occur through a licensed wholesale dealer and be reported to SCDNR, these responses from individuals with no landings history indicate that some level of harvest is occurring that is not reflected in existing landings data.

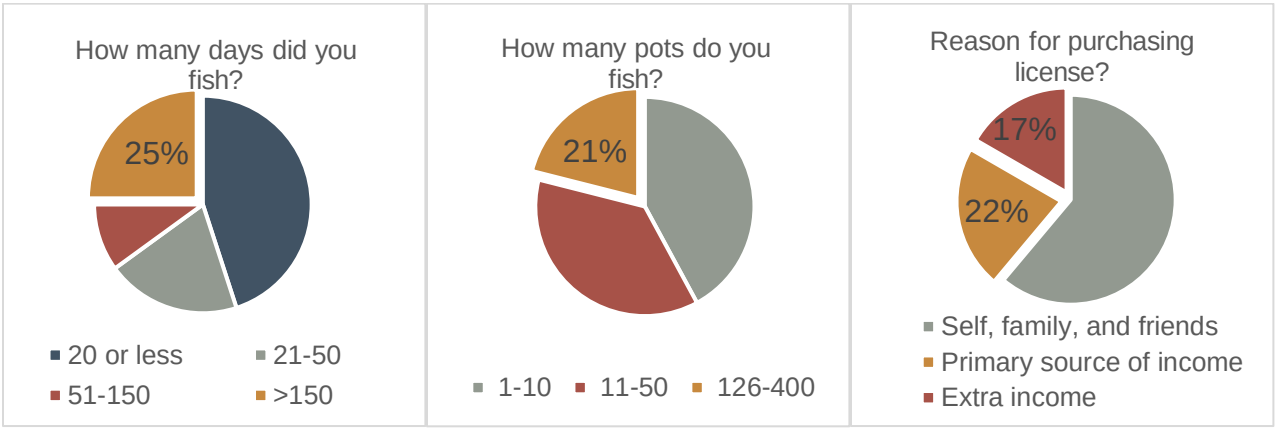

Figure 3-1. Effort data and primary reason for purchasing license by commercially licensed crabbers with no reported landings history.

Commercial licensees also provided input about how they felt the blue crab population had changed over the course of their crabbing career. Responses between those with and without reported landings were not appreciably different and are combined below. The majority of respondents (57%) indicated that the population had either decreased or greatly decreased during that time (Figure 3-2). They were also asked how satisfied they were with the current fishery, with a nearly equal proportion of individuals responding that they were satisfied/very satisfied (41%) as dissatisfied/very dissatisfied (38%). Among respondents that had commercially crabbed for more than 10 years, however, 60% were dissatisfied/very dissatisfied with the current state of the fishery (Figure 3-2).

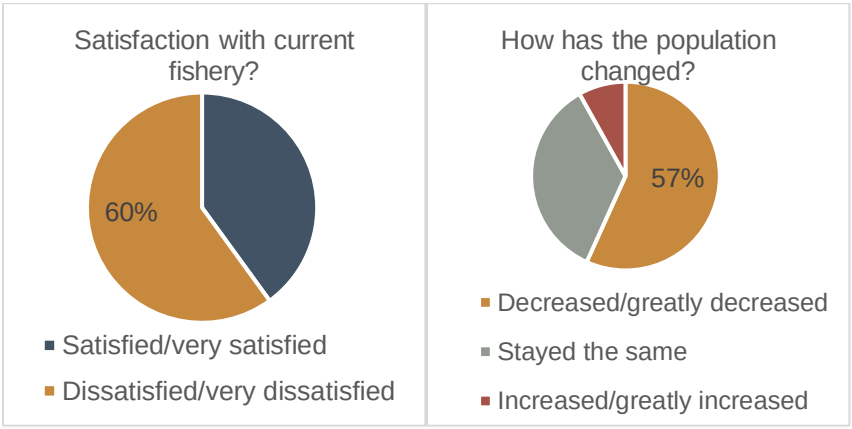

Figure 3-2. Perceptions of the current blue crab population and satisfaction with the fishery among commercial crabbers who have more than 10 years of experience.

Licensed crabbers were also presented with a list of potential management options and asked to rank those options in order of most preferred to least preferred. Responses were given a weighted score (*i.e.,* most points for first-place ranking, least for sixth) and ordered by preference (Table 3-1). The highest-ranked options by respondents were reducing the number of commercial pots and commercial licenses, followed by the seasonal protection of females. Area closures were the least-preferred option.

Table 3-1. Weighted ranking order of management options by respondents from most- to least-preferred.

Management Option	Weighted Rank
Reduce the overall number of commercial pots in the water	1
Reduce the total number of crab licenses as crabbers leave the fishery	2 (tie)
Seasonal protection of female crabs when the population is low	2 (tie)
A short (two weeks) "all pots out" period to allow for the removal of abandoned pots	4
Recreational creel limit for blue crabs	5
Close certain areas (*e.g.,* ocean waters) to crabbing if the crab population crashes	6

Finally, survey participants were asked in an open-ended question if they had any suggestions for improving South Carolina's management of blue crabs. Respondents provided 38 suggestions that were coded into general categories. The most common theme (39% of responses) was an expression of the need to reduce the number of commercial licenses and/or commercial pots in the water, followed by the need for better protection of female crabs and concerns over the peeler crab fishery.

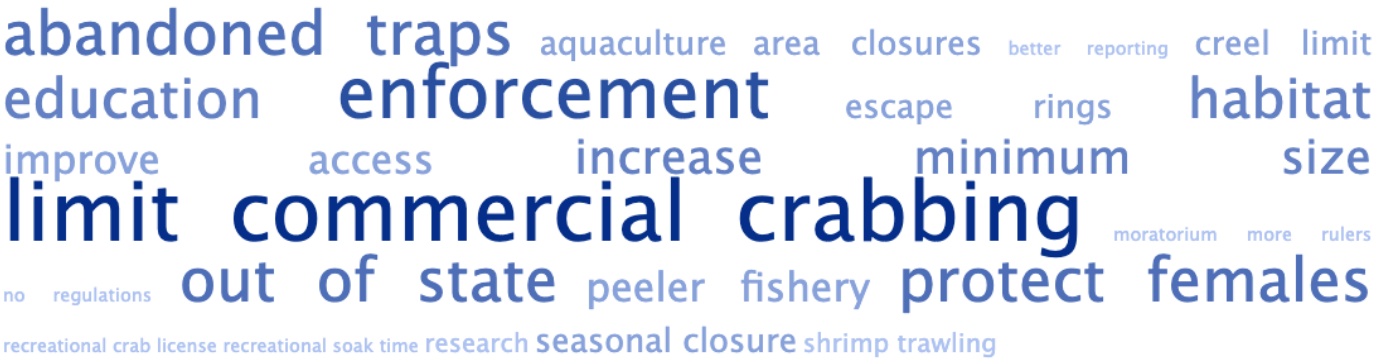

Figure 3-3. A word cloud visualizing comments by survey participants. The larger the words, the more frequent the sentiment among survey respondents.

RECREATIONAL CRABBER SURVEY

Unlike the commercial crab survey, which could be targeted to a relatively small and known universe of participants, the recreational crab survey was designed to sample a proportion of all recreational crabbers in South Carolina and extrapolate those results to the overall fishery. For this task, SCDNR partnered with Southwick Associates, a firm with significant experience in natural resource-related social science, to devise and implement the survey and analyze the results.

Approximately 50,000 individuals (20,000 coastal, 20,000 non-coastal, 10,000 nonresident) that purchased a saltwater fishing license in South Carolina during July 1, 2021-June 30, 2022 were asked to take the survey via email. Of these, 9,311 individuals responded to the survey, with 16% indicating that they had crabbed during the previous year. Respondents were equally split between primarily using crab pots and some combination of

drop nets/hand lines/fold-up traps. Private docks were the most popular location for crabbing, followed by boats, public docks and the shore.

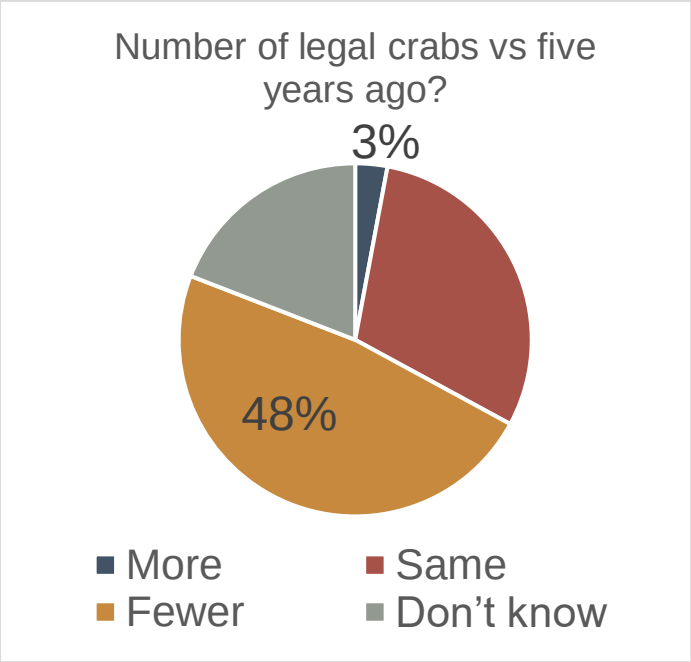

Figure 3-4. Perception of the current legal blue crab population vs five years ago.

A harvest estimate for all recreational crabbers (both resident and nonresident) in the previous year was calculated using a combination of respondents' reports of number of crabs harvested per trip, total number of trips taken and the total number of recreational crabbers. Using this method, the estimated total recreational harvest was 677,000 crabs, totaling 270,800 pounds, over the previous year.

Participants were asked how they would rate the number of legal-sized crabs they catch now compared to five years ago. For this question, analysis focused on residents who had crabbed for five years or more as they had the appropriate frame of reference to answer the question. Results were similar to the commercial survey, with nearly half (48%) responding that they catch fewer legal-sized crabs now and only 3% responding that they catch more (Figure 3-4).

As with the commercial survey, participants were given the opportunity to weigh in on a series of potential management options (Table 3-2). For each option, anglers were asked if they supported it, opposed it or were neutral.

Table 3-2. Recreational crabbers were asked about their support for the following management options.

Management option
Seasonal protection of female crabs
Recreational creel limit for blue crabs
Require pots that allow undersized crabs to escape
Require pots that reduce take of nontarget species, like turtles
A short (2 weeks) "all pots out" period to allow for the removal of abandoned pots
Reduce the number of commercial pots in the water
Limit the number of commercial crab licenses.

Overall, the options that were presented were broadly supported, and there were more respondents supportive of than opposed to each of the seven options. The most-supported options were seasonal protection of female crabs and a two-week "all pots out" period. The least-supported option was a recreational creel limit, although more respondents supported this option (47%) than opposed it (21%). Support/opposition for each of the seven management options can be found in Figure 3-5 below.

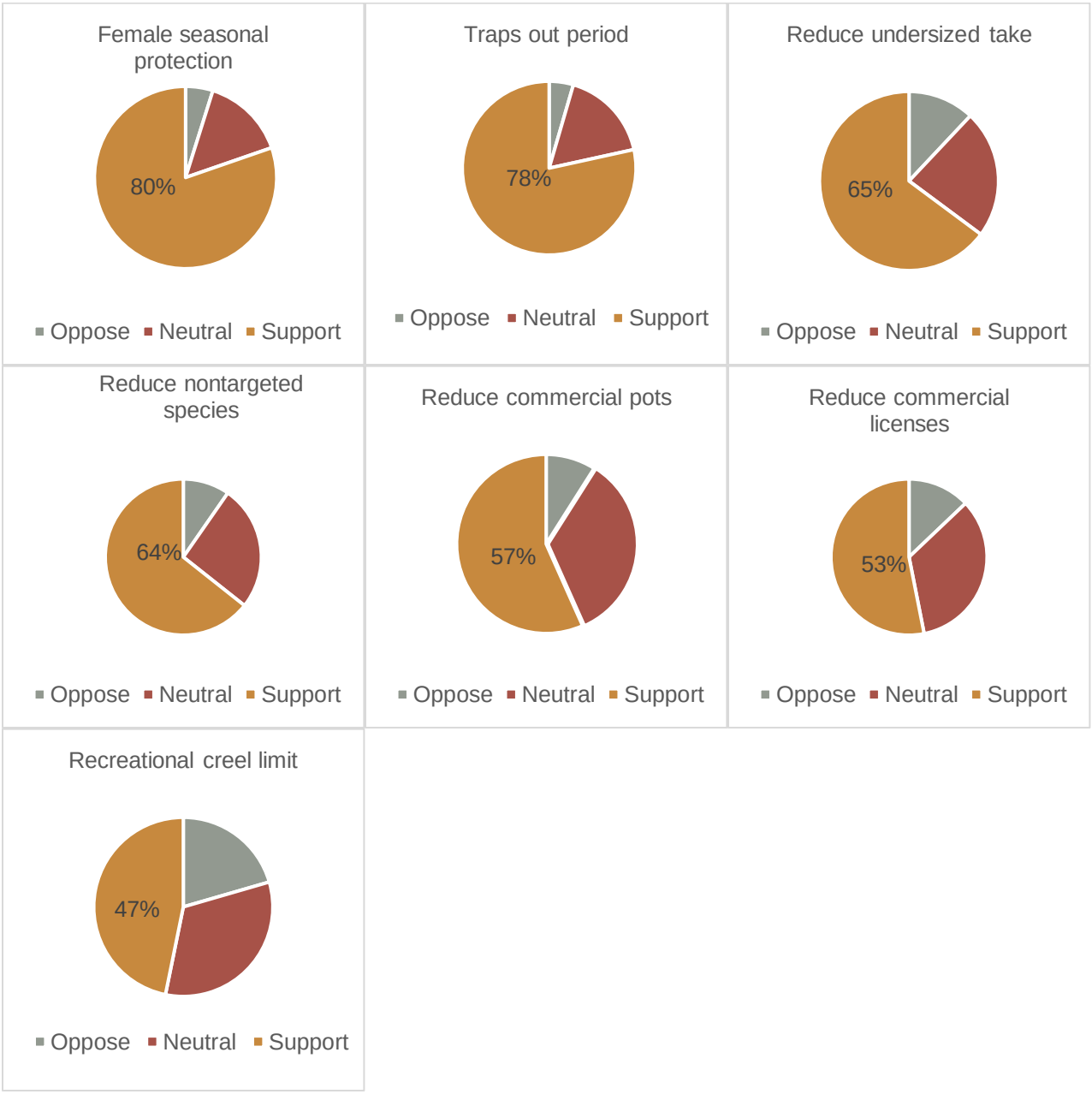

Figure 3-5. Support/opposition for potential management options in the blue crab fishery.

Finally, survey participants were asked, "do you have any suggestions for improving South Carolina's management of blue crabs?" Over 300 individuals provided suggestions, which were then coded into general categories for the purpose of analysis. The most common themes, in order of prevalence, were the needs for limitation of commercial fishing effort and harvest, enforcement of existing regulations, harvest and transport of crabs out of South Carolina, protection of female crabs and the removal of abandoned gear.

Figure 3-6. A word cloud visualizing comments by survey participants. More common themes are represented by larger text.

RECOMMENDATIONS FOR A MORE SUSTAINABLE FISHERY

South Carolina is a relatively small player in the blue crab fishery on the Atlantic coast of the United States. Compared with other Atlantic states, however, its current regulatory framework leaves the state's blue crab fishery more open to exploitation. As such, SCDNR staff make the following recommendations to Code to bring South Carolina in line with neighboring states in terms of regulation, provide more robust management and protection of blue crabs and allow continued access to a sustainable resource by both commercial and recreational users into the future.

Recommendation 1: *Set a cap of 100 commercial crabbing licenses in the blue crab fishery.*

South Carolina is the only state in the country without a cap on commercial crabbing licenses or minimum conditional requirements to participate in the fishery. This leaves the blue crab population in South Carolina vulnerable to overfishing. A reduction in total commercial licenses would be accomplished through attrition over time. Any commercially licensed harvester that is in good standing at the time of regulation change would be able to continue renewing their license annually. The actual reported commercial landings (as reported in monthly Wholesale Dealer Reports) show that fewer than 100 crabbers account for almost all of the commercial catch in any given year (Figure 4-1). On average, 74 crabbers have accounted for 90% of the reported catch for 2012-2021. Of all the licensed crabbers, an average of 43% show up in the Wholesale Dealer Reports in any given year. This means that the majority (57%) of commercially licensed crabbers either do not participate in commercial crabbing or are not selling to licensed Wholesale Seafood Dealers, as required by law.

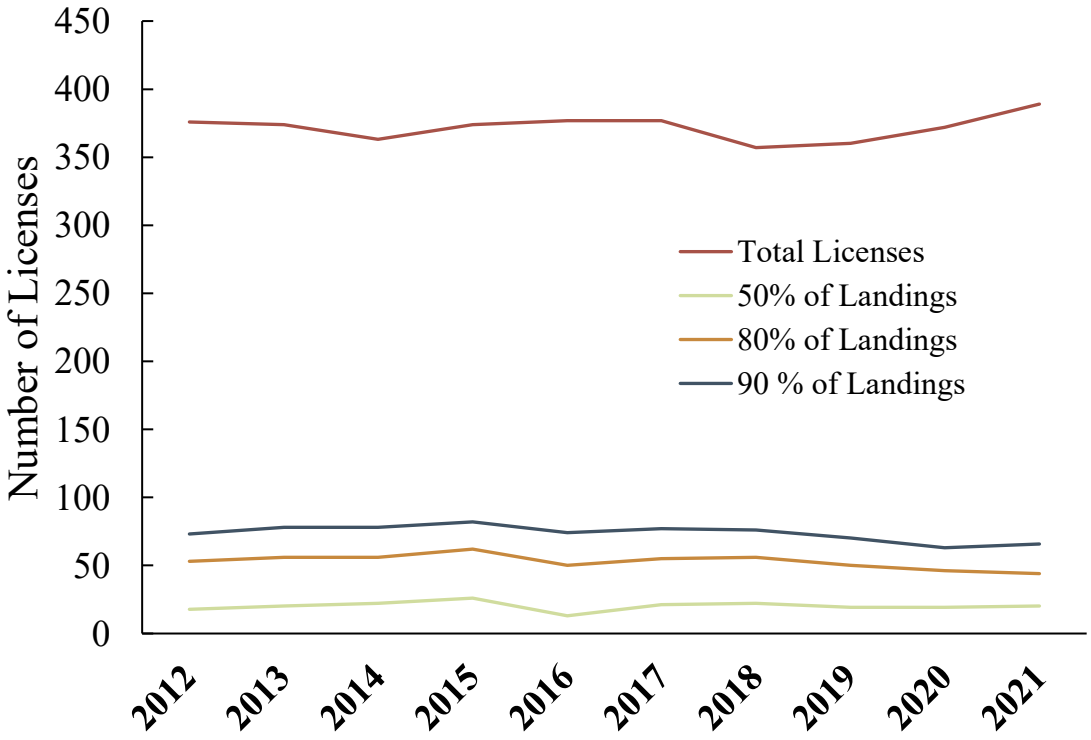

Figure 4-1. The number of annual (fiscal year) commercial crabbing licenses and the number of licenses accounting for different proportions of the total harvest (2012-2021).

A closer look at license data further underscores the fact that most commercially licensed crabbers do not actively participate in the fishery or do not report (Figure 4-2). Since 2015, SCDNR has required commercial crabbers to declare whether or not they intend to sell crabs. From 2015-2022, the vast majority of crabbers reported their intention to sell. The actual number of commercial harvesters with reported sales through Wholesale Dealer Reports, however, is far less, ranging from 136 to 189 individuals over the last eight years. This unreported exploitive capacity allows for the possibility of significant overcapitalization in the fishery. Given that annual landings have been at or near 50-year record lows for the last few years, the unrealized potential of licensed gear that is not being tracked in the fishery could have significant impacts on South Carolina's blue crab resource and further reduce already low landings. The low level of reporting among licensed crabbers makes it difficult to determine whether individuals are fishing at a low level without selling their catch, failing to legally report their commercial catch or are simply not using their license at all.

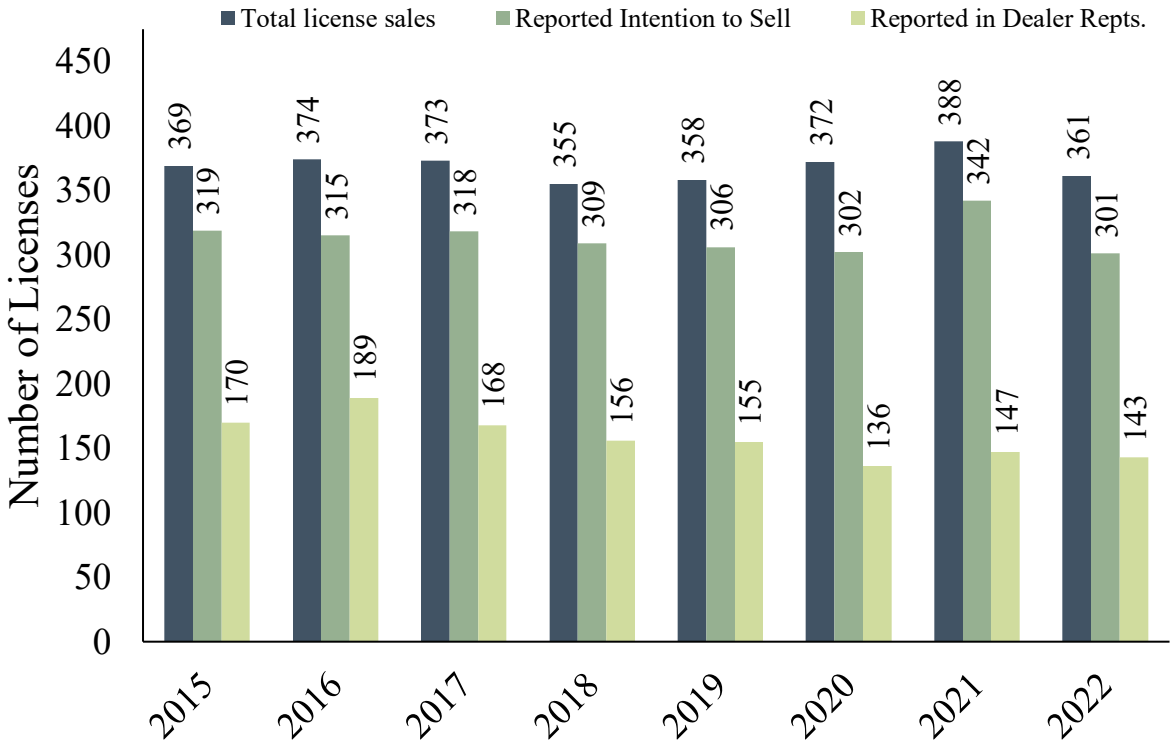

Figure 4-2. Annual (fiscal year) number of commercial crabbing licenses by status type.

Reducing the number of commercial crabbing licenses to 100 through attrition would occur over time. The blue crab fishery has high turnover, with an average of 60-70 crabbers entering the fishery each year that never buy a license again. Additionally, crabbers have been aging out of the fishery through retirement, switching to other fisheries or purchasing a commercial license simply to fish more than the two pots permitted by a recreational license. The development of a recreational permit allowing the use of more than two pots (see Recommendation #6) would likely eliminate some of the non-reporting license-holders from the commercial fishery. Upon enactment of a commercial license cap, renewal would be based on the following conditions:

a. All current license holders would be able to renew licenses with the reduction being reached through attrition with a set date by which an individual or entity must be licensed in order to remain in the fishery. Only persons holding a crab license would be able to renew in subsequent fiscal years.
b. Commercially licensed crabbers would be required to maintain a minimum level of landings, as reported through a wholesale dealer, to show that they are indeed engaged in commercial

fishing/commerce. This would be required in order to renew a commercial crabbing license (*e.g.,* Florida has a 500-lb required landings minimum for crabbers).

c. When the number of commercial crabbing licenses sold drops below 100 in a fiscal year, SCDNR staff must determine if aggregate fishing effort has declined to a level suitable for sustaining the resource. If determined to be sustainable, then the Department will conduct a lottery in June for the coming fiscal year to allow for new entrants in the fishery (up to the 100-license cap). Unsuccessful applicants will be given preference in future years by having their names entered in the lottery for each previously unsuccessful year.

Recommendation 2: *Set the maximum number of crab pots allowed per commercial license at 200.*

Currently, the vast majority of licensed commercial crabbers (93%) purchase 200 or fewer pots (Figure 4-3). Approximately 60% of commercial license holders fish 50 pots (the minimum) or fewer, with 79% fishing 100 or fewer. Licensees fishing more than 200 pots would be allowed to maintain their current level as long as they renew their license and remain in good standing with the Department. No license holder that already has fewer than 200 pots would be able to renew their license with more than 200.

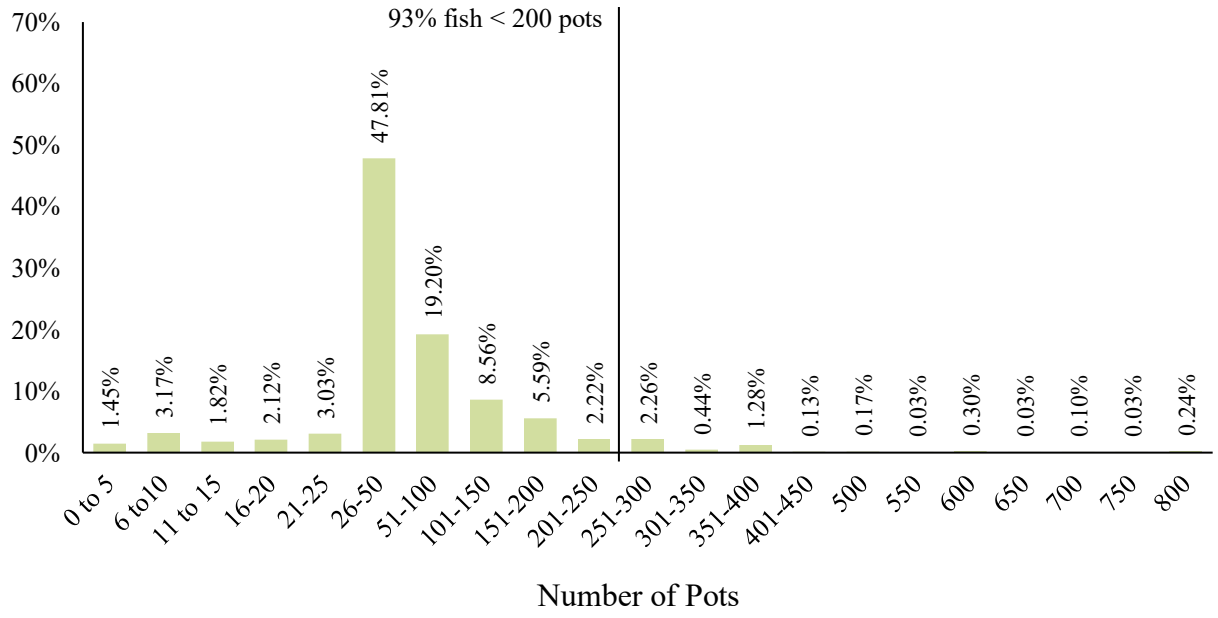

Figure 4-3. Percentage of crab pots fished by commercial blue crab harvesters by pot count increments for 2015-2022 (fiscal year).

Recommendation 3: *Establish a recreational blue crab daily catch limit of 1/2 bushel per person per day and a daily boat limit of 1 bushel per day.*

South Carolina is the only state on the United States Atlantic coast that does not have a recreational daily bag limit. The recent survey of recreational crabbers indicated that the average daily harvest of blue crabs was 4-6 crabs; a ½ bushel limit would thus more than encompass the current typical recreational catch.

Recommendation 4: *Authorize the Department to respond in a timely manner to ensure sustainability of the fishery through management actions such as closures on an as needed basis in response to resource conditions or trends, environmental or biological factors related to blue crab population health and emerging threats.*

The ability to both anticipate and respond to a changing fishery is foundational to effective management of marine resources. Currently, the Department lacks authority or ability to employ management measures such as seasonal, area or other closures on the blue crab fishery. Because blue crabs are highly responsive to environmental conditions and relatively short lived, they would be most effectively and efficiently managed through an approach that allows for timely responsiveness to actual conditions utilizing closures or other restrictions on an as-needed basis. This approach would allow the Department to, when warranted, limit harvest effort in specific areas or during specific times of the year to protect key aspects of the resource like mating- and spawning-ready female crabs, migrating males or recruiting juvenile crabs, depending on which is necessary at the time to ensure sustainability.

By way of example, the Department has the authority to open and close the shrimp fishery and shellfish areas as needed based on resource status, environmental conditions, and other pre-determined factors as well as on an emergency basis to address emergent concerns. As opposed to a regime where certain area or seasonal closures are pre-designated, this approach would allow for continued harvest where and when it is sustainable and employ a closure only where and when it is required to maintain sustainability. The Department proposes that closures or restrictions would only be considered after meeting a set of pre-determined criteria designed to limit overharvest or respond to adverse environmental or biological conditions. Any criteria that could trigger management action would be developed with stakeholder input and defined in advance of employing management actions. In combination with the other recommendations contained herein, the ability to responsively manage the fishery provides the opportunity to balance harvest of the resource with sustainability.

Recommendation 5: *Establish an annual two-week period (January 16-January 29) when all crab pots must be pulled from the water to allow for the identification and removal of abandoned and derelict pots.*

This would provide a designated time for the removal of abandoned pots and derelict crabbing gear in state waters. South Carolina and Georgia are the only United States Atlantic states without a mechanism for the removal of such debris. The recommended dates (January 16-January 29) are based on the lowest annual water temperatures of the year, when landings in the commercial crab fishery are low. Abandoned and derelict pots are a common source of marine debris and continue to trap crabs and other animals long after being abandoned, usually resulting in their deaths. The pots collected during this time period could be repurposed for other functions, primarily as oyster reef substrate, using methods currently employed by Department biologists. Florida and Virginia provide a precedent for such a program.

Recommendation 6: *Reduce latent capacity in the fishery by (a) creating an "enhanced recreational crab pot fishery endorsement" for individuals who hold a valid saltwater recreational fishing license that wish to fish up to 10 pots, (b) adjusting the current fee structure for commercial crab trap/pot licensing to allow for desired effort and (c) clarifying language in existing South Carolina Code Sections regarding operation of licensed commercial blue crab pots by others than the licensee.*

With an average of 57% of commercial license holders not showing up in Wholesale Dealer Reports, an enhanced recreational endorsement represents an opportunity for those individuals that purchase a commercial license in order to fish more than two pots for personal use to instead register as recreational crabbers. Under the current rules, these crabbers are able to fish 50 or more pots under the basic commercial license even if they are not engaged in commercial activity. Survey evidence suggest that 15-20% of current commercial license holders would make the transition to a recreational endorsement if given the opportunity. This would further reduce the number of total commercial licenses (towards the 100-license cap) and overcapitalization in the crab fishery. We propose that the enhanced recreational endorsement would cost an additional $5 and a require a different buoy marking scheme for law enforcement identification.

Adjusting the current fee structure would incentivize commercial crab harvesters to license and pay for the number of pots they need/use and reduce overcapitalization. The proposed commercial fee structure would be: $2 per pot for up to 25 pots, $3 per pot for 26-100 pots and $4 per pot for any number greater than 100 for residents; and $10 per pot for up to 25 pots, $15 per pot for 26-100 pots and $20 per pot for any number greater than 100 for non-residents.

Section 50-5-350 has language stating that commercial crab gear may only be operated by a licensed resident commercial saltwater fisherman. Section 50-5-555 has language that allows other "persons" to retrieve/work gear that is not theirs with a letter from the licensee and does not specify that that individual is a licensed commercial saltwater fisherman. To reduce confusion and aid in enforcement, these two sections should better qualify who can work different crab pot gear, that they must do so with documentation and that they must be licensed saltwater commercial fishermen.

Recommendation 7: *Codify the description of a legal blue crab pot/trap, including a requirement for escape rings/vents for both recreational and commercial pots.*

A standard description of a crab pot does not currently exist in the South Carolina Code of Laws. All other Atlantic states define crab pots/traps in law, and most other fishery gear types are described. The dimensions of a standard crab pot are no greater than 2 ft x 2 ft x 2 ft with escape rings in the upper/bottom chambers for both commercial and recreational pots. Escape rings are currently required on commercial pots to allow for the release of undersized crabs but not on recreational pots. We propose a one-year grace period for recreational pots to be modified. Additionally, consideration should be given to adding diamondback terrapin excluders in commercial pots in order to cut down on terrapin mortalities from crab pots. North Carolina requires terrapin excluders during specific times and areas and Florida will require them on all recreational pots beginning in 2023.

Recommendation 8: *Establish a certification process for all Peeler (soft-shell crab) Dealers to certify that said dealers have bona fide peeler crab shedding facilities.*

SCDNR officials would annually inspect peeler operations and certify the business premises and blue crab shedding facilities prior to granting a crab shedding operational license. A peeler dealer/shedding operation license and site certification document must be on the premises when peeler crabs are present. The current state code for Peeler Dealers already requires that dealers purchase peeler crabs only from licensed commercial crabbers who have been identified in advance to SCDNR and are licensed for peeler pots/traps and that any Peeler Dealer license holder shedding live blue crabs must have a valid Wholesale Seafood Dealer license. This change in the Code would ensure that those who hold peeler licenses are indeed shedding operations and are operating under "best practices" guidelines. SCDNR staff already perform a similar role certifying live bait shrimp operations.

Recommendation 9: *Increase funding to support expanded and new, essential blue crab-focused biological, population and fishery data collection and monitoring capabilities.*

Stock assessments are generally used as the gold standard for developing effective fishery management strategies. These assessments rely on the ability to account for a multitude of factors that can influence population dynamics. This includes changes to intrinsic biological factors such as the timing of female reproductive activity, as well as the effects of environmental factors on population dynamics. A summary of how these factors affect blue crab in South Carolina are included in this report. In addition, stock assessments also rely on biological information from commercial catch (*e.g.*, relative importance of each sex to the commercial catch and the mean size of crabs). Unfortunately, SCDNR does not currently collect sex-specific

size or abundance information that is required for effective development of stock assessments. Additional funding, and the data it could provide, would allow the Department to eventually conduct a stock assessment of blue crab and be more responsive to real-time issues in the fishery.

APPENDIX A. A FULL HISTORY OF SOUTH CAROLINA'S BLUE CRAB FISHERY WITH EMPHASIS ON LEGISLATION

Up until 1934, South Carolina's crab landings information is incomplete – and what is available is not necessarily reliable. From 1880 to 1934, available landings data exist for only 17 years, with an average of 45,500 pounds per year.

The South Carolina Board of Fisheries began in 1906 and focused on the management of oysters, clams, sturgeon, shad, and diamondback terrapins. There is little mention of blue crabs until an impost tax on crabs was noted in 1924. The cost of stamps was two cents per dozen on soft shell crabs, ten cents on a bushel of hard crabs and two cents per gallon on processed crab meat. A $5.00 annual blue crab fishing license was also required by the General Assembly in 1924, although records suggest very few were purchased, presumably because the fee was relatively high for those times, and there were few people to enforce it. Despite these legal requirements, there is no mention in Board of Fisheries Reports of crab-related licenses or crabmeat stamp sales in reports until 1935, when the legislature gave the Board of Fisheries authority to manage blue crabs.

The first crab-picking and processing facility appears to have been created in 1937, a development that likely contributed to improved reported crab landings. In 1937, 20,813 gallons of crab meat and 1,804 dozen soft-shell crabs were reported.

From 1938 to 1959, landings data were available for only 16 of 23 years and averaged 2,740,000 pounds per year. All crabs at this time were caught by trotline or trawl. A surge in landings in 1938 appears to have been related to the emergence of crab picking and canning facilities in the state. These facilities probably provided a reliable and easy place to sell crabs, and they were probably more reliably reported landings than individual fishermen. Soft-shell crabs appear to have been first reported in 1937, when approximately 21,650 crabs were harvest. It is likely that peeler crabs were collected as mature males carried them when attracted to trotlines.

In 1938, the General Assembly passed a law making it illegal to harvest or possess sponge (egg-bearing) crabs. In 1941 another new law established a minimum carapace width of five inches for blue crabs, although an exception was made for peeler crabs. The five-inch law was hailed as a conservation move by the Board of Fisheries, but years later, a survey of all states indicated that the five-inch law was adopted largely at the request of the picking houses. Small crabs were difficult to pick and yield was low, making them an economic drain on picking houses.

The General Assembly reduced the fee for a crabbing license in 1939 from $5.00 to $1.50 to encourage more crabbers to buy licenses and therefore help the state better quantify total effort and catch.

In 1953, crab trawls towed by shrimp trawlers became legal in the state's sounds and bays. Trawlers were allowed to trawl from December 1 to March 15 using four-inch stretch mesh with no chafing gear. Trawling in sounds continued until 1986, when the General Assembly outlawed all trawling in the sounds and bays (in reality, trawling is still allowed in the mouths of sounds).

The modern crab pot was invented in the Chesapeake Bay in 1947, and as they began appearing in South Carolina in the late 1950s, the legislature required that each pot or string of pots be licensed. Crab pots became dominant in South Carolina around 1960, a year in which landings jumped to 7,120,000 pounds. Landings remained at about 5 to 10 million pounds per year until 2001, when the last of the state's crab picking houses closed.

The popularity of the much more efficient crab pots resulted in some controversy in the late 1950s and early 1960s. Robert Lunz of the Bears Bluff Marine Laboratory assessed the situation and concluded that crab abundance as indicated by routine trawl sampling remained stable and that the new pots were not overfishing the resource. Soft shell crab landings all but disappeared with the almost total decline in use of trotlines.

In 1976, the legislature allowed the importation of sponge crabs from other states, provided they were properly documented. In time, however, all states outlawed the harvest of sponge crabs.

The first comprehensive peeler crab law was enacted in 1979 (Act 142), amending sections 50-17-1820 and 50-17-1930 to allow possession of small crabs that were identified peelers (crabs nearing molting). The South Carolina Wildlife and Marine Resources Department (predecessor to the present-day SCDNR) provided instructional material to crabbers and interest began growing in the harvesting and shedding of peeler crabs.

In 1979, Act 122 of the General Assembly created a reciprocity law that prevented the sale of a crab license to anyone from a state the prohibits the sale of commercial crab licenses to residents of South Carolina.

In 1984, Act 469 made it lawful to import small crabs as peelers provided the importer had a permit.

In 1989, the General Assembly passed Act 170, which outlawed the use of crab pots (traps) in the legally defined freshwaters of the state.

In 1990, Act 541 required that crab trawling was allowable by permit from December 1 to the following March 29 by permit. Retention of crabs in the shrimp trawl fishery was already allowed.

Also enacted in 1990 was Act 536 (Code 50-17-716) which required that all crab pot floats must be of solid construction. Many were using plastic bleach bottles and other hollow floats to mark crab pots. These floats would sink if struck be a boat propeller or would become brittle in sunlight. All floats were to be made of a solid, buoyant material and must be 10 inches long if rectangular, cylindrical, or conical. Round floats must be at least 6 inches in diameter. Identification numbers on floats would now be assigned by SCDNR to assist law enforcement in identifying pot owners.

In 1994, Act 314 (50-17-30 (g)) moved the commercial crabbing line in the Cooper River farther inland to the "Tee." The new line was moved to where the river forks at the confluence of the east and west branches of the Cooper River. This was done because flow in the rivers had declined due to rediversion of Cooper River water into the Santee River, resulting in much higher salinity water.

In 1996, a committee of blue crab fishermen was assembled by the Office of Fisheries Management to recommend improvements in blue crab laws. Several recommendations went on to be enacted by the legislature in Act 44 in 1997.

Also in 1997, the General Assembly made it legal for persons engaged in clam mariculture to temporarily possess blue crabs and stone crabs of any size (Act 44, 50-17-120). This was to allow removal of crabs from mariculture cages or pens for live release away from the pens.

The first research on escape rings in crab pots was done in the late 1970s. Based, in part, upon South Carolina's work, other states began mandating escape rings (cull vents) in blue crab pots. It was not until 1997 when the General Assembly approved legislation (Act 44, 50-17-1826) requiring all commercial crab pots/traps to have three 2 and 3/8-in. inside diameter escape rings in every pot, except during the peeler crab season.

Also in Act 44 of 1997 was code 50-17-770 which required that each commercial boat fishing for or transporting blue crabs must have the crab pot identification number on the sides of the boat along with a painted circle of no less than eight inches in diameter to match the color of the licensee's crab pot floats.

Another new provision in Act 44 was that a person using another's pots must have a written, signed statement from the owner that he may use the pots. Legal fishing hours were established, such that crabbers were prohibited from fishing pots from 9 pm to 5 am the following day, from April 1 to September 15, and from 7 pm to 6 am the following day from September 15 to March 31. This was done to help reduce theft of pots and crabs in pots.

In 2001, Act 105 allowed the use of a single piece of fish having no dimension greater than three inches as food for the male crab which was in the pot to attract female peeler crabs. Previously, peeler pots could not have fish in the bait well because it would attract non-peeler crabs.

In response to reports of poor catch rates of blue crab by both recreational and commercial crabbers in 2001-2002, the Marine Advisory Committee asked the MRD to establish a citizen's committee in 2002. The committee included two Marine Advisory Committee members, one of whom was director of the USC Graduate marine biology program, another USC biology professor, commercial fishermen, recreational fishermen and SCDNR staff. The public perception at the time was that the problem with the resource was overfishing and that there were too many crab pots in the water. However, the citizens' committee agreed with SCDNR staff that the primary problem at the time was the historic drought. However, the committee also identified that the fishery was likely overcapitalized (too many pots for the well-being of the fishery) and there was too much competition among crabbers (particularly during the drought when many fishermen competed for space at the saltwater/freshwater line in the rivers). Theft of pots and crabs as well as vandalism continued to be significant problems.

This initial committee met into fall 2002 (eight meetings) and made several recommendations. One conclusion was that the drought at the time was the primary cause of the perceived biological problems and in fact, by December 2002, there were some indications that the resource was beginning to recover. To address the perceived overcrowding of pots in the fishery, the committee proposed limiting the number of pots per fisherman to 150 and limiting the fishery to 300 licenses.

Representative Chip Limehouse introduced a joint resolution in April 2003 to place a moratorium on the sale of new pot licenses through June 30, 2005, to give SCDNR time to research the decline in blue crabs. The resolution failed to get a hearing.

The proposals from this initial citizens' committee proved to be very unpopular with what appeared to be a majority of the commercial crabbing community. Crabbers attended the February 2003 SCDNR board meeting to complain, and as a result, the board instructed staff to explore other alternatives, namely a limited entry plan for the fishery. In response to this charge, the Office of Fisheries Management solicited volunteers for a fisherman's committee through a mailout to all licensed crabbers. A new committee of 10 commercial crabbers from across the coast. and 2 recreational crabbers was formed and met over 12 evenings, beginning in April 2003. These meetings were chaired by David Whitaker and attended by SCDNR biologists, the staff economist, and SCDNR law enforcement officers (Alvin Taylor and Chisholm Frampton). After much debate and compromise, the committee's recommendations were taken out to three public hearings (Georgetown, Charleston, and Beaufort) in October 2003. The proposals were modified through the 2003-04 winter and the SCDNR Board was updated in February 2004. The committee met again in August 2004 to review the final product. Although some members of the committee were not pleased with all aspects of the committee's proposals, all agreed to the final product. Final recommendations went to the SCDNR Board in February 2005.

The Committee's final draft was complex. A major component of the draft was a proposed 25% reduction in the number of pots in the water – primarily through attrition (people leaving the fishery on their own accord). Once the targeted goal for pot reduction was achieved, new entrants were to be allowed via a lottery. License Fees would increase slightly ($125 basic license and $2/pot). Nonresidents would pay five times more than residents, and escape rings would be required in recreational pots along with a daily recreational limit of one bushel per person. Peeler pots would be licensed separately, and SCDNR would have more latitude to deal with derelict pots. Although widely supported, the SCDNR director stopped action on the bill after three crabbers from the St. Helena Sound area attended a SCDNR board meeting and strongly opposed the proposals.

In 2008, as crab stocks continued to decline, there was renewed interest in resurrecting the proposed legislation. Most blue crab fishermen never lost interest in the previous proposal. The South Atlantic region was amid a prolonged, severe drought resulting in declining landings, and crabbers were crowding into the upper reaches of the coastal rivers where crabs were attracted to the lower salinity waters. Because almost all other states had imposed limited-entry programs, there was also concern among the industry that crabbers from other areas, particularly Chesapeake Bay, would relocate in South Carolina. Again, the interest failed to translate into a legislative proposal.

APPENDIX B. GLOSSARY OF TERMS

Term	*Definition*
Crab pot	An enclosed wire basket with entrance funnels used to catch crabs. Often used interchangeably with 'crab trap.'
Escape ring/vent	Standardized hole/ring in a crab pot that allows undersized crabs and other wildlife to escape the pot. Also referred to as cull rings.
Jimmies	Colloquial term for immature male blue crabs.
Landings	Catch or harvest of a marine species.
Megalopa	The final larval stage of a crab, in which its legs and claws appear. This is the life stage when crab larvae migrate from the ocean into the estuary.
Peeler	A crab in a pre-molt stage; after molting, they become soft-shell crabs, which are highly prized in the culinary world.
Sallies	Colloquial term for immature female blue crabs.
Sooks	Colloquial term for mature adult female blue crabs.
Sponge crab	An adult female crab carrying eggs on her abdomen. Also referred to as ovigerous or egg-bearing, these gravid females are easily recognizable by the round, bright orange 'sponge' of eggs they carry.
Trotline	A fishing device characterized by a length of heavy line from which multiple shorter lengths of baited line hang.
Trawl	A method of fishing whereby a boat tows or drags a netted bag (also called a trawl) behind it.
Zoae	Early larval stages of a crab.

APPENDIX C. REFERENCES

Archambault, J. A., E. L. Wenner & J. D. Whitaker. 1990. Life history and abundance of blue crab, *Callinectes sapidus* Rathbun, at Charleston Harbor, South Carolina. *Bulletin of Marine Science* 46(1):145–158.

Bishop, T. D., H. L. Miller III, R. L. Walker, D. H. Hurley, T. Menken & C. E. Tilburg. 2010. Blue crab (*Callinectes sapidus* Rathbun, 1896) settlement at three Georgia (USA) estuarine sites. *Estuaries and Coasts* 33:688-698.

Boylan, J. M. & E. L. Wenner. 1993. Settlement of brachyuran megalopae in a South Carolina, USA, estuary. *Marine Ecology Progress Series* 97:237-246.

Colton, A. R., Wilberg, M. J. Coles, V. J. & Miller, T. J. (2014). An evaluation of the synchronization in the dynamics of blue crab (*Callinectes sapidus*) populations in the western Atlantic. *Fisheries Oceanography* 23(2):132-146.

Costlow, J. D., Jr. 1965. Variability in larval stages of the blue crab, *Callinectes sapidus*. *Biological Bulletin* 128(1):58-66.

Cushman, E. & T. Darden. 2017. Genetic characterization of Atlantic blue crab (*Callinectes sapidus)* in Charleston Harbor, South Carolina. *Journal of Shellfish Research* 36(1):243-247.

DeLancey, L. B., Jenkins, J. E., Maddox, M. B., Whitaker, J. D. & Wenner, E. L. 2005. Field observations on white shrimp, *Litopenaeus setiferus*, during spring spawning season in South Carolina, U.S.A., 1980-2003. *Journal of Crustacean Biology* 25(2):212-218.

Eggleston, D. B., *E.G.,* Johnson & J. E. Hightower. 2004. Population dynamics and stock assessment of the blue crab in North Carolina. North Carolina State University, Final Report for 99-FEG-10 and 00-FEG-11, Raleigh, North Carolina.

Eldridge, P. J. & W. Waltz. 1977. Observations on the commercial fishery for blue crabs, *Callinectes sapidus*, in estuaries in the southern half of South Carolina. South Carolina Marine Resources Center, Technical Report, 21 pp.

Epifanio, C. E. 2019. Early life history of the blue crab *Callinectes sapidus*: A review. *Journal of Shellfish Research* 38(1):1-22.

Fabrizio, M. C., T. D. Tuckey, J. R. Buchanan & R. A. Fisher. 2021. Predation impacts of invasive blue catfish on blue crabs in estuarine environments. Virginia Institute of Marine Science, William & Mary. https://scholarworks.wm.edu/reports/2531

Fischler, K. J. & C. H. Walburg. 1962. Blue crab movement in coastal South Carolina, 1958-59. *Transactions of the American Fisheries Society* 91(3):275-278.

Fitz, H. C. & R. G. Wiegert. 1991. Utilization of the intertidal zone of a salt marsh by the blue crab *Callinectes sapidus:* Density, return frequency, and feeding habits. *Marine Ecology Progress Series* 76:249-260.

Forward, R. B., D. A. Frankel & D. Rittschof. 1994. Molting of megalopae from the blue crab *Callinectes sapidus*: Effects of offshore and estuarine cues. *Marine Ecology Progress Series* 113:55-59.

Forward, R. B., R. A. Tankersley & J. M. Welch. 2003. Selective tidal-stream transport of the blue crab *Callinectes sapidus*: An overview. *Bulletin of Marine Science* 72(2):347-365.

Heck, K. L., Jr., & L. D. Coen. 1995. Predation and abundance of juvenile blue crabs: A comparison of selected East and Gulf Coast (USA) studies. *Bulletin of Marine Science* 57(3):877-883.

Heck, K. L., Jr., L. D. Coen & S. G. Morgan. 2001. Pre- and post-settlement factors as determinants of juvenile blue crab Callinectes sapidus abundance: Results from the north-central Gulf of Mexico. *Marine Ecology Progress Series* 222:163-176.

Hines, A. H. 2007. Ecology of juvenile and adult blue crabs. *In:* The blue crab: *Callinectes sapidus*. Kennedy, V. S. & L. E. Cronin (eds). Maryland Sea Grant Press, College Park, pp. 565-654.

Hines, A. H., P. R. Jivoff, P. J. Bushmann, J. van Montfrans, S. A. Reed, D. L. Wolcott & T. G. Wolcott. 2003. Evidence for sperm limitation in the blue crab. *Bulletin of Marine Science* 72:24.

Jivoff, P. R. 2003. A review of male mating success in the blue crab, *Callinectes sapidus*, in reference to the potential for fisheries-induced sperm limitation. *Bulletin of Marine Science* 72:14.

Johnson, D. S. 2022. Beautiful swimmers attack at low tide. *Ecology* e3787. https://doi.org/10.1002/ecy.3787

Johnson, E. G. & D. B. Eggleston. 2010. Population density, survival and movement of blue crabs in estuarine salt marsh nurseries. *Marine Ecology Progress Series* 407:135-147.

Judy, M. H. & D. L. Dudley. 1970. Movements of tagged blue crabs in North Carolina waters. *Commercial Fisheries Review* 32(11):29.

Julien, A. R., D. J. McGlinn, A. W. Tweel & P. R. Kingsley-Smith. 2020. Associations between nekton assemblages and ribbed mussel (*Geukensia demissa*) patches in a South Carolina salt marsh. *Southeastern Naturalist* 19(1):45-61.

Lipcius, R. N., E. J. Olmi III & J. van Montfrans. 1990. Planktonic availability, molt stage and settlement of blue crab postlarvae. *Marine Ecology Progress Series* 58:235-242.

McConougha, J. R., D. F. Johnson, A. J. Provenzano & R. C. Maris. 1983. Seasonal distribution of larvae of *Callinectes sapidus* (Crustacea: Decapoda) in waters adjacent to Chesapeake Bay. *Journal of Crustacean Biology* 3(4):582.

Mense, D. J. & E. L. Wenner. 1989. Distribution and early life history stages of the blue crab, *Callinectes sapidus*, in tidal marsh creeks near Charleston, South Carolina. *Estuaries* 12(3):157-168.

Miller, A. J., M. J. Wilberg, A. R. Colton, G. R. Davis, A. Sharov, R. N. Lipcius, G. M. Ralph, E. G. Johnson & A. G. Kaufman. 2011. Stock assessment of blue crab in Chesapeake Bay 2011. Technical Report Series No. TS-614-11 of the University of Maryland Center for Environmental Science.

Milliken, M. R. & A. B. Williams. 1984. Synopsis of biological data on the blue crab, *Callinectes sapidus* Rathbun. National Oceanic and Atmospheric Administration Technical Report. National Marine Fisheries Service 1, Food and Agriculture Organization of the United Nations Fish Synopsis, 138: 1-39.

Murphy, M. D., A. L. McMillen-Jackson & B. Mahmoudi. 2007. A stock assessment for blue crab, *Callinectes sapidus*, in Florida waters. Report to the Florida Fish and Wildlife Commission Division of Marine Fisheries Management.

North Carolina Division of Marine Fisheries (NCDMF). 2022. 2021 [Blue crab] Fishery Management Plan Review.

Ogburn, M. B. 2019. The effects of sex-biased fisheries on crustacean sex ratios and reproductive output. *Invertebrate Reproduction & Development* 63:200–207.

Olmi, E. J., III. 1986. Factors affecting the abundance of penaeid shrimps in macroplankton samples from open and impounded brackish marsh systems in South Carolina. M.S. Thesis. College of Charleston, South Carolina. 95 pp.

Olmi, E. J. & P. A. Sandifer. 1986. Recruitment of blue crab, *Callinectes sapidus* in open and impounded marsh systems in South Carolina. *Journal of Shellfish Research* 7:128.

Olmi-Graham, H. D. & M. Z. Darnell. 2022. Evidence for sperm limitation in the Louisiana blue crab spawning stock. *Transactions of the American Fisheries Society* 151:399-407.

Orth, R. J. & J. van Montfrans. 1987. Utilization of marsh and seagrass habitats by early stages of *Callinectes sapidus*: A latitudinal perspective. *Bulletin of Marine Science* 46(1):126-144.

Parmenter, K. J., P. A. Vigueira, C. K. Morlok, J. A. Micklewright, K. M. Smith, K. S. Paul & M. J. Childress. 2013. Seasonal prevalence of *Hematodinium* sp. infections of blue crabs in three South Carolina (USA) rivers. *Estuaries and Coasts* 36:174–191.

Posey, M. H., T. D. Alphin, H. Harwell & B. Allen. 2005. Importance of low salinity areas for juvenile blue crabs, *Callinectes sapidus* Rathbun, in river-dominated estuaries of southeastern United States. *Journal of Experimental Marine Biology and Ecology* 319(102):81-100.

Prager, M. H., J. R. McConaugha, C. M. Jones & P. J. Geer. 1990. Fecundity of blue crab, *Callinectes sapidus*, in Chesapeake Bay: Biological, statistical and management considerations. *Bulletin of Marine Science* 46(1):170-179.

Rogers, T. L. & S. B. Munch. 2020. Hidden similarities in the dynamics of a weakly synchronous marine metapopulation. *Proceedings of the National Academy of Sciences* 117:479–485.

Ruiz, G., A. Hines & M. Posey. 1993. Shallow water as a refuge habitat for fish and crustaceans in non-vegetated estuaries: an example from Chesapeake Bay. *Marine Ecology Progress Series* 99:1–6.

Smith, S. G. & E. S. Chang. 2007. Molting and growth. *In*: The Blue Crab, *Callinectes sapidus* (eds) V. S. Kennedy & L. E. Cronin, pp. 197-245.

Schmitt, J. D., B. K. Peoples, A. J. Bunch, L. Castello & D. J. Orth. 2019. Modeling the predation dynamics of invasive blue catfish (*Ictalurus furcatus*) in Chesapeake Bay. *Fishery Bulletin* 117:277–290.

Sulkin, S. D. & W. F. van Heukelem. 1986. Variability in the length of the megalopae stage and its consequences to dispersal and recruitment in the portunid crab *Callinectes sapidus* Rathbun. *Bulletin of Marine Science* 39:269-278.

Tagatz, M. E. 1968. Biology of the blue crab, *Callinectes sapidus* Rathbun in the St. Johns River, Florida. *Fishery Bulletin* 67:2.

van Engel, W. A. 1958. The blue crab and its fishery in the Chesapeake Bay. Part 1 – Reproduction, early development, growth, and migration. *Commercial Fisheries Review* 20(6): 6-17.

VanderKooy, S. 2013. Stock assessment report: Gulf of Mexico blue crab. Gulf Data, Assessment, and Review. Gulf States Marine Fisheries Commission, Ocean Springs, MS.

Whitaker, J. D., L. B. DeLancey, J. E. Jenkins & M. B. Maddox. 1998. A review of the fishery and biology of the blue crab, *Callinectes sapidus*, in South Carolina. *Journal of Fisheries Research* 17(2):459-463.

Williams, A. H., L. D. Coen & M. S. Stoelting. 1990. Seasonal abundance, distribution, and habitat selection of juvenile *Callinectes sapidus* (Rathbun) in the northern Gulf of Mexico:19.

Wong, R.A. 2010. 2010 Assessment of the Delaware Bay blue crab (*Callinectes sapidus*) stock. Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife, Dover. 117 pp.