# The Blue Crab Fishery of the Gulf of Mexico

A Regional Management Plan

Gulf States Marine Fisheries Commission

2015 Revision

June 2015

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# THE BLUE CRAB FISHERY OF THE GULF OF MEXICO, UNITED STATES:

# A REGIONAL MANAGEMENT PLAN

## 2015 Revision

by

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edited by

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published by

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The Blue Crab TTF would not be able to revise and update the material in the management plan without the support of the various academic libraries and library staff across the five Gulf states and the libraries of our federal partners. We would especially like to thank Ms. Joyce Shaw, Ms. Cathy Schloss, and Ms. Maryanne Anthony at the Gulf Coast Research Laboratory's Gunter Library.

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## Preface

The Gulf States Marine Fisheries Commission (GSMFC) was established by the Gulf States Marine Fisheries Compact under Public Law 81-66 approved May 19, 1949. Its charge was to promote better management and utilization of marine resources in the Gulf of Mexico.

The GSMFC is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an *ex officio* member. The second is a member of the legislature. The third is a governor-appointed citizen with knowledge of or interest in marine fisheries. The offices of the chairman and vice chairman are rotated annually from state to state.

The GSMFC is empowered to recommend to the governor and legislature of the respective states action on programs helpful to the management of marine fisheries. The states, however, do not relinquish any of their rights or responsibilities to regulate their own fisheries as a result of being members of the Commission.

One of the most important functions of the GSMFC is to serve as a forum for the discussion of various problems and needs of marine management authorities, the commercial and recreational industries, researchers, and others. The GSMFC also plays a key role in the implementation of the Interjurisdictional Fisheries (IJF) Act. Paramount to this role are the GSMFC's activities to develop and maintain regional fishery management plans for important Gulf species.

This revision of the regional blue crab fishery management plan is a cooperative planning effort of the five Gulf States under the IJF Act. Members of the task force contributed by drafting individually-assigned sections. In addition, each member contributed their expertise to discussions that resulted in revisions and led to the final draft of the plan.

The GSMFC made all necessary arrangements for task force workshops. Under contract with the NMFS, the GSMFC funded travel for state agency representatives and consultants other than federal employees.

## Abbreviations and Symbols

| | |
|---|---|
| ADCNR | Alabama Department of Conservation Natural Resources |
| ATC | air-tight containers |
| BRD | bycatch reduction device |
| ℃ | degrees Celsius |
| CPUE | Catch-per-unit-effort |
| CW | Carapace Width |
| DO | dissolved oxygen |
| DWH | Deepwater Horizon |
| EEZ | Exclusive Economic Zone |
| FDD | Fishery-independent data |
| FID | Fishery-dependent data |
| FMP | Fishery Management Plan |
| ft | feet |
| FWC | Florida Fish and Wildlife Conservation Commission |
| g | grams |
| GCRL | Gulf Coast Research Laboratory |
| GMFMC | Gulf of Mexico Fisheries Management Council |
| GPM | Growth per molt |
| GSMFC | Gulf States Marine Fisheries Commission |
| ha | hectare |
| IFA | Interjurisdictional Fisheries Act |
| IJF | Interjurisdictional Fisheries Management Program |
| IP | Intermolt period |
| kg | kilograms |
| km | kilometer |
| lbs | pounds |
| LDWF | Louisiana Department of Wildlife and Fisheries |
| m | meters |
| MDMR | Mississippi Department of Marine Resources |
| mm | millimeters |
| MRFSS | Marine Recreational Fisheries Statistical Survey |
| MRIP | Marine Recreational Information Program |
| MSY | Maximum Sustainable Yield |
| mt | metric tons |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| ppm | parts per million |
| ‰ | parts per thousand |
| SD | standard deviation |
| SE | standard error |
| S-FFMC | State-Federal Fisheries Management Committee |
| TED | turtle exclusion device |
| TPWD | Texas Parks and Wildlife Department |
| TTC | Technical Coordinating Committee |
| TTF | Technical Task Force |
| TTS | Texas Territorial Sea |
| TW | total weight |
| U.S. | United States |
| USDOC | United States Department of Commerce |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| YOY | young-of-the-year |

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## 1.0 SUMMARY

The State-Federal Fisheries Management Committee (S-FFMC) is charged with responsibility for developing regional management plans for fisheries resources that move between or are broadly distributed between the territorial waters and areas seaward thereof and for recommending suitable policies and strategies to each member state. The blue crab (*Callinectes sapidus*) FMP is a broad and comprehensive document which addresses all relevant aspects of the biology and fishery. It is intended to provide a framework for conservation of the resource and economic viability of the fishery.

The native range of the blue crab is from Nova Scotia to northern Argentina and includes Bermuda and the Antilles. The species occurs almost exclusively in state waters, where it occupies a variety of habitats in fresh, brackish, and shallow oceanic waters. Two potential management units may exist in the Gulf of Mexico; a Florida or 'Eastern Gulf of Mexico (GOM) stock' unit occurring along the Florida coast to Apalachee (centered in Tampa Bay), and a 'Western GOM stock' unit occurring from central Texas to Apalachicola Bay and centered in Louisiana. Darden (2004) found that gene flow was restricted among western Gulf locations, particularly Louisiana and Texas bays (sample locations), while the Florida 'populations' from Goodland to Apalachicola showed no significant population structuring. This is coincident with seasonal current circulation patterns, larval mixing and migration behaviors, and migratory patterns of adult females along the Florida Peninsula.

The blue crab life history is typical of other estuarine-dependent species in the Gulf of Mexico. Juvenile growth and development takes inshore and with larval development occurring offshore. Mating occurs in brackish areas of the estuary. Spawning is protracted with egg-bearing females found in coastal Gulf and lower estuarine waters in the spring, summer, and fall. Spawning takes place in high salinity coastal waters. Early larval forms (zoeae) are principally oceanic. The postlarval form (megalopa) is transported from offshore waters to estuarine areas where the molt to the first crab stage takes place. Juvenile crabs are widely distributed in estuaries. Adults show a differential distribution by sex and salinity with mature females commonly found in high salinity waters and males in waters of low salinity. Extensive alongshore migration northward by Gulf of Mexico blue crabs has been documented along the Florida west coast.

Essential habitat for blue crab includes all habitats required during its life cycle, including offshore waters used for spawning and larval development and estuarine nursery grounds. Nursery habitats of critical concern include intertidal marshes, sub-tidal grass beds, and unvegetated, soft sediment shoreline habitats. Essential marine/estuarine habitats have undergone dramatic changes. Substantial marsh habitats across the Gulf, especially in Louisiana, have been lost or altered, and chronic pollution of estuarine habitats from urban and agricultural runoff and industrial discharges have occurred.

Various state laws, regulations, and policies are applicable to management of the Gulf of Mexico blue crab fishery and habitat. Legislative authority for enactment and enforcement of such laws in the Gulf usually resides with the individual state's conservation and/or fisheries management agency or commission. In addition, numerous federal laws, policies, and regulations apply to management of blue crab habitats.

The blue crab supports one of the largest commercial and recreational fisheries in the Gulf of Mexico. Hard crabs are currently harvested almost exclusively by traps. Since 2000, annual Gulf hard crab commercial landings have averaged ~ 34% of total U.S. harvest, despite a reduction in effort for several of those years. In 2006, following hurricanes Katrina, Rita, and Wilma of 2005, the Gulf's contribution reached an all-time high of 41.3% of the total U.S. hard crab landings. Louisiana has dominated blue crab landings for hard and soft crabs in the Gulf over the last decade, with harvest increasing from 75.5% of the total Gulf landings in 2000 to 86.6% by 2009. Landings in Florida averaged ~10%, Alabama 4%, Mississippi 1%, and Texas 7% of the Gulf region total harvest over the same time period. The recreational fishery is thought to contribute significantly to total fishing pressure, with estimates of recreational harvest equal to 4%-20% of reported commercial catch in different areas of the Gulf.

Fishing effort, as measured by the number of fishermen, has increased dramatically; from 1,516 in 1980 to 4,028 in 1991, an increase of 166%. Over the last decade, Gulf-wide license sales for resident commercial crab trap fishermen have remained steady, averaging 4,282 per year. Collection of Gulf-wide effort data is currently undergoing a transition from the NMFS port agent collections to individual state effort estimates via trip tickets. Several states have initiated effort reduction programs to reduce overcapitalization which was identified as a substantial problem in the last FMP (Guillory et al. 2001). Texas passed the Texas' Crab License Management Program in 1997 and Florida enacted the Blue Crab Effort Management Plan (BCEMP) in 2007.

Blue crab landings and values have exhibited similar trends over the last 49 years. Blue crab products move through various outlets and some undergo significant transformation before reaching the consumer. Most product sold by processors is cooked crab meat in the form of meat alone or breaded meat. Other product forms include claws, soups, gumbos, etc. The number of processors increased in the Gulf to a peak of 110 in 1992. Destruction of infrastructure associated with hurricanes in the mid-2000s coupled with the influence of imported crab products led to a decline in processing capacity. The number of blue crab processors in the region fell from 67 in 2000 to 30 by 2011.

The early blue crab fishery was organized around a narrow group of traditional Caucasian fishing families. Entry of southeast Asians and Hispanics into the fishery brought about greater diversity, however, the fishery continues to be dominated by Caucasian fishermen. Based on the 2013 socio-economic survey of the commercial fishery, participants are ageing with fewer young people entering the fishery. New entrants or 'rookie' fishermen remain in their early 40s but their educational level has increased. Movement between fisheries was common and was dependent on fishing logistics, seasonal resource availability, and market value of the product. Employment in fishing was centered on family groups (either a father and his sons or brothers) with kinship and social structure important factors in their economic well-being.

The blue crab possesses unique life history characteristics which should be considered in management of the species. Blue crabs are an 'r-selected' species meaning they are highly productive, short-lived, and fast-growing. This indicates that they can sustain high exploitation rates and recover rapidly should overfishing ever occur. Populations are limited by postsettlement biotic processes that influence survival of small juveniles.

Fishery-independent estimates of abundance for both juvenile and adult stocks have shown either decreasing or steady trends throughout the last two decades while commercial landings have declined. The Western GOM stock has undergone a strong decline in juvenile abundances since the mid-1980s and a decline in adult abundances from the mid-1980s until the mid-1990s, after which catch has remained relatively stable. Eastern GOM stock adult abundances have shown a similar trend (declining through the mid-1990's and stable since), while the juvenile abundance has been relatively stable since the late 1980's. In both stocks, the abundances have experienced substantial variability from year-to-year, and in the case of the Eastern stock, these abundances typically peaked in years following high rainfall. The results of the GDAR01 regional assessment found that both the Western and the Eastern GOM stocks are currently not overfished nor are they undergoing overfishing. The population abundance in the two stocks are currently approximating the optimal abundance for achieving MSY, however the assessment model indicated that in the last few years the Western GOM stock has been slightly lower than that optimal abundance. Prior to the next benchmark assessment there is a critical need to develop a clear and defensible stock structure to determine if the Gulf of Mexico should be managed as a single or mixed stock.

The GDAR01 assessment expressed specific concern over the Gulf-wide trend in decreasing biomass in recent decades. The trend is suggestive of a population level response to changing hydrologic cycles which have the potential to incrementally force the fishery into overfishing. Future assessments should include climatic drivers that affect abundance within management regions and development of routine indices based on regional climate trends which would allow for adjustments of management reference points that account for fluctuations in recruitment and population abundance.

Responsible management of the Gulf of Mexico blue crab fishery will require continuation and improvement of ongoing long-term fishery-dependent and fishery-independent sampling programs to support future assessments. Additionally, short-term biological, ecological, fishery-dependent, industrial, technological, economic, and social research studies are needed to meet critical information needs.

## 2.0 INTRODUCTION

Significant changes have occurred in the blue crab (*Callinectes sapidus* Rathbun) fishery in the Gulf of Mexico since publication of the initial blue crab regional FMP (Steele and Perry 1990) and the revision which was completed in 2001. Since the last revision, a number of significant changes have occurred in the region in the last decade which have directly and indirectly impacted the blue crab population and the fishery participants; the decline of local and global economies, continued environmental perturbations, and a number of natural and man-made disasters.

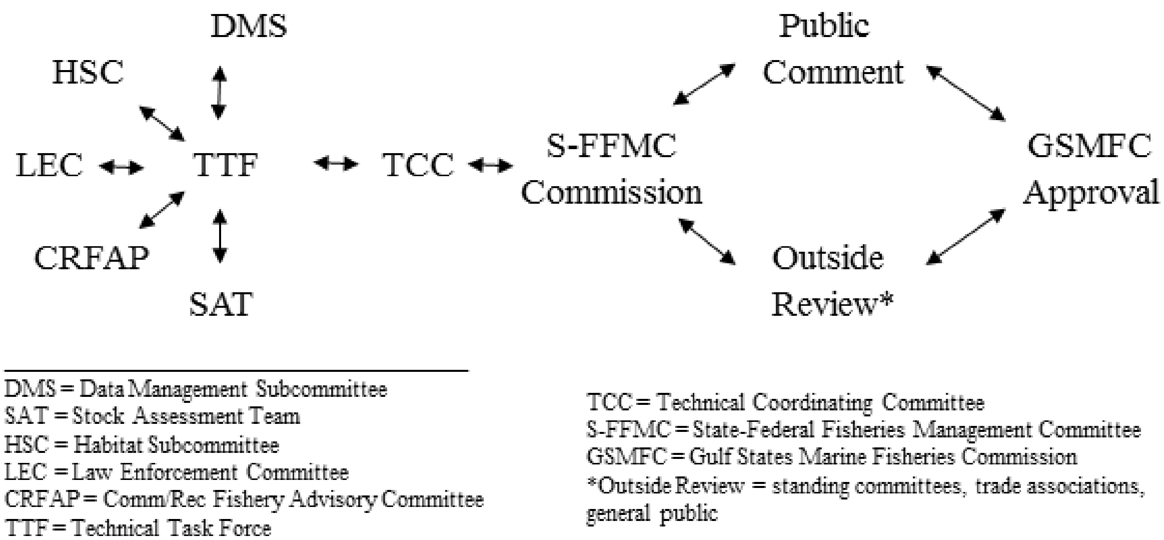
In addition, recent advances in population dynamics modeling has resulted in much wider acceptance of alternative approaches to stock assessment utilizing surplus production models. As with most crustacean species there is not a way to determine population age so rather than using age-based models, these assessments have relied on length-based or dynamic biomass structured models. Since the last revision, Florida, Texas and Louisiana produced quantitative stock assessments for blue crabs using various statistical techniques to handle the uncertainty inherent to fishery-dependent data. Likewise, researchers in Chesapeake Bay have applied a sex specific, catch multiple survey model to establish management reference points and stock status for their blue crab populations and equally applicable versions have been emulated in Delaware and North Carolina.

At the Spring 2011 meeting of the GSMFC, the TCC Crab Subcommittee considered all these factors and recommended that the regional blue crab FMP be revised. The TCC and S-FFMC agreed to the revision and the first meeting of the Blue Crab Technical Task Force (TTF) took place in September 2011. In an effort to provide a rigorous 'stock status' for the Gulf, the Blue Crab TTF agreed to include a comprehensive stock assessment in the FMP revision utilizing a modification of the Chesapeake Bay approach, coupled with the models used previously by Florida and Louisiana. The resulting 'Gulf Assessment' was reviewed independently by four outside experts in June 2013 and determined the assessment was well done and successfully described the blue crab population in the Gulf of Mexico. The detailed assessment report is available through the GSMFC office, the GDAR01 executive summary is included as Appendix 13.3.

### 2.1 IJF Program and Management Process

The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was approved by Congress to: (1) promote and encourage state activities in support of the management of interjurisdictional fishery resources and (2) promote and encourage management of interjurisdictional fishery resources throughout their range. Congress also authorized federal funding to support state research and management projects that were consistent with these purposes. Additional funds were authorized to support the development of interstate FMPs by the GSMFC and other marine fishery commissions. The GSMFC decided to pattern its plans after those of the Gulf of Mexico Fishery Management Council (GMFMC) under the Magnuson Fishery Conservation and Management Act of 1976. This decision ensured compatibility in format and approach to management among states, federal agencies, and the GMFMC.

After passage of the act, the GSMFC initiated the development of a planning and approval process for the FMPs. The process has evolved to its current form outlined below:




The TTF is composed of a core group of scientists from each Gulf state and is appointed by the respective state directors that serve on the S-FFMC. Also, a TTF member from each of the GSMFC standing committees (Law Enforcement, Habitat Advisory, Commercial Fisheries Advisory, and Recreational Fisheries Advisory) is appointed by the respective committee. In addition, the TTF may include other experts in economics, socio-anthropology, population dynamics, and other specialty areas when needed. The TTF is responsible for development of the FMP and receives input in the form of data and other information from the DMS and the SAT.

Once the TTF completes the plan, it may be approved or modified by the Technical Coordinating Committee (TCC) before being sent to the S-FFMC for review. The S-FFMC may also approve or modify the plan before releasing it for public review and comment. After public review and final approval by the S-FFMC, the plan is submitted to the GSMFC where it may be accepted or rejected. If rejected, the plan is returned to the S-FFMC for further review.

Once approved by the GSMFC, plans are submitted to the Gulf states for their consideration for adoption and implementation of management recommendations.

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| Section | 11.0 | All |
| Section | 12.0 | Staff |
| Section | 13.1 | All |
| Section | 13.2 | VanderKooy and Jacob |
| Section | 13.3 | All |
| Section | 13.4 | Gandy and Perry |

## 2.5 FMP Management Objectives

The objectives of the Blue Crab FMP are:

1. To summarize, reference, and discuss relevant scientific information and studies regarding the management of blue crabs.

2. To describe the biological, social, and economic aspects of the blue crab fishery.

3. To review state and federal management authorities and their jurisdictions, laws, regulations, and policies affecting blue crabs.

4. To describe the problems and needs of the blue crab fishery and to suggest management strategies and options.

## 3.0 DESCRIPTION OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

### 3.1 Geographic Distribution

The genus *Callinectes* belongs to the family Portunidae which contains approximately 300 extant species. *Callinectes* is a warm water genus whose pole-ward distribution appears to be limited by summer temperatures. According to Norse (1977), no species occur regularly in waters where peak temperatures fail to approach 20°C. Ten species are listed from the United States and Canada (McLaughlin et al. 2005) with eight species of *Callinectes* reported from the Gulf of Mexico; *C. sapidus* Rathbun, *C. bocourti* A. Milne Edwards, *C. danae* Smith, *C. ornatus* Ordway, *C. exasperatus* (Gerstaecker), *C. marginatus* (A. Milne Edwards), *C. similis* Williams, and *C. rathbunae* Contreras (Williams 1974, Perry 1973, Rathbun 1930). *Callinectes marginatus* (now *C. larvatus*), *C. exasperatus,* and *C. danae* are known from the southernmost portion of the Gulf bordering the Caribbean. *Callinectes ornatus* occur off central Florida through the southern Gulf to Yucatan. Extraterritorial occurrences include *C. bocourti* recorded from Biloxi Bay, Mississippi, (Perry 1973) and *C. marginatus* from Louisiana waters (Rathbun 1930). The lesser blue crab, *C. similis,* and the blue crab, *Callinectes sapidus,* are distributed Gulf-wide.

*Callinectes sapidus* has the broadest latitudinal distribution of all the *Callinectes*. The type locality for *C. sapidus* Rathbun is the eastern coast of the United States. Williams (1974) defined the range as: occasionally Nova Scotia, Maine, and northern Massachusetts to northern Argentina, including Bermuda and the Antilles; Oresund, Denmark; the Netherlands and adjacent North Sea; northwest and southwest France; Golfo di Genova; northern Adriatic; Aegean, western Black and eastern Mediterranean seas; and Lake Hamana-ko, central Japan. Williams (2007) noted that the species has been introduced to California and Hawaii.

Two potential management units may exist in the Gulf of Mexico; a Florida or 'Eastern Gulf of Mexico (GOM) stock' unit occurring along the Florida coast to Apalachee (centered in Tampa Bay), and a 'Western GOM stock' unit occurring from central Texas to Apalachicola Bay and centered in Louisiana (Figure 3.1). This separation is based on the study of Darden (2004) who examined molecular variance and phylogenetic analyses in multiple locations around the Gulf of Mexico (Section 3.2.1.3 for genetics details). Darden found that gene flow was restricted among western Gulf locations, particularly Louisiana and Texas bays (sample locations), while the Florida 'populations' from Goodland to Apalachicola showed no significant population structuring. Seasonal current circulation patterns, larval mixing and larval migration behaviors (Johnson and Perry 1999, Perry et al. 2003, Johnson et al. 2009) and migration patterns of adult females (Steele 1987 and 1991) along the West Florida Peninsula may combine in the blue crab to separate "east from west" in Gulf of Mexico blue crab populations (Section 3.2.8.2 for tagging details). A similar separation was also reported for red snapper by Johnson et al. (2009 and 2013) who found that red snapper larval transport across the northern Gulf of Mexico from west to east was complicated by topographic impediments to the along-shelf flow that included the Apalachicola Peninsula. They noted that there "seems to be a natural population break near Florida's Apalachee Bay", just east of Apalachicola Bay in the panhandle region.

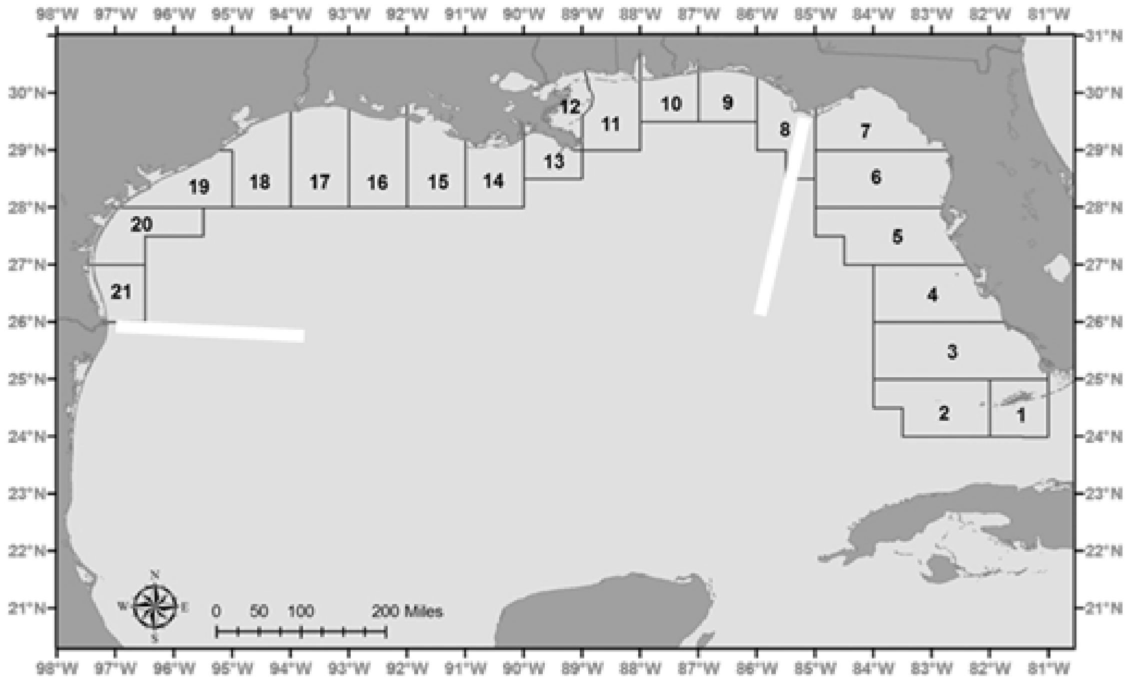



Figure **3.1** Proposed stock division of Gulf of Mexico blue crabs based on genetics and tagging studies in the northern Gulf. White line in NMFS statistical zone 8 (Apalachicola, Florida) defines the break between eastern (Zones 1-7) and western Gulf blue crab stocks (Zones 8-21).

Other species exhibit faunal discontinuities in the Gulf of Mexico. Portnoy and Gold (2012) noted that at least 15 pairs of fishes and invertebrates described as sister species (species, subspecies, or genetically distinct populations) can be found in a marine suture zone whose eastern boundary is located in the Apalachee Bay area of Florida. Within the zone, multiple vicariance events have occurred over geological time scales that may have contributed to observed patterns of divergence for these species.

## 3.2 Biological Description

### 3.2.1 Classification, Morphology, Genetics

#### 3.2.1.1 Classification

Classification of Crustacea continues to change as knowledge of these groups advances. The classification scheme listed below is taken from McLaughlin et al. (2005) and represents a consensus of opinions of members of the Crustacean Society's Committee on Names of Decapod Crustaceans.

Superclass Crustacea
- Class Malacostraca
  - Subclass Eumalacostraca

Order Decapoda
Infraorder Brachyura
Section Brachyrhyncha
Superfamily Portunoidea
Family Portunidae

**3.2.1.2 Morphology**

**3.2.1.2.1 Adults**

Rathbun (1930), Williams (1974 and 2007), and Millikin and Williams (1984) contain detailed morphological descriptions of *C. sapidus*. The frontal margin of the carapace has four inner orbital teeth. The antero-lateral margin of the carapace has nine spines or teeth with the posterior-most strongly developed. The carapace is about 2.5 times as wide as long, is moderately convex, and nearly smooth. There are granulations on the inner branchial and cardiac regions of the carapace.

The abdomen and telson of the male reach about midlength of thoracic sternite IV. The telson is lanceolate and much longer than broad. The first gonopods are long, reaching beyond the suture between thoracic sternites IV and V but not exceeding the telson. The mature female abdomen and telson reach about midlength of thoracic sternite IV. The mature abdomen is broad and rounded. The abdomen in immature females is triangular in shape. Color is variable and includes shades of gray, blue and brownish green. The propodi of the chelae of males are blue on the inner and outer surfaces and tipped with red. The fingers of the chelae of mature females are orange with purple tips. The chelae are modified into a major or crusher claw and a minor claw or pincher.

According to Williams (1974), "there are morphological variations in [the] species having far greater systematic interest than size and color." Chace and Hobbs (1969) noted that extreme variants "are so different from each other that they could easily be interpreted as distinct species;" however, there is "no point of demarcation" either morphological, geographic, or bathymetric between the usual blunt-spined individuals (typical form; *C. sapidus sapidus*, Rathbun 1896) found along the east coast and the acute spined individuals (*C. acutidens* form of Rathbun 1896) found from Florida southward. Williams (1984) noted that even "though *acutidens* individuals are uncommon outside of the tropics, intermediates occur everywhere to some degree and some typical individuals occur in the tropics." He now considers the:

> "whole *C. sapidus* complex to be a single species which has diverged into ill-defined populations in certain parts of its range. *Callinectes sapidus* is the member of the genus which has most successfully invaded the Temperate Zone, and in this respect it may be that speciation into forms associated with temperature regimes is progressing, but the process is not yet complete enough that morphological separation is distinct."

Weber et al. (2003) examined genetic relationships among common swimming crabs of Brazil and concluded, as did Williams (1984), that the forms identified as *C. sapidus sapidus* and *C. sapidus acutidens* by Rathbun (1896) are not subspecies and morphological differences between the two forms are probably determined environmentally.

### 3.2.1.2.2 Larvae

Kennedy and Cronin (2007) provided detailed descriptions and illustrations of the zoeal and megalopal stages of the blue crab. Bullard (2003) provided a more general description of the zoea as follows. The zoeal carapace has a rostral and dorsal spine and a pair of lateral spines. The rostral spine is short relative to carapace length and does not extend beyond the maxillipeds. There is a small lateral knob on the second abdominal somite, a hook on the third abdominal somite, and postero-lateral spines on abdominal somites 3-5. There are two rows of spines on the distal portion of the antennae. The telson is bifurcate. The eyes are sessile in Zoea I and become stalked in Zoea II. Setation and size of various appendages increases through zoeal development and is used to determine stage; appearance of chelae buds and pereiopods also help to delineate stage. Molt to the megalopal stage is metamorphic. The megalopal stage has a long pointed rostral spine and large postero-lateral spines on abdominal somite 5 that project past abdominal somite 6. Chromatophores are present in eight distinct locations. Morphological differences in both size and setation exist between *C. sapidus* larvae reared from the northern Gulf of Mexico stocks and descriptions of larvae reared from Atlantic stocks (Stuck et al. 2009, Ogburn et al. 2011).

### 3.2.1.3 Genetic Characterization

Although genetic characterization of population structure is recognized as an important component of fisheries resource management, relatively few studies have been conducted on blue crabs. Cole and Morgan (1978) found no significant genetic differences between populations of blue crabs from Chesapeake and Chincoteague bays and attributed the observed homogeneity to mixing of larvae in offshore waters of the mid-Atlantic Bight. In Texas, Kordos and Burton (1993) examined allele frequencies in blue crab megalopae and adults and found significant spatial and temporal heterogeneity which they attributed to seasonal variation in larval source populations, low gene flow, and genetic drift. One of the most comprehensive studies was that of McMillen-Jackson et al. (1994) who used electrophoretic allozyme analysis to examine genetic structure of blue crab populations over a broad geographic area (New York to Texas). The majority of the genetic indices derived from their study indicated range-wide genetic homogeneity. Although there was a high level of gene flow between populations, they noted the occurrence of two patterns of geographic differentiation; a range-wide genetic patchiness and a clinal variation along the Atlantic Coast. Genetic variability within and between populations was of similar magnitude and this genetic patchiness was attributed to pre-settlement processes associated with larval pulses, dispersal and settlement, and post-settlement ontogenetic changes brought about by localized selection. Comparing their results with those of Kordos and Burton (1993), they suggested post-settlement processes modify allele frequencies in pre-settlement assemblages that are already genetically heterogeneous. Berthelemy-Okazaki and Okazaki (1997) assayed 28 enzymes and proteins from adult crabs from four northern Gulf estuaries (Aransas Bay, Texas; Barataria Bay, Louisiana; Lake Pontchartrain, Louisiana; Mobile Bay, Alabama). They found a low level of genetic variation between the populations and noted that genetic exchange was not impeded by physical or physiological barriers in the region of study.

Studies of the genetic structure of blue crab populations from Mexico to New York were performed by McMillen-Jackson et al. (1994) and McMillen-Jackson and Bert (2004). These studies examined the genetic structure of blue crab populations over a broad geographic range using electrophoretic allozyme analysis (1994) and mitochondrial DNA (2004). They found genetic homogeneity throughout the range with greater latitudinal clines in the Atlantic than in the Gulf of Mexico. The 2004 study, using mtDNA, suggested regional gene flow occurs over short ecological time periods while long distance gene flow may be low and occur over longer evolutionary time periods. The range-wide genetic patchiness and a clinal variation within and between populations was of similar magnitude, and these authors attributed the genetic patchiness to pre-settlement processes associated with larval pulses, dispersal and settlement, and post-settlement ontogenetic changes brought about by localized selection. Comparing their results with those of Kordos and Burton (1993), they suggested post-settlement processes modify allele frequencies in pre-settlement assemblages that are already genetically heterogeneous.

Genetic analyses by Darden (2004) help explain and clarify the patchy but broad-scale structure suggested by McMillen-Jackson et al. (1994) and concur with McMillen-Jackson and Bert (2004) for the entire Gulf, as well as local structuring seen in western locations (Kordos and Burton 1993). Analysis of the entire 1,534-bp mitochondrial *cytochrome c oxidase subunit I* (COI) gene identified a 622-bp region sufficiently variable for population-level study. Using this functionally conservative, but highly variable nucleotide sequence, a total of 213 sequences were evaluated from 11 locations in the Gulf from Goodland, Florida to Brownsville, Texas. Traditional population genetic analyses and nested cladistic analysis were used to evaluate recurrent and historic gene flow. An extremely high level of genetic variation within the entire meta-population of Gulf of Mexico blue crabs was observed: of 213 sequences evaluated, there were 146 distinct genetic haplotypes resolved, indicating that enormous sample sizes would be necessary to confidently characterize population structuring. Nevertheless, the combined results from analysis of molecular variance and phylogenetic analyses lend support to Kordos and Burton's (1993) suggestion of eastern and western populations within the Gulf. In Darden's (2004) study, gene flow was restricted among western Gulf locations, particularly Louisiana and Texas bays (sample locations), while the Florida 'populations' from Goodland to Apalachicola showed no significant population structuring. While variation was mainly due to that within the 'total' sample pool, moderate but statistically significant variation (9.170%) was detected among locations ($\Phi_{ST}$ = 0.092, $p < 0.0001$). Nested cladistic analysis identified a contiguous historic range expansion in Gulf of Mexico blue crabs which likely coincided with increases in estuarine habitats following late Pleistocene sea level rise. Haplotype networks revealed four distinct lineages that represent the widespread ancestral dispersal that was subsequently overlain by high contemporary gene flow of descendent haplotypes which was accomplished according to the stepping stone model. Overall, results from the studies summarized here serve as a reminder that species with long-lived planktonic larval phases and potentially highly mobile adults do not always demonstrate the long distance dispersal that might be predicted. The influences of seasonal current circulation patterns, larval mixing, and larval migration behaviors (Johnson and Perry 1999, Perry et al. 2003 and Johnson et al. 2009), as well as long-distance migration of adults (Evink 1976, Oesterling 1976, Oesterling and Evink 1977, Oesterling and Adams 1982 and Steele 1987, 1991) may combine in the blue crab to separate 'east from west' in Gulf of Mexico blue crab populations. More distinct 'western' Gulf populations with low but detectable (significant) population structure are likely due to less influential seasonal wind-driven currents than those observed in the northern and eastern Gulf of Mexico. The data of Darden (2004), when combined with larval transport and tagging/migration studies, provide strong evidence of population structuring between eastern and western regions and thus have important management implications for blue crabs in the Gulf of Mexico.

### 3.2.2 Age, Growth, and Maturation

#### 3.2.2.1 Age

Although no quantitative procedure exists for determining size-at-age for blue crabs, the need to derive parameters for stock assessment models has necessitated estimation of size-at-age for the determination of growth rates used in estimating total mortality. It is inappropriate to infer age and growth for Gulf of Mexico blue crabs from studies performed under ambient conditions in latitudes higher than the northern Gulf of Mexico (N 30º 45'). Climatologically different study sites and the winter hibernation of blue crabs in northern estuaries are two significant problems with the application of northern studies to Gulf of Mexico blue crab populations. Winter temperatures in the Chesapeake Bay region significantly affect the molting/growth and the subsequent timing of recruitment to the fishery (Smith 1997 and Brylawski and Miller 2006). During winter, blue crabs experience several months of inactivity in the Chesapeake Bay estuary. In this region, blue crabs spawned in late summer recruit to the fishery and females reach maturity by the late summer or early fall of the following year (Miller et al. 2011). Blue crabs in the Gulf of Mexico have not been documented to overwinter; however Steele and Bert (1994) suggested the potential for semi hibernation needs further study. In many Gulf states, blue crabs are found to grow throughout the winter. Size-at-age for pond reared crabs in Florida indicates that crabs spawned during the summer are able to mature and recruit to the fishery at 127 mm CW by the end of that winter or early spring of the following year, at an age of ~6-7 months (Crowley 2012). This is further supported by the blue crab growout aquaculture work of USM/GCRL where similar trends are apparent (Perry personal communication, Graham personal communication) (Table 3.1). Therefore, the use of age and growth studies should be limited to those performed under environmental conditions similar to those in the Gulf of Mexico.

Tagatz (1968a) determined molt increment and growth per molt for crabs maintained in floats at two areas in the St. Johns River, Florida. Using mean percentage growth per molt and mean molt interval, he estimated size at age one of 142 mm. Perry (unpublished data) found mean pre and post-molt carapace widths of 119 and 163 mm, respectively, for pubertal molt females (n=159) taken in traps in Mississippi. Pre and post-molt carapace widths for male crabs (n=49) approaching one year of age were 120 and 151 mm, respectively, a size more closely approximating the estimate of Tagatz (1968a). If you assume that crabs in the northern Gulf reach maturity within a year (Perry 1975, Tatum 1980), these crabs provide an estimate of size at age-1. The average size of mature female crabs in Perry's study was comparable to data from other areas: average size of mature females in Delaware Bay was 160 mm CW, and in Chesapeake Bay mature females were 165 mm CW. Larger size at age-1 (163 mm CW) for mature females when compared to

**Table 3.1** Summary of growth studies for blue crabs in the Gulf of Mexico. GPM = growth per molt.

| | MOLT INTERVAL (DAYS) | MOLT INCREMENT | GROWTH RATE | DATA SOURCE | REFERENCE |
|---|---|---|---|---|---|
| **FIELD STUDIES** | | | | | |
| **MS** | | | | | |
| *Width-frequency distribution* | | | 24-25 mm/mo. | seine & trawl data (July - Jan) | Perry 1975 |
| *pubertal molt females* | | 38.5-40.5% increase | | | Perry unpublished data |
| **LA** | | | | | |
| *young crabs* | | | 14 mm/mo. | | Adkins 1972 |
| *crabs >85 mm* | | | 15-20 mm/mo. | | Adkins 1972 |
| *young crabs* | | | 16.7 mm/mo. | seine data (June - Sept) | Darnell 1959 |
| **TX** | | | | | |
| *Width-frequency distributions* | | | 15.3-18.5 mm/mo. | seine & trawl data | More 1969 |
| *Seine data* | | | 21.4 mm/mo. | seine data (Feb - Aug) | Hammerschmidt 1982 |
| *Trawl data* | | | 25.2 mm/mo. | trawl data (Feb - Aug) | Hammerschmidt 1982 |
| **AL** | | | | | |
| *April recruits* | | | 19 mm/mo. | | Tatum 1980 |
| *August recruits* | | | 10 mm/mo. | | Tatum 1980 |
| *December recruits* | | | 5 mm/mo. | | Tatum 1980 |
| **FL** | | | | | |
| *pubertal molt females* | | 30.2-34.4% increase | | | Tagatz 1968b |
| **AQUACULTURE** | | | | | |
| **MS** | | | | | |
| *Grow-out (early juvenile)* | | | 16.5 mm/mo. | Tanks | GCRL unpublished data |
| *Grow-out (late juvenile – adult)* | | | 20.2 mm/mo. | Ponds | GCRL unpublished data |
| **FL** | | | | | |
| *Pond* | | | | | |
| *Male growth rate from 15 mm to 127mm (legal size)* | | | 12.4 mm/mo. | Ponds with wild cohort | Crowley 2012 |
| *Female growth rate from 15 mm to 127mm (legal size)* | | | 12.7 mm/mo. | Ponds wild cohort | Crowley 2012 |

| | MOLT INTERVAL (DAYS) | MOLT INCREMENT | GROWTH RATE | DATA SOURCE | REFERENCE |
|---|---|---|---|---|---|
| **LABORATORY STUDIES** | | | | | |
| **Temperature** | | | | | |
| *15°C* | 25.5-61.0 | 15.95-21.55% | 7.0 mm/mo. | Controlled experiment | Leffler 1972 |
| *20°C* | 17.3-40.7 | 19.66-39.54% | 7.82 mm/mo. | Controlled experiment | Leffler 1972 |
| *27°C* | 11.7-29.5 | 13.49-27.08% | 11.3 mm/mo. | Controlled experiment | Leffler 1972 |
| *34°C* | 7.4-18.6 | 13.31-23.35% | 14.8 mm/mo. | Controlled experiment | Leffler 1972 |
| *16°C* | | GPM, 118.1% | | Controlled experiment | Brylawski and Miller 2006 |
| *20°C* | | GPM, 121.4% | | Controlled experiment | Brylawski and Miller 2006 |
| *24°C* | | GPM, 116.1% | | Controlled experiment | Brylawski and Miller 2006 |
| *28°C* | | GPM, 121.8% | | Controlled experiment | Brylawski and Miller 2006 |
| **Salinity** | | | | | |
| *5 ppt* | | | 0.24 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |
| *5 ppt Female* | | | 0.24 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |
| *15 ppt Male* | | | 0.35 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |
| *15 ppt Female* | | | 0.33 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |
| *25 ppt Male* | | | 0.38 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |
| *25 ppt Female* | | | 0.44 mm/day | Controlled experiment | Cházaro-Olvera and Peterson 2004 |

the estimated size of 142 mm CW proposed by Tagatz (1968a) may be attributed to sex-related morphological changes associated with lateral spine length in pubertal molt females (Gray and Newcombe 1938, Olmi and Bishop 1983, Guillory and Hein 1997a) and/or greater incremental growth in female crabs (sub-adult) than in similar-sized male crabs (Tagatz 1968a).

#### 3.2.2.1.1 Precise Age Determination Techniques

Ageing of crustaceans is hindered by their complicated life cycles, inconsistent growth patterns and lack of retention of mineralized structures. Biological interactions, discrete and determinate growth patterns and the effects of environmental parameters (salinity and temperature) on molting have significant effects on blue crab growth (Steele and Bert 1994, Hartnoll 2001) thus precise age determinations using length-frequency measurements (commonly used in vertebrates) are precluded. When size-distribution and modal analysis has been applied to crustacean fisheries it has usually proved unsuccessful in accurate age estimation (Puckett et al. 2008) due to its vulnerability to interpretation (Hartnoll 2001).

Alternative methods for determining age in crustaceans have been investigated. The most promising has been the use of the compound lipofuscin which accumulates as a function of oxidative stress (Brunk and Terman 2002, Terman and Brunk 2004a and 2004b) and exhibits a progressive increase with age in both vertebrate and invertebrate taxa (Brunk and Terman 2002, Szweda et al. 2003, Cassidy 2008). Lipofuscin has been investigated histologically and used for age determination in crustaceans (Sheehy 1990, Medina et al. 2000, Pereira et al. 2009). However, the process of histological examination is expensive and time consuming. An alternative method for rapid lipofuscin assay with high throughput of samples was developed using extraction and spectroflurometry and applied to blue crab fisheries in the Chesapeake Bay region of the U.S. (Ju et al. 1999 and 2001, Puckett et al. 2008). Puckett and Secor (2006) used the extraction method on known-age crabs to validate the age of blue crab for this region of the U.S. under natural environmental conditions (Puckett and Secor 2006).

Researchers in Florida attempted to apply the extraction techniques developed by Ju et al. (1999 and 2001) and Puckett et al. (2008) to aging blue crabs in the Florida fishery (Crowley 2012). Crowley (2012) investigated the robustness of the extraction technique for lipofuscin age determination in Florida blue crabs using two known age cohorts. Cohorts were from different sources, one wild (n=570) and one from the Blue Crab Aquaculture program at the University of Southern Mississippi's Gulf Coast Research Laboratory (n= 188). Each cohort was cultured under different conditions to develop a known age curve and subsequently determine the reliability of the extraction technique for ageing blue crabs before its application in the Florida blue crab fishery. Results of the Florida study did not support the conclusions of Ju et al. (1999 and 2001) and Puckett et al. (2008) that linked accumulation of extracTable lipofuscin with chronological age in blue crab (Crowley 2012). In contrast to those authors, the Florida study found negative correlations with age in the pond ($y = -0.05x + 0.43$, $p<0.001$, $r^2 = 0.13$) and tanks ($y = -0.012x + -0.919$, $p<0.07$, $r^2 = 0.002$). The lipofuscin indices generated by the extraction method were not correlated with age and precluded the development of a calibration curve and age determination of blue crabs in the Florida fishery. Use of lipofuscin methodology has been found to be unsuccessful in other studies on different species (Manibabu and Patnaik 1997, Majhi et al. 2000) and Sheehy (2008) noted that the accuracy of the extraction methodology may not be sufficiently validated for use in ageing.

A more recent methodology for age determination in crustaceans uses growth bands found in calcified regions of the eyestalk or gastric mill in shrimp, crabs and lobsters (Kilada et al. 2012). While these authors were able to use cuticular growth bands to estimate age in longer-lived, cold water crustaceans such as the American lobster (*Homarus americanus*) and snow crab (*Chionoecetes opilio*), its applicability to short-lived, fast-growing species is untested.

#### 3.2.2.2 Growth

Larvae undergo metamorphic development passing through a series of zoeal molts to the megalopal stage. Robertson (1938), Churchill (1942), Truitt (1942), and Davis (1965) reported prezoeae emerging from the eggs with time estimates for duration of the stage ranging from one to three minutes (Davis 1965) to several hours (Robertson 1938). Sandoz and Hopkins (1944) and Sandoz and Rogers (1944) noted that larvae emerged as prezoeae only in response to adverse biological or environmental conditions. Costlow and Bookhout (1959) made specific reference to the lack of the prezoeal stage for *C. sapidus* noting that the larvae emerged as zoeae and that there were usually seven zoeal stages and one megalopal stage. They sometimes observed an eighth zoeal stage though survival to the megalopal stage was rare. Stuck et al. (2009) found the number of zoeal molts variable, ranging from six to nine, but usually consisting of seven.

Estimation of growth parameters in blue crab populations is problematic due to their discontinuous or stepwise pattern of incremental growth. Somatic growth takes place during ecdysis or molting, while small increases in weight occur during intermolt as a result of changes in tissue content (Millikin and Williams 1984). The rate of growth is determined by the increase in size at each molt (molt increment) and the interval between successive molts (molt interval); thus, growth per molt and molt frequency are used as determinants of growth. Early crab stages have short molt intervals with molting occurring every few days. As crabs increase in size the molt frequency decreases. Blue crab growth is determinate (Hartnoll 1985) in both females and males (Smith and Chang 2007). Females reach the terminal instar at their nuptial molt with males passing through additional adult molts to reach a terminal instar. Smith and Chang (2007) noted that both sexes have the physiological ability to molt following attainment of the terminal instar, but do not. Whether the number of postlarval instars is fixed or varies to some degree among individuals is not known. Newcombe et al. (1949a) estimated the postlarval instars for male and female blue crabs to be 20 and 18, respectively. Maximum size attained thus reflects incremental growth per molt rather than the number of molts (Leffler 1972).

Growth data exist for Gulf of Mexico blue crabs from length-frequency distributions and more recently from aquaculture studies conducted in Florida and Mississippi. Perry (1975) estimated seasonal (July through January) growth by tracing modal progressions in monthly width-frequency distributions for crabs in Mississippi Sound. The estimated growth rate of 24-25 mm/month is somewhat higher than rates found for other Gulf estuaries. Adkins (1972a) found growth in Louisiana waters to be about 14 mm/month for young crabs with slightly higher rates (15-20 mm/month) as crabs exceeded 85 mm in carapace width. Darnell's (1959) growth estimate of 16.7 mm/month for crabs in Lake Pontchartrain falls within the average reported by Adkins.

A recently completed study in Galveston Bay used internally implanted coded wire tags to determine growth of juvenile blue crabs released into the wild (Sutton et al. 2013). Growth rates averaged 14.6 mm/month, but were significantly influenced by water temperature. This illustrates the need to include temperature and seasonality in developing blue crab growth models. The study also included a control group of tagged and caged individuals held in the same water body and treated with 1) a weekly food supplement of frozen shrimp, and 2) no food supplement apart from what grew on or entered the cages. Growth rates from the caged crabs were significantly correlated to food availability (supplement food) and water temperature.

More (1969) noted a growth rate of 15.3-18.5 mm/month in Texas. Plotting the progression of modal groups from February through August, Hammerschmidt (1982) reported higher growth rates for crabs in Texas (21.4 and 25.2 mm/month for seine and trawl samples, respectively) and attributed these rates to the use of seasonal rather than yearly data.

Tatum (1980) also found seasonal changes in the rate of growth of young blue crabs in Mobile Bay, Alabama. He observed monthly rates of 19, 10, and 5 mm for crabs recruited in April, August, and December, respectively. Pond studies in Florida (Crowley 2012) found growth rates of males and females from 15 mm to a legal size of 127 mm to be 12.4 and 12.7 mm/month, respectively. Mississippi aquaculture research has estimated crab growth from studies in tanks and ponds (Perry unpublished data). During the early grow-out period (megalopae to beginning crab stages) in recirculating tanks, crabs had a growth rate of 16.5 mm/month. In pond studies (early juvenile crabs to adults), crab growth was 20.2 mm/month.

Studies examining the influence of environmental parameters on molt frequency and incremental growth are conflicting. Newcombe (1945), Porter (1955), Cargo (1958), and Van Engel (1958) associated increasing size with decreasing salinity and suggested a possible correlation of size with the salinity of the water in which growth occurred. Van Engel (1958) believed that an osmoregulatory mechanism was involved; differences in the levels of salt concentration between the crabs and their environment affected the uptake of water resulting in increased growth per molt. Millikin and Williams (1984), however, reported that salinity values ranging from 6.0-30.0‰ did not differentially affect growth of juvenile and adult blue crabs. In studies of growth increments occurring during the terminal molt of female blue crabs under different salinity regimes, Haefner (1964) found that growth was not affected by salinities of 9.0‰, 16.0‰, or 27.0‰. Haefner and Shuster (1964) concluded that "within the parameters of the experiment, the salinity variation of the environment was not related to percentage increase in length at the terminal molt." Tagatz (1968a) found that a decrease in salinity did not produce an increase in size and suggested that some factor other than salinity appeared to account for larger crabs in certain waters. Perry examined size increases in pubertal molt females in salinities of 5.0‰, 12.0‰, and 25.0‰ for crabs in Mississippi and also found that percent increases in carapace width were not significantly different among the test groups (Guillory et al. 2001). Average increases were 38.5%, 40.4%, and 40.5% at salinities of 5.0‰, 12.0‰, and 25.0‰, respectively. Tagatz (1968a) reported incremental growth increases in pubertal molt females of 34.4% and 30.2% in salt (>5‰) and fresh (<1‰) waters, respectively. Smith and Chang (2007) noted that the influence of salinity on molting was subtle and was more easily observed at salinity extremes. Hartnoll (1982) found that, at very low or very high salinities, the general response was a decrease in molt increment, or an increase in the intermolt period, or both.

Growth of blue crabs appears to be more strongly affected by temperature. In laboratory studies, Leffler (1972) demonstrated that the molting rate (molts per unit of time) increased rapidly with increasing temperature from 13.0-27.0°C but continued at a slower rate between 27.0°C and 34.0°C. Growth per molt was significantly reduced above 20.0°C, and at temperatures below 13.0°C, growth virtually ceased. Cadman and Weinstein (1988) and Holland et al. (1971) observed accelerated growth with increasing temperature until a threshold was reached, after which growth per molt decreased and Winget et al. (1976) found growth per molt higher at 20°C. Thus, while the molting rate increases with temperature, the number of molts necessary to attain a certain size also increases. Leffler (1972) reported that the number of molts required for a 22 mm CW crab to attain 60.0 mm CW increased from five at 15°C to seven at 34°C. Leffler (1972) noted that because the number of molts is fixed, maximum size attained reflected growth per molt modified by ambient thermal surroundings; thus, environmental temperatures may contribute to observed variation in size at maturity. In contrast, Tagatz (1968a) found that growth per molt was similar in summer and winter regardless of temperature; however, intermolt intervals increased in colder months. Winter temperatures in his study averaged about 14°C with an average summer temperature of approximately 26°C. Tagatz held his crabs in outdoor floats as opposed to controlled laboratory temperatures, and fluctuating temperatures associated with the natural environment may not have affected growth per molt as profoundly as constant exposure to low temperature.

Tagatz (1968a) observed that growth per molt and molt interval were highly variable within juvenile size groups and noted that this variability may cause irregularity in recruitment. He found growth per molt ranged from 7.8-50.0% with a mean of 25.3%. Both Tagatz (1968a) and Millikin and Williams (1984) noted that growth rate of juvenile crabs did not vary between males and females.

Injuries to blue crabs may influence both molt increment and molt interval. Van Engel (1958) noted that injuries may reduce the growth increment to 5% to 10% or may result in no increase in size. Smith (1990) found that multiple autotomy reduced growth increments in laboratory-held crabs, but noted that size differences resulting from limb removal were confined to the first post-autotomy molt. At the second molt following autotomy, size and weight of autotomized crabs were indistinguishable from controls. Skinner and Graham (1972) were able to stimulate precocious molting in *C. sapidus* by removing both chelae and four pereiopods. A summary of blue crab growth studies from the Gulf of Mexico can be found in Table 3.1.

Blue crab growth rates in the Gulf of Mexico can be modeled using the von Bertalanffy growth equation,

$$CW_t = CW_\infty (1-e^{-K(t-t_0)}) \quad [1]$$

where $CW_t$ is the carapace width at time *t*; $CW_\infty$ is the mean carapace width of very old blue crabs occurring in the Gulf of Mexico; *K* is the von Bertalanffy growth coefficient; and $t_0$ is the time at which carapace width is theoretically zero. This continuous growth function does not literally describe the incremental growth of blue crabs, but since model fitting is essentially a data smoothing technique and since members of a cohort molt at different times, the average growth of a cohort becomes a smooth curve (Sparre et al. 1989). Smith (1997) and Rothschild and Ault (1992) modified the von Bertalanffy model to consider incremental growth but this assessment agreed with Rugolo et al. (1997) who concluded that the von Bertalanffy model adequately described blue crab widths at ages. Required inputs for the model included estimates of $CW_\infty$, widths at ages, and maximum age.

In addition to the von Bertalanffy growth model, a temperature-dependent individual-based molt-process model was adapted from Bunnell and Miller (2005) and fit to the aquaculture studies from both Florida and Mississippi (Cooper personal communication). The model was structurally similar to Bunnell and Miller (2005), but instead of basing the growth parameters on Tagatz (1968a), the growth parameters [growth per molt (GPM), intermolt period (IP)] were fit to the aquaculture size-at-age data using metaheuristic maximum likelihood approach. To provide more flexibility in GPM as a function of size, GPM was modeled using a polynomial spline, while the IP parameters were modeled as in Bunnell and Miller (2005). Growth and temperature data were available for one aquaculture study in Florida, and seven aquaculture studies in Mississippi (Figure 3.2). The molt-process model was fit to the combined studies from Florida and Mississippi, providing a single set of parameter estimates for GPM as a function of size and IP a function of size and temperature. The fit of the model to the observed growth data from the eight aquaculture studies is shown in Figure 3.3.

Due to the strong temperature dependence on growth in blue crabs, von Bertalanffy growth parameter estimates from individual studies would only be appropriate for individuals spawned during similar months, since those spawning in spring could have markedly different growth parameter estimates than those spawned in the fall. To distill a single set of growth parameter estimates for the western and eastern stock in the Gulf of Mexico, the climatological average of temperatures for the two regions were calculated from the fisheries independent monitoring data, and these temperature time series were input into the molt-process model to simulate size-at-age data for individuals spawning throughout the entire spawning season (VanderKooy 2013). The spawning season was based on the proportion of ovigerous females sampled in various studies, and these proportion data were used to assign the spawning date using an empirical distribution.
A von Bertalanfy model was then fit to these simulated size-at-age data for the Eastern and Western GOM stocks to obtain a single estimate for both stocks (Figure 3.4):

$$CW_t \text{ (Western GOM stock)} = 165.95\ (1\text{-}e^{-1.9325(t-0.1668)}) \quad [2]$$

$$CW_t \text{ (Eastern GOM stock)} = 166.05\ (1\text{-}e^{-2.1582(t-0.1740)}) \quad [3]$$

Maximum age of Gulf of Mexico blue crabs was assumed to be six years. Fischler (1965) found crabs attaining an age of at least five years in a tagging study conducted in North Carolina. Smith (1997) inferred a maximum age of 5.5 years based on a molt-process model and Churchill (1919) presumed six years from anecdotal evidence. Rothschild and Ault (1992) also assumed a maximum age of six years in their assessment of Chesapeake Bay blue crabs.

#### 3.2.2.2.1 Width-Weight Relationships

Width-weight relationships differ between the sexes of blue crabs, with males generally heavier than females for a given carapace width (Newcombe et al. 1949b, Tagatz 1965, Pullen and Trent 1970). Olmi and Bishop (1983) found that maturity, molt stage, and carapace form significantly affected width-weight relationships. In their study, mature males weighed more than similar sized immature males; however, mature females weighed less than immature females of equal size. Crabs with short lateral spines were heavier than those of the same sex and width with long spines. Intermolt (Stage C) and premolt (Stage D) blue crabs of both sexes were heavier than recently molted (Stages A and B) crabs of the same sex (Drach 1939 as modified by Passano 1960).

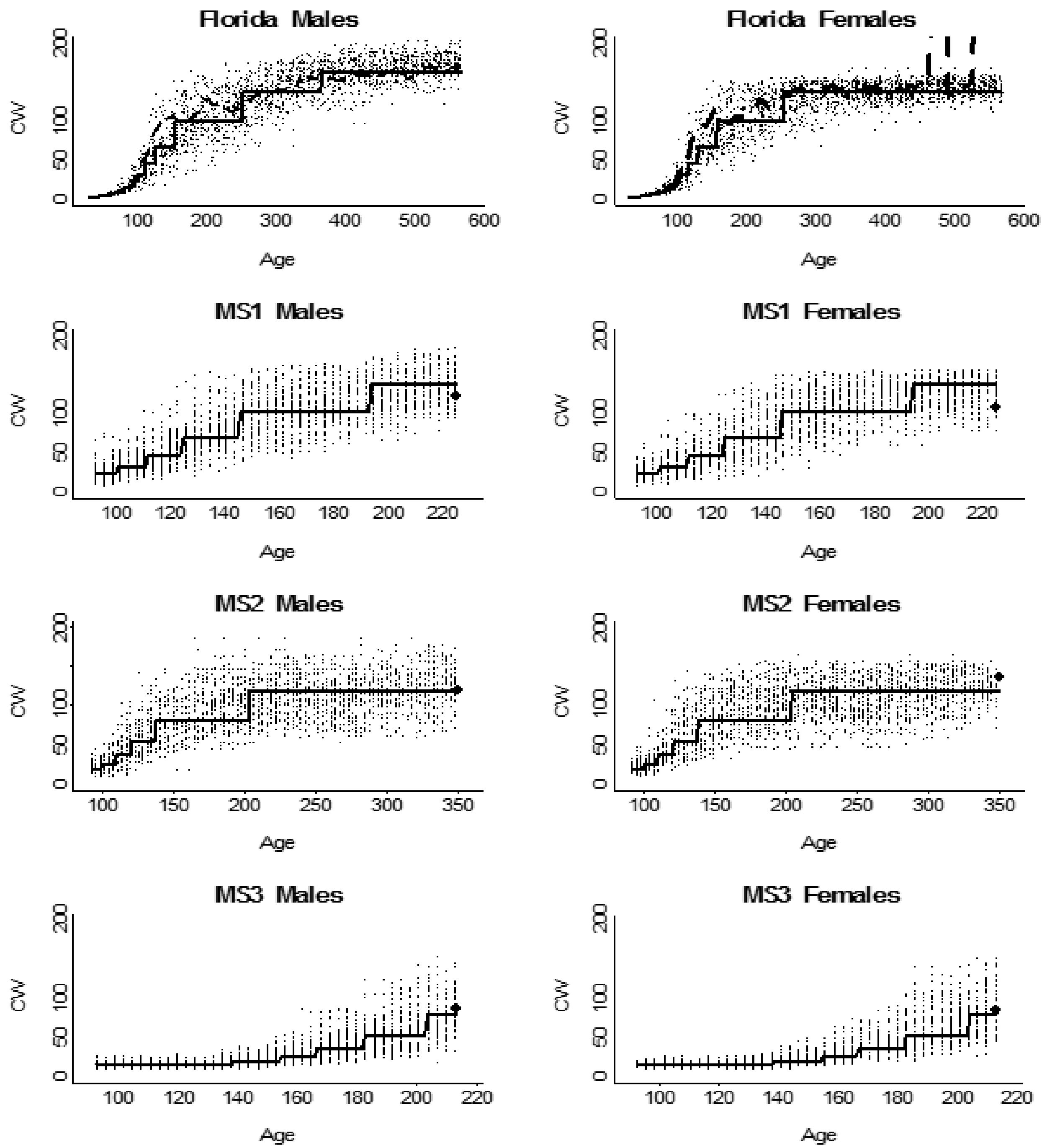



**Figure 3.2** Estimated size-at-ages per sex for the temperature-dependent molt-process growth model, fit to aquaculture studies from Florida (one pond) and Mississippi (seven ponds, MS1-MS7). The solid line represents the expected size-at-age (i.e., no stochastic variability in growth parameters), while the dots represent the expected size-at-age for a sample of individuals with stochastic variability in their growth parameters. The dotted line for Florida is the observed mean size-at-age (weekly throughout time period), and the large points for Mississippi are the observed mean size-at-age at the termination of each pond experiment (*from* VanderKooy 2013).

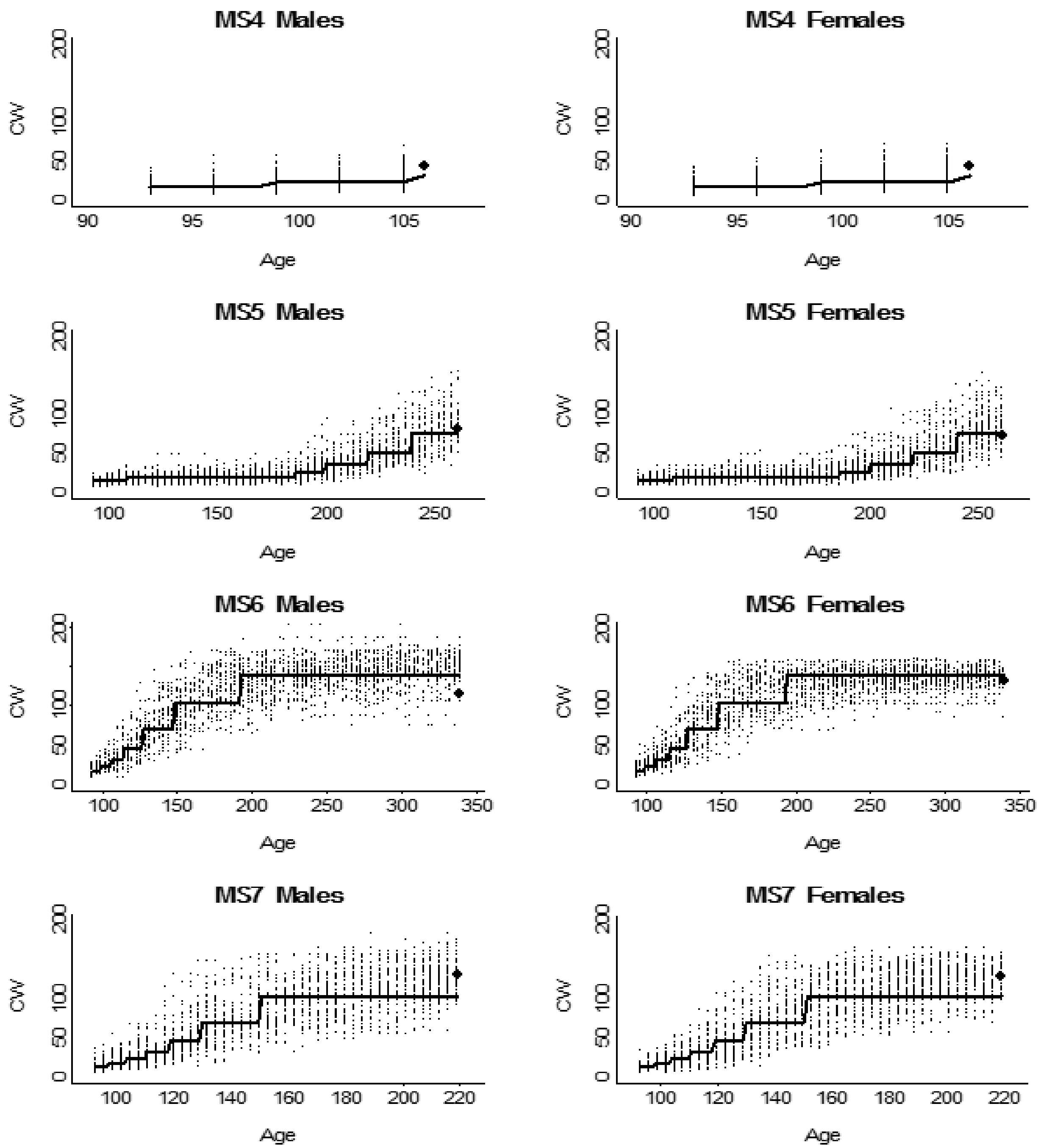



**Figure 3.2** continued.

Premolt females were heavier than intermolt females; this difference was not observed for males.

Carapace width-to-weight relationships have been estimated for blue crabs sampled from estuaries the Gulf of Mexico. Guillory and Hein (1997a) developed a relationship for blue crabs from the Terrebonne Basin, Louisiana. Blue crab weight (grams) at carapace width (CW) for both sexes combined was determined as:

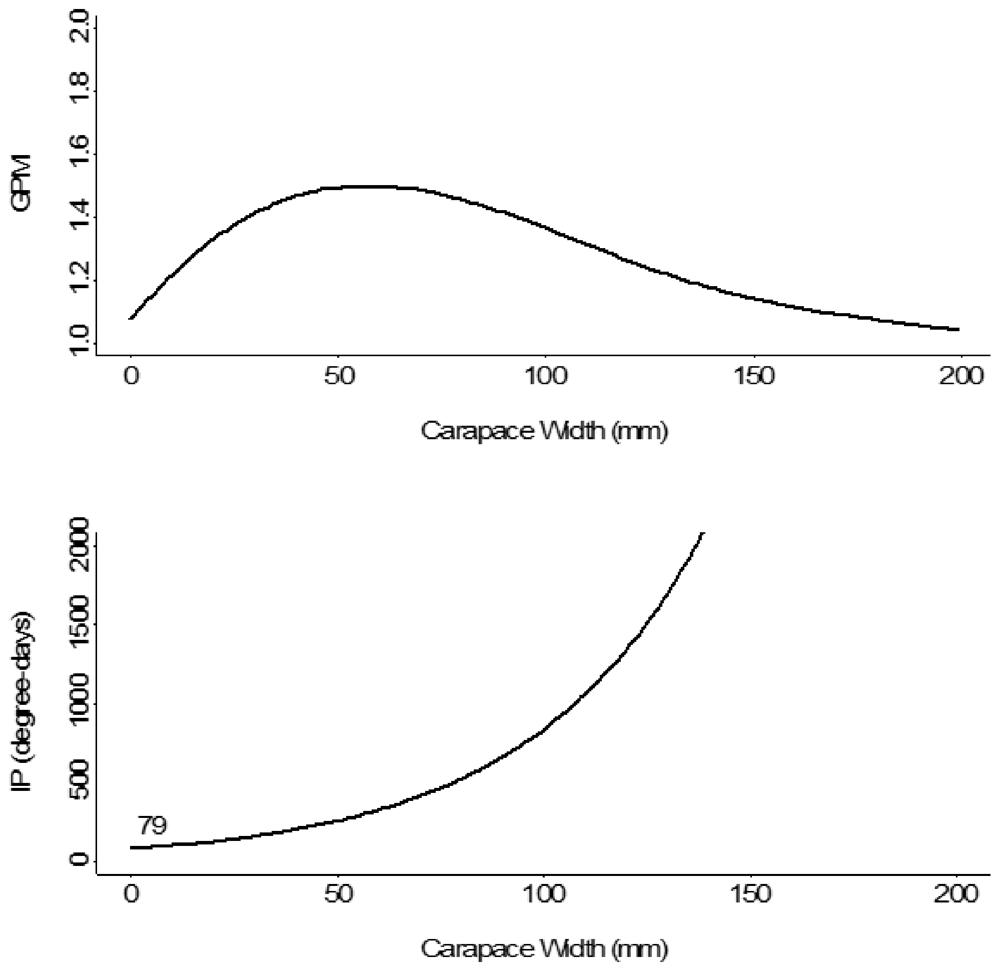



**Figure 3.3** Estimated growth per molt (GPM) and intermolt period as a function of size from the temperature-dependent molt-process model (*from* VanderKooy 2013).

$$Weight = 8.26x10^{-4}CW^{2.446} \quad [4]$$

Relationships from Mississippi fishery-independent monitoring are presented in Figure 3.5A and fishery-dependent are presented in Figure 3.5B. The composite weight-length relationship [both sexes, fishery-independent (FID), and fishery-dependent data (FDD)] and category-specific relationships were estimated as follows:

$$Weight\ (Composite) = 8.88x10^{-4}CW^{2.429} \quad [5]$$

$$Weight\ (FDD,Males) = 1.41x10^{-3}CW^{2.373} \quad [6]$$

$$Weight\ (FDD,Females) = 2.64x10^{-3}CW^{2.199} \quad [7]$$

$$Weight\ (FID,Males) = 1.85x10^{-4}CW^{2.751} \quad [8]$$

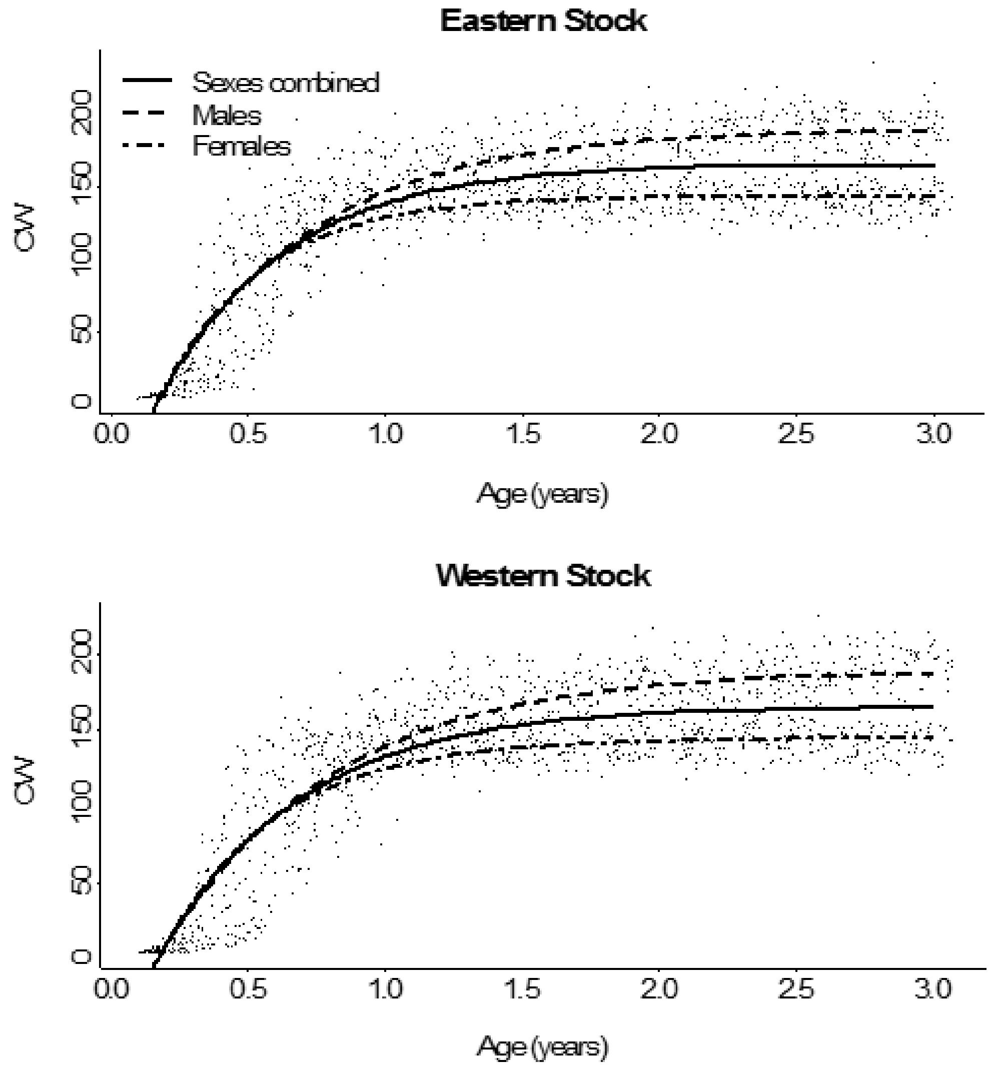



**Figure 3.4** von Bertalanffy growth model fits to simulated size-at-age data from the individual-based molt-process growth model, using virtual individuals spawned throughout the entire spawning season (note: only a small sample of the virtual individuals used for the model fits are shown) (from VanderKooy 2013).

$$Weight\ (FID,Females) = 3.37x10^{-4}CW^{2.613} \quad [9]$$

In Florida, multiple data sources were used from commercial biostatistical sampling, disease sampling contracted through commercial crab fishermen, and fishery-independent monitoring (n=11,727 crabs) to produce the following relationships for the composite fit to all data, and separated out by category (Figures 3.5C and 3.5D):

$$Weight\ (Composite)=8.42x10^{-3}CW^{1.998} \quad [10]$$

$$Weight\ (FDD,Males)=2.27x10^{-3}CW^{2.278} \quad [11]$$

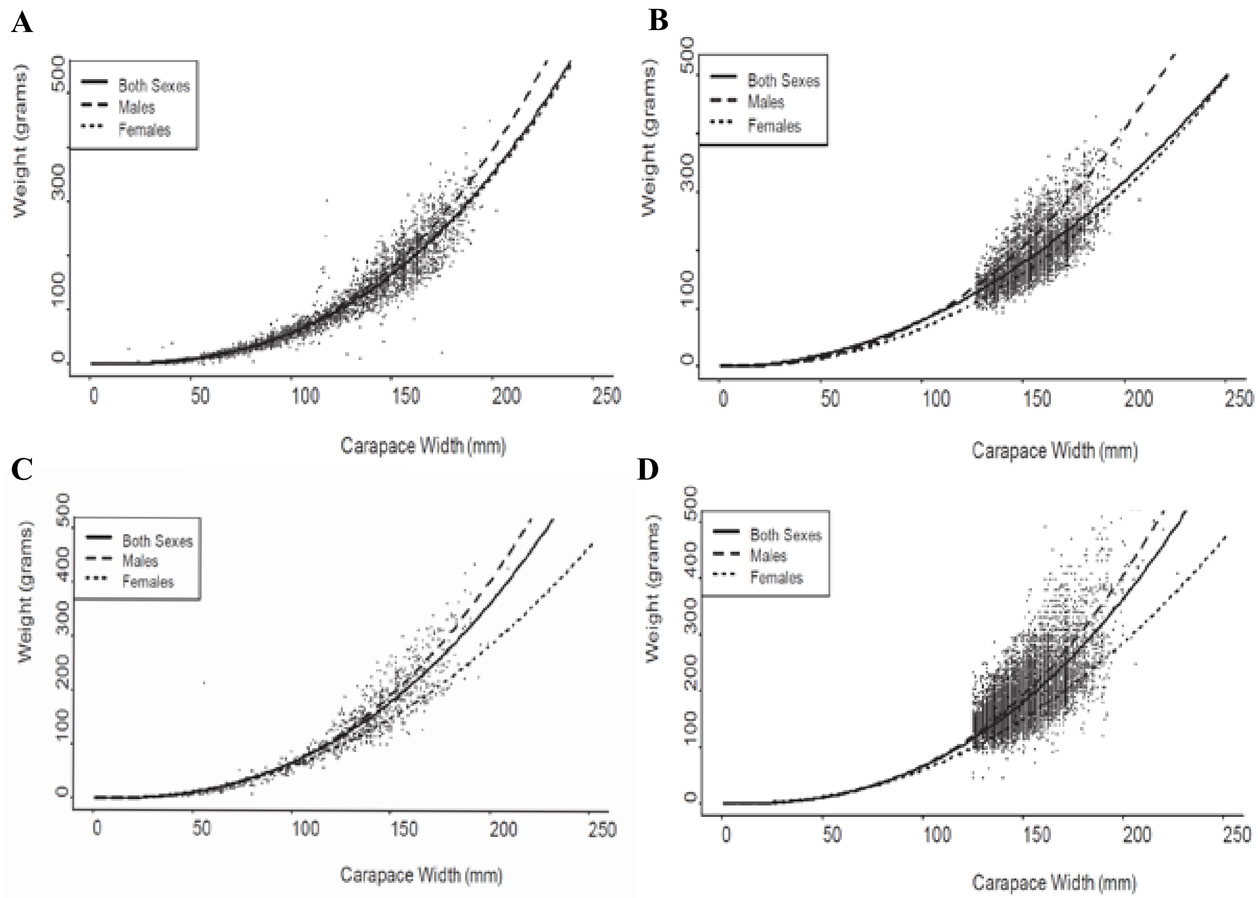



**Figure 3.5** Carapace width-weight (mm) relationships for legal size (> 127 mm) blue crabs from A) Mississippi FID sampling (1973-2011), B) Mississippi FDD sampling (2007-2011), C) Florida FID sampling, and D) Florida FDD sampling (from VanderKooy 2013).

$$\textit{Weight (FDD,Females)} = 8.43 \times 10^{-3} CW^{1.967} \quad [12]$$

$$\textit{Weight (FID,Males)} = 4.63 \times 10^{-4} CW^{2.583} \quad [13]$$

$$\textit{Weight (FID,Females)} = 2.13 \times 10^{-3} CW^{2.228} \quad [14]$$

Pullen and Trent (1970) reported CW to total weight relations for crabs >25 mm CW from Galveston Bay, Texas:

$$\log \textit{Weight (male)} = -3.74 + 2.775 \log CW \quad [15]$$

$$\log \textit{Weight (female)} = -3.54 + 2.639 \log CW \quad [16].$$

Newcombe et al. (1949b) reported CW to total weight relationships for blue crabs from Chesapeake Bay using untransformed data: male weight = 0.00026 width$^{2.67}$ and female weight = 0.00034 width$^{2.57}$. Olmi and Bishop (1983) determined separate total width-weight relationships for males and females, immature and mature crabs by sex and carapace form (i.e., *typica*, intermediate, and *acutidens*) by sex and molt stage (intermolt, premolt, and postmolt). They suggested that because of the influence of sex, maturity, molt stage, or carapace form, comparisons of width-weight relationships may lead to erroneous conclusions if these variables are not considered.

Carapace width has historically been used for minimum size regulations. However, measurements of carapace length or width at the base of the lateral spines would be more accurate in developing a regression analysis because of the variability in lateral spine length (Olmi and Bishop 1983). Carapace length was originally suggested by Gray and Newcombe (1939) as an alternative to CW for prediction of body weight. Williams (1974) suggested the use of CW measured at the base of the lateral spines rather than from tip to tip to predict body weight.

**3.2.2.2.2 Nutrition**

Data on the relationship between dietary quality and growth are inconsistent. Millikin et al. (1980) found that juvenile crabs fed 44% or 60% crude protein diets (% dry weight) achieved better growth than those fed a 27% crude protein diet over a 105 day period. Winget et al. (1976), however, observed no significant difference in growth in crabs fed diets of 26%, 46%, 62%, and 75% crude protein over a 60-day period. Millikin et al. (1980) also noted that juvenile crabs fed live brine shrimp (*Artemia salina*, 58-64% crude protein) exhibited better growth than did crabs fed formulated laboratory diets (60% crude protein) and suggested that there are important nutritional differences other than dietary protein accounting for the observed difference in growth.

Seasonal size differences have been reported in wild caught *C. sapidus* megalopae and first crab stages. Stuck and Perry (1982) and Stuck et al. (2009) noted that megalopae in spring plankton samples were substantially larger than those collected in the fall. They also noted that spring brood first zoeae were significantly larger than fall brood first zoeae. In laboratory-rearing experiments, initial size differences between spring and fall brood zoeae became less apparent as larvae developed through the zoeal stages, and no seasonal size differences were detected in megalopae and first crabs. Because fall brood zoeae were able to catch up and equaled the size of spring brood larvae in a food-unlimited environment, Stuck and Perry (1982) noted that size differences in spring and fallcaught megalopae may be related to seasonal differences in food availability. The trend for larger megalopae in the spring has also been found in other studies (Ogburn et al. 2011).

**3.2.2.2.3 Autotomy**

Autotomy and regeneration of appendages are common in blue crabs and other crustaceans. When an appendage is firmly held or severely damaged, a break occurs along a fracture plane located at the appendage's distal base. A functional, but smaller, appendage is formed by regeneration at the next molt. Autotomy may affect growth by diverting metabolic resources to regenerate autotomized appendages. In the laboratory, Smith (1990) found that regenerating chelipeds (single autotomized treatment) measured 88% of the length of the undamaged contra-lateral limbs after the first molt following autotomy. The second molt after autotomy resulted in nearly 100% length regeneration. Smith (1990) also investigated the effect of autotomy on growth and molting frequency in blue crabs in the Rhode River, a sub-estuary of Chesapeake Bay. In laboratory studies, he found that loss of a single cheliped did not have a significant effect on molt increment or molt interval; however, multiple autotomy did reduce growth increment in some crabs. Based on laboratory studies and field observations, he concluded that the overall effect of autotomy on growth in the population of crabs in the Rhode River was minor.

Autotomy is an important survival mechanism. Smith and Hines (1991a) evaluated geographic, temporal, and ontogenetic variation in autotomy of blue crabs. A substantial percentage (17%-39%) of crabs in their study were either missing or regenerating one or more limbs. Injury levels were generally correlated positively with crab size, suggesting that intraspecific interactions may be a major cause of limb loss. The most frequent injury involved loss of a single cheliped.

Hamilton et al. (1976) showed that while all hatchery raised crabs had a right 'crusher' claw and a left 'cutter' claw, only 79% of 1,156 crabs sampled from natural waters displayed this morphological pattern. Larger crabs tended to have a greater percent occurrence of left 'crusher' claws and right 'cutter' claws, which they attributed to reversed cheliped laterality through autotomy and regeneration. Smith (1990) observed that removal of the major claw (crusher) resulted in the regeneration of a minor, cutting claw in both single and multiple autotomy treatments. Crabs failed to regenerate a distinct crusher even after three molts.

#### 3.2.2.3 Maturation

The length of time required for crabs to reach maturity varies regionally. Up to 18 months is necessary for maturation in Chesapeake Bay (Van Engel 1958), while blue crabs in the Gulf of Mexico may reach maturity within a year (Perry 1975, Tatum 1980). Florida pond studies of Crowley (2012) found the first mature female raised from a wild cohort in a one-quarter acre pond at 7.7 months of age and the last immature female was captured in the pond at 10.3 months of age.

One of the more controversial issues concerning growth and maturation involves the concept of permanent anecdysis in female crabs. Havens and McConaugha (1990) and Steele and Bert (1994) found seasonal size differences in mature females and proposed that females may not enter a permanent anecdysis. Mature females with limb buds (11.2% of sampled population), molting by females with ablated eyestalks, and seasonal size differences in mature females prompted Havens and McConaugha (1990) to suggest that females can molt following the pubertal ecdysis. Although mature females in the process of molting (Abbe 1974) or in proecdysis (Olmi 1984, Millikin and Williams 1984) have been observed in other studies, they have been few in number suggesting that this rarely occurs. There is little evidence for molting of mature females in the northern Gulf.

Size at maturity is highly variable, and a number of factors appear to influence maturation size. Temperature exerts control on maximum size by affecting incremental growth and molt interval. Tagatz (1968a) suggested that differences in growth per molt and molt interval within juvenile size groups may account for observed variation in size at recruitment to adult populations. Morphological changes associated with maturation also contribute to variability in size. Newcombe et al. (1949b), Olmi and Bishop (1983), and Guillory and Hein (1997a) found maturity associated differences in width-weight relationships between male and female crabs. They attributed these differences to changes in carapace form (pubertal molt transformation in females to the long-spined form) and heavier individual body components in male crabs. Perry (unpublished data) examined growth per molt between males and pubertal molt females of similar size. There was no significant difference in pre-molt size between males and females in her study; however, post-molt females were significantly larger in size. Percent gain in carapace width was 28% for males and 40% for females (Figure 3.6).

Data are available for size at 50% and 100% sexual maturity for male and female blue crabs from Louisiana (Guillory and Hein 1997b), Mississippi (Perry unpublished data), and Texas (females only, Fisher 1999). In the Louisiana study, blue crabs attained 50% sexual maturity at carapace widths of 110 and 125 mm for males and females, respectively. One hundred per cent sexual maturity occurred at 130 mm CW in males and 160 mm CW in females. Size at maturity was somewhat larger in Mississippi crabs. Males attained 50% sexual maturity at carapace widths between 145 and 150 mm. Females reached 50% sexual maturity at carapace widths between 125 and 130 mm. Both males and females attained 100% sexual maturity between 190 and 195 mm

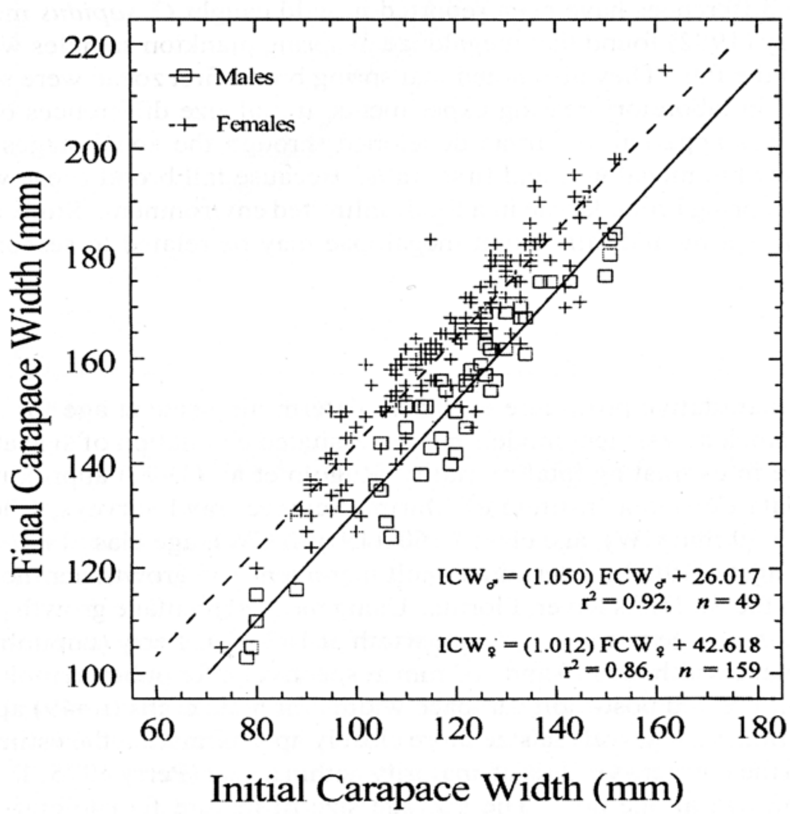



**Figure 3.6** Post-molt gain in carapace width for similar-sized male and pubertal molt female blue crabs in Mississippi (Perry unpublished data).

CW. Fisher (1999) estimated size at 50% sexual maturity for females at approximately 120mm CW in Texas. Estimates of sizes at 50% sexual maturity were similar for females in all three studies. Size at 50% and 100% sexual maturity for males and 100% sexual maturity for females was markedly different in the Louisiana and Mississippi studies. Techniques used to determine sexual maturation in male crabs may have contributed to these reported size differences. Guillory and Hein (1997b) used external morphological features associated with the method and degree of adherence of the male abdomen to the sternum as described by Van Engel (1990). Perry (unpublished data) used internal examination of the male reproductive system to determine size and color of the median vasa differentia (MVD): mature crabs have a distended MVD that is bright pink (Cronin 1947, Pyle and Cronin 1950, Johnson 1980). Van Engel (1990) noted that in addition to the method and degree of abdominal adherence to the sternum, there had to be spermatophores present in the anterior vasa differentia (AVD); however, Johnson (1980) reported that although completed spermatophores are present in the AVD in crabs at 65 mm CW, these males have not developed voluminous secretion (passed to the female during copulation) in the MVD and posterior vasa differentia (PVD) and are not ready to mate. Hinsch and Walker (1974) also noted that even though juvenile males of the spider crab *Libinia emarginata* had completed spermatophores in AVD, they were too small to mate. Because physiological changes other than those described by Van Engel (1990) appear to be necessary before attainment of full sexual maturity, assigning maturity using this technique may result in underestimation of size at sexual maturation. Using size and color of the MVD to determine sexual maturity also has drawbacks. Following copulation, the MVD collapses, becomes smaller and may be only pale pink in color, thus some sexually mature individuals may be classified as immature. Discrepancies in size at 100% sexual maturity in female crabs cannot be fully explained but may be related to factors associated with rhizocephalan infection which is prevalent in many Louisiana estuaries

Rate of growth and size-at-maturity may be affected by parasites and disease. Fischler (1959), Williams (1974), and Overstreet et al. (1983) reported mature females at carapace widths of 52-55 mm, 55 mm, and 46.7 mm, respectively. Causes of dwarfing or stunted development in blue crabs are not well understood. The influence of the rhizocephalan parasite *Loxothylacus texanus* on growth and development of its blue crab host has been addressed in several studies, but many issues remain unresolved. The parasite is distributed throughout the Gulf of Mexico from south Florida to Sontecomapan, Mexico (Alvarez and Calderon 1996). Highest average incidence of infection occurs in the western Gulf from Mississippi to Sontecomapan Lagoon, Veracruz, Mexico (Christmas 1969, Ragan and Matherne 1974, Perry and Stuck 1982, Perry et al. 1984, Hochberg et al. 1992, Alvarez and Calderon 1996, Lazaro-Chavez et al. 1996).

The effect of parasitization on growth and molting has not been clearly delineated. In general, hosts infected with rhizocephalans continue to molt while the interna is developing and then enter a parasite mediated arrest of growth or parasitic anecdysis (O'Brien and van Wyk 1985). Whether this parasitic anecdysis is permanent has not been resolved. Reinhard (1956) noted that blue crabs with mature externae of *L. texanus* ceased molting; however, Overstreet (1978, 1983) reported molting of blue crabs following the loss of the externa. The relationship between *L. texanus* and the seasonal occurrence of populations of small mature crabs known as dwarf or button crabs in the northern Gulf needs investigation (Overstreet 1978). He proposed that these small crabs may harbor prepatent sacculinid infections (period between initial infection and visible signs of the parasite). Ragan and Matherne (1974) examined crabs from 33 to 78 mm CW in Bayou Jean LaCroix, Louisiana, and found an overall infection rate of 37% for crabs with externae and monthly infection rates of 62%, 61%, and 50% in May, June, and July, respectively. They suggested that actual infection rates may be higher because crabs with pre-emergent endoparasitic stages may be difficult to detect. With visible rhizocephalan infection rates of this magnitude, distribution and abundance of this parasite could have a decided impact on numbers of harvestable adults. The fishery implications of rhizocephalan infection have not been adequately assessed. Rhizocephalan infections have been associated with smaller adult size in the portunid *Carcinus meanas.* Parasitic anecdysis following the emergence of the externa, coupled with a reduced molt increment during the period of time the interna was developing, were identified as being responsible for the decrease in adult size (Veillet 1945). Although the prevalence of molting following loss of the externa is unknown, the effect of rhizocephalan infection on growth and reproductive capacity and the contribution of infection to size at maturity must be considered in evaluating factors responsible for observed variability in size in Gulf blue crabs.

Van Engel (1958) noted that molt increment may be a heritable trait in part, but that growth was also tempered by environmental conditions. Overstreet (1978) also suggested a genetic component to growth and proposed that the seasonal occurrence of small mature crabs may be related to genetic factors. Genotypic differences in geographically separated populations of the same species have been suggested as a cause of variation in size at maturity in some crustacean groups (Strong 1972). Although evidence of genetic selection is scant in brachyuran crabs, Methot (1986) suggested that selection could occur in the highly exploited Dungeness crab fisheries, given the effects of size limits on partial recruitment at age. Kruse (1993) described harvest strategies for Alaskan crab stocks and noted that for >3-S= (primary management regulations concern size, sex, and season) and >2-S= (primary management regulations concern size and sex) managed fisheries with unregulated effort, genetic selection must be given serious consideration.

All Gulf states set a minimum size for harvest of blue crabs at 127 mm CW, and all but Alabama restrict the harvest of egg-bearing females. Life history characteristics of female blue crabs, size selective harvesting gear and intense fishing pressure suggests the possibility that genetic selection could occur in this fishery. The terminal anecdysis in female blue crabs, size at 50% sexual maturity (125-130 mm CW), size selectivity of harvesting gear, and a high exploitation rate could contribute to genetic selection. Size at 50% sexual maturity in females corresponds with minimum legal harvestable size, thus some fraction of the population reproduces at a sublegal size and is not susceptible to commercial harvest. Over time, these individuals may contribute disproportionately to the population and the size of 50% sexual maturity in females could decrease. Selection would be for those females that reproduced at a sublegal size. If size-at-reproduction has a heritability component and because maturation occurs at the terminal molt, both the size at 50% sexual maturity for females and the average maximum size attained by females could eventually decrease (Bert personal communication).

### 3.2.3 Reproduction

#### 3.2.3.1 Gonadal Description

The reproductive system of the adult male consists of paired testes, vasa efferentia, vasa differentia, external penes, and highly modified first and second abdominal pleopods (Cronin 1947). Spermatozoa along with secretions of the vasa differentia are formed into oval-shaped bundles called spermatophores. The anterior vasa differentia is the primary storage area for completed spermatophores. The first pleopod is the functional intromittent organ. It receives the spermatophores and semen from the penis and acts as a tube of transport in copulation. Hartnoll (1969) described copulation in blue crabs as follows. The male and female face each other head to head with sternal surfaces closely opposed and abdomens extended; the abdomen of the female overlaps with that of the male. The apical portions of the first pleopods of the male are inserted into the paired vulvae of the females. Spermatophores are ejected through the penis into the lumen of the first pleopod. The second pleopod pumps the spermatophores into the female seminal receptacles where they are stored until ovulation. Males need 9-20 days between matings to fully recover number of sperm (Kendall et al. 2001). Sperm remain viable for at least one year in the female and are used for repeated spawnings (Van Engel 1958).

The female reproductive system consists of paired ovaries, oviducts, and seminal receptacles or spermathecae (Pyle and Cronin 1950). The spermathecae are specialized portions of the oviducts modified into flattened, storage pouches (Johnson 1980). Transfer of spermatophores during copulation causes extreme enlargement of the pouches which become pink in color due to the deposition of secretory products of the median vasa differentia. Hard (1942) used histological techniques to develop a method of determining stages of ovarian growth and maturation by gross examination of the ovary. Immediately following copulation, the ovary is small and white, and the spermathecae are distended and pink. Ovarian maturation occurs over a two-month period with the ovary gradually increasing in size. Vitellogensis requires 8-12 weeks after the terminal molt and primarily occurs in the hepatopancreas (Zmora et al. 2007) and is regulated by a molt-inhibiting hormone in mature females (Zmora et al. 2009). Prior to the first ovulation, the ovary is bright orange and occupies a large portion of the body cavity. The ovary following the first ovulation still remains large and orange in color. The post-ovulated ovary may be distinguished from the ovary of the unspawned crab by the presence of egg cases on the swimmerets. Additionally, the presence of a large, red nemertean worm, *Carcinonemertes carcinophila*, in the gills of adult females or in the egg mass of ovigerous females is an indication that a female has produced at least one brood (Hopkins 1947). After the final ovulation, the ovary is collapsed and grey or tan in color. Oocyte maturation stages have been developed and can be determined based on morphological characteristics of ovarian tissues and ooyctes (Brown 2009).

### 3.2.3.2 Mating

For most estuarine animals mating and spawning are synonymous; however, in the case of the blue crab the two events occur at different times. Prior to her pubertal molt, the female travels to brackish waters of the upper estuary to mate. Sex recognition in blue crabs occurs by visual, chemical, and tactile stimuli. Courtship behavior in males is elicited by release of a pheromone in the urine of pubertal molt females (Gleeson 1980). Detection of this pheromone occurs through chemoreceptors located on the outer flagella of the antennules, and courtship behavior may be initiated within six minutes. A male exhibiting courtship behavior approaches the female with its chelae extended in the lateral position, the fifth pereiopods (swimming appendages) wave anterodorsally from side to side above the carapace, and the walking legs are extended to elevate the body to maximum height above the substrate. Blue crabs practice mate guarding, in which males pair with pre-molt females up to seven days prior to mating and for up to four days after mating (Jivoff 1995). The male carries the female using the first walking legs to hold the female against his sternum. Mating occurs while the female is soft and may last from five to 12 hours (Van Engel 1958). Following copulation, the male remains with the female until her shell has hardened. Teytaud (1971) observed that unimpregnated pubertal molt female crabs retained sexual receptivity for over two weeks and were able to mate even though the exoskeleton had hardened. Field studies have indicated that approximately 12% of females mate twice (Jivoff 1997).

Harvest of large male crabs has increased concern over the incidence of insemination in female blue crabs. However, Wenner (1989) surveyed the commercial catch in South Carolina and found that 97% of the females were inseminated, despite heavy fishing pressure on males. Similarly, Hines et al. (2003) found that >98% of females were mated at sites in Maryland, Virginia, and Florida. While blue crabs have very high mating success, there is evidence that females become sperm limited at the end of their lifetime. Females producing their final broods can have infertile eggs (Hines et al. 2003, Dickinson et al. 2006, Darnell et al. 2009).

#### 3.2.3.3 Spawning

Spawning of blue crabs in northern Gulf waters is protracted with egg-bearing females occurring in coastal Gulf and estuarine waters in the spring, summer, and fall (Gunter 1950, Daugherty 1952, More 1969, Adkins 1972a, Perry 1975). Additionally, Adkins (1972a) found evidence of winter spawning in offshore Louisiana waters based on commercial catches of 'berried' females in December, January, and February. Daugherty (1952) noted that crabs in southern Texas may spawn year-round in mild winters. Spawning usually occurs within two months of mating in the spring and summer. Females that mate in the fall usually delay spawning until the following spring. Spawning usually occurs in waters with temperatures and salinities favorable for hatching of eggs and growth of larvae; 19+°C, 21.0+‰ (Costlow and Bookhout 1959, Sulkin and Epifanio 1975, Bookhout et al. 1976, Sulkin et al. 1976). Sulkin et al. (1976) induced winter spawning in female crabs and noted that water quality, temperature, and diet were the important variables in obtaining eggs. Simulation of the summer photoperiod was not required to induce spawning.

Sperm transferred to the female are used for repeated spawnings. Females have been found to produce a first brood 23 days after mating (Darnell et al. 2009). During spawning, oocytes are forced from the ovaries through the seminal receptacles where they are fertilized. The fertilized eggs are extruded and attached to fine setae on the endopodites of the pleopods forming an egg mass known as a 'sponge,' 'berry,' or 'pom-pom.' The sponge is initially bright orange but becomes progressively darker as the larvae develop and absorb the yolk. Prior to hatching, the sponge is black. The developmental stages of blue crab embryos have been determined and embryonic development was temperature dependent (Walker et al. 2006); at constant temperature (28°C), eggs will develop in 10-13 days. In colder temperatures, embryos need longer than 12 days to hatch.

Most females spawn more than once and have the potential to spawn up to 18 times over their lifetime (Hines et al. 2003). Dickinson et al. (2006) found that females that began spawning in June had as many as seven broods by October of the same year. In North Carolina, larger crabs had a longer clutch production interval than smaller crabs (Dickinson et al. 2006, Darnell et al. 2009). There is some evidence of sperm limitation in blue crabs that influences lifetime reproductive potential (Kendall and Wolcott 1999, Kendall et al. 2001, Hines et al. 2003, Dickinson et al. 2006). Females generally return to inland waters to develop their second sponge (Tagatz 1968b, Adkins 1972a). After spawning for the second time, females generally do not re-enter estuaries (Tagatz and Frymire 1963, More 1969). Crabs that have been offshore are usually encrusted with the acorn barnacle, *Chelonibia patula*, and are a dull grey/green in color (Tagatz 1968b). Perry (1975) reported that large numbers of spent females occasionally litter barrier island beaches in the northern Gulf during the late summer, and these females are fouled with *C. patula* and heavily infested with the parasites *Carcinonemertes carcinophila* and *Octolasmis lowei*. Perry (1975) used the ovarian stages described by Hard (1942) to define the reproductive seasonality of the population in Mississippi. Recently mated females (Stage I) and crabs with developing ovaries (Stage II) were found in the spring, summer, and fall. Females with mature ovaries (Stage III) occurred throughout the year. Stage IV (berried) females appeared in March and April suggesting that overwintering Stage III females spawned when the water temperatures rose in the spring. Stage IV females were also abundant during the middle and late summer corresponding with the influx of 'Gulf' crabs from offshore waters.

### 3.2.3.3.1 Spawner-Recruit Relationship

Stearns (1976) suggested that for populations in fluctuating environments, age and size at first reproduction should be respectively lower and smaller, reproductive effort higher, size of young smaller, and number of young per brood higher. This combination of life history traits (labeled rselection) is associated with organisms that mature early, produce a large number of young, practice semelparity, have a large reproductive effort, and exercise no parental care. With the exception of semelparity, blue crabs exhibit those life history strategies associated with r-selection. Based on these traits, Van Engel (1987) summarized blue crab life history characteristics relevant to management of the fishery as follows:

> "The blue crab is characterized by the annual production of a large number of young, inter-annual fluctuations in production, rapid growth, early attainment of maturity, high mortality, and a short life span. These are the characteristics of a densityindependent species, exposed to a variable environment in which the population's resources are spent mostly on reproductive (r) functions. In short, the blue crab appears to be an r-selected strategist. Because of these characteristics, the blue crab can be fished at high levels of fishing effort, and, because of the short life span and rapid succession of year classes, would have a quick recovery if overfishing occurred."

Several authors have attempted to quantify the spawner-recruit relationship for blue crabs in the Chesapeake Bay region. Rugolo et al. (1997) fitted forty-two pairwise stock-recruitment model combinations and found weak to no relationships between adult stock and subsequent recruitment.

Lipcius and Van Engel (1990) fit a Ricker-type model to Virginia commercial landings data and trawl data from two stations in the York River, Virginia. They found a significant correlation between recruits as measured by trawl survey abundance and spawning stock (catch in the winter dredge fishery).

A spawner-recruit relationship was determined in the GDAR01 stock assessment (VanderKooy 2013). While the model used in the assessment determined a stock-recruitment relationship, fishery-independent data are inconclusive as to whether spawning reproductive potential or environmental factors drive recruitment success. VanderKooy (2013) noted that the base model indicated less of a relationship between spawners and recruits for the Eastern GOM stock than the Western GOM stock. Though no large-scale patterns were evident, residuals in the Eastern GOM stock exhibited a pattern that could correspond to periods of similar environmental conditions (e.g., multi-year drought periods; 1999-2003).

Fishery-independent and dependent data provide inconclusive evidence for a quantifiable stock recruitment relationship for the blue crab fishery. While blue crab populations in the Gulf of Mexico are generally not recruitment limited but appear to be influenced by post-settlement biotic processes that affect juvenile survival, the fishery-independent indices of abundance used in the GDAR01 assessment (VanderKooy 2013) generally support a relationship between winter recruit abundance and the previous summer's adult abundances (Figure 3.7). However, this apparent stock-recruit relationship could be partially driven by environmental drivers impacting the abundance of both adult and juveniles over the 6mo period between survey times, given the short life span of crabs (i.e., one-year old crabs provide the primary spawning potential for the stock).

Perry et al. (1998) tabulated numbers of crabs in 5 mm size intervals to examine the relationship between early crab stages and numbers of late stage juveniles. Data were grouped into years of high, intermediate, and low abundance of early recruits (1974-1995). In each group, numbers of small crabs in samples decreased rapidly from 10.0-30.0 mm CW (Figure 3.8). As juveniles approached 30.0 mm CW, the rate of disappearance from samples began to level off and gradually decrease. For crabs 30.0+ mm CW, the rate of disappearance from samples between the groups was not significantly different. High levels of juvenile recruits in their samples did not translate into proportionally elevated levels of later-stage juveniles and they suggested that estuarine survivorship of juveniles, not initial recruitment, may be more influential in determining year-class strength. King (1971), in an earlier study, found comparable population densities of juvenile blue crabs between two years even though recruitment was markedly different. The importance of biotic factors in structuring population levels of blue crabs in the northern Gulf of Mexico gained recognition in the late 1970s. Very early investigations into factors affecting population dynamics of blue crabs attempted to relate fluctuations in abundance to physiological tolerances to temperature and salinity. Livingston (1976) was among the first to suggest that the influence of salinity might be operating extrinsically by structuring the surrounding biotic community. The work of Heck and Coen (1995) and Spitzer et al. (2003) in Alabama and Guillory and Prejean (2001) in Louisiana identified predation as a major factor influencing abundance of juvenile blue crabs. Factors that increase or decrease refuge availability are now known to be important regulators of abundance and include predator-prey interactions (Heck and Coen 1995,

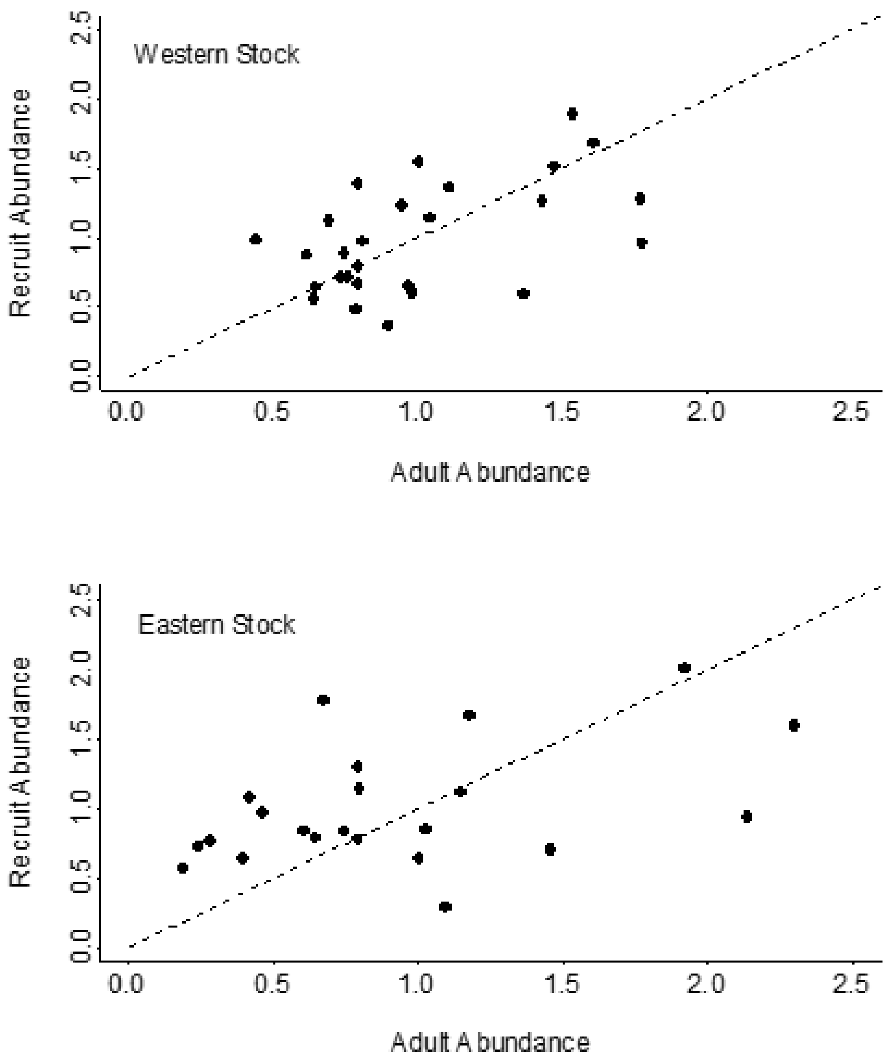



**Figure 3.7** Relationship between blue crab adult abundance in the summer months and the recruiting abundance during the subsequent winter months (6 month lag) for the two stocks. Abundance data are from the fisheries-independent indices of abundance used in the assessment model. Dotted line represents a 1:1 linear relationship (from VanderKooy 2013).

Guillory and Prejean 2001, Moksnes and Heck 2006), habitat selection and utilization (Williams et al. 1990, Morgan et al. 1996, Rakocinski et al. 2003), and global climate regimes and their influence on Gulf of Mexico hydrology (Sanchez-Rubio et al. 2011). Heck and Coen (1995) noted that a large and diverse suite of predators, few predation-free refuges, and year round predation activity (i.e., a lack of seasonality in predation) all contributed to the high regional mortality of juvenile crabs observed in the Gulf of Mexico. They observed predation rates of 80% per day on early crab stages in Alabama estuaries and concluded that although megalopal numbers in the Gulf greatly exceed numbers in Atlantic Coast estuaries, the higher predation rates in the Gulf resulted in similar juvenile abundances.

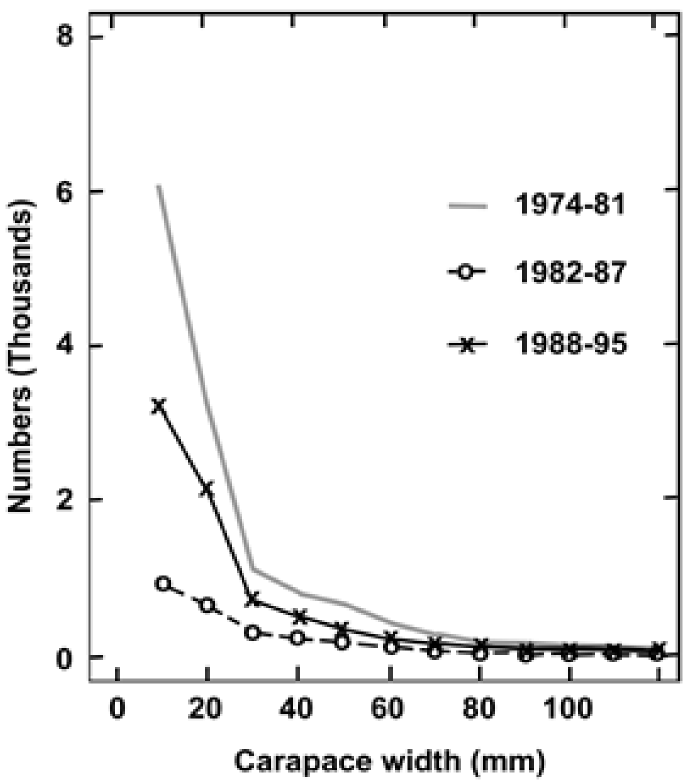



**Figure 3.8** Number of blue crabs by 10-mm CW size intervals for selected years (from Perry et al. 1998b).

Fishery-dependent catch-per-unit-effort (CPUE) data are available for Mississippi. Because regulatory restrictions were placed on fishermen that limited their harvest, a fishery-dependent survey was initiated in 2007 to record actual catch so that recent commercial catch statistics could be estimated for comparison with historic data. Trips were made twice monthly with selected fishermen. Catch-per-unit-effort data were collected and reported as pounds/trap/day. A similar study was conducted from 1971-1973 by Perry (1975). Harvest of egg crabs in Mississippi was banned from the 1960s until the mid-1970s, but the regulation was loosely enforced and egg-bearing females were landed and processed (Perry personal observation). In 1975, the prohibition was lifted and harvest was legal in all waters with the exception of the barrier islands (one-mile sanctuary around the islands). From 1977-1997, egg crab harvest was allowed with seasonal and/or area closures. A total prohibition on harvest was instituted in 1997. The contribution of ovigerous females to the commercial harvest was not insignificant in the early days of the fishery. Using recent data on catch composition, egg crabs may have comprised as much as 79.2% of the harvest in some areas in Mississippi with the average maximum CPUE from April through September over 50%. While exact sex composition of the early fishery data is unknown, it is expected that it would be similar. Highest numbers of blue crab juveniles in the northcentral Gulf of Mexico occurred over a time period that allowed for unrestricted harvest of egg-bearing females in some Gulf states and limited harvest in others (protected areas or seasons). Conversely, lowest numbers have occurred during the time period that spawning stock has been protected throughout most of the Gulf region. Steele and Perry (1990) noted this lack of correlation between spawning stock size and subsequent recruitment in many marine species and concluded that:

> "recruitment for most species is now considered to be the result of a synergistic combination of biological and physical factors that occur through the first year of life, with density-independent factors of primary importance during the larval stage and density-dependent factors more important for juvenile survivorship".

### 3.2.3.4 Fecundity

Estimates of fecundity are based on the number of eggs spawned per batch and on the number of batches produced per season. Early studies estimated the number of eggs per brood to be between $1.75 \times 10^6$ and $2.00 \times 10^6$ (Churchill 1919, Van Engel 1958). The more recent estimates are higher: $2.75 \times 10^6$ (Hines 1982), $3.2 \times 10^6$ (Prager et al. 1990), $2.1\text{-}3.2 \times 10^6$ (Hsueh et al. 1993), $3.5 \times 10^6$ (Ealy 2001), and $2.8 \times 10^6$ (Graham et al. 2012). Hines (1982) noted that of the factors that may place allometric constraints on the mass or volume of reproductive output, physical or mechanical constraints (not energetics) were limiting in many species of Brachyura, including *C. sapidus*. Volume of the body cavity limits brood size: rigidity of the exoskeleton in brachyurans precludes distensibility of the body during yolk accumulation and thus places an anatomical constraint on brood size. Brood weight was generally constrained to approximately 10% of body weight. Fecundity in brachyuran crabs is variable and highly dependent upon the size of the female. Similar to the positive correlation between female body weight and fecundity found by Hines (1982), a positive relationship between carapace width and fecundity (Prager et al. 1990, Darsono 1992, Ealy 2001, Pereira et al. 2009, Graham et al. 2012) and CW and clutch volume (Darnell et al. 2009 and 2010) have been well documented.

Early studies research suggested that blue crabs only produced one to six broods (Churchill 1919, Truitt 1939, Van Engel 1958, Tagatz 1968b). New studies suggest that females may produce up to eight broods in a spawning season, with potential for 18 broods during their lifespan (Hines et al. 2003, Dickinson et al. 2006). Ealy (2001) suggested primiparous (first brood) females were less fecund than multiparous (second and successive broods) crabs; however, Graham et al. (2012) did not find a statistical difference between fecundity for primiparous and multiparous crabs. Research on clutch volume, an alternative measure of fecundity, has been found to decrease with successive egg masses (Dickinson et al. 2006, Darnell et al. 2009, 2010). In these studies, females producing three or more broods showed a consistent decrease in clutch volume.

Prager et al. (1990) found that fecundity varied within and between years, but did not vary significantly over the course of embryonic development for *C. sapidus* in the Chesapeake Bay region. Ovigerous blue crabs have been found to commit egg mass mutilation when captured in crab traps (Dickinson et al. 2006, Darnell et al. 2010). Graham et al. (2012) found 30% brood loss in primiparous females, compared to 3% loss of eggs with multiparous crabs.

Hines (1982) noted that *C. sapidus* had extremely small eggs (251 μm mean ovum diameter), large numbers of eggs per brood, and a high adjusted yearly fecundity. Egg size increases throughout embryonic development for the blue crab (Davis 1965, Amsler and George 1984, Jacobs et al.

2003). Seasonal differences in egg size in *C. sapidus* were noted by Jacobs et al. (2003); spring eggs were 6% larger than summer eggs. Graham et al. (2012) found similar results, with spring eggs 9.9% larger than summer/fall eggs. This study also found that a positive relationship between egg diameter and maternal size and an inverse relationship between fecundity and egg diameter. Other studies found that egg diameter was not correlated to CW or clutch number for *C. sapidus* (Darnell et al. 2009, 2010).

### 3.2.4 Distribution and Abundance

#### 3.2.4.1 Zoeae

The larval life history of *C. sapidus* in the Gulf of Mexico is poorly understood. Blue crab larvae are exported from estuaries to adjacent shelf waters where they develop through seven zoeal molts and then metamorphose into the megalopal stage. Only the early larval stages and megalopae occur near estuaries (Andryszak 1979, Perry and Stuck 1982). Although Daugherty (1952), Menzel (1964), and Adkins (1972a) specifically discussed the distribution of blue crab larvae, the possibility of occurrence of the larvae of *C. similis* must be considered. The temporal and spatial overlap in spawning habits of the two species (Perry 1975), coupled with the difficulty in using the early morphological descriptions of *C. sapidus* from Atlantic specimens (Costlow and Bookhout 1959) to reliably identify Gulf blue crab larvae, suggest that published accounts of the seasonality of *C. sapidus* larvae are questionable. Recognizing the difficulty in separating the two species, King (1971), Perry (1975), and Andryszak (1979) did not differentiate between the larvae of *C. sapidus* and *C. similis*.

Perry and Stuck (1982) noted that early stage *Callinectes* zoeae (I and II) were present in Mississippi coastal waters in the spring, summer, and fall. Adkins (1972a) reported *C. sapidus* larvae present year-round in Louisiana but did not separate the zoeal and megalopal stages. The sampling programs of Menzel (1964) and Andryszak (1979) were of limited duration with no seasonal distribution data available.

#### 3.2.4.2 Megalopae

*Callinectes* spp. megalopae have been reported year round in coastal waters. Perry (1975) found megalopae in Mississippi Sound in all months with peak abundance in the late summer-early fall and in February. In Texas coastal waters, *Callinectes* spp. megalopae have been found in all seasons (Daugherty 1952, More 1969, King 1971). King (1971) noted three waves of megalopae in Cedar Bayou, the first from January-March, the second in May/June, and the third in October.

Early attempts to separate the megalopae of *C. sapidus* from *C. similis* using the characters developed by Bookhout and Costlow (1977) were largely unsuccessful due to apparent morphological differences in larvae from the Gulf and Atlantic. Stuck et al. (1981) provided characters useful in distinguishing the megalopae and early crab stages of the two species. Subsequent analysis of archived plankton samples from Mississippi and Louisiana coastal waters has furnished information on the seasonality of *C. sapidus* and *C. similis* megalopae in the northern Gulf of Mexico. Stuck and Perry (1981) found *C. similis* megalopae in offshore waters adjacent to Mississippi Sound throughout the year with a peak in abundance in February and March. *Callinectes sapidus* megalopae were rarely found in their samples before May. Large numbers of *C. similis* megalopae were also identified in February and March in samples from Whiskey Pass, Louisiana (Stuck personal communication). Based on the identification of first crabs reared from megalopae, Perry (1975) reported a February occurrence of *C. sapidus*. Re-examination of these specimens found them to be *C. similis*. These data suggest that the reported winter peaks of *Callinectes* larvae in the northern Gulf are, in all probability, *C. similis*.

Reports on the vertical distribution of *Callinectes* megalopae are conflicting. Williams (1971), King (1971), Perry (1975), and Smyth (1980) reported *Callinectes* megalopae to be most abundant in surface waters. In contrast, 96% of the *Callinectes* megalopae collected by Tagatz (1968b) and all of the megalopae collected by Sandifer (1973) were from bottom waters. Stuck and Perry (1981) found that portunid megalopae (*C. sapidus, C. similis*, and *Portunus* spp.) showed no affinity for surface or bottom waters. They noted that the majority of large catches of *C. sapidus* megalopae were taken on rising or peak tides whereas the megalopae of *C. similis* and *Portunus* spp. were commonly collected on both rising and falling tides.

### 3.2.4.2.1 Settlement

Blue crabs re-invade Gulf estuaries as megalopae with the molt to the first crab stage taking place in nearshore waters (More 1969, King 1971, Perry 1975, Perry and Stuck 1982). Megalopal settlement in selected Gulf estuaries was monitored as part of an inter-regional cooperative research program to address recruitment dynamics across broad latitudinal scales. Settlement was measured using standardized collectors and protocol. Data for the Gulf were summarized by Rabalais et al. (1995a). Average number of megalopae per collector was considerably greater in the Gulf than in Atlantic estuaries. Settlement in the northern Gulf was episodic within an estuary and asynchronous among coast-wide sites. Settlement predominantly occurred in small numbers interspersed with large aperiodic peaks. Temporal periodicity of settlement was similar among estuaries and between years, with peak numbers of megalopae collected in the late summer/early fall. Although spawning of blue crabs in the Gulf is protracted and megalopae are available offshore throughout most of the year (Stuck and Perry 1981), there was a noticeable lack of settlement in the spring and early summer in most estuaries. Settlement data from 1993 through 1997 in Mississippi Sound confirmed both temporal periodicity of settlement events, and the paucity of spring settlement as observed in earlier studies (Perry et al. 1998 and 1999, Johnson and Perry 1999). Perry and Stuck (1982) noted little or no relationship between megalopal numbers in spring nekton samples and the subsequent occurrence of early crabs in Mississippi Sound; however, high catches of megalopae in nekton samples in the fall were usually followed by increased catches of small crabs in October and November.

Megalopae are abundant in the offshore neuston and thus susceptible to wind-driven transport mechanisms. Although no clear environmental variables were associated with high settlement events in some northern Gulf estuaries, wind-driven and tidal circulation processes appeared to influence megalopal recruitment in Mississippi (Perry et al. 1995) and Alabama (Rabalais et al. 1995a). Onshore winds coupled with equatorial (Mobile Bay) and tropic (Mississippi Sound) tides were correlated with the majority of peak events in these northern Gulf estuaries. Estuarine systems in the northern Gulf of Mexico are generally meteorologically dominated (Ward 1980), and subtidal exchanges resulting from wind driven circulation may account for a substantial portion of the volume flux in coastal bays (Swenson and Chuang 1983, Smith 1977). Winds can reverse or accentuate the effect of tides and can be a very effective mechanism in moving megalopae into estuarine areas. In addition to meteorological forcing, Johnson and Perry (1999) noted that intrusion of Loop Current eddies onto the shelf in the northern Gulf may alter shelf circulation patterns and influence recruitment and settlement (Section 4.2.2; Figure 4.1). Perry et al. (2003) used seasonal circulation patterns in the Mississippi Bight to determine favorable conditions for offshore dispersal of larvae and their subsequent return to nearshore waters. They found that large-scale basin events such as Loop current intrusions with spin-off eddy generation and anomalies in average wind stress have the potential to affect settlement success rate. Comparing these meteorological and hydrological factors to daily records of megalopal abundance (1991-1999), they noted that wind stress was strongly correlated with settlement success. Eastward wind stress in July and August when larvae were at sea and westward wind stress in September and October when larvae recruited to estuaries were important in retention of larvae in the Bight and their return to nearshore waters, respectively. Loop Current intrusion onto the northern shelf and warm core ring detachment during the late summer changed circulation patterns and decreased settlement.

Processes that facilitate movement upstream or into tidal marshes may differ between regions. Olmi (1995) suggested that tidally timed, vertical migration of megalopae resulted in a net movement of megalopae up the York River, Virginia. Megalopae moved between the bottom during ebb tide and the water column during flood tide with the degree of upward movement dependent on light. Stuck and Perry (1981), in their study of the distribution and seasonality of portunid megalopae in Mississippi barrier island passes, found that most large catches of *C. sapidus* megalopae were taken on rising or peak tides, but no preference for surface or bottom waters was observed. The lack of vertical positioning in the water column may be related to the hydrodynamic characteristics associated with Mississippi's barrier island passes. Mississippi Sound is primarily a well-mixed/partially-mixed estuary, and the two-layered flow characteristic of vertically stratified estuaries is not as well developed or consistent. Offshore waters enter Mississippi Sound through a series of barrier island passes that constrict water flow and create turbulence. Waters entering from the open Gulf tend to be homogeneous and enter as a wave sweeping through the pass. Megalopae in the vicinity of island passes would be swept in regardless of position in the water column. Lyczkowski-Shultz et al. (1990) noted another tidal characteristic favoring transport of organisms into Mississippi Sound. They observed unequal flow durations between flood and ebb tides in Dog Keys Pass and noted that transport of fish larvae into the Sound was favored regardless of depth in the water column because landward flow lasted 1.5-2.0 times longer than seaward flow. Although factors facilitating movement of megalopae into tidal marshes in Mississippi Sound are poorly understood, the close proximity of the mainland to the barrier islands passes coupled with the speed and duration of tidal flood currents should facilitate rapid transport of megalopae to shoreline marshes. Rabalais et al. (1995a) noted a two to three-day lag in settlement between the Mobile Bay mouth and a mid-estuary site at Fowl River in Alabama. Megalopae at the mid-estuary site were also in a more advanced developmental state than were those collected at the bay mouth. In Chesapeake Bay, initial retention of megalopae within the estuary and movement upstream appear to be behaviorally mediated (Goodrich et al. 1989) and related to tidally timed vertical migrations (Olmi 1995). Retention of fish larvae in northern Gulf estuaries may be dependent upon movement of larvae to shallow, slow-moving waters nearshore on ebb tides to keep from being advected back into open water (Sabins and Truesdale 1974, Lyczkowski-Shultz et al. 1990). Based on the observed behaviors of selected larval fish species in different geographic areas, Lyczkowski-Shultz et al. (1990) suggested that species specific, behaviorally mediated responses to environmental cues may be location specific. Megalopae in Mississippi Sound are routinely observed clinging to crab trap lines and bait wells of traps set in the lower and middle Sound, and this thigmotactic response may be a mechanism favoring maintenance of position on ebb tides.

#### 3.2.4.2.2 Settlement and Juvenile Abundance

The relationship between numbers of megalopae recruited and subsequent abundance of young crabs is not well defined. Perry and Stuck (1982) noted that large catches of *C. sapidus* megalopae in August and September were usually followed by an increased catch of small crabs (10.0-19.9mm) in October or November in Mississippi estuaries; however, inconsistencies between recruitment of megalopae and subsequent occurrence and abundance of juveniles were noted in the spring and summer in their samples. Perry et al. (1998) tabulated numbers of crabs in 5-mm size intervals to examine the relationship between early crab stages and numbers of late stage juveniles. Data were grouped into years of high abundance of early recruits (1974-1981 and 1988-1995) and low abundance (1982-1987). In each group, numbers of small crabs in samples decreased rapidly from 10.0 to 30.0 mm CW (Figure 3.8). As juveniles approached 30.0 mm CW, the rate of disappearance from samples began to level off and gradually decrease. For crabs 30.0+ mm CW, the rate of disappearance from samples between the groups was not significantly different. High levels of juvenile recruits in their samples did not translate into proportionally elevated levels of later-stage juveniles. Thus, estuarine survivorship of juveniles, not initial recruitment, may be more influential in determining year-class strength. Spitzer et al. (2003) conducted two identical settlement surveys (1990/1991 and 1997/1998) within the Mobile Bay system and compared megalopal settlement and post-settlement mortality for the two time periods. Peak recruitment months were similar for the two periods, however, megalopae were more abundant in the early study. Although there were differences in megalopal numbers, the overall patterns in settlement and post-settlement mortality were qualitatively similar. The authors concluded that, as in other Gulf of Mexico estuaries, the Mobile Bay system appeared limited by high levels of post-settlement mortality and not initial megalopal abundance. King (1971) found comparable population densities of juveniles between two years although recruitment was markedly different. Interpretation of his data is complicated by the taxonomic problems associated with the separation of *C. sapidus* and *C. similis* megalopae, but it seems to add additional evidence of the importance of juvenile survivorship in year-class success.

### 3.2.4.3 Juvenile Distribution and Abundance

Young blue crabs show wide seasonal and areal distribution in Gulf estuaries. Livingston et al. (1976) found maximum numbers of blue crabs in Apalachicola Bay in the winter and summer noting that an almost 'continuous succession' of young crabs entered the sampling area during the year. Perry (1975) and Perry and Stuck (1982) found first crab stages in all seasons indicating continual recruitment to the juvenile population in Mississippi. In Lake Pontchartrain, Louisiana, Darnell (1959) noted recruitment of young crabs was highest in the late spring-early summer and in the fall.

Although juvenile crabs occur over a broad salinity range, they are most abundant in low to intermediate salinities characteristic of middle and upper estuarine waters. Daud (1979) found early crab stages (5-10 mm) in shallow brackish/saline waters and observed movement into fresher waters in larger juveniles. Swingle (1971), Perret et al. (1971), Christmas and Langley (1973), and Perry and Stuck (1982) determined the distribution of blue crabs (primarily juveniles) by temperature and salinity using temperature-salinity matrices (Table 3.2). Both Perret et al. (1971) and Swingle (1971) found maximum abundance in salinities below 5.0‰. In contrast, Christmas and Langley (1973) and Perry and Stuck (1982) found highest average catches associated with salinities above 14.9‰ in Mississippi. Based on one year of fishery-independent bag seine data, Hammerschmidt (1982) found no direct relationship between catches of juvenile crabs and salinity in Texas. Walther (1989) examined the relationship between recruitment of juvenile blue crabs (as measured by CPUE in 16ft trawl samples) in Barataria Bay and salinity. He found a significant negative relationship between February-May blue crab catch per unit effort and salinity for the same time period ($r^2$=0.80). Although salinity influences distribution, factors such as bottom type, food availability, and competition also play a role in determining distributional patterns of juvenile blue crabs.

The importance of bottom type in the distribution of juvenile blue crabs is well established. More (1969), Holland et al. (1971), Adkins (1972a), Perry (1975), Evink (1976), Livingston et al. (1976), Perry and Stuck (1982), and Rakocinski et al. (2003) all noted the association of juvenile blue crabs with soft mud sediments. Unvegetated soft sediment habitats may influence distribution by providing protection from predators. Moody (1994) found that both seagrass and mud habitats provided refuge from predation that was unavailable in sand sediments. He suggested that predators relying on visual cues may be less effective in mud habitats and that soft sediments allow crabs to bury quickly and deeply.

Availability of trophic resources has also been identified as a factor affecting distribution of blue crabs. Laughlin (1979) reported that crabs (>60 mm CW) were predominant in areas of high

**Table 3.2** Distribution of *C. sapidus* by salinity intervals showing number of samples (above) and catch per sample (below).

| Modified from: | Salinity (ppt) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.0-4.9 | 5.0-9.9 | 10.0-14.9 | 15.0-19.9 | 20.0-24.9 | 25.0-29.9 | 30+ | Total |
| Swingle (1971) | 41<br>6.0 | 15<br>4.7 | 14<br>2.6 | 19<br>2.3 | 33<br>3.1 | 18<br>3.3 | 18<br>4.4 | 179<br>3.9 |
| Perret et al. (1971) | 197<br>12.0 | 185<br>6.0 | 263<br>6.0 | 278<br>6.0 | 182<br>6.0 | 82<br>5.0 | 12<br>5.0 | 1,199<br>7.0 |
| Christmas and Langley (1973) | 134<br>1.2 | 87<br>2.7 | 110<br>3.8 | 99<br>3.2 | 145<br>4.1 | 169<br>2.2 | 74<br>0.9 | 818<br>2.6 |
| Perry and Stuck (1982) | 561<br>7.6 | 423<br>7.8 | 482<br>7.1 | 520<br>8.3 | 517<br>5.9 | 489<br>3.0 | 257<br>2.7 | 3,249<br>6.3 |

food abundance regardless of salinity. Mansour (1992) examined foraging ecology of blue crabs in soft sediments in Chesapeake Bay and found that they aggregated in areas of highest preferred prey abundance. Evink (1976), Gallaway and Strawn (1975), and Moody (1994) also cited food availability as important in determining distribution of blue crabs.

Laughlin (1979) concluded that the temporal and spatial distribution of blue crabs in the Apalachicola estuary was determined by "complex interactions of abiotic, trophic, and intra-specific factors" that have varying significance with season and area.

### 3.2.5 Food and Feeding

#### 3.2.5.1 Larval Diet

The diet of blue crab larvae is unknown under natural conditions. Culture of blue crab larvae, however, has provided some information on diet and larval development. Zoeae are filter feeders, and zooplankters in the range of size from 45-80μm are thought to be the chief source of food (Millikin and Williams 1984). Although phytoplankton may be consumed, Costlow and Sastry (1966) suggested that plant material alone does not provide sufficient protein for successful molting and development. Larvae have been reared successfully on: 1) a combination of sea urchin (*Arbacia punctulata*) embryos and *Artemia* nauplii (Costlow and Bookhout 1959), 2) rotifers *(Brachionus plicatilis)* or polychaete larvae (*Hydroides dianthus*) in combination with *Artemia* nauplii (Sulkin and Epifanio 1975, Sulkin 1978), and 3) algae, rotifers, fresh and enriched *Artemia* nauplii, and Cyclop-eeze® (Zmora et al. 2005). Based on a review of food items used in successful larval culture and the inability to rear larvae on a single food item, Sulkin (1978) suggested the presence of an unidentified dietary requirement in *C. sapidus* and noted that this nutritional vulnerability may have evolutionary implications. The combination of long pelagic duration, large and variable instars, and large numbers of small eggs is characteristic of primitive reproduction (Lebour 1928). To that list, Sulkin (1978) added the lack of nutritional flexibility observed in *C. sapidus* larvae. He noted that the vulnerability of some brachyuran larvae to absence of favorable prey at specific points in their ontogeny is a primitive feature. Those species with a shortened pelagic existence and expanded pre-hatching development (characteristic of some xanthids) are more advanced, and there is a significant reduction in nutritional vulnerability.

Megalopae have well developed chelae which are used to capture food in a manner similar to adults. Megalopae feed on other planktonic organisms while inhabiting the water column but become opportunistic omnivores after assuming a benthic existence (Van Engel 1958, Darnell 1959, Benson 1982). Zmora et al. (2005) developed a diet for feeding megalopae under laboratory conditions, which included algae, rotifers, enriched *Artemia* nauplii, and Cyclop-eeze®.

#### 3.2.5.2 Juvenile and Adult Diets

Blue crabs perform a variety of ecosystem functions and play a major role in energy transfer within estuaries (Van Den Avyle and Fowler 1984). Food habit studies have shown that predominant food items vary greatly, and juvenile and adult blue crabs have been described as opportunistic benthic detritivores, omnivores, primary carnivores, cannibals, and general scavengers (Hay 1905, Darnell 1958, Tagatz 1968b, Laughlin 1979 and 1982, Alexander 1986, Mansour 1992). Darnell (1961) and Laughlin (1982) noted that the blue crab did not conform to specific trophic levels but utilized alternate food sources from time to time depending upon availability. Zmora et al. (2005) developed a feeding regime for rearing juvenile crab stages 1-6 which included live and artificially formulated diets.

Ontogenic shifts in blue crab feeding habits were discussed by Darnell (1958), Laughlin (1979 and 1982), Alexander (1986), and Stoner and Buchanan (1990). Changes in ontogenic feeding habits appear to be mediated by two factors: 1) differences in the functional morphology of the feeding apparatus, locomotory system, and sensory capabilities and 2) life cycles which may place size classes exclusively in the estuary at different times of the year when different food items are available (Laughlin 1979). Laughlin (1979, 1982) divided blue crabs from Apalachicola Bay, Florida, into three trophic groups based upon their stomach contents. Juveniles <31 mm CW fed mainly on bivalves, plant material, detritus, and ostracods. Crabs 31 to 60 mm CW consumed fish, gastropods, and xanthid crabs. Animals >60 mm CW fed on fish, bivalves, xanthid crabs, and other blue crabs. In Lake Pontchartrain, Louisiana, Darnell (1958) noted that differences in juvenile and adult diets were not pronounced but in crabs >124 mm CW, molluscs, particularly *Rangia cuneata*, became the dominant food item. Stoner and Buchanan (1990) found that the diet of *C. sapidus* clustered into four major size classes: 10-20 mm CW, 21-30 mm CW, 31-80 mm CW, and 81-150 mm CW. Amphipods were major dietary constituents in 10-20 mm CW size group, foraminiferans were important in 21-30 mm CW crabs, and detritus (which was important in the smaller size groups) was rare or absent in diets of larger crabs. The occurrence of polychaetes also decreased as crab size increased. Crab and fish remains were important dietary items in crabs >30 mm CW, and bivalves were common in 81-150 mm CW crabs. According to Alexander (1986), young crabs (<31 mm CW) feed on vascular plants, algae, and foraminiferans more frequently than molluscs, fish, and crustaceans; the reverse of adult crabs (>60 mm CW). Stomachs of young crabs also contained more sand. In contrast, Tagatz (1968b) found that all sizes of crabs basically ate the same food types.

Feeding habits of blue crabs vary as a function of locality and season and reflect differences in food availability and diversity (Laughlin 1982). The importance of molluscs in blue crab diet was documented by Menzel and Hopkins (1956), Darnell (1958), Tagatz (1968b), Tarver (1970), and Alexander (1986). Plant material may also contribute significantly to the diet of blue crabs (Truitt 1939, Darnell 1958, Tagatz 1968b, Laughlin 1982, Alexander 1986). Alexander (1986) attributed the presence of large amounts of plant material in blue crab diets to their association with salt and brackish marsh shorelines where plant material was abundant. Truitt (1939) found that roots, shoots, and leaves of eelgrass (*Zostera*), ditch grass (*Ruppia*), sea lettuce (*Ulva*), and salt marsh grass (*Spartina*) were commonly consumed by crabs in shallow estuarine areas. Laughlin (1979) and McClintock et al. (1991) found evidence for detritivory blue crabs.

Laughlin (1982) reported that by weight the main food items taken by blue crabs of all size classes were: bivalves (35.7%), fishes (11.9%), xanthid crabs (11.4%), shrimp (4.6%), gastropods (4.8%), and plant material (3.9%). In order of frequency of occurrence, the following food items were tabulated by Tagatz (1968b): organic debris, fish, clams, mussels, amphipods, crabs, other crustaceans, algae, vascular plants, nemerteans, polychaetes, insects, ostracods, snails, and oysters. Darnell (1958) calculated the volumetric importance of different food items to blue crabs as follows: molluscs (45.5%), crustaceans (24.3%), organic debris (21.7%), plants (4.3%), fishes (2.1%), hydroids (0.3%), and insects (0.l%). Heard (1982) described blue crabs as voracious feeders with a variable diet. He noted that in tidal marshes, fiddler crabs (*Uca* spp.) and marsh periwinkles (*Littorina irrorata*) were important components of the diet of blue crabs.

STable isotope analysis is able to account for food ingestion and assimilation over time, giving it an advantage over gut content analysis. Barcenas (2013) used this method to describe the trophic dynamics in Galveston Bay including a calculated trophic level value and a primary food source for each of the dominant species; blue crabs were found to have an overall average trophic level value of 2.83 (for all bays/regions combined). This value is indicative of an omnivore that feeds near the lower end of the food web and consumes substantial amounts of vegetation and detritus. Derived carbon signatures for blue crabs were most strongly aligned with epiphyte algae as the predominant primary food source.

### 3.2.5.3 Foraging Behavior

Darnell (1958) suggested that juvenile crabs primarily feed either at night or early morning, while adults feed mainly during daytime. Ryer (1987) found a weak trend toward nocturnal feeding with an apparent peak at dusk. Blue crabs feed in three different ways. *Raptorial feeding* involves feeding on large prey organisms; *interface feeding* involves feeding from the surface of objects and on sediment surfaces; and *plankton feeding* involves consuming small suspended material (Norse 1975). Distance and contact chemoreception, touch, and vision are used when appropriate. During interface feeding, blue crabs can feed on aufwuchs (plants, animals and detritus adhering to solid surfaces) and living and nonliving components in sediment using the third maxillipeds and feeding appendages to remove food particles from the interface (Norse 1975). Using this method, crabs may seize encrusted blades of seagrass and process them through their mouth parts to remove hydroids, foraminiferans, and algae. In plankton feeding, blue crabs use the three pairs of flagellae on the exopodites of the maxillipeds to create currents that bring food particles past the oral area where they are trapped by setae on the maxillipeds (Norse 1975). Eggleston (1990) described foraging behavior of adult blue crabs feeding on juvenile oysters. In laboratory studies, foraging was generally prefaced by an increase in antennule flicking and gill bailing rates followed by vigorous movements of the mouthparts. The dactyls of the first and second walking legs and the chelae were used to probe for and manipulate oyster spat attached to cultch. Norse (1975) also noted that crabs used their chelae and the dactyls of the walking legs to probe for food. When a buried mollusc is located by chemosensory or tactile means, blue crabs thrust the walking legs into the sediment and excavate the mollusc using the chelae and walking legs (Blundon and Kennedy 1982, Alexander 1986). Blundon and Kennedy (1982) observed that crabs excavated clams to a depth of 20 cm in laboratory aquaria, and they measured pits as deep as 10-15 cm in natural clam beds. Food is grasped by the chelae and first pairs of walking legs and brought to the oral area with assistance from the third maxillipeds. Hard objects are crushed and broken by chelae before swallowing (Norse 1975, Blundon and Kennedy 1982). Molluscs which are too large to crush may be exposed by chipping the edge of the shell and prying it open (Blundon and Kennedy 1982, Eggleston 1990). Eggleston (1990) found that vulnerability of a given oyster to crab predation and the specific opening technique used was dependent on shell height and thickness, attachment site, and growth geometry. Consumption rates increased with oyster density and decreasing shell height. Persistence time, the time of the initial encounter with the prey until the prey was rejected, was also dependent on prey size and density.

#### 3.2.5.4 Predator/Prey Dynamics

##### 3.2.5.4.1 Predation by Blue Crabs

A comprehensive list of documented prey items is included in Table 3.3. Laughlin (1982) concluded that because of its opportunistic feeding habits and high abundance levels, blue crabs are a crucial factor in the estuarine food web. They are especially effective estuarine predators because of their great tolerance to salinity extremes (Carriker 1967). Blue crabs are key predators of estuarine benthos: they affect species composition, abundance, and distribution of infauna (Virnstein 1977, Hines et al. 1990). Mansour (1992) stated that "blue crab predation may be the most important biotic determinant of community structure in soft sediment habitats in Chesapeake Bay".

Blue crabs are major predators of the eastern oyster, *Crassostrea virginica*. Eggleston (1990) found that predation by large male *C. sapidus* can lead to local extinction of juvenile oysters (1535 mm shell length) regardless of density, and Lunz (1947) identified them as the most serious predators of young oysters (5-30 mm) in South Carolina waters. Marshall (1954) studied the effects of predation on oysters in Florida and found survival of oysters was only 9% in a natural area as opposed to 85%-86% in areas where oysters were protected from predation. In the Chesapeake Bay, Bisker and Castagna (1987) found that while blue crabs preyed upon oyster spat, the mud crab (*Panopeus herbstii*) caused higher mortalities. For both crab species, predation rates increased as oyster size decreased or crab size increased. Carriker (1967) noted that blue crabs pose an additional threat as estuarine oyster predators, because unlike starfish and oyster drills, they can move into low salinity waters. Menzel and Hopkins (1956) found that blue crabs consumed an average of 19 oyster spat per day and concluded that while this species is an important predator of spat, it is a scavenger of adult oysters, eating only dead or sick individuals.

Blue crabs also prey upon the clams *Mercenaria mercenaria* (Van Engel 1958, Sponaugle and Lawton 1990), *Rangia cuneata* (Darnell 1958), and *Mya arenaria* (Blundon and Kennedy 1982, Smith and Hines 1991b, Eggleston et al. 1992). Blundon and Kennedy (1982) investigated the mechanical and behavioral aspects of blue crab predation on eight bivalve species. Forces required to crack shells were determined and compared to the crushing strength of blue crabs. Only large (>40 mm) *Rangia cuneata* had shells strong enough to resist the crushing capabilities of large blue crabs. Blue crab predation is a major constraint in hard clam culture (Castagna et al. 1970, Gibbons and Castagna 1985, Kraeuter and Castagna 1985). Bisker et al. (1989) reported that the oyster toadfish (*Opsanus tau*) reduced xanthid and portunid crab predation on juvenile hard clams in field cultures. Bisker and Castagna (1989) compared crab predation on juvenile hard clams in trays and found that clam survival was 69.5% in the presence of toadfish and 2.3% without toadfish. Molloy et al. (1994) found circumstantial evidence of blue crab predation on zebra mussels (*Dreissena polymorpha*) in the Hudson River, New York, and suggested that they might serve as a limited natural control agent.

**Table 3.3** Prey items documented in the diet of blue crabs.

| SPECIES | REFERENCES |
|---|---|
| Diatoms | Darnell 1958 |
| Foraminifera | Alexander 1986 |
| Algae | Darnell 1958, Alexander 1986 |
| *Ulva* sp. | Truitt 1939, Tagatz 1968a |
| *Ceratophyllum* sp. | Tagatz 1968a |
| *Vallisneria* sp. | Tagatz 1968a |
| *Sargassum* sp. | Alexander 1986 |
| *Zostera, Ruppia* | Truitt 1939 |
| Unidentified vascular plants/ *Spartina* | Truitt 1939, Darnell 1958, Tagatz 1968a, Alexander 1986 |
| Organic debris | Darnell 1958, Tagatz 1968a, McClintock et al. 1991 |
| Detritus | Darnell 1958, Laughlin 1979, Stoner and Buchanan 1990, McClintock et al. 1991 |
| Hydroids | Darnell 1958 |
| Molluscs | Alexander 1986 |
| *Mercenaria mercenaria* | Van Engel 1958, Sponaugle and Lawton 1990 |
| *Mya arenaria* | Blundon and Kennedy 1982, Smith and Hines 1991a, Eggleston et al. 1992 |
| *Crassostrea virginica* | Tagatz 1968a, Laughlin 1979, Bisker and Castagna 1987, Eggleston 1990 |
| *Rangia cuneata* | Darnell 1958, Tagatz 1968a, Laughlin 1979 |
| *Mulinia lateralis* | Tagatz 1968a |
| *Brachidontes* | Laughlin 1979 |
| *Macoma balthica* | Mansour and Lipcius 1991 |
| *Mactra* sp. | Laughlin 1979 |
| *Tellina* sp. | Laughlin 1979 |
| *Dreissena polymorpha* | Molloy et al. 1994 |
| *Congeria leucopheata* | Darnell 1958 |
| *Geukensia demissa* | Tagatz 1968a, Seed 1980 |
| *Mytilopsis leucophaeta* | Darnell 1958, Tagatz 1968a |
| *Musculus niger* | Tagatz 1968a |
| *Neritina reclivata* | Tagatz 1968a, Laughlin 1979 |
| *Neritina virginica* | Darnell 1958 |
| *Odostomia* sp. | Laughlin 1979 |
| *Bittium* sp. | Laughlin 1979 |
| *Nassarius obsoletus* | Tagatz 1968a |
| *Littorina irrorata* | Hamilton 1976 |
| *Melampus coffeus* | Darnell 1958 |
| Polychaetes | Alexander 1986 |
| *Neanthes succinea* | Laughlin 1979 |
| *Laeonereis culveri* | Laughlin 1979 |

| SPECIES | REFERENCES |
|---|---|
| *Nereis pelagica* | Tagatz 1968a |
| Ostracods | Tagatz 1968a, Laughlin 1979 |
| Barnacles | Darnell 1958 |
| *Balanus eburneus* | Tagatz 1968a |
| Decapods | Alexander 1986 |
| *Penaeus* sp. | Laughlin 1979 |
| *Palaemonetes pugio, P. vulgaris* | Tagatz 1968a |
| *Rhithropanopeus harrisi* | Darnell 1958, Tagatz 1968a, Laughlin 1979 |
| *Callinectes sapidus* | Darnell 1958, Tagatz 1968a, Laughlin 1979 |
| *Arenaeus cribrarius* | Alexander 1986 |
| *Neopanope* sp. | Laughlin 1979 |
| *Clibanarius* sp. | Laughlin 1979 |
| Mysids | |
| *Mysidopsis* sp. | Laughlin 1979 |
| *Neomysis americana* | Tagatz 1968a |
| Amphipods | Alexander 1986 |
| *Gammarus fasciatus* | Tagatz 1968a |
| *Corophium* sp. | Laughlin 1979 |
| *Ampelisca* sp. | Laughlin 1979 |
| Bryozoans | Darnell 1958, Tagatz 1968a |
| Fish | Alexander 1986 |
| *Anchoa mitchilli* | Laughlin 1979 |
| *Micropogonias undulatus* | Laughlin 1979 |
| *Microgobius* sp. | Laughlin 1979 |
| *Etropus* sp. | Laughlin 1979 |
| *Trinectes* sp. | Laughlin 1979 |
| *Fundulus heteroclitus* | Kneib 1982 |
| Insects | |
| Coleoptera, Diptera | Tagatz 1968a |
| Hemiptera, Hymenoptera | Tagatz 1968a |
| Odonata | Darnell 1958, Tagatz 1968a |
| Birds | |
| *Anas strepera* | Milne 1965 |

### 3.2.5.4.2 Predation on Blue Crabs

#### 3.2.5.4.2.1 Interspecific Predation

Predation intensity on blue crabs varies with the species of predator, its size, life history stage, physical characteristics, feeding habits, residency in the estuary, and tolerance to environmental parameters (Van Engel 1987). Predation on blue crab zoeae and megalopae is largely unknown because remains of early stage brachyurans in fish stomachs are seldom identified other than as 'crab zoea,' 'brachyuran zoea,' or 'megalopae' (Van Engel 1987). Blue crab megalopae were specifically identified from stomachs of weakfish, *Cynoscion regalis* (Van Engel and Joseph 1968), and McHugh (1967) and Millikin and Williams (1984) suggested that herring or menhaden species, which consume zooplankton, are probably important predators of blue crab larvae. Larval blue crabs are fed upon by other plankters, fish, jellyfish, and comb jellies (Van Engel 1958), and predation by sand shrimp (*Crangon septemspinosa*) and grass shrimp (*Palaemonetes pugio*) may impact survival rates of megalopae settling into Chesapeake Bay grass beds (Olmi and Lipcius 1991).

Interspecific predation is an important regulator of abundance of early stage blue crabs. Greater diversity of predators, fewer predation-free refuges, and lack of seasonality in predation activity all contribute to high mortality of early stage blue crabs in the Gulf (Heck and Coen 1995). A large number of fish species have been identified as blue crab predators (Table 3.4). Juvenile and adult blue crabs are important dietary items of sport and commercial fish such as spotted sea trout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), sheepshead (*Archosargus probatocephalus*), black drum (*Pogonias cromis*), southern flounder (*Paralichthys lethostigma*), alligator gar (*Lepisosteus spatula*), yellow bass (*Morone interrupta*), largemouth bass (*Micropterus salmoides*), and blue catfish, *Ictalurus furcatus* (Lambou 1961, Fox and White 1969, Fontenot and Rogillio 1970, Van Engel 1987). In the Terrebone estuary of Louisiana, Guillory and Prejean (2001) found blue crab in the stomachs of 31% of the red drum examined. Blue crab made up 37% and 31% of the total red drum diet by weight and number, respectively, and was 13.8 times greater in the relative importance index than the next ranked prey species. The consumption rate of blue crab per kg of red drum was 1.86 or 1.92/day (679 or 701/year), dependent upon sampling method used. Almost half of the blue crabs consumed were from 10-29 mm CW.

### 3.2.5.4.2.2 Intraspecific Predation

*Callinectes sapidus* is highly cannibalistic, and in some size classes blue crabs make up as much as 13% of the diet (Darnell 1958, Tagatz 1968b, Laughlin 1979). Healthy individuals may deter cannibalism but those in poor health, missing important appendages, heavily fouled with other organisms, or those within or immediately following ecdysis are more likely to fall prey to other blue crabs. Peery (1989) evaluated effects of size and abundance on blue crab cannibalism. He found that small *C. sapidus* predators were limited to smaller juveniles while larger *C. sapidus* predators cannibalized the upper size range of juveniles. However, when small crab abundance was high, larger *C. sapidus* predators also fed on the small juveniles leading Peery to suggest that the potential of larger crabs to cannibalize juveniles is great enough to produce strong density-dependent regulation of juveniles. Mansour (1992) found cannibalism common and noted that its frequency increased with increasing crab size and was predominant during the period of juvenile recruitment.

## 3.2.6 Parasites and Disease

**Table 3.4** Documented predators of blue crabs.

| TAXONOMIC GROUP | REFERENCES [LIFESTAGE] |
|---|---|
| **INVERTEBRATES** | |
| Jellyfish | Van Engel 1958 [larvae] |
| Comb jellies | Van Engel 1958 [larvae] |
| *Asterias forbesi* – starfish | Auster and Dequoursey 1994 |
| *Callinectes sapidus* - blue crab | Hay 1905, Darnell 1958, Laughlin 1979, Mansour 1992, Moody 1994 |
| *Crangon septemspinosa* - sand shrimp | Olmi and Lipcius 1991 [megalopae] |
| *Menippe adina* - western gulf stone crab | Powell and Gunter 1968 |
| *Palaemonetes pugio* - grass shrimp | Olmi and Lipcius 1991 [megalopae] |
| **FISHES** | |
| *Carcharhinus leucas* - bull shark | Darnell 1958 |
| *Carcharhinus obscurus* - dusky shark | Kemp 1949 |
| *Carcharhinus plumbeus* - sandbar shark | Medved and Marshall 1981 |
| *Galeocerdo cuvier* - tiger shark | Kemp 1949 |
| *Mustelus canis* - smooth dogfish | Bigelow and Schroeder 1953 |
| *Sphyrna tiburo* – bonnethead | Gunter 1945, Hoese and Moore 1958 |
| *Dasyatis centroura* - roughtail stingray | Hess 1961 |
| *Dasyatis sabina* - Atlantic stingray | assumed by Darnell 1958 |
| *Dasyatis say* - bluntnose stingray | Hess 1961 |
| *Raja eglanteria* - clearnose skate | Hildebrand and Schroeder 1928 |
| *Lepisosteus oculatus* - spotted gar | Lambou 1961, Darnell 1958, Suttkus 1963, Goodyear 1967 |
| *Lepisosteus osseus* - longnose gar | Suttkus 1963 |
| *Lepisosteus spatula* - alligator gar | Darnell 1958, Lambou 1961 |
| *Brevoortia tyrannus* - Atlantic menhaden | McHugh 1967 |
| *Anchoa mitchilli* - bay anchovy | Johnson et al. 1990 [*Callinectes* spp. zoeae and megalopae] |
| *Anguilla rostrata* - American eel | Wenner and Musick 1975 |
| *Arius felis* - hardhead catfish | Gunter 1945, Darnell 1958 |
| *Bagre marinus* - gafftoposail catfish | Gudger 1916, Gunter 1945, Odum 1971 |
| *Ictalurus catus* - white catfish | Heard 1973, Van Engel and Joseph 1968 |
| *Ictalurus furcatus* - blue catfish | Darnell 1958, Lambou 1961 |
| *Ictalurus punctatus* - channel catfish | Menzel 1943 |
| *Urophycis regius* - spotted hake | Sikora and Heard 1972 |
| *Opsanus beta* - gulf toadfish | Heard unpublished data |
| *Opsanus tau* - oyster toadfish | Verrill 1873, Schwartz and Dutcher 1963 |
| *Strongylura marina* - Atlantic needlefish | Brooks et al. 1982 |
| *Tylosurus acus* - agujon | Brooks et al. 1982 |
| *Fundulus grandis* - gulf killifish | Levine 1980 |
| *Fundulus heteroclitus* - mummichog | Morgan 1987 [larvae only] |
| *Menidia beryllina* - inland silverside | Levine 1980 |
| *Menidia menidia* - Atlantic silverside | Morgan 1987 [larvae only] |

| TAXONOMIC GROUP | REFERENCES [LIFESTAGE] |
|---|---|
| *Prionotus tribulus* - bighead searobin | Diener et al.1974 |
| *Morone americana* - white perch | Brooks et al. 1982 |
| *Morone mississippiensis* - yellow bass | Darnell 1958, Lambou 1961 |
| *Morone saxatilis* - striped bass | Truitt and Vladykov 1937, Hollis 1952, Darnell 1958, Manooch 1973 |
| *Centropristis striatus* - black sea bass | Brooks et al. 1982 |
| *Centropristis philadelphica* - rock sea bass | Ross et al. 1989 |
| *Epinephelus itajara* - jewfish | Kemp 1949, Pew 1954 |
| *Micropterus salmoides* - largemouth bass | Darnell 1958, Lambou 1961 |
| *Pomatomus saltatrix* - bluefish | Lascara 1981, Brooks et al. 1982 |
| *Rachycentron canadum* - cobia | Meyer and Franks 1996 |
| *Caranx hippos* - crevalle jack | Heard unpublished data |
| *Lutjanus campechanus* - red snapper | Felder 1971 |
| *Lutjanus griseus* - gray snapper | Starck 1971 |
| *Lobotes surinamensis* - tripletail | Gunter 1945, Franks unpublished data |
| *Archosargus probatocephalus* - sheepshead | Gunter 1945, Darnell 1958, Overstreet and Heard 1982 |
| *Lagodon rhomboides* - pinfish | Darnell 1958 |
| *Aplodinotus grunniens* - freshwater drum | Darnell 1958 |
| *Bairdiella chrysoura* - silver perch | Darnell 1958, Thomas 1971, Brooks et al. 1982 |
| *Cynoscion arenarius* - sand seatrout | Overstreet and Heard 1982, Kasprzak and Guillory 1984 |
| *Cynoscion nebulosus* - spotted seatrout | Gunter 1945, Tabb 1961, Overstreet and Heard 1982 |
| *Cynoscion regalis* - weakfish | Van Engel and Joseph 1968, Thomas 1971, Merriner 1975, Lascara 1981, Brooks et al. 1982 [larvae also] |
| *Leiostomus xanthurus* - spot | Levine 1980, Brooks et al. 1982 |
| *Sciaenops ocellatus* - red drum | Gunter 1945, Simmons 1957, Darnell 1958, Overstreet and Heard 1978a |
| *Pogonias cromis* - black drum | Gunter 1945, Van Engel and Joseph 1968, Thomas 1971, Overstreet and Heard 1982 |
| *Micropogonias undulatus* - Atlantic croaker | Darnell 1958, Stickney et al. 1975, Overstreet and Heard 1978b, Merriner 1975, Thomas 1971 |
| *Tautoga onitis* - tautog | Moody 1994 |
| *Scomberomorus cavalla* - king mackerel | Kemp 1949 |
| *Ancylopsetta quadrocellata* - ocellated flounder | Stickney et al. 1974 |
| *Citharichthys spilopterus* - bay whiff | Stickney et al. 1974 |
| *Paralichthys albiguitta* - gulf flounder | Stokes 1977 |
| *Paralichthys dentatus* - summer flounder | Moody 1994 |
| *Paralichthys lethostigma* - southern flounder | Darnell 1958, Overstreet and Heard 1982 |
| *Sphoeroides maculatus* - northern puffer | Van Engel 1987 |
| *Sphoeroides nephelus* - southern puffer | Reid 1954 |

| TAXONOMIC GROUP | REFERENCES [LIFESTAGE] |
|---|---|
| **REPTILES** | |
| *Alligator mississippiensis* - American alligator | Valentine et al. 1972 |
| *Caretta caretta* - loggerhead sea turtle | Van Engel 1987 |
| *Lepidochelys kempi* - Atlantic ridley | Van Engel 1987 |
| **BIRDS** | |
| *Ardea herodias* - great blue heron | Steele and Perry 1990 |
| *Casmerodius albus* - great egret | Bailey 1971 |
| *Grus americana* - sandhill crane | Stevenson and Griffith 1946, Hedgpeth 1950 |
| *Lophodytes cucullatus* - hooded merganser | Steele and Perry 1990 |
| *Mergus merganser* - American merganser | Steele and Perry 1990 |
| *Rallus longirostris* - clapper rail | Bateman 1965 |
| *Somateria mollissima* - American eider | Burnett and Snyder 1954 |
| **MAMMALS** | |
| *Lutra canadensis* - river otter | Chabreck et al. 1982 |
| *Procyon lotor* – raccoon | Hedgpeth 1950 |

The range of the blue crab spans a significant portion of the northern and southern hemisphere in the western Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico. Within this range blue crabs are exposed to a wide variety of diseases, parasites and physiological stressors with the potential to significantly impact their population dynamics.

Reviews and synopses of the parasites and pathogens of blue crabs have been provided by several authors including: Overstreet (1978, 1982, 1983), Couch and Martin (1982), Couch (1983), Johnson (1983, 1984, 1985), Brock and Lightner (1990), Meyers (1990), Messick and Sinderman (1992), Bradbury (1994), Messick (1998), Noga et al. (1998), Wang (2011), and Bonami and Zhang (2011). A comprehensive review of parasites and pathogens of blue crab was developed by Shields and Overstreet (2007). Information in this section addresses known diseases of concern for the blue crabs in the Gulf of Mexico. A listing of parasites, diseases, symbionts, and other associated organisms reported from blue crabs is found in Section 13.4. Classification of some species is in flux and subject to change. Classification of organisms in this review followed the format found in the World Register of Marine Species (WoRMS 2013) with the exception of *Cambarincola vitrea* whose classification data was taken from the Intergrated Taxonomic Information System (ITIS).

### 3.2.6.1 Kingdom Viruses

There are a number of viruses with the ability to impact the health of wild and captive populations. Shields and Overstreet (2007) reviewed viral infections of blue crabs and noted that the following have been found the Gulf of Mexico: Rhabdo-like Virus A (RhVA), Rhabdo-like Virus B (RhVB), and white spot virus (WSV). Rhabdo-like Virus A is associated with host stress and infected crabs exhibit disease when maintained under stressful laboratory conditions or are infected with other viruses (Johnson 1983). In laboratory studies, crabs injected with RhVA and RLV died rapidly (Johnson 1983, 1984). Rhabdo-like Virus B, identified in the mandibular organs of crabs from the Gulf of Mexico, has not been associated with disease (Yudin and Clark 1978) and Messick and Sindermann (1992) characterized the virus as relatively benign. White spot virus (WSV), a cause of great economic loss in penaeid shrimp culture, has been identified in blue crabs from the Gulf of Mexico (Chang et al. 2001). In laboratory studies, Flowers et al. (2000) reported that all blue crabs injected with the virus died and 66% of those fed the virus died. Shields and Overstreet (2007) observed that the blue crab may serve as host to WSV and noted that factors necessary to transform infected individuals into a panzootic with high mortalities are unknown.

A Reo-like virus (RLV) associated with significant mortality in soft shell crab culture systems on the Atlantic coast has recently been reported in Louisiana and Florida (Bowers et al. 2010, Hanif et al. 2011). The virus, infecting both juveniles and adults (Shields and Overstreet 2007), occurs in blue crabs in soft shell production facilities as well as in wild-caught broodstock held in a recirculating systems. Bowers et al. (2010) cautioned that the virus, if not the sole cause of observed mortalities, may act synergistically with other factors to cause death. Stresses associated with handling, crowding, and poor water quality in holding systems can cause immune suppression in invertebrates (Le Moullac and Haffner 2000, Lacoste et al. 2002) allowing latent infections of disease causing organisms to proliferate. Johnson (1983, 1984) also noted that crabs with RLV harbored other viruses (RhVA) that may act synergistically in producing a response.

### 3.2.6.2 Kingdom Bacteria

Bacteria have been implicated in mortality of blue crabs and their hemolymph may harbor bacterial infections known to be human pathogens (Shields and Overstreet 2007). Bacteria have also been associated with mortalities in shedding systems (Messick and Kennedy 1990). Overstreet and Rebarchik (1995) found 49 different bacterial isolates from blue crabs collected in waters around Pensacola, Florida including ten species of *Vibrio* and species of *Salmonella, Pseudomonas, and Aeromonas*. Davis and Sizemore (1982) isolated bacteria taxonomically identical to *V. cholerae*, *V. vulnificus,* and *V. parahaemolyticus* from blue crabs collected in Galveston Bay, Texas and they noted that *Vibrio* spp. were the predominant bacterial types in the hemolymph occurring in 50% of the crabs sampled in the summer. *Vibrio cholerae* and *V. vulnificus* were isolated from 3.5% and 9.0% of the crabs, respectively, with *V. parahaemolyticus* occurring in 30% of the study organisms. *Vibrio parahaemolyticus* and *V. vulnificus* were commonly isolated from the same crab; however, *V. parahaemolyticus* and *V. cholerae* were never found together. Intensity of infection was highest in the summer with proliferation of bacteria occurring quickly when crabs were subjected to stressful situations (water temperature, handling, and capture stress). *Vibrio parahaemolyticus* has caused mortalities in blue crabs and food poisoning symptoms in humans eating contaminated crabs (Overstreet 1978). Keel and Cook (1975) found *V. parahaemolyticus* in Mississippi coastal waters and related its prevalence to temperature and distance from land. In 1978, Gulf coast blue crabs were linked to an outbreak of human cholera in Louisiana. Evidence indicated that the outbreak was due to poor sanitary practices in home-prepared crabs with no implication of commercially processed crab meat. Moody (1982) discussed zoonotic diseases associated with blue crabs and reviewed the history of the 1978 Louisiana cholera outbreak. Marshall et al. (1996) found *Plesiomonas shigelloides*, identified from blue crabs in Mississippi, resistant to streptomycin.

Other species of bacteria identified in blue crabs can also pose food safety issues and there are data to suggest that some species are becoming resistant to anti-biotics.

Microbial infections of blue crabs also include the nonfatal bacteria responsible for shell disease or 'box burn'. In their study of the chitinoclastic bacteria associated with blue crabs and penaeid shrimp, Cook and Lofton (1973) isolated one strain, *Beneckea* type I, from all necrotic lesions but noted in all cases there was no penetration of the epicuticle by the bacteria. Genera of bacteria associated with shell disease included *Vibrio*, *Beneckea* (now *Vibrio*), and *Pseudomonas* (Cook and Lofton 1973). Overstreet and Rebarchik (1995) found that 14 of the 49 species of bacteria collected near Pensacola, Florida produced chitinase and added the genera *Pseudomonas*, *Aeromonas*, *Kingella*, and *Serratia* to the list of agents associated with shell disease. The disease may be an indicator of pollution as several studies have related increased incidence of shell disease with deteriorating water quality (McKenna et al. 1990, Gemperline et al. 1992, Weinstein et al. 1992). Shell disease, while not a significant factor in mortality of wild populations, may negatively affect crabs held in blue crab aquaculture facilities. The disease is contagious and has proven to be a cause of mortality in lobster holding systems (Rosen 1970).

#### 3.2.6.3 Kingdom Chromista

The Chromista represent an independent evolutionary line that diverged from the same common ancestor as plants, fungi, and animals. The Chromista are described as a paraphyletic eukaryotic supergroup, which may be treated as a separate kingdom or included among the Protista (Wikipedia 2013). Classification of organisms discussed below follows the World Register of Marine Species (WoRMS 2013) which treats the supergroup as a separate Kingdom. Organisms are listed by phylum followed by lower taxonomic categories.

##### 3.2.6.3.1 Oomycota/Pythiaceae

Classified as fungi in earlier literature, the genus *Lagenidium* has now been placed under the Kingdom Chromista by many authors. *Lagenidium callinectes*, a pathogen that feeds on the embryos of blue crabs, can, in concert with other egg symbionts, cause significant mortality in egg clutches (Wickham 1986, Shields and Kuris 1988). Lightner (1981) noted that *L. callinectes* in concert with other fungi imposed a serious threat to crustacean culture and Shields and Overstreet (2007) characterized the pathogen as perhaps the greatest fungal threat to the successful culture of several marine decapods.

##### 3.2.6.3.2 Myzozoa/Dinoflagellata/Syndiniaceae

*Hematodinium* sp., a dinoflagellate found predominantly in the hemolymph has been identified in *C. sapidus* from the Gulf of Mexico (Couch and Martin 1982, Messick and Shields 2000). The disease exhibits limited external signs although infected crabs are weak and lethargic. In heavily infected crabs, the dinoflagellates may be found in the musculature, gonads, and hepatopancreas. In the past decade, the knowledge base and literature on *Hematodinium* sp. has expanded tremendously, with at least 50 peer reviewed articles published. Shields (1994) and Stentiford and Shields (2005) provided overviews of the disease in blue crabs and other crustaceans.

Several species of *Hematodinium* sp. have been identified, each with a preferred host range. There are two major clades; one that infects portunid crabs in warmer waters and one found in crustaceans in colder waters of the North Atlantic and North Pacific (Jensen et al. 2010). Most studies on *Hematodinium* in blue crabs have been conducted in the mid-Atlantic. Messick and Shields (2000) found moderate to high prevalence along the Atlantic and Gulf of Mexico coasts. Mortalities from *Hematodinium* sp. infections correlate with high salinity and extended drought periods. A collapse of the blue crab fishery attributed to *Hematodinium* sp. occurred in Georgia in 1999-2000 (Frischer et al. 2006). Prevalence of *Hematodinium* sp. is highest 1-3 months after peak summer temperatures and after persistent summer dry spells.

Development of highly specific and sensitive PCR assays for the parasite have facilitated investigations of transmission, disease reservoirs and alternate hosts (Nagle et al. 2009, Gruebl et al. 2002, Pagenkopp Lohan et al. 2011). Transmission of *Hematodinium* sp. is not well understood, with conflicting accounts of whether cannibalism is a likely route (Walker et al. 2009, Li et al. 2011). While the parasite is most associated with high salinity, it is able to proliferate in crabs in salinities as low as 11‰, yet dinospores (the presumed environmental transmission route) do not survive in low salinity (Coffey et al. 2012). The pathogen is found in sediments throughout the year (Schott unpublished data) leading to speculation that annual recurrence of *Hematodinium* sp. in coastal bays may be a reflection of a parasite reservoir in sediment.

#### 3.2.6.3.3 Myzozoa/Apicomplexa/Eucoccidiorida

*Cryptosporidium parvum* is a human enteric pathogen that can be transmitted directly from person-to-person and indirectly via contaminated water and food consumption. Graczyk et al. (2007) reported the mechanical passage of *C. parvum* oocysts from fish to the hands of recreational anglers and found that blue crabs commercially harvested on the Atlantic Coast served as a vehicle for infectious waterborne oocysts.

#### 3.2.6.3.4 Cercozoa/Haplosporida

*Urosporidium crescens* is a parasite of trematode metacercariae. Metacercariae of the microphallid trematode *Microphallus basodactylophallus* [as *Carneophallus basodactylophallus* (Perry 1975, Overstreet 1978)] are commonly infected by this hyperparasite in Gulf waters. The metacercariae are found in the hepatopancreas and musculature of blue crabs. With the maturation of the spores of *U. crescens*, the metacercariae become black. Metacercariae containing such spores cause the condition known as 'buckshot' by crab fishermen. Crabs thus affected are also known as 'pepper' crabs. According to Perkins (1971), rupture of the metacercariae is necessary for the release of the spores of *U. crescens*, and this occurs after the death of the crab. He found no evidence that the trematode infection caused mortalities in crabs. Blue crabs infected with *U. crescens* pose problems to processors who must either pick around the cysts or discard the crab. According to Adkins (1972a), buckshot crabs are fairly common in Louisiana. More (1969) and Perry (1975) found infected metacercariae in crabs from Texas and Mississippi, respectively.

#### 3.2.6.3.5 Ciliophora/Sessilida

Heavy infestations of ectocommensal ciliates have been implicated in mortalities of blue crabs held in confinement. Couch (1966) identified peritrichous ciliates of the genera *Lagenophrys* and *Epistylis* from gill lamellae of blue crabs from Chincoteague and Chesapeake bays. He suggested that severe infestations of these epibionts may interfere with respiration and contribute to mortality of crabs in holding or shedding tanks. Couch and Martin (1982) reported that the prevalence and intensity of infestation of *Lagenophrys callinectes* in natural populations of *C. sapidus* in Chincoteague Bay increased through the spring and summer peaked in August. They noted that this ciliate may seasonally affect the survival of blue crabs, particularly at times when oxygen tension in the water is borderline.

#### 3.2.6.3.6 Ciliophora/ Philasterida

Two parasitic scuticociliates of the blue crab have been described as being associated with lethargy and mortality. Both occur in low temperatures, and both were found in crabs from Chesapeake Bay. *Mesanophrys chesapeakensis* was described by Messick and Small (1996) in crabs from the Chesapeake Bay. A related species, *M. pugettensis* infects Dungeness crab in the North Atlantic (Morado and Small 1994). Recently, another lethal parasitic scuticociliate, *Orchitophyra stellarum* was discovered in blue crabs being held in outdoor enclosures in Virginia (Small et al. 2011). Like *M. chesapeakensis, O. stellarum* is associated with waters below 15ºC.

### 3.2.6.4 Kingdom Protozoa

#### 3.2.6.4.1 Amoebozoa/Paramoebidae

*Paramoeba perniciosa* is a lethal pathogen of blue crabs. The history of the incidence of *P. perniciosa* along the eastern coast of the U.S. was reviewed by Couch and Martin (1982). This highly pathogenic amoeba was thought to be responsible for outbreaks of gray crab disease that caused mass mortality of blue crabs in South Carolina, North Carolina, and Georgia in June of 1966 and in South Carolina and Georgia in June 1967. While *P. perniciosa* was alluded to as the probable cause of the mortalities, there was some implication that pesticides may have been involved. According to Newman and Ward (1973), blue crab mortalities of greater and lesser magnitude have occurred during May and June along the Atlantic Coast with *Paramoeba* involved in the majority of the kills that were investigated. Couch and Martin (1982) described *P. perniciosa* as an opportunistic parasite/pathogen of blue crabs and other Crustacea. Messick (2002) sampled the Gulf and Atlantic coasts of the U.S. for this parasite and failed to detect *P. perniciosa* in the 228 samples of blue crabs from the Gulf of Mexico.

### 3.2.6.5 Kingdom Fungi

#### 3.2.6.5.1 Microsporidia/Microsporida

*Ameson michaelis* (formally known as *Nosema michaelis*) is found in blue crabs from Gulf and Atlantic waters (Shields and Overstreet 2007). The parasite infects the musculature and is thought to cause lysis of the muscle tissue. Infected crabs are often weakened and infection may cause death. Overstreet (1978) noted the occurrence of this species in crabs from lakes Pontchartrain and Borgne in Louisiana and in crabs taken from Mississippi Sound. Heavily infected crabs can be distinguished from healthy individuals by the chalky opaque appearance of the muscle tissue; fishermen refer to the diseased crabs as 'cotton crabs' (Shields and Overstreet 2007). While *Ameson michaelis* is the more widely known microsporidan parasite of the blue crab, Couch and Martin (1982) reported that *A. sapidi* and *Pleistophora cargoi* have also been identified from muscle tissues of *C. sapidus*. Overstreet and Weidner (1974) are describing a species of *Thelohania* associated with morbidity and mortalities of blue crabs from the Gulf of Mexico.

### 3.2.6.6 Kingdom Animalia

#### 3.2.6.6.1 Platyhelminthes/Trematoda/Digenea

Digenetic trematodes of the family Microphallidae often use a crustacean as a second intermediate host. In those species infecting the blue crab, a snail usually serves as the first intermediate host with a fish, bird, or mammal serving as the final host. Heavy infections may result in death of the crab (Heard and Overstreet 1983). The cercariae (shed from the snail) enter the branchial chamber of the crab, attach to the gill lamellae and penetrate into the gill lumen. The circulatory fluid of the crab carries the cercariae to various parts of the body where they encyst (usually in the hepatopancreas and/or musculature). The encysted or metacercarial stage may or may not be visible depending upon the species. The metacercariae of *Levinseniella capitanea* are very large and easily seen; whereas the metacercariae of *Microphallus basodactylophallus* are not visible unless they are hyperparasitized by *U. crescens* (Shields and Overstreet 2007).

Perry (1975) and Overstreet (1978) found the metacercariae of *M. basodactylophallus* (as *Carneophallus basodactylophallus*) in blue crabs from the northern Gulf of Mexico. More (1969) and Adkins (1972a) reported a metacercaria similar to *Spelotrema nicolli* in blue crabs from Texas and Louisiana, respectively. These metacercariae were in all probability *M. basodactylophallus* as *S. nicolli* is known only from New England (Cable and Hunninen 1940). *Levinseniella capitanea* was described from blue crabs from lower Lake Borgne and western Mississippi Sound by Overstreet and Perry (1972). The large metacercariae of this species appear as opaque, white cysts in the hepatopancreas, gonads, or musculature. There are no published data on the prevalence of this species in the Gulf; however, it is reported to occur with more frequency in crabs from Alabama and northwestern Florida (Overstreet personal communication).

Because the types of habitats in which these trematodes complete their life cycle are often quite specific, they have potential use as 'biological tags' (Heard personal communication). In the northern Gulf of Mexico, the life cycle of *L. capitanea* is completed in the high salinity marshes and baylets of the offshore barrier islands; thus the presence of the metacercariae of this species is an indication that the crab has spent time in the marsh habitats of these islands. Another example is *Megalophallus diodontis*, the metacercariae of which are found only in the gills of crabs that have spent all or part of their juvenile and/or adult life in high salinity turtle grass beds where the life cycle of this digenean is completed.

#### 3.2.6.6.2 Platyhelminthes/Cestoda

Blue crabs serve as intermediate hosts for several marine cestodes (Overstreet 1983, Shields and Overstreet 2007). Plerocercoid larvae of *Prochristianella* sp. have been found in the hepatopancreas of blue crabs in Mississippi (Shields and Overstreet 2007) and Overstreet (1978) reported that other cestode plerocercoids occur in *C. sapidus* that remain unidentified. Shields and Overstreet (2007) noted that cestode infection does not appear to harm the blue crab host and may, in the future, provide a 'biological tag' providing information on host range and migration patterns.

#### 3.2.6.6.3 Nematoda/Ascaridida and Monhysterida

Both parasitic and free-living nematodes are associated with Gulf of Mexico blue crabs and neither group appears to affect the health of the crab (Shields and Overstreet 2007). The juvenile stage of the ascaridoid nematode *Hysterothylacium reliquens*, infects blue crabs in the northern Gulf of Mexico, but the species is also found in other hosts (Deardorff and Overstreet 1981a, 1981b). Free-living nematodes (Monhysterida) occur as symbionts on or in blue crabs.

#### 3.2.6.6.4 Annelida/Clitellata/Hirudinea

Leeches (*Myzobdella lugubris*) are common on crabs from low salinity waters and occur primarily on male crabs. They attach their eggs to the posterior margin of the carapace and are dependent on blue crabs to complete their life cycle (Shields and Overstreet 2007). Although Perry (1975) and Overstreet (1978) found no evidence to suggest a harmful relationship, Hutton and Songandares-Bernal (1959) noted that *M. lugubris* may have been responsible for mortalities of blue crabs in Bulow Creek, Florida. The leech, *Calliobdella vivida* (now *Cystobranchus vividus*), is also found on blue crabs, but is not dependent upon the blue crab to complete its life cycle. Blackford (1966), Curran and Overstreet (1998), and Shields and Overstreet (2007) noted it as epizoic on blue crabs in freshwater bayous in the northern Gulf of Mexico.

#### 3.2.6.6.5 Annelida/Clitellata/Branchiobdellida

A branchiobdellid annelid, *Cambarincola vitrea*, infests blue crabs from low salinity and freshwater habitats. These small worms (2-3 mm long) are found in the gill chambers and on the external shell surface and apparently cause no harm to the crab (Overstreet 1978).

#### 3.2.6.6.6 Nemertea/Carcinonemertidae

*Carcinonemertes carcinophila*, a semi-parasitic nemertean, is common on the gills and egg masses of mature female crabs (More 1969, Perry 1975). According to Shields and Overstreet (2007), juveniles and adults of this species encapsulate in mucous sleeves cemented between the gill lamellae between spawns. Following oviposition, the worms migrate to the clutch and begin feeding on the yolk of the eggs. The worms mature only after feeding on the embryos. Hopkins (1947) discussed the use of this worm as an indicator of the spawning history of *Callinectes sapidus*. Overstreet (1978) noted that while the blue crab is the usual host, it has been found on other portunids.

### 3.2.6.6.7 Arthropoda/Crustacea/Cirripedia/Sessilia

A variety of cirripede symbionts are either ecto-commensal or parasitic on blue crabs. Fouling species include the barnacles *Balanus venustus niveus*, *B. eburneus*, and *Chelonibia patula* (Overstreet 1978). Barnacle fouling of mature female blue crabs is common (Adkins 1972a, Perry 1975). Perry (1975) noted that large numbers of spent female crabs occasionally litter barrier island beaches in the northern Gulf, and these crabs are heavily fouled and parasitized. Weight of fouling barnacles increases energy demands associated with movement and impairs swimming due to increased drag thus making the crabs more vulnerable to predation (Key et al. 1997).

### 3.2.6.6.8 Arthropoda/Crustacea/Cirripedia/Lepadiformes

The pedunculate barnacle *Octolasmis muelleri* [as *O. lowei* (Perry 1975)] is found on the gills and in the gill chamber of *C. sapidus*. Infestations have been observed on male and female crabs from waters of high salinity (More 1969, Perry 1975). Overstreet (1978) noted that heavy infestations may interfere with respiration by decreasing the amount of available gill surface. Shields and Overstreet (2007) suggested that heavy infestations may be lethal.

### 3.2.6.6.9 Arthropoda/Crustacea/Cirripedia/Rhizocephala

The barnacle, *Loxothylacus texanus,* is a true parasite of blue crabs in the Gulf of Mexico. Reinhard (1950a, 1950b, 1951), Overstreet (1978), and O'Brien and van Wyk (1985) described aspects of the process of parasitization. The biology of this parasite is well documented under laboratory conditions (Glenner et al. 2000, Glenner 2001, Lawrence 2001, Boone et al. 2003 and 2004). Blue crabs are infected by the cypris stage of the barnacle. The cyprid larva enters freshly molted, immature crabs through the cuticle and begins the endoparasitic stage by development of the interna. The interna initially attaches to the exterior of the intestinal wall, but later moves along the intestine to the ventral region of the abdomen where emergence of the externa or brood sac occurs. The externa is nourished by root-like branches of the interna that invade the tissue of the host. The parasite was found in laboratory studies to emerge within 94 to 216 days of infection as a small bud on the external surface (O'Brien 1999). The sac enlarges as the barnacle larvae within the sac develop. Both male and female reproductive tissues are found in the externa with the gonads comprising most of the visceral mass. Larvae are released as nauplii, and the cycle begins again. The parasite feminizes male crabs by destroying the androgenic glands, thus male hosts have an abdomen resembling that of an adult female. Small females also develop a wide apron and appear to be mature.

The influence of environmental parameters on distribution and abundance of *L. texanus* has not been clearly established. Ragan and Matherne (1974) reported that infections in northern Gulf estuaries were directly related to salinity. They noted that in low salinity waters, maturing externae did not protrude and that protruded externae took on water and ruptured. Adkins (1972b), Ragan and Matherne (1974) and Wardle and Tirpak (1991) found peak occurrence of the barnacle in higher salinities. Tindal et al. (2004) found, under laboratory conditions, that *L. texanus* larval survival is highest in salinities >20‰ and these authors suggested that lower salinities may provide a refuge for crabs from the larvae.

Hochberg et al. (1992) found that incidence of infection in west Florida was not associated with salinity, but with temperature. They suggested a temporal relationship in the developmental cycles of the barnacle and its blue crab host with barnacle larvae present during the period of maximum availability of susceptible crabs. They collected highest numbers of crabs with mature externae in August, and based on the time required from maturation of the externa to the infective cyprid stage and the number of broods produced, they suggested that high relative abundance of cypris-stage larvae would coincide with elevated levels of juvenile crabs. In Mississippi, Overstreet (1978) reported high numbers of infected crabs in the spring and fall, and Perry (unpublished data) found highest numbers of infected crabs from April through June and in October. Spring and fall peaks of parasitic infection are coincident with elevated numbers of small juveniles associated with molting of overwintering crabs and peak spawning by females in the late summer. Adkins (1972b) also found a correlation between temperature and infection rate in Louisiana estuaries. Infected crabs occurred during the summer and fall with the highest incidence (17.1%) of parasitism in September.

The abundance and size of infected crabs reported is variable and, in part, may be related to gear selectivity. Largest individuals were recorded by Hochberg et al. (1992) and occurred in traps in south Florida (mean size between 110-120 mm CW) and Apalachee Bay (mean size between 80-90 mm CW). They reported that 51% of the infected crabs in their samples were ≥100 mm CW. Incidence of infected crabs is highest in the northern Gulf and parasitized crabs are much smaller. Size range of infected crabs (n=668) in Mississippi estuaries ranged from 15.0-98.0 mm CW with a mean carapace width of 48.1 mm (Perry unpublished data). Shields (2012) reported infection rates of 30-70% in blue crabs from estuaries in the Gulf of Mexico (Christmas 1969, Ragan and Matherne 1974, Wardle and Tirpak 1991, Alvarez and Calderon 1996, Lázaro-Chávez et al. 1996, Alvarez et al. 1999).

The influence on stocks is of particular concern due to the stunting effect caused by parasite interference with molting and reduced or cessation of growth in the infected host (Overstreet 1978, Overstreet et al. 1983, Høeg 1995). In a later paper, Shields and Overstreet (2007) reported that infected crabs do not molt and emphasized that the 'dwarf' or 'button' crabs that appear seasonally in the commercial catch in the northern Gulf of Mexico are not to be confused with infected crabs.

In Bayou Jean LaCroix, Ragan and Matherne (1974) examined juvenile crabs from 33-78 mm CW and reported infection rates of 62%, 61%, and 50% in May, June, and July, respectively. Adkins (1972b) found a peak occurrence of infected crabs from July through September with a 17.1% infection rate in September. Blue crabs infected with *L. texanus* are becoming more prevalent in Mississippi coastal waters. Christmas (1969) noted that the rate of infection in Mississippi Sound was negligible in 1966. Perry (1975) reported that the barnacle was found on less that 1.0% of the crabs collected in 1971 and 1972, and Perry and Herring (1976) noted that 0.1% of the crabs taken in samples from October 1973 through September 1976 carried an externa or had a modified abdomen. Since these data were collected, the incidence of parasitism has risen to over 4% (Perry and Stuck 1982). Additionally, parasitized crabs now show wider areal distribution in Mississippi Sound. From 1971-1976, catches of parasitized crabs were highest in the western portion of Mississippi Sound. Subsequently, infected crabs have been collected throughout local waters. Overstreet (1978) noted that over half of the crabs taken aboard a shrimp trawler in Mississippi Sound in July 1977 exhibited infections. Gunter (1950) observed that only 1.5% of the crabs collected in Aransas and Copano bays, Texas, were parasitized. Daugherty (1952), however, noted that 25.8% of the crabs collected near the southwestern end of Mud Island in Aransas Bay from 1947-1950 were infected. More (1969) found 8.0% and 5.8% infection rates in crabs examined from the lower Laguna Madre and upper Laguna Madre, respectively, with the incidence of infection never exceeding 1.0% in other Texas bays. In Galveston Bay, Wardle and Tirpak (1991) noted externae on 10.3% of the crabs collected from May-July. In Florida, Steele and Hochberg (1987) reported a 4% incidence rate of *L. texanus* infection of blue crabs in Tampa Bay. The development of inexpensive molecular techniques has the potential to expand investigations into the spatial and temporal abundance of *L. texanus* in asymptomatic adults and pelagic larvae from water samples and bring the laboratory to the field to complete our understanding of the life history of this parasite in wild populations of blue crabs (Sherman et al. 2008).

### 3.2.7 Behavior

#### 3.2.7.1 Larvae

Sulkin et al. (1980) and Sulkin (1984) investigated ontogenetic changes in geotaxis and barokinesis of larval *C. sapidus* and proposed a behavioral basis for depth regulation in brachyuran crab larvae. Early stage larvae exhibited positive phototaxis, negative geotaxis, high barokinesis, and increased swimming rate with increased salinity. Stage IV zoeae had a higher sinking rate than Stage I zoeae and were in a transitional period between negative and positive geotaxis. Additionally, the swimming rate of Stage IV zoeae decreased as pressure and salinity increased and water temperature dropped. Stage VII zoeae exhibited positive geotaxis and a reduced swimming rate in response to increased salinity and pressure and decreased temperature. Based on these data, Sulkin et al. (1980) proposed a behaviorally-based pattern of larval dispersal that allowed for maintenance of early stage zoeae in surface layers of the water column with a deeper depth distribution in late-stage larvae. Newly hatched zoeae would be transported from the estuary in seaward-flowing surface waters and returned as late stage larvae in landward-flowing bottom layers. Evidence from field studies, however, did not support this hypothesis. Although zoeae possess behavioral adaptations that would allow for ontogenic vertical migration, McConaugha et al. (1983), Epifanio et al. (1989), and Epifanio (1988) found larvae remained in surface waters throughout zoeal development. Provenzano et al. (1983) and Epifanio et al. (1984) found an abundance of Stage I zoeae during ebbing tides at night, and they suggested that hatching occurs synchronously at night on high slack tides. Morgan (1987) observed antipredatory adaptations in blue crab zoeae.

Megalopae are more abundant in surface waters (Smyth 1980, Johnson 1983, Epifanio 1988, Epifanio et al. 1989) and no evidence for vertical migration in offshore waters has been reported (Johnson 1985). Once in the estuary, however, megalopae exhibit behaviors that favor retention and up-estuary transport. Chemically mediated cues associated with estuarine settlement sites are thought to trigger behavioral changes in megalopae. Little and Epifanio (1991) and Olmi (1995) observed tidally rhythmic vertical migration of megalopae in Delaware and Chesapeake bays, respectively. Luckenbach and Orth (1992) conducted laboratory experiments to evaluate swimming velocities and behavior of blue crab megalopae. Results suggested that at low to moderate current velocities megalopae can move in search of desirable settlement sites and maintain their positions, rather than only being passively moved by currents.

#### 3.2.7.2 Juvenile and Adult Behaviors

##### 3.2.7.2.1 Agonistic and Escape Behavior

The term ‘agonistic’ includes both aggressive and defensive behavior and all degrees of intermediate forms. Brachyuran crabs are highly aggressive animals, having agonistic interactions consisting of visual threat displays and actual physical combat, which may be formal and ritualized or wild and irregular (Schone 1968). Agonistic behavior of blue crabs was reviewed in detail by Jachowski (1974) from both field and laboratory observations. Most agonistic acts employed chelipeds as organs of expression as well as weapons. Such acts as cheliped extending, shielding, leaning, fending, embracing, poking, striking, grasping, and crouching were described and illustrated. Responses during encounters varied with orientation of the two individuals, the distance between them, their size and sex, and presence of food. Vigorous combat was seen only when threats failed to deter crabs attracted to food or only among males when a sexually-receptive female was held by one of them. Agonistic behavior was also studied by Teytaud (1971) and Norse (1975). Blue crabs react to predatory attacks with two general types of behavior: *stand-and-fight* which involves displaying, fending, and striking, much the same as in encounters with other blue crabs; and *fleeing* accomplished by walking, swimming, or digging (Norse 1975). Blue crabs chelae may be substantial weapons of defense. Chelae may be extended to angles >160° in high intensity displays, while during lower levels of defensiveness, chelae may be angled slightly forward from the resting position (Wright 1968). Passive and attack autotomy play roles in blue crab escape behavior (Robinson et al. 1970). Attack autotomy may deter attackers while passive autotomy, a well-known defense mechanism in lizards, may serve to appease or confuse predators. Most blue crabs, especially smaller individuals, usually resort to flight when confronted with danger rather than standing and fighting (Norse 1975). Unless pursued, escape flight is usually followed by attempts at concealment. The swimming of *C. sapidus* was studied through analysis of high speed cinematographs (Spirito 1972). Progression through water is effected by means of a sculling motion of the broad oar-like posterior limbs. Blue crabs can swim forward to a limited extent, hover, and swim backwards quite well; however, swimming sideways is most common.

##### 3.2.7.2.2 Other Behaviors

In addition to previously discussed behavioral traits, a complex behavioral repertoire has been documented that include: climbing behavior (Abbott 1967), death feigning (Bullock and Horridge 1965), predator avoidance (Gunter 1954), galvanotropism (Kellogg 1958), burying (MacGregor 1950), crab schooling (Tyler and Cargo 1963), cleaning mechanisms (Norse 1975), directional orientation (Nishimoto and Herrnkind 1978), tonic immobility (O’Brien and Dunlap 1975), rhythms of color change (Fingerman 1955), detection of food (Pearson and Olla 1977) or pollutants (Pearson and Olla 1979, 1980), sexual recognition (Chidester 1911, Teytaud 1971, Jachowski 1974), mate competition (Smith 1992), pheromone communication (Gleeson 1980, 1982), movement patterns and behavior in the intertidal zone (Nishimoto 1980), locomotory activity patterns (Halusky 1975), avoidance reactions to storm water runoff (Laughlin et al. 1978), and symbionts on scyphozoans (Jachowski 1963, Phillips et al. 1969, Cargo 1971).

### 3.2.8 Movements and Migrations

#### 3.2.8.1 Movements According to Lifestage

Blue crabs are migrants that occupy various estuarine and nearshore habitats, according to the physiological requirements of each life cycle stage. After a period of larval development in high salinity offshore waters, the megalopae recruit to estuarine waters. Molt to the first crab stage takes place in the estuary with early crab stages (5-10 mm CW) found in shallow areas of low to intermediate salinity. Juvenile crabs remain in the upper and middle estuary where growth, maturation, and mating take place. Following mating, female crabs move to more saline waters to spawn while males tend to remain in brackish waters. Jaworski (1972), through observations of commercial fishing activity, identified five migration patterns in the Barataria estuary that are probably applicable to other Louisiana estuaries: 1) spring up-estuary migration of large juveniles and adult males; 2) recruitment of small juveniles to the upper estuary; 3) return of spawned females from offshore to the lower estuary in the summer; 4) upper-to-lower estuary and offshore migration of gravid females in autumn (the fall run of females); and 5) down-estuary migration of large juveniles and adult males from the upper estuary in November and December. Similar migration patterns in which movements appear to be related to phases of the life cycle have been reported by Cronin (1954), Van Engel (1958), Darnell (1959), Tagatz (1968b), More (1969), Judy and Dudley (1970), Perry (1975), and Eldridge and Waltz (1977).

#### 3.2.8.2 Tagging Studies

Tagging studies in the Gulf include those of More (1969), Perry (1975), Oesterling and Evink (1977), and Steele (1987). Migrational patterns observed by More (1969) and Perry (1975) were typical of the onshore/offshore movements as characterized in other studies (Fiedler 1930, Van Engel 1958, Fischler and Walburg 1962, Tagatz 1968b, Judy and Dudley 1970, Benefield and Linton 1990).

Perry (1975) tagged and released 1,023 adult blue crabs (155 males, 868 females) in the fall in Lake Borgne, Louisiana, and Mississippi Sound. Total recoveries numbered 304 (29.7% return), of which 69 were males and 235 were females. Ninety-two percent of females and 81% of males were recovered in Mississippi Sound northeast of release sites. Recovered crabs traveled from 3.2-61.1 km, with recapture times ranging from 4-261 days at large. Results confirmed Darnell's (1959) theory that female crabs leave the low salinity waters of lakes Pontchartrain and Borgne in Louisiana to overwinter in high salinity waters of Mississippi Sound as water temperatures decrease. During the spring and summer, Perry (1975) tagged and released adult crabs in the estuaries adjoining Mississippi Sound: Biloxi Bay, Bay St. Louis, and the Pascagoula River. Recoveries were generally made within 40 days of release. Movements appeared to be random with little movement between adjacent estuaries.

More (1969) studied adult crab movement in Galveston Bay, Texas. About 85% of male and 45% of female crabs were recovered within 3.5 km of the release site. Females demonstrated a southward movement to areas of higher salinity, whereas male crabs remained in the brackish areas of the bay. In Trinity Bay, Texas, Benefield and Linton (1990) tagged and released 300 adult blue crabs (249 males, 51 females) during December. Fifty-four crabs (48 males, six females) were recaptured (18% recovery). Crab movement was generally southward. Average distance traveled was 7.9 km for males and 19.1 km for females. Time to recapture averaged 112 days and ranged from 76-144 days at large.

Blue crab migratory patterns along the west coast of Florida are unique and differ from patterns observed in the northern Gulf. Oesterling (1976), Evink (1976), Oesterling and Evink (1977), Oesterling and Adams (1982), and Steele (1987 and 1991) provided evidence of an alongshore movement of females in Florida coastal waters. In their studies, females moved to sites north of their mating estuary. Oesterling (1976) tagged and released 6,287 blue crabs (51.4% males, 48.6% females) from September-March. The overall return rate was 10.7%, of which 51% were females and 48% were males. Females traveled the greatest distance. While 95% of recaptured males were found within 17.7 km (10.6 mi) of the release site, approximately 25% of recaptured females moved >48.3 km, 43% moved >16.1 km, 4% traveled >322 km, and three individuals traveled 494.1 km from release sites. All non-local movement of females was in a northerly direction along the west coast of peninsular Florida and westerly along the panhandle, with the majority of returns near Apalachicola Bay. Based on the return data, Oesterling and Evink (1977) characterized the Apalachicola Bay region as a primary spawning area and Oesterling and Adams (1982) suggested that surface circulation patterns associated with the Loop Current and the Apalachicola River may be responsible for transport of blue crab larvae to southwestern Florida, thus providing for blue crab recruitment along the entire Gulf coast of peninsula Florida.

Steele (unpublished data) tagged 13,366 blue crabs in Tampa Bay, Florida, during 1982-1983. As in previous studies, an alongshore, single sex migration of female blue crabs in a northward direction was indicated. The overall return rate was 24.9%. Several crabs traveled >800 km in approximately 100 days. Twenty-nine of the tag returns were recovered >765 km from Tampa Bay. Steele (unpublished data) also conducted a two-part tagging program during 1984-1985. In the first segment, crabs (n = 2,767) were tagged in Apalachee Bay; 43% crabs were returned. Only 5% of the crabs were recaptured west of the tagging area suggesting that the low salinity barrier created by the Apalachicola River impedes further westward migration. In the second part of the study, crabs were tagged along the southwest coast of Florida from Key Largo to Sarasota Bay to determine the contribution of various populations to westward migration. Some of these tagged crabs moved northward along the west coast of Florida as far as Apalachee Bay. Crabs tagged at the Key Largo site moved northward along both coasts. Those crabs migrating along the east coast moved as far as Biscayne Bay.

### 3.2.9 Factors Affecting Survival

#### 3.2.9.1 Abiotic Factors

Variations in salinity, temperature, pollutants, predation, disease, habitat loss, and food availability all affect blue crab survival. The diversity of these parameters and their possible synergistic effects can make precise identification of the influence of specific variables difficult. Additionally, the effect of variables such as salinity may be intrinsic (physiological) and/or extrinsic (affecting the composition of the biotic environment). Mortalities associated with chemical and biological pollutants, temperature, salinity, and dissolved oxygen were discussed by Van Engel (1982). Millikin and Williams (1984) provided a review of chemical toxicity of organic compounds and inorganic contaminants on life history stages of the blue crab.

Van Engel (1982) suggested that temperature, salinity, and substratum are primary factors affecting growth, survival, and distribution of blue crabs in Chesapeake Bay. Daud (1979) stated that the principal factors which control the abundance of blue crabs are food, salinity, water temperature, water circulation, and tides. In contrast, Livingston et al. (1976) noted that temperature and salinity may not be as critical in the determination of estuarine population levels as are biological parameters related to trophic levels. Heck and Coen (1995) also concluded that biotic factors play a significant role in determining juvenile population levels. They observed predation rates of 80% per day on early crab stages in Alabama estuaries and concluded that although megalopal numbers in the Gulf greatly exceed numbers in Atlantic Coast estuaries, the higher predation rates in the Gulf resulted in similar juvenile abundances.

### 3.2.9.1.1 Temperature/Salinity

Costlow (1967) emphasized that survival and rate of megalopal development were highly variable under different conditions of temperature and salinity. Megalopal development was most rapid (5-11 days) at 30ºC in salinities from 10-40‰. Duration of the megalopal stage was prolonged from 30-67 days at salinities ≥20‰ at a temperature of 15ºC. Costlow (1967) concluded that survival and duration of the megalopal stage were directly associated with: 1) the time of hatching, 2) the time at which the megalopal stage is reached in relation to seasonal changes in water temperature, and 3) the salinity of the water when the final zoeal molt occurs.

Temperature/salinity tolerance limits of blue crabs have been reported by Tagatz (1969), Mahood et al. (1970), and Holland et al. (1971). Both Tagatz (1969) and Holland et al. (1971) found that blue crabs were less tolerant to temperature extremes at lower salinities. A temperature-salinity tolerance zone was constructed by Mahood et al. (1970) for adult blue crabs using 96-hour total lethal mortality values. Crabs were acclimated to 20ºC. At 0ºC, there was no survival at any salinity. At 8.6‰ the tolerance zone extended from 3.2º-22ºC, and at 36‰, it extended from 18.5º-35.2ºC. The greatest tolerance zone extended over 27ºC at a salinity of 24.2‰. Tagatz (1969) evaluated maximum and minimum median thermal tolerance limits of juvenile and adult blue crabs acclimated at 7‰ or 35‰ in temperatures of 6º, 14º, 22º, or 30ºC. At both low and high salinities, the upper and lower thermal tolerance limits increased as acclimation temperature increased. Tolerance limits for adults and juveniles were similar. Blue crab mortalities in nature have been related to extreme cold or to sudden drops in temperature (Gunter and Hildebrand 1951, Van Engel 1982, Couch and Martin 1982).

#### 3.2.9.1.2 Pollutants

The dissolved phases of cadmium and mercury, methoxychlor, malathion, Mirex, Kepone, juvenile hormone mimic (MONO-585), and insect growth regulator (Dimilin) have been found to be toxic to blue crab larvae and a review of these contaminants can be found in Millikin and Williams (1984). One of the most serious instances of chemical pollution affecting the blue crab fishery occurred in Virginia and was associated with the release of the chlorinated hydrocarbon Kepone into the James River from the 1950s to late 1975. The annual mortality of young and adult blue crabs due to exposure to Kepone remains unknown; however, both commercial landings and juvenile crab abundance were lower in the James River than in the York or Rappahannock rivers as noted by (Van Engel 1982). Lowe et al. (1971) reported Mirex, a compound closely related to Kepone, to be toxic to blue crabs either as a contact or stomach poison. Mirex accumulation in blue crabs and their sensitivity to this compound have been documented (Williams and Duke 1979). In a cooperative study among the states of North Carolina, South Carolina, Georgia, and Florida, Mahood et al. (1970) found 35% of the crabs collected contained detectable levels of Mirex. McHugh (1966) speculated that the ban on DDT (dichloro-diphenyl-trichloroethane) and other chlorinated hydrocarbons resulted in the recovery of the blue crab resource in New York in the late 1970s. High mortality rates of blue crabs near Alligator Harbor, Florida, in November and December of 1973 were attributed to reduced temperatures (<18ºC) and high body burdens of DDT (Koenig et al. 1976).

Long-term effects of oil exposure can alter the physiology and ecology of populations; however, there have been few studies on the cumulative effect of chronic inputs of oil into the marine ecosystem (Farrington and McDowell 2013). Catastrophic spills can devastate the environment with the impact dependent upon the type and toxicity of the oil involved, duration of the spill, species and life history stage present and environmental conditions at the time of the spill (Cooper and Cristini 1994). Acute effects occur quickly and are usually associated with intake of elevated levels of water-soluble components and physical clogging and morphological damage to gills or lungs. The largest release of crude oil in history occurred in the north-central Gulf of Mexico from April through July of 2010. The Deepwater Horizon (DWH) disaster was unprecedented due to the amount of oil released and depth of occurrence.

Anderson (2010) reviewed routes of exposure. Blue crabs can be exposed directly to the oil or they can ingest it from contaminated plant and animal material they consume. Mortality and toxicity effects are not always immediate. Long-term chronic effects are often decreased survival and can include lowered reproductive success. Oil contaminants that do not result in immediate death may be passed along to offspring resulting in defects in future generations or increased juvenile mortality. Karinen and Rice (1974) found that Tanner crabs, *Chionoecetes bairdi*, exposed to oil suffered reduced molting success and limb autotomy and noted that oil pollution may cause significant biological damage other than immediate death of the affected organisms.

During the spring and early summer of 2010, the offshore larval grounds in the northcentral Gulf of Mexico were impacted by surface oil associated with the DWH disaster. Based on the co-occurrence of oil and larvae offshore and the oiling of nearshore settlement marshes and barrier island spawning areas, there was a high potential for impact to blue crab populations. Studies regarding the effects to the Gulf of Mexico's natural resources including blue crab from the Deepwater Horizon oil spill are ongoing through the Natural Resource Damage Assessment process.

### 3.2.9.1.3 Dissolved Oxygen

In Florida, local hypoxic events have been reported in Tampa, Sarasota, and Florida bays. Extensive areas (1,650,000 ha) of low bottom oxygen levels (<2 ppm) occur in the Gulf off of Louisiana and Texas during summer (Rabalais et al. 1995b, Rabalais et al. 1997). Increased levels of nutrient influx from freshwater sources coupled with high summer water temperatures, strong salinity-based stratification, and periods of reduced mixing appear to contribute to what is now referred to in the popular press as the 'Dead Zone', an area approximately 18,200 $km^2$ located south of Louisiana on the continental shelf (Justic et al. 1993). Blue crabs appear to be moderately susceptible to the low oxygen levels and generally move out of the area when dissolved oxygen levels get too low resulting in displacement rather than mortality.

Trap death due to anoxia is a serious problem in many areas. Tatum (1982) reported that oxygen deficient bottom waters covered as much as 44% of Mobile Bay, Alabama, in the summer of 1971, and blue crab mortalities were commonly associated with this event. During the summer, large areas of bottom water in Mobile Bay experience oxygen depletion in summer due to salinity stratification and decomposition of accumulated organic material on the bay floor (Loesch 1960). When these low-oxygen water masses are forced against the beach by winds and tides, demersal fishes and crustaceans migrate shoreward creating a phenomenon known as a 'Jubilee'. May (1973) reported that 81,000 kg of blue crabs died during an anoxic event along Great Point Clear, Alabama. Smaller jubilees have been reported in Mississippi Sound and are associated with localized blooms of phytoplankton (Gunter and Lyles 1979).

### 3.2.9.1.4 Freshwater Inflow

Even though physiography, geology, climatology, watershed characteristics, water quality, and population demographics differ among the subregions, the critical driver of blue crab population dynamics in all areas appears to be freshwater inflow.

Oceanic atmospheric modes of variability from the Atlantic and Pacific Oceans influence the strength and position of the mid-latitude and subtropical jet streams and Bermuda High and thus determine climatic conditions along the U.S. Gulf of Mexico. The jet streams and Bermuda High are associated with the interaction of dry cold air from the polar region and moist warm air from the Pacific and Atlantic oceans and Gulf of Mexico. The confluence of these distinct air masses generates storm fronts across the continental U.S. affecting the series of watersheds that drain into the northern Gulf of Mexico. The size and location of those watersheds determine the climatic influence that decadal and annual climate factors have on hydrology. The vast basin of the Mississippi River and its distributary, the Atchafalaya River, respond to decadal meteorological and hydrological regimes imposed by the Atlantic and Pacific oscillations. Rivers with basins located entirely within the coastal region respond strongly to inter-annual meteorological and hydrological conditions driven by the equatorial Pacific oscillation (ENSO, El Niño/La Niña events). Twilley et al. (2001) divided the Gulf into three distinct climatic regions: eastern, central and western. The western region covered Texas; the central region included Louisiana, Mississippi and Alabama; and the eastern region included all of Florida. Sanchez-Rubio and Perry (2013), in a more comprehensive review of climate data (precipitation and Palmer Drought Severity Index along the Gulf Coast), also found three distinct climate regions, but boundaries for the eastern region differed. In their study, the eastern region consisted of peninsular Florida, the central region included the Florida panhandle and extended through Louisiana and the western region included the State of Texas.

Four major rivers (the Mississippi, Atchafalaya, Pearl, and Pascagoula rivers) in the central region discharge more than 90% of fresh water into the Gulf of Mexico (Perret et al. 1971, Eleuterius 1978). The vast basin of the Mississippi River and its distributary, the Atchafalaya River, respond to decadal meteorological and hydrological regimes imposed by the Atlantic and Pacific oscillations. Smaller rivers in the central Gulf of Mexico with basins located entirely within the coastal region respond strongly to inter-annual meteorological and hydrological conditions driven by the equatorial Pacific oscillation (ENSO, El Niño/La Niña events). In the western region (Texas), coastal river discharge is primarily associated with minor influxes of fresh water into coastal areas and inter-annual ENSO events are influential. Coastal river discharge in Florida (eastern region) is also associated with smaller influxes of fresh water into coastal areas making inter-annual ENSO important. Because of the proximity of Florida to the Atlantic Ocean, hydrology also responds to the Atlantic multi-decadal and North Atlantic oscillations.

Current research in the Gulf of Mexico has related juvenile blue crab abundances to the influence of global climate factors on regional hydrology and how hydrology structures habitat (Sanchez-Rubio et al. 2011). In the northcentral Gulf of Mexico, climate and hydrology operate to structure available habitat in ways that influence survival of juvenile blue crabs. Sanchez-Rubio et al. (2011) examined decadal [Atlantic Multidecadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), North Atlantic Oscillation (NAO)] and annual (ENSO) climate regimes affecting hydrology in the northern Gulf of Mexico and related juvenile blue crab abundances in Louisiana and Mississippi to global climate factors and their effect on regional hydrology. They identified two dominant climate-related hydrological regimes; a wet regime from 1973-1994 (AMO cold, NAO positive) and a dry regime from 1997 - present (AMO warm, NAO negative). Years of high juvenile abundance occurred during the wet years with years of decreasing abundance occurring during the dry period: declines in numbers in the dry period were significant in both States. Riedel et al. (2010) noted that significant downward trends in the abundance of juvenile blue crabs and other estuarine-dependent species taken in trawls in Alabama and Mississippi have occurred over a period characterized by drought and unprecedented changes in habitat associated with catastrophic storms and the cumulative consequences of man-made alterations to coastal wetlands. For many species (including blue crabs), they noted that recruitment has been adequate and numbers of postlarvae and early juveniles did not exhibit the significant declines evident in the trawl data.

High river flows in northern Gulf of Mexico estuaries have been linked to increased commercial landings of blue crabs in Texas (More 1969) and Florida (Wilber 1992, 1994). Wilbur (1992, 1994) correlated 38 years of commercial landings to flows from northwestern Florida rivers (the Apalachicola, Suwannee, Econfina, St. Marks, and Ochlokonee) and concluded that significant long term spatial and temporal relationships existed between flows and crab productivity in the region. Both commercial landings and abundance of juvenile crabs (<40 mm CW) were related to high river flow in Louisiana (Guillory 2000). Gandy et al. (2010) reviewed the relationships between freshwater inflow and blue crab abundance from Texas to Georgia in a report to the Southwest Florida Water Management District and found statistically positive, negative, and mixed correlations between freshwater inflow and blue crab abundance. In general, studies showing positive associations used long term, life history based, lagged inflow regressions applied over large regional data sets to identify significant associations. Negative associations were commonly generated from short term, life history based, lagged inflow regressions applied to data collected within an individual river. Using FID from long-term monitoring programs, Sanchez-Rubio et al. (2011) linked abundance of juvenile blue crabs in Louisiana and Mississippi estuaries to hydrological conditions with highest crab densities associated with increased river flow.

Demands on freshwater resources by cities, farms, and industries are expected to continue to increase leaving the Gulf Coast vulnerable to even slight changes in the seasonal or geographic distribution of fresh water (Twilley et al. 2001). Increases in water withdrawals for public use and agriculture have already resulted in declines in groundwater levels in Florida aquifers and groundwater rationing is already being implemented periodically during dry conditions in urban regions of Texas, Alabama, and Florida. Twilley et al. (2001) noted that the increasing drawdown of surface and underground water reservoirs could combine with sea-level rise to increase saltwater contamination of aquifers near the coast and in most of South Florida. They reported that large groundwater withdrawals in the coastal zones of Baldwin and Mobile counties in Alabama, which include the Mobile Bay and Gulf Shores regions, have increased salinity in wells and drinking water supplies taken from the Mississippi River for coastal communities such as New Orleans are frequently threatened by saltwater intrusion caused by a combination of sea-level rise, land subsidence, and periodic low river flows. Changes in the supply and distribution of rainfall could have significant impacts on estuarine productivity and threaten blue crab fishery sustainability.

### 3.2.9.2 Biotic Factors

#### 3.2.9.2.1 Predation

Blue crab populations in the Gulf of Mexico are regulated by post-settlement biotic processes that affect juvenile survival. Predation-induced juvenile mortality in the Gulf is extremely high and a primary determinant of population size (Heck and Coen 1995). Heck and Coen (1995) observed predation rates of 80% per day on early crab stages in Alabama estuaries and noted that although megalopal numbers in the Gulf greatly exceeded numbers in Atlantic Coast estuaries, higher predation rates in the Gulf resulted in similar juvenile abundances. They attributed the predation rate to a large and diverse suite of predators, fewer predation-free refuges, and year round predation activity (i.e., a lack of seasonality in predation). Intraspecific predation also contributes to mortality. Blue crabs are highly cannibalistic, and in some size classes, blue crabs make up as much as 13% of larger crabs diets (Darnell 1958, Tagatz 1968b, Laughlin 1979). Peery (1989) suggested that the potential of larger crabs to cannibalize juveniles is great enough to produce strong density-dependent regulation of juveniles. Predation on blue crab zoeae and megalopae is largely unknown because remains of early stage brachyurans in fish stomachs are seldom identified other than as ‘crab zoea,’ ‘brachyuran zoea,’ or ‘megalopae’ (Van Engel 1987). Larval blue crabs are fed upon by other plankters, fish, jellyfish, and comb jellies (Van Engel 1958).

#### 3.2.9.2.2 Parasites/Disease

Heavy parasite loads and disease have the potential to reduce the survival of blue crabs at all life stages and can significantly impact their population dynamics. Although mass mortalities have been associated with disease and may contribute to periodic fluctuations in population levels, most outbreaks are seasonal, localized and relatively short-lived (Couch and Martin 1982, Bonami and Zhang 2011, Shields and Overstreet 2007, Newman and Ward 1973).

There are a significant number of viruses found in blue crabs, some of which have been associated with mortality. A reo-like virus (RLV), was associated with significant mortality in soft shell crab culture systems on the Atlantic coast and at least one soft shell system in the Gulf of Mexico (Bowers et al. 2010).

The barnacle, *Loxothylacus texanus,* is a true parasite of blue crabs in the Gulf of Mexico. The influence of this barnacle on blue crab stocks is of particular concern due to the stunting effect it has on its host. The parasite interferes with molting which results in reduced growth or cessation of growth in the infected crab (Overstreet 1978, Overstreet et al. 1983, Høeg 1995). Shields (2012) reported infection rates of 30-70% in blue crabs from estuaries in the Gulf of Mexico.

The highly pathogenic amoeba, *Paramoeba perniciosa*, is responsible for outbreaks of gray crab disease with mass mortalities of blue crabs occurring in South Carolina, North Carolina, and Georgia in June 1966 and in South Carolina and Georgia in June 1967. While the pathogenic amoeba (*P. perniciosa*) was alluded to as a possible cause of the mortalities, there was some implication that pesticides may have been involved. According to Newman and Ward (1973), blue crab mortalities of greater and lesser magnitude have occurred during May and June along the Atlantic Coast with *Paramoeba* involved in the majority of the kills that were investigated. *Paramoeba perniciosa* has not been detected in samples of blue crabs from the Gulf of Mexico (Messick 2002).

*Hematodinium* sp., a dinoflagellate found predominantly in the hemolymph, has been identified from *C. sapidus* from the Gulf of Mexico (Couch and Martin 1982, Messick and Shields 2000). The disease exhibits no external signs although infected crabs are weak and lethargic. A study by Messick and Shields (2000) found a moderate to high prevalence of the disease along the Atlantic and Gulf of Mexico coasts. In Georgia, a local collapse of the blue crab fishery was associated with *Hematodinium* in 1999/2000 (Frischer et al. 2006).

Heavy infestations of ectocommensal ciliates have been implicated in mortalities of blue crabs held in confinement. Couch (1966) identified peritrichous ciliates of the genera *Lagenophrys* and *Epistylis* from gill lamellae of blue crabs from Chincoteague and Chesapeake bays. He suggested that severe infestations of these epibionts may interfere with respiration and contribute to mortality of crabs in holding or shedding tanks. Couch and Martin (1982) reported that the prevalence and intensity of infestation of *Lagenophrys callinectes* in natural populations of *C. sapidus* in Chincoteague Bay increased through the spring and summer peaked in August. They noted that this ciliate may seasonally affect the survival of blue crabs, particularly at times when oxygen tension in the water is low. The parasitic scuticociliate, *Mesanophrys chesapeakensis,* has been associated with mortalities in the Chesapeake Bay (Messick and Small 1996). A more lethal parasitic scuticociliate, *Orchitophyra stellarum*, was recently discovered in blue crabs being held in outdoor enclosures in Virginia (Small et al. 2011). Ciliate protozoan infestations appear to be more prevalent along the Atlantic Coast.

Several species of *Vibrio* have been identified from blue crabs. Davis and Sizemore (1982) isolated bacteria taxonomically identical to *V. cholerae*, *V. vulnificus,* and *V. parahaemolyticus* from blue crabs collected in Galveston Bay, Texas. Species of *Vibrio* were the predominant bacterial types in the hemolymph occurring in 50% of the crabs sampled in the summer. *Vibrio cholerae* and *V. vulnificus* were isolated from 3.5% and 9.0% of the crabs, respectively, with *V. parahaemolyticus* occurring in 30% of the study organisms. *Vibrio parahaemolyticus* has caused mortalities in blue crabs and food poisoning symptoms in humans eating contaminated crabs (Overstreet 1978).

Synopses of the parasites and pathogens of blue crabs have been provided by several authors over the past three decades: Couch and Martin (1982), Couch (1983), Johnson (1983), Overstreet (1983), Brock and Lightner (1990), Meyers (1990), Messick and Sinderman (1992), Bradbury (1994), Messick (1998), Noga et al (2000), Shields and Overstreet (2007), Wang (2011), and Bonami and Zhang (2011).

**3.2.9.2.3 Invasive Species**

Two non-indigenous portunid species have been reported and verified from the Gulf of Mexico: *Callinectes bocourti* and *Charybdis hellerii.* Perry (2011) noted several extra-territorial occurrences of *C. bocourti* from 1971 to 1999 in the Biloxi Bay estuary, Mississippi with all specimens collected in the fall of the year. The first Mississippi specimen was collected in a commercial crab trap in 1971 (Perry 1971). A single juvenile specimen was collected in Mobile Bay, Alabama in 2000 (Hartman personal communication). The species has also been reported in Atlantic waters from Florida, South Carolina, and North Carolina (Gore and Grizzle 1974, Williams and Williams 1981, Knott personal communication). *Callinectes bocourti* is associated with *C. sapidus* in many estuaries along the South and Central American coasts. The two species share similar life history traits, thus competition for food and refuge may occur. Extra-territorial occurrences in the northern Gulf are sporadic and suggest that the species is not currently reproducing in the region.

*Charybdis hellerii*, a native of the Indo-West Pacific faunal province, was first found in coastal North American Atlantic waters in South Carolina (Knott personal communication), an observation made prior to the published discovery of this species in the Indian River Lagoon system in Florida by Lemaitre (1995). Lemaitre (1995) suggested that the species was established in the Lagoon based on the capture of adult males and females, ovigerous females and juveniles. Knott (personal communication) reported that this species occurs sporadically in South Carolina waters with specimens collected in benthic sampling trays and in trawls. In 2004, a single specimen of *C. hellerii*, an ovigerous female, was captured in the Gulf of Mexico off Tampa, Florida (McMillen-Jackson 2008).

Knott also reported the extra-territorial occurrences of *Callinectes exasperatus* (native range from the southern tip of Florida to Brazil, western Gulf of Mexico, and Bermuda) and *C. larvatus* (native range from the southern tip of Florida to Brazil, and Bermuda) in South Carolina waters. To date, these species have not been recorded from the Gulf of Mexico.

### 3.3 Summary of Life History Characteristics Relevant to Management

- ‘r’ selected strategist; high fecundity, rapid growth, early maturation, and short life span.

- Determinate growth in males and females; maximum size attained reflects incremental growth per molt rather than the number of molts.

- Terminal anecdysis in females and size at 50% sexual maturity; Size at 50% sexual maturity in females corresponds with minimum legal harvesTable size, thus some fraction of the population reproduces at a sublegal size and is not susceptible to commercial harvest. Over time, these individuals may contribute disproportionately to the population and the size of 50% sexual maturity in females could decrease. Selection would be for those females that reproduced at a sublegal size. If size-at-reproduction has a heritability component and because maturation occurs at the terminal molt, both the size at 50% sexual maturity for females and the average maximum size attained by females could eventually decrease (Bert personal communication).

- High natural mortality related to predation on juveniles.

- Genetics, larval dispersal, migratory patterns, and regional climatology suggest two or more blue crab populations in Gulf of Mexico.

## 4.0 DESCRIPTION OF THE HABITAT OF THE STOCK COMPRISING THE MANAGEMENT UNIT

### 4.1 Habitat Requirements

The life history of the estuarine-dependent blue crab involves a complex cycle of planktonic, nektonic, and benthic stages which occur throughout the estuarine-nearshore marine environment. A variety of habitats within the estuarine environment are occupied depending upon the particular physiological requirements of each life history stage (Perry et al. 1984). These habitats can be divided into offshore and estuarine phases. Female blue crabs are catadromous; they migrate from hyposaline waters to higher salinity water to spawn and hatch their eggs. The high salinity, oceanic water not only serves as habitat for the spawning female but ensures larval development, increases dispersal capabilities, decreases osmoregulatory stress, and reduces predation. Eggs hatch into free swimming larvae (zoeae) which pass through a series of molts. Newly-hatched blue crab larvae normally develop through seven zoeal stages before transforming into a megalopal stage. Megalopae return to the estuary where they molt into the first crab stage. Both juvenile and sub-adult crabs are widely distributed in estuarine areas. Mature female crabs occupy lower estuarine areas and the open Gulf of Mexico waters, while male blue crabs remain within the estuary during their entire post-settlement life.

The estuarine phase is perhaps the most critical because juvenile growth, the initial components of the reproductive cycle, and determination of year-class success occur there. Predation-induced juvenile mortality in the Gulf is extremely high and a primary determinant of population size (Heck and Coen 1995). Juvenile blue crab abundances have been related to the influence of global climate factors on regional hydrology and how hydrology structures habitat to provide refuge from predation (Sanchez-Rubio et al. 2011). Laughlin (1979) concluded that the temporal and spatial distribution of *C. sapidus* in the Apalachicola estuary appeared to be determined by complex interactions of abiotic, trophic, and other biotic factors which have different significance with respect to season and area.

Copeland and Bechtel (1974) reviewed blue crab resource survey data and associated environmental parameters from the Gulf of Mexico and proposed that catches were distributed as follows:

1) Water temperature range, 0º-40ºC; optimum catch between 10º and 35ºC.
2) Salinity range, 0.0-40.0‰; optimum catch between 0.0-27.0‰.
3) Season range, all months; maximum catch during spring and fall.
4) Location range, all estuarine locations; optimum catch in primary rivers, secondary streams, marsh, and tertiary bays.

#### 4.1.1 Larvae

Female *C. sapidus* spawn near the offshore barrier islands in the northern Gulf of Mexico (Perry 1975, Adkins 1972a) or in high-salinity waters near bay mouths (Oesterling and Adams 1982, Steele and Bert 1994). Perry and Stuck (1982) noted that early Stage I and II zoeae of

*Callinectes* spp. were present in Mississippi coastal waters in the spring, summer, and fall. Vertical and areal patterns of zoeal distribution are similar for the Atlantic and Gulf coasts. After hatching, first stage zoeae move into surface waters where they remain for the duration of larval development (McConaugha et al. 1983, Provenzano et al. 1983, Johnson 1985, Epifanio 1988). Larvae are exported from estuaries on an ebbing tide (Provenzano et al. 1983, Johnson 1995), and zoeal development and metamorphosis to the megalopal stage takes place on the adjacent continental shelf (Andryszak 1979, Perry and Stuck 1982, Epifanio et al. 1984, Epifanio 1988, McConaugha 1988, Epifanio 1995, Blanton et al. 1995).

The temporal and spatial distributions for megalopae of *C. sapidus* in Gulf of Mexico estuaries have been investigated by Stuck and Perry (1981), Perry et al. (1995), Rabalais et al. (1995a), and Morgan et al. (1996). Stuck and Perry (1981) reported that peak numbers of blue crab megalopae in plankton samples occurred during late spring/early summer and late summer/early fall in barrier island passes along the Mississippi Coast. Although high numbers of megalopae have been taken in plankton samples in the spring and early summer, few megalopae settle on artificial substrate collectors during this period (Perry et al. 1995, Rabalais et al. 1995a). Morgan et al. (1996) found that settlement of megalopae in Mobile Bay, Alabama occurred from June-November with a peak during July to mid-October. Chemical cues from the estuary have been shown to speed metamorphosis of megalopae to the first juvenile stage (Wolcott and De Vries 1994, Forward et al. 1994, Brumbaugh and McConaugha 1995, Forward et al. 1996, 1997). More specifically, it is the combination of the lower salinity and chemical cues from vegetation that allows the megalopae to settle in preferred habitats (Forward et al. 1994, 1996, Welch et al. 1997, Forward et al. 2003). Welch et al. (1997) and Forward et al. (2003) showed that megalopae were attracted to the chemical cues of vegetation and were repelled by the odors of predators. If a preferred habitat is not present when molting to the first crab stage becomes obligatory, settlement, and metamorphosis can occur anywhere (Orth and van Montfrans 1990). Initial settlement and nursery habitat for postlarval blue crabs occur in seagrass beds in the Chesapeake Bay (Heck and Thoman 1984, Orth and van Montfrans 1987). In the northcentral Gulf of Mexico, megalopae settle in shoreline habitats (Holt and Strawn 1983, Perry et al. 1995, Rabalias et al. 1995a) and prefer vegetated habitats to unvegetated habitats (Morgan et al. 1996).

### 4.1.2 Juveniles

Juvenile blue crabs show wide areal distribution in Gulf estuaries. The importance of habitat to the distribution and abundance of juvenile blue crabs has been well documented. Faunal distribution studies by Heck and Wilson (1987), Zimmerman et al. (1984), Orth and Van Montfrans (1987, 1990), Thomas et al. (1990), Morgan et al. (1996), Heck et al. (2001), and Able et al. (2007) have shown that vegetated habitats (seagrass and salt marsh) are important nursery areas for estuarine-dependent species such as the blue crab. Vegetated habitats were characterized by higher overall abundances of blue crabs and lower predation rates than were non-vegetated habitats (Orth and van Montfrans 1990, Morgan et al. 1996, Etherington and Eggleston 2000, Heck et al. 2001, King et al. 2005, Florido and Sanchez 2010). The quantity of marsh and seagrass habitats may contribute to stock size by providing food and refuge which increases survival of early juvenile stages (Boesch and Turner 1984, Turner and Boesch 1988). Significant positive relationships were found between penaeid shrimp production and total vegetated area by Turner (1977) and for blue crab production by Orth and van Montfrans (1990). The latter authors observed that availability of marsh-edge habitat, low tidal amplitudes, and long periods of tidal inundation favor utilization of salt marshes by juvenile blue crabs, especially in the northern Gulf where seagrass coverage is not extensive. Studies in Texas estuaries demonstrated that juvenile blue crabs were significantly more abundant in flooded salt marshes than in subtidal areas without vegetation (Zimmerman and Minello 1984, Thomas et al. 1990).

Oyster reefs were shown to have higher densities of nekton, including decapod crustaceans, than unvegetated bottoms (Zimmerman et al. 1989, Glancy et al. 2003, Plunket and La Peyre 2005, Shervette and Gelwick 2008, Stuntz et al. 2010, Shervette et al. 2011). Stuntz et al. (2010) and Shervette et al. (2011) both showed that blue crab densities were similar in marsh edge and oyster habitats and that both were significantly higher when compared to unvegetated substrates. Shervette et al. (2011) also noted that the sizes of blue crabs were different between marsh edge and oyster reef habitats with smaller crabs found in the oyster habitat. It is suggested that the oyster reef had smaller spaces for the juvenile blue crabs to seek refuge from predators (Shervette et al. 2011).

Unvegetated substrates with drift algae or attached macroalgae also provide important habitat in some areas. Mats and drifting patches of sea lettuce (*Ulva lactuca*) enhanced survival of juvenile blue crabs and were identified as refuge areas by Wilson et al. (1990). Epifanio et al. (2003) and Dittel et al. (2006) showed that macroalgal beds were important nursery areas for juvenile blue crabs, not just for the shelter but at the trophic level, and were just as important as seagrass habitat. Heck and Thoman (1984) and Heck and Wilson (1987) suggested a positive relationship existed between biomass of some macroalgal species and prey survivorship, and Wilson et al. (1990) noted that abundance of blue crabs in areas that lack rooted submerged aquatic vegetation suggested that marsh and macroalgae were important nurseries.

While numerous studies have cited the importance of structurally complex habitats as refuge, there is some evidence that unvegetated soft-sediment habitats also provide protection from predation. The association of juvenile blue crabs with soft mud sediments has been noted in several Gulf studies including: More (1969), Holland et al. (1971), Adkins (1972a), Perry (1975), Evink (1976), Livingston et al. (1976), Perry and Stuck (1982), Rakocinski et al. (2003), and Rakocinski and McCall (2005). Seitz et al. (2005) also determined that mud and sand habitats up river in the Chesapeake Bay system were important nurseries for juvenile blue crabs due to higher densities of preferred food sources. Johnson and Eggleston (2010) showed that juvenile blue crabs in North Carolina had high survivability in salt marshes but they moved short distances to utilize mud substrate when the vegetation was exposed during ebb tides. Moody (1994) found that mud habitats provided refuge from predation that was unavailable in sand sediments. He suggested that predators relying on visual cues may be less effective in mud habitats, and soft sediments allow crabs to bury quickly and deeply. In the northern Gulf, juvenile crabs utilize sand and mud bottoms in the colder months because water levels are low and intertidal salt marshes are largely unavailable during the winter (Thomas et al. 1990).

Although juvenile blue crabs occur over a broad range of salinities, they are most abundant in low to intermediate salinities characteristic of middle and upper estuarine waters. Daud (1979) concluded that shallow, brackish to saline waters are the major habitat for the early crab stages (5-10 mm). As they grow to a larger size, these blue crabs move into fresher waters. Swingle (1971), Perret et al. (1971), and Perry and Stuck (1982) determined the distribution of juvenile blue crabs by temperature and salinity using temperature-salinity matrices. Both Perret et al. (1971) and Swingle (1971) found maximum abundance for larger juveniles in salinities <5.0‰. In contrast, Perry and Stuck (1982) found highest average catches of juvenile blue crabs were associated with salinities >14.9‰. Hammerschmidt (1982) found no direct relationship between catches of juvenile blue crabs and salinity in Texas. Steele and Bert (1994) found maximum abundance for subadult males and adult females in salinities >20.0‰ in Tampa Bay, Florida.

The partitioning of estuarine habitat among size classes of blue crabs is thought to be related to predator avoidance (including cannibalism), food availability and nutritional requirements, reproductive success, and growth (Millikin and Williams 1984, Perry et al. 1984, Hines et al. 1987, Thomas et al. 1990). Habitat segregation of juveniles of *C. sapidus* by size was described by several researchers (Daud 1979, Perry and Stuck 1982, Rounsefell 1964, Thomas et al. 1990, Williams et al. 1990). Distribution of juvenile blue crabs in Mississippi waters was as follows: 1) first and early crab stages (3-10 mm CW) occurred most often in salinities from 15-20‰; 2) 10-20 mm CW juveniles were most frequently found in salinities <10.0‰; and 3) maximum number of 20-40 mm CW crabs were sampled from salinities <5.0‰ (Perry and Stuck 1982). Rounsefell (1964) and Daud (1979) observed a movement of crabs into low salinity Louisiana marshes with growth. Juvenile crabs in Christmas Bay, Texas, were larger in salt marshes than in seagrass or on sand and mud bottoms (Thomas et al. 1990); possible reasons for the observed habitat-related size patterns included differential predation, differential recruitment of megalopae, inability of small crabs to effectively move with tides in and out of salt marshes, and active selection. In Mobile Bay, Alabama, newly-recruited crabs (<5 mm CW) exhibited some association with high-density, submergent vegetation; slightly larger individuals (5-10 mm CW) showed a tendency toward association with low density grass; and juveniles >10 mm CW exhibited no association with any particular substratum. In Barataria Bay, Louisiana, larger juvenile blue crabs (>20 mm CW) moved out of marsh-edge microhabitats (Baltz and Gibson 1990). In the Chesapeake Bay system and North Carolina, there is an ontogenetic shift in habitat utilization when juvenile blue crabs secondarily disperse from their initial settlement habitats into habitats with fewer conspecifics and increased food availability (Pile et al. 1996, Moksnes et al. 1997, Etherington and Eggleston 2000, Blackmon and Eggleston 2001, Etherington and Eggleston 2003, Etherington et al. 2003, Reyns and Eggleston 2004)

Microhabitat selection of molting juveniles of *C. sapidus* was discussed by Hines et al. (1987), Ryer et al. (1990), Wolcott and Hines (1990), and Shirley and Wolcott (1991). In Chesapeake Bay, crabs approaching ecdysis aggregated in seagrass meadows possibly to escape predators (Ryer et al. 1990) or selected shallow, marsh-lined banks of tidal creeks for ecdysis (Hines et al. 1987, Wolcott and Hines 1990). The adaptive significance of habitat selection by molting blue crabs was discussed by Shirley et al. (1990). A higher proportion of male crabs molted in main tributary marsh creeks of the Rhode River sub-estuary in Maryland while maturing females remained in the river basin to molt and mate.

### 4.1.3 Adults

Adult blue crabs use submerged vegetation (including macroalgae), unvegetated sediments, and *Spartina* marsh for refuge and foraging (Heck and Thoman 1984, Wilson et al. 1990). High-salinity waters (>30.0‰) are occupied almost exclusively by mature crabs, particularly females. Females move to the estuary entrances to spawn and they head back up estuary after the spawn (Tankersley et al. 1998). In Tampa Bay, Florida, large (mature) males were more common in low-salinity areas of the upper bay; large females were found in the seaward region of the bay; and subadult males were significantly more abundant in the extensive seagrass beds located in the lower bay (Steele and Bert 1994). Although adult blue crabs are ubiquitous throughout an estuarine system, they are distributed seasonally with respect to salinity and sex (Steele and Bert 1994) as well as size and molt stage (Hines et al. 1987). Hines et al. (1987) showed that premolt blue crabs moved upstream in salt creeks and most of the individuals moving downstream in the salt creek were postmolt. Ryer et al. (1997) expected that seagrasses would be an ideal refuge for molting individuals but found that grass beds were comparable to large marsh creeks. Three subhabitats (spawning, wintering, and maturation) were recognized in the Barataria, Louisiana, estuary by Jaworski (1972). The spawning habitat for females included tidal passes and nearshore Gulf waters, while the lower bays where juvenile and male crabs concentrated after water temperatures fell below 15°C comprised the wintering habitat. The maturation habitat included the shallow, brackish marshes of the upper estuaries.

Throughout the Gulf of Mexico, adult blue crabs are widely distributed and occur on a variety of bottom types in fresh, estuarine, and shallow oceanic waters. In Louisiana, blue crabs have been reported 305 km upstream in the Atchafalaya River (Gunter 1938); other published records of their freshwater occurrence are found in Florida (Odum 1953, Gunter and Hall 1963) and Texas (Wurtz and Roback 1955). Conversely, *C. sapidus* has been collected in hypersaline lagoons in Texas at 60.0‰ (Simmons 1957) and in Florida at 55.0‰ (Rouse 1969). In the Gulf of Mexico, the species has been recorded offshore to depths of 90 m (Franks et al. 1972). Gelpi et al. (2009) found high abundances of female blue crabs on Ship and Trinity Shoals in the Gulf of Mexico during August when the salinities ranged from 23.8-36.3‰. Laughlin (1979) suggested the spatial distribution of adult crabs in Apalachicola Bay, Florida, appeared unrelated to abiotic or depth regimes, but crabs sought areas of high food abundance regardless of salinity or water depth. Seitz et al. (2003) found that blue crab densities were mainly affected by the availability of food at small spatial scales (<10 km).

## 4.2 Gulf of Mexico General Description

Much of the material in Sections 4.2 and 4.3 were taken from the Cooperative Gulf of Mexico Estuarine Inventory and Study (GMEI; Barrett et al. 1971, McNulty et al. 1972, Christmas 1973, Deiner 1975) unless otherwise noted.

Galtsoff (1954) summarized the geology, marine meteorology, oceanography, and biotic community structure of the Gulf of Mexico. Later summaries include those of Jones et al. (1973), Beckert and Brashier (1981), Holt et al. (1982), and the Gulf of Mexico Fishery Management Council (GMFMC 1998). In general, the Gulf is a semi-enclosed basin connected to the Atlantic

Ocean and Caribbean Sea by the Straits of Florida and the Yucatan Channel, respectively. The Gulf of Mexico has a surface area of approximately 1,510,000 $km^2$ (Wiseman and Sturges 1999), a coastline measuring 2,609 km, one of the most extensive barrier island systems in the United States, and is the outlet for 33 rivers and 207 estuaries (Buff and Turner 1987). Water depths range from 3,000 to >4,300 m with an average depth of 1,655 m (Turner 1999). Oceanographic conditions throughout the Gulf are influenced by the Loop Current and major episodic freshwater discharge events from the Mississippi/Atchafalaya Rivers. The Loop Current directly affects species dispersal throughout the Gulf while discharge from the Mississippi/Atchafalaya Rivers creates areas of high productivity that are used by many commercially and recreationally important marine species.

The Gulf Coast wetlands and estuaries provide habitat for an estimated 95% of the finfish and shellfish species landed commercially in the Gulf and 85% of the recreational catch of finfish (Thayer and Ustach 1981). Commercial fishing accounted for an estimated 1.76B pounds of harvested fish and shellfish in 2011 or 17.8% of the nation's total commercial landings (NMFS 2012). These landings were worth an estimated $817M in dockside value (NMFS 2012). Gulf coast wetlands, estuaries, and barrier islands also provide important feeding, breeding, and cover habitat to wildlife species such as waterfowl, shorebirds and wading birds; improve water quality; and play a significant role in lessening flood and storm surge damage and minimizing erosion.

### 4.2.1 Sediments

Two major sediment provinces exist in the Gulf of Mexico. Carbonate sediments predominate east of Desoto Canyon and along the Florida west coast while terrigenous sediments are commonly found west of Desoto Canyon and into Texas coastal waters (GMFMC 1998). Bottom sediments are coarse in nearshore waters extending northward from the Rio Grande River to central Louisiana and are the dominant bottom type in deeper waters of the central Gulf. Fine sediments are common in the northern and eastern Gulf and south of the Rio Grande due to riverine influence, particularly the Mississippi and Rio Grande Rivers. Fine sediments are also found in deeper shelf waters (>80 m) (GMFMC 1998).

### 4.2.2 Circulation Patterns and Tides

Hydrographic studies depicting general circulation patterns of the Gulf of Mexico include those of Parr (1935), Drummond and Austin (1958), Cochrane (1965), Jones et al. (1973), Ochoa et al. (2001). Circulation patterns in the Gulf are dominated by the influence of the upper-layer transport system of the western North Atlantic. Driven by the northeast trade winds, the Caribbean Current flows westward from the junction of the Equatorial and Guiana currents, crosses the Caribbean Sea, continues into the Gulf through the Yucatan Channel, and eventually becomes the eastern Gulf Loop Current (Figure 4.1). Upon entering the Gulf through the Yucatan Channel, the volume transported by the Loop Current is estimated to be between 2.38-2.8M cubic meters per second (Johns et al. 2002, Sheinbaum et al. 2002).

Moving clockwise, the Loop Current dominates surface circulation in the northeast Gulf and generates permanent eddies over the northwest Gulf. During late summer and fall, the progressive expansion and intrusion of the loop reaches as far north as the continental shelf off the Mississippi River Delta. High productivity associated with the discharge from the Mississippi/Atchafalaya River systems benefits numerous finfish and invertebrate species that use the northern Gulf as a nursery ground. Additionally, dispersal of tropical species from the Caribbean into the Gulf is accomplished via Loop Current transport. Nearshore currents are driven by the impingement of regional Gulf currents across the shelf, passage of tides, and local and regional wind systems. The orientation of the shoreline and bottom topography may also place constraints on speed and direction of shelf currents.

Gulf tides are small and noticeably less developed than along the Atlantic or Pacific coasts. Tides range from 0.5-1.0 m and are driven mostly by atmospheric pressure and wind direction (Solis and Powell 1999). Despite the small tidal range, tidal current velocities are occasionally high, especially near the constricted outlets that characterize many of the bays and lagoons. Tide type varies widely throughout the Gulf with diurnal tides (one high tide and one low tide each lunar day of 24.8 hours) existing from St. Andrew's Bay, Florida, to western Louisiana. The tide is semi-diurnal in the Apalachicola Bay of Florida and mixed in western Louisiana and in Texas.

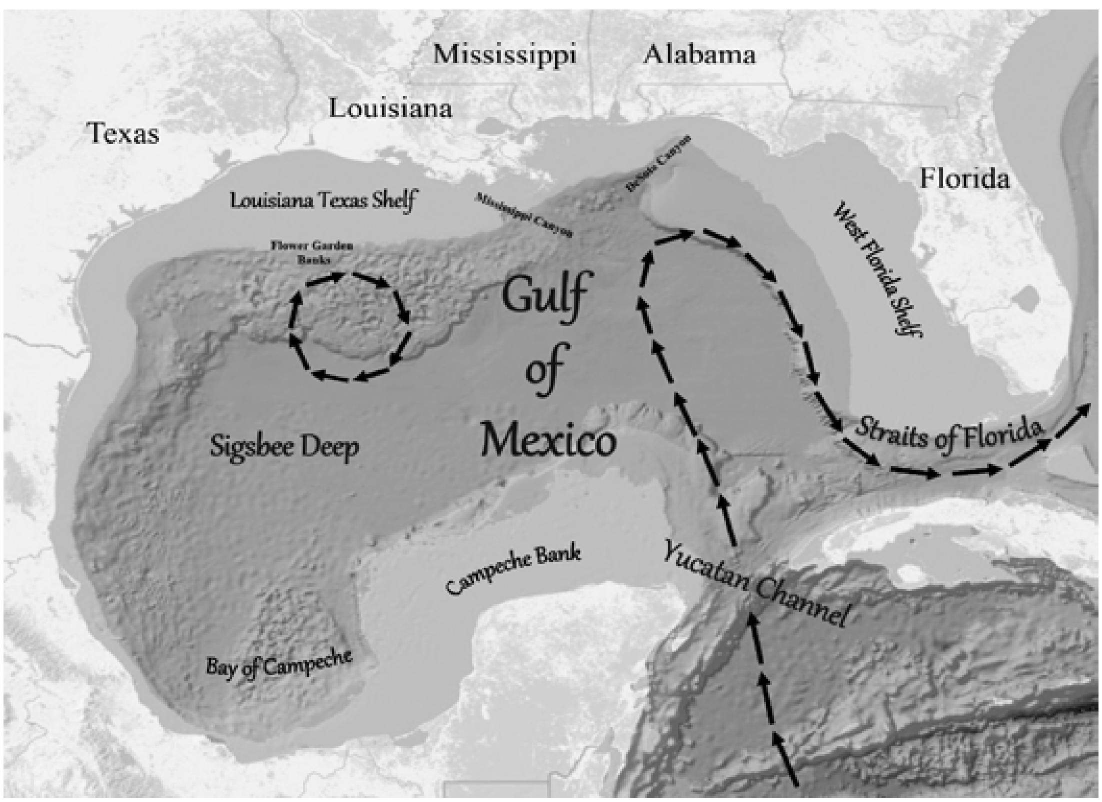



**Figure 4.1** Generalized circulation pattern in the Gulf of Mexico. Also included are some geologic features of the Gulf of Mexico including shallower continental shelf regions and geologic breaks such as DeSoto Canyon off the panhandle of Florida and Mississippi Canyon on the Mississippi River Delta.

### 4.2.3 Salinity

Runoff from precipitation on almost two-thirds of the land area of the United States eventually drains into the Gulf of Mexico via the Mississippi River. The combined discharge of the Mississippi and Atchafalaya Rivers is a major influence on salinity levels in coastal waters on the Louisiana/Texas continental shelf. The annual freshwater discharge of the Mississippi/Atchafalaya River system represents approximately 10% of the water volume of the entire Louisiana/Texas shelf to a depth of 90 m. The Loop Current and Mississippi/Atchafalaya River system, as well as the semi-permanent, anticyclonic gyre in the western Gulf, significantly affect oceanographic conditions throughout the Gulf of Mexico.

Surface salinities in the Gulf of Mexico vary seasonally. During months of low freshwater input, surface salinities near the coastline range between 29.0-32.0‰ (MMS 1997). High freshwater input conditions during the spring and summer months result in strong horizontal salinity gradients with salinities less than 20.0‰ on the inner shelf in the northern Gulf of Mexico. The waters in the open Gulf are characterized by salinities between 36.0-36.5‰ (MMS 1997).

### 4.2.4 Temperature

Surface water temperatures for the entire Gulf of Mexico were reported by NOAA (1985). Surface temperatures were measured in January and July. During January, temperatures ranged from 14°-24°C. Minerals Management Service (MMS 1997) found surface temperatures in the Gulf of Mexico in January to range from 25°C in the Loop current core to 14°-15°C along the shallow northern coastal estuaries. The coldest water along the Louisiana/Texas border occurs on the upper shelf (NOAA 1985) and the warmest was found off the southwestern tip of Florida. Winter water temperatures gradually increased with distance from shore in the entire Gulf. Temperatures also increased southward on the Florida peninsula with temperatures ranging from 16°-24°C.

Gulf surface water temperatures in July ranged from 28°-30°C (NOAA 1985) with the coolest water found off the south Texas coast. The warmest water was found off the Mississippi/Alabama coast, the Big Bend area of Florida, and the southern tip of Florida. Summer water temperatures gradually decreased with distance from shore. Most of the Gulf had surface temperatures of 29°C. These temperatures agree closely with MMS (1997) data showing 29°-30°C water throughout the Gulf during August.

### 4.2.5 Dissolved Oxygen (DO)

Dissolved oxygen (DO) values in the Gulf of Mexico average about 5 ppm at 10 m below the surface during winter, with values averaging about 4.6 ppm during the summer months 10 m below the surface (Garcia et al. 2010). The surface layer in the northern Gulf of Mexico shows an oxygen surplus during February through July (Justic et al. 1993). The oxygen maximum that occurs during April and May coincides with the maximum flow of the Mississippi River. From January to July the oxygen in bottom waters decreases at an average rate of 0.7 ppm per month, and reaches its lowest value in July (Justic et al. 1993).

Areas of anoxic bottom water have not been reported from the eastern Gulf continental shelf. However, summer hypoxia of bottom water has been noted for Mobile Bay and Tampa Bay. Areas of excessively low bottom DO values (less than 2.0 ppm) have long been known to occur off central Louisiana and Texas during periods of stratification in the warmer months. Oxygen-deficient conditions occur primarily from April through October each year with the location and extent varying annually (Rabalais et al. 1997). In 2002, the hypoxic zone was its largest ever at approximately 22,000 $km^2$, while the long-term average since mapping began in 1985 is 13,500 $km^2$ (Rabalais et al. 2007). Hypoxic waters can include 50 to 80% of the lower water column between 5-30 m water depth, and can extend as far as 130 km offshore to depths of 60 m (Rabalais and Turner 2001).

### 4.2.6 Submerged Vegetation

Seagrass meadows are often populated by diverse and abundant fish faunas (Zieman and Zieman 1989). Both seagrasses and macroalgae have been found to be important nursery habitats for numerous fish species (Rydene and Matheson 2003). The seagrasses and their attendant epiphytic and benthic fauna and flora provide shelter and food to the fishes in several ways and are used by many species as nursery grounds for juveniles.

According to Handley et al. (2007), six distinct species of seagrasses have been identified in the bays, lagoons, and shallow coastal waters of the northern Gulf region. These species include paddle grass (*Halophila decipiens*), star grass (*Halophila engelmannii*), turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), and widgeon grass (*Ruppia maritima*). Widgeon grass and water celery (*Vallisneria americana*) are freshwater species capable of tolerating saline waters. Turtle grass is the most abundant seagrass found in the Gulf of Mexico. Shoal grass predominates in Mississippi and Alabama while widgeon grass is the dominant species found in Louisiana. Light, salinity, temperature, substrate type, and currents are important local factors that affect distributional patterns.

The structural components of seagrass leaves, rhizomes, and roots act to modify water currents and waves. Seagrasses trap and store both sediments and nutrients and filter nutrient inputs. This structure baffles waves, reduces erosion, and promotes water clarity while increasing bottom area and providing a surface upon which epiphytes and epibenthic organisms can live. Invertebrate abundance is much higher in seagrass beds than in adjacent unvegetated habitats (Pérez-Castañeda et al. 2010).

### 4.2.7 Emergent Vegetation

Emergent vegetated wetlands provide essential habitat for many of the Gulf's managed fish species and their prey. Marshes and mangroves are integral parts of the estuarine system, serving as nursery areas for larval and juvenile invertebrates and fish, and as a source of detritus needed to supply organic matter to local estuarine and marine food webs.

In the Gulf of Mexico, salt marshes dominated by smooth cordgrass (*Spartina alterniflora*), needlerush (*Juncus roemarianus*), and marsh hay cordgrass (*Spartina patens*) are found in the temperate north. In southern areas, mangrove communities composed of red mangrove (*Rhizophora mangle*) or black mangrove (*Avicennia germinans*) are found. The vegetated wetlands found in estuaries are among the most productive ecosystems on earth (Teal and Teal 1969, Odum et al. 1982). Both marshes and mangroves require soft sediments, regular inundation from tides, freshwater, and low to moderate wave energy. Emergent wetlands may alter the sediment on which they grow and function as sediment builders through peat formation and their effect on local sedimentation patterns (Odum et al. 1982, Mitsch and Gosselink 1993). In addition, marshes and mangroves also act as filters by removing contaminants from water and recycling inorganic nutrients such as nitrogen and sulfur.

Salinity and tidal inundation control the zonation patterns of plant communities throughout Gulf estuaries. Salt marsh communities are dominated by salt tolerant smooth cordgrass in the intertidal zone, with marsh hay cordgrass or rushes in the upper intertidal zone. As elevation increases and tidal inundation decreases, cordgrass density declines and various other halophytic grasses and succulents replace cordgrass communities. The width and density of the cordgrass zone is greatest from Galveston Bay, Texas through the Big Bend region of Florida. This region of the Gulf has the largest amount of freshwater inflow.

The complex root system of red mangroves provides fish habitat by providing shelter and abundant detritus for local food webs on which fish and invertebrates depend (Zieman et al. 1984). Black mangrove roots do not have a well-developed invertebrate fauna. Black mangroves are the only mangrove species found in south Texas where the fauna consists of a few species of molluscs that are derived from other similar habitats such as salt marshes (Britton and Morton 1989) and fiddler crabs. During periods of high tide, this habitat also provides a refuge for fish and shrimp similar to that provided by salt marshes.

### 4.3 Estuaries

The northern Gulf of Mexico contains 31 major estuarine systems extending from the Rio Grande River in Texas eastward to Florida Bay in Florida. Estuaries typically include wetlands and open bay waters in which nutrients from river inflows, adjacent runoff, and the sea support a productive community of plants and animals. Estuarine tidal mixing is limited by the small tidal ranges that occur within the Gulf of Mexico, but shallow estuarine depths tend to amplify the mixing effect. Estuaries in Florida and south Texas generally are clearer and have lower nutrient concentrations than those in other parts of the Gulf.

#### 4.3.1 Florida

McNulty et al. (1972), in conducting the Florida portion of the Gulf of Mexico Estuarine Inventory (GMEI), provided a comprehensive description of the natural and manmade features of the estuaries on the Florida Gulf Coast. The report covers some 40 estuarine areas from Perdido Bay at the Florida/Alabama border south to Florida Bay.

The total area of Florida west coast estuaries is 12,154 km$^2$, including open water, tidal marsh, and mangroves (McNulty et al. 1972). Considerable changes occur in the type and area of submergent and emergent vegetation from south to north. Mangrove tidal flats are found from the Florida Keys to Naples. Sandy beaches and barrier islands occur from Naples to Anclote Key and from Apalachicola Bay to Perdido Bay (McNulty et al. 1972). Tidal marshes are found from Escambia Bay to Florida Bay and cover 2,139 $km^2$ with the largest area occurring in the Suwannee Sound and Waccasassa Bay. The coast from west of Apalachee Bay to the Alabama border is characterized by wide sand beaches situated either on barrier islands or on the mainland itself. Beds of mixed seagrasses and/or algae occur throughout the eastern Gulf with the largest areas of submerged vegetation found from Apalachee Bay south to the Florida Keys.

Black needlerush predominates, but several species are locally abundant, among them smooth cordgrass, marsh hay cordgrass, seashore saltgrass (*Distichlis spicata*), *Salicornia perennias*, seaoxeye (*Borrichia frutescens*), *Batis marina*, and *Limonium carolinianum* FWC/FWRI (unpublished data). GIS mapping by FWC/FWRI (unpublished data) showed 2,192 $km^2$ of mangroves along Florida's Gulf coast. The three common mangroves in their order of abundance and zonation landward are the red (*Rhizophora mangle*), black (*Avicennia germinans*), and button wood (*Conocarpus erectus*). A fourth and less abundant species, the white mangrove (*Laguncularia racemosa*), generally grows landward of the black mangrove.

Approximately 6,794 $km^2$ of seagrass or submerged aquatic vegetation (SAV) occurs in Florida (Handley et al. 2007). GIS mapping by FWC/FWRI (unpublished data) showed 7,807 $km^2$ of seagrass along Florida's Gulf coast. The Big Bend region has the largest total seagrass area of 2,072 $km^2$, followed by the Florida Keys and surrounding areas with 2,201.5 $km^2$. Seagrass in Florida Bay was measured at 1,477 $km^2$ while the region from Cape Sable to Anclote Key contains 433.4 $km^2$. The Panhandle region contains 174.8 $km^2$ of seagrass. Shoal grass and widgeon grass are abundant intertidally, whereas turtle grass, manatee grass, paddle grass, and star grass are found only below low water levels. In most of Florida's estuaries, seagrasses are found at depths to about 2.1 m, except where water is exceptionally clear (e.g., portions of Pensacola Bay) where they are found to about 3.6 m (McNulty et al. 1972).

McNulty et al. (1972) found nearly 56.7 $km^2$ of live oyster beds (20.7 $km^2$ in private leases and 35.3 $km^2$ in public beds) in the panhandle estuaries of Apalachicola Bay and St. George Sound. GIS mapping by FWC/FWRI (unpublished data) showed 30.7 $km^2$ of oysters in Rookery Bay, Estero Bay, Tampa Bay, Big Bend, and Apalachicola Bay.

Coastal waters in the eastern Gulf may be characterized as clear, nutrient-poor, and highly saline. Rivers which empty into the eastern Gulf carry little sediment load. Stream discharge in north Florida estuaries is much greater than that in central and south Florida. Mean stream discharge for the west coast is 1,988 $m^3/s$ (70,251 CFS) (McNulty et al. 1972). More than 70% of the runoff is from the Apalachicola, Suwannee, Choctawhatchee, and Escambia rivers. The Apalachicola River accounts for about 35%, and the Suwannee River accounts for nearly 15%.

Primary production is generally low except in the immediate vicinity of estuaries or on the outer shelf when the nutrient rich Loop Current penetrates into the area. Presumably, high primary production in frontal waters is due to the mixing of nutrient-rich, but turbid, plume water (where photosynthesis is light-limited) with clear, but nutrient-poor, Gulf of Mexico water (where photosynthesis is nutrient-limited) creating good phytoplankton growth conditions (GMFMC 1998).

### 4.3.2 Alabama

Crance (1971) divided the Alabama coastal zone into five estuarine systems: Mississippi Sound, Mobile Bay, Mobile Delta, Perdido Bay, and Little Lagoon. Combined, these estuaries contain an open-water surface area of 1,608 $km^2$. Mean tidal range is small, varying from about 0.3 m at the head of Mobile Bay to about 0.5 m at the entrance. Annual mean discharge of gauged streams in the Mobile River system is 1,659 $m^3/s$ (58,636 CFS). Salinity is highly variable with oceanic levels occurring at the Gulf passes at times, and freshwater at the upward end of the estuary is often present.

There were 10,614 ha of estuarine emergent wetlands, 17.6 $km^2$ of palustrine emergent wetlands, and a total of 123.7 $km^2$ of emergent wetlands in coastal Alabama in 2002 (Handley et al. 2013a). From 1955-2002, Alabama lost 147.6 $km^2$ (54.4 %) of the emergent wetlands in the coastal area (Handley et al 2013a).

In higher salinity areas, the major emergent species are black needlerush, smooth cordgrass, big cordgrass (*Spartina cynosuroides*), marsh hay cordgrass, and seashore saltgrass. Submerged vegetation includes patches of shoal grass, widgeon grass, and slender pondweed (*Potamogeton pusillus*) (Crance 1971).

In lower salinity areas, alligator weed (*Alternanthera philoxeroides*) and *Phragmites communis* are more abundant. The major species of submerged vegetation are southern naiad (*Najas guadalupenis*), wild celery, horned pondweed (*Zannichellia spiralis*), slender pondweed, and *Nitella* spp. (Crance 1971).

Vittor and Associates (2009) found shoal and widgeon grass were the dominant seagrass species in coastal Alabama in 2009 with ~2.0 $km^2$ of shoal grass, ~1.0 $km^2$ of widgeon grass, and ~1.0 $km^2$ of mixed shoal and widgeon grass. Overall, 8.5 $km^2$ of submerged aquatic vegetation were mapped in coastal Alabama with the majority being freshwater species in upper Mobile Bay (Vittor and Associates 2009). There are some 203.9 $km^2$ of live oyster beds, with more than 121.4 $km^2$ of public beds and nearly 80.9 $km^2$ in private leases. More than 8.5 $km^2$ of estuarine habitat were filled for various purposes.

### 4.3.3 Mississippi

Mississippi Sound is a relatively shallow estuary aligned in a generally eastwest direction along Mississippi and Alabama bounded on the east by Mobile Bay and the west by Lake Borgne. Barrier islands form a partial boundary separating the sound from the Gulf of Mexico. Numerous marsh isles in southeast Louisiana complete the southern boundary. Unless otherwise noted, the following information on Mississippi estuaries was condensed from Christmas (1973) and Eleuterius (1976a, 1976b).

Mississippi Sound is a system of estuaries adjoining a lagoon. The sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The complexity of the system does not readily lend itself to concise hydrological classification. Both northsouth and eastwest salinity gradients exist in addition to vertical gradients. Overall, positive salinity gradients exist from the mainland seaward and vertically, surface to bottom. In periods of peak river discharge, the water column may be homogeneous.

The salinity regime of eastern Mississippi Sound is determined largely by the influx of Gulf waters through Petit Bois, Horn, and Dog Keys passes and the outflow of waters from Mobile Bay, the Pascagoula River, and Biloxi Bay. Water from Mobile Bay appears to exit Mississippi Sound entirely through Petit Bois Pass; thus, the west branch of the Pascagoula River becomes the major source of freshwater into the Sound. The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River, the Lake Borgne-Lake Pontchartrain complex, and St. Louis Bay.

Silty clay is the dominant sediment in Mississippi Sound. Coastal bays receive large volumes of sandy and siltysandy sediments from the surrounding mainland. In addition, these embayments and the sound proper receive claysilt sediments from the rivers. Fine sediments are also carried into the sound via tidal currents from Lake Pontchartrain and Mobile Bay. The central portion of the sound is composed of silt and clay mud. In some areas, these sediments grade into fine and very fine sands. Medium and coarse sands characterize the barrier islands and are also found along the mainland beach west of the Pascagoula River. Medium to coarse sands extend from Round Island in Mississippi Sound to Horn Island.

The shallowness of the sound (average depth at mean low water is 2 m), its sediments, and wave action are responsible for the turbidity of the water. In most months, nearshore waters are brown in color due to suspended fine sediment in the water column. In periods of peak river flow, these muddy waters may reach and extend beyond the barrier islands.

There were 215.5 km$^2$ of estuarine emergent wetlands, 51.2 km$^2$ of palustrine emergent wetlands, and a total of 268.2 km$^2$ of emergent wetlands in coastal Mississippi in 2007 (Handley et al. 2013b). Between 1979 and 2007, Mississippi lost ~174 km$^2$ (54.5%) of its emergent wetland habitat (Handley et al. 2013c). Common species of emergent wetlands include black needlerush, smooth cordgrass, marsh hay cordgrass, and threecorner grass (*Scirpus olneyi*). Emergent wetlands are most extensive in the Pascagoula and Pearl River basins.

Moncreiff (2007) using 1999 aerial imagery estimated that 114.9 km$^2$ of seagrass were present in coastal Mississippi with the majority of the seagrass found around Cat Island.

### 4.3.4 Louisiana

Coastal Louisiana is predominately a broad marsh indented by shallow bays containing innumerable valuable nursery areas. Total estuarine area in 1970 encompassed more than 29,000 km$^2$, over 15,000 km$^2$ in marsh vegetation, and more than 13,000 km$^2$ of surface water area (Perret et al. 1971). These waters are generally shallow with over half between zero and 1.8 m in depth. Sediments consist of mud, sand, and silt and are very similar across the coast ranging from coarse near the Gulf and barrier islands to fine in the upper estuaries (Barrett et al. 1971). Extensive wetlands loss is occurring in coastal Louisiana. The current loss of wetlands in the Louisiana Coastal Zone is estimated to be 43 $km^2$/yr (Couvillion et al. 2011).

Emergent marsh amounts to more than 15,800 $km^2$ and is made up of four main types; saline, brackish, intermediate, and fresh (USGS 1997). Approximately 3,492.3 $km^2$ of saline marsh consisting of smooth cordgrass, glasswort (*Salicornia* sp.), black needlerush, black mangrove, seashore saltgrass, and saltwort (*Batis marina*) are located in the Louisiana Coastal zone; 4,871.7 $km^2$ of brackish marsh made up of marsh hay cordgrass, threecorner grass, and coco (*Scirpus robustus*); 2,632.9 $km^2$ of intermediate marsh consisting of marsh hay cordgrass, deer pea (*Vigna repens*), bulltongue (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), and sawgrass (*Cladium jamaicense*); and 4,829.4 $km^2$ of fresh marsh consisting of maiden cane (*Panicum hemitomon*), pennywort (*Hydrocotyle* sp.), pickerelweed (*Pontederia cordata*), alligator weed, bulltongue (*Sagittaria* sp.), and water hyacinth (*Eichhornia crassipes*).

In general, estuaries and nearshore Gulf waters of Louisiana are low saline, nutrient-rich, and turbid due to the high rainfall and subsequent discharges of the Mississippi, Atchafalaya, and other coastal rivers. The Mississippi and Atchafalaya Rivers deliver approximately 172M metric tons of sediment annually to coastal Louisiana (Meade and Moody 2010). Average daily discharge for the Mississippi and Atchafalaya Rivers is 464,400 CFS and 223,800 CFS, respectively (USEPA 1994). Peak discharge usually occurs in April and May; low flow occurs typically in September and October. During floods, freshwater is carried far into the Gulf resulting in lower salinities near the mouths of the rivers and into neighboring estuaries. As a probable consequence of the large fluvial nutrient input, the Louisiana nearshore shelf is considered one of the most productive areas in the Gulf of Mexico.

The public oyster seed grounds and reservations encompass approximately 6,803.6 $km^2$ and private oyster leases cover approximately 1,558.1 $km^2$ of water bottoms in Louisiana (Banks personal communication). Mapped oyster reefs account for approximately 3.7% of total water bottom coverage (254.5 $km^2$) within the public oyster areas and additional hectares of reefs exist, but these areas have not been delineated. The largest portion of known oyster reef within these public oyster areas is located east of the Mississippi River in St. Bernard and Plaquemines Parishes where 209.4 $km^2$ are located (82.3%). It is unknown what portion of the total hectares of private leases is covered in oyster reef, although it is likely significant considering the majority of Louisiana's oyster landings come from private leases (Banks personal communication). Additional habitat is also located in extensive reef complexes near Marsh Island (Iberia Parish) and in both Calcasieu and Sabine Lakes (Cameron Parish). Total area of live oyster reef is currently unknown, although Perret et al. (1971) estimated more than 538.3 $km^2$.

More than 1,610 km of navigation channels designed and/or maintained by the U.S. Army Corps of Engineers are in the estuarine zone. The longest is the Gulf Intracoastal Waterway (486 km) from Lake Borgne to the Sabine River. Navigation channels account for nearly all of the more than 105.2 $km^2$ of fill.

Cho and Poirrier (2005) reported SAV in Lake Pontchartrain had declined by more than 50% since the mid1950s. No grass beds were found along the south shore of the lake between 1996 and 1998 (Penland et al. 2002). By the early 1990s, most of the extensive beds of wild celery had disappeared, but there was an increase in widgeon grass during 1996-2000 (Cho and Poirrer 2005). Cho and Poirrier (2001) estimated SAV coverage in Lake Pontchartrain in 2000 was 1.5 $km^2$ of widgeon grass plus 0.12 $km^2$ of water celery. Cho and Poirrier (2002) stated that total SAV habitat was about 4.5 $km^2$. Poirrier and Handley (2007) reported that approximately 450.0 $km^2$ of seagrass were present around the Chandeleur Islands in 1995 with turtle grass being the predominant species. Representatives from the LDWF reported beds of widgeon grass around the Mississippi River delta and in the Pointe aux Chenes Wildlife Management Area.

Ship Shoal and Trinity Shoal have been identified as important blue crab spawning areas in offshore areas of Louisiana (Gelphi et al. 2009). Gelphi et al. (2009) found actively spawning, hatching, and foraging blue crabs present from at least April-October on Ship and Trinity Shoals with highest abundances occurring in August. According to Gelphi et al. (2009), Ship and Trinity Shoals support an important component of the Gulf of Mexico blue crab spawning stock since the shoals have a combined area of approximately 1,000 $km^2$.

### 4.3.5 Texas

Unless otherwise noted, the following information on Texas estuaries was compiled from Diener (1975). The estuaries in Texas are characterized by extremely variable salinities and reduced tidal action. Estuarine salinities trend low to high from north to south. Texas has approximately 612 km of open Gulf shoreline and contains 3,528 km of bay-estuary-lagoon shoreline. Coastal habitats in Texas contain more than 2,476.7 $km^2$ of fresh, brackish, and salt marshes. Saline and brackish marshes are most widely distributed south of Galveston Bay, while intermediate marshes are the most extensive marsh type east of Galveston Bay. The lower coast has only a narrow band of emergent marsh but has an extensive system of bays and lagoons.

From the Louisiana border to Galveston, the coastline is comprised of marshy plains and low, narrow beach ridges. From Galveston Bay to the Mexican border, the coastline consists of long barrier islands and large shallow lagoons. The Laguna Madre contains profuse seagrass beds while Padre Island is the longest barrier island in the world (TGLO 1996). The Intracoastal Waterway, a maintenance-dredged channel, extends from the Lower Laguna Madre to Sabine Lake. Dredging of the channel has created numerous spoil banks on islands adjacent to the channel.

Eight major estuarine systems are located in Texas. The major bay systems from the lower to upper coast are Lower and Upper Laguna Madre; Corpus Christi and Aransas bays; San Antonio, Matagorda and Galveston bays; and Sabine Lake. Riverine influence is highest in Sabine Lake and Galveston Bay. In 1992, these estuaries contained 6,275.6 $km^2$ of open water (estuarine subtidal areas), and 15,768 $km^2$ of wetlands. About 85.3% of the total wetlands were palustrine, 14.5% estuarine, and 0.1% marine. There were 7,115.8 $km^2$ of deepwater rivers (243.6 $km^2$); reservoirs (596.6 $km^2$); and estuarine bays (6,275.6 $km^2$) (Moulton et al. 1997). Climate ranged from semi-arid on the lower coast (where rainfall averages 25 inches) to humid on the upper coast where average annual rainfall is 55 inches (Diener 1975).

Texas estuaries support a number of species of emergent vegetation consisting of shoregrass (*Monanthochloe littoralis*), glasswort (*Salicornia bigelovii*), seacoast bluestem (*Schizachyrium scoparium*), marsh hay cordgrass, rush saltwort (*Batis maritima* and *B. maritima*), glasswort (*Salicornia bigelovii*), smooth cordgrass, coastal dropseed (*Sporobolus virginicus*), seashore saltgrass, seablite (*Suaeda linearis*), sea oats (*Uniola paniculata*), black needlerush, bulrush (*Scirpus maritimus* and *S. olneyi*), and gulfdune paspalum (*Paspalum monostachyum*) (Diener 1975). Common reed (*Phragmites communis*) was reported in a few areas as well.

Submergent aquatic vegetation includes a number of species with the dominants consisting of turtle grass and manatee grass. In addition, shoal grass, paddle grass, star grass, and widgeon grass also occur (Diener 1975, Pulich et al. 1997, Pulich 1998). Submerged seagrass coverage was approximately 690 $km^2$ in 1998 (Pulich and Onuf 2007) with the overwhelming majority being located in the Upper and Lower Laguna Madre.

### 4.4 EFH vs. Essential Habitat

The GSMFC has endorsed the definition of essential fish habitat (EFH) as found in the Final Rule to implement the Essential Fish Habitat provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) of 1996. The Magnuson-Stevens Act defines EFH as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat, the Final Rule defines ‘waters’ to include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; ‘substrate’ includes sediment, hard bottom, structures underlying the waters, and associated biological communities; ‘necessary’ means the habitat required to support a sustainable fishery and the managed species’ contribution to a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species’ full life cycle.

For this FMP, we will utilize this definition but refer to such areas as ‘essential habitats’ to avoid confusion with the EFH mandates in the Magnuson-Stevens Act. These mandates include the identification and designation of EFH for all federally-managed species, development of conservation and enhancement measures including those which address fishing gear impacts, and require federal agency consultation regarding proposed adverse impacts to those habitats.

#### 4.4.1 Essential Habitats of Particular Concern

##### 4.4.1.1 Florida

The demand for waterfront property throughout the coastal regions of Florida has resulted in substantial losses of productive bay bottoms due to dredge and fill activities (Lewis et al. 1985). Wetlands bordering Tampa Bay have declined 44% since the 1950s (Lewis and Lewis 1978). Seagrass beds, mangrove swamps, and tidal marshes in Sarasota Bay and Charlotte Harbor have experienced similar declines. Alteration of freshwater inflow and heavy nutrient and pesticide loads from agricultural activities in southern Florida have severely impacted essential habitats in Florida Bay and the Everglades.

#### 4.4.1.2 Alabama

The Alabama estuarine system is comprised of numerous bays, tidal marshes, and open water, all of which are necessary for maintaining the habitat necessary for commercially and recreationally important marine species. Surveys conducted from 1955-2002 have shown that emergent wetland habitats have declined approximately 147.6 $km^2$ (54.4%), saltmarshes have declined approximately 51.9 $km^2$ (32.8%), and coastal fresh marshes have declined approximately 95.7 $km^2$ (84.5%) (Duke and Kruczynski 1992, Handley et al. 2013a). This loss of wetlands is due to multiple factors including commercial and residential development, erosion, and subsidence (Duke and Kruczynski 1992).

#### 4.4.1.3 Mississippi

Between 1979 and 2007, Mississippi lost ~174 $km^2$ (54.5%) of its emergent wetland habitat (Handley et al. 2013c). Increased bulkheading, channelization, and changes in upland drainage patterns and buffering/filtering capacities due to commercial and residential development all affect marsh quality and function. Primary mechanisms for this include decreased overland flow, decreased bio-filtration, increased sediment loads, and greater exposure of marshes and their associated fauna and microflora to pesticides and fertilizers.

Seagrass coverage in Mississippi Sound has declined 40-50% since 1969 (Moncreiff et al. 1998). Additional problems impacting the estuarine habitat include declining water quality and accelerated dredge and fill activities for shoreline development. Disposal of dredge soil has affected water circulation patterns in the eastern sound. Unvegetated soft-sediment shoreline areas have been identified as an important component of the nursery habitat for small juvenile crabs (Rakocinski et al. 2003) and continued development of these areas may impact juvenile population abundances.

#### 4.4.1.4 Louisiana

The extensive salt marshes in Louisiana are responsible for the high production of estuarinedependent finfish and shellfish in the northcentral Gulf of Mexico. Marsh loss in Louisiana due to erosion, subsidence, sediment and freshwater deficits, channelization, and sea-level rise is a particular concern as that state contains approximately 69% of the Gulf=s salt marsh (GMFMC 1998). Approximately 51% of the state's emergent marsh and 59% of forested wetlands were lost between 1956 and 1978. An estimated 34% of marsh was converted to open water from 1940-1980 with the subsequent loss of about 102 $km^2$ during that period (Duke and Kruczynski 1992). Statewide coastal wetland losses increased from 36 $km^2$/year in the 1940s and 1950s to over 100 $km^2$/year in the 1970s and fell to approximately 65 $km^2$/year in the 1980s and 1990s (Britsch and Dunbar 1993). The current loss of wetlands in the Louisiana Coastal Zone is estimated to be 43 $km^2$/ year (Couvillion et al. 2011). Regional differences in wetland loss patterns have occurred;

the annual land loss rates by region were 65.7 $km^2$/year in the coastal plain, 51.8 $km^2$/year in the Mississippi River deltaic plain, and 13.9 $km^2$/year in the Chenier plain.

#### 4.4.1.5 Texas

Overall, Texas estuarine wetlands decreased approximately 240 $km^2$ between the mid-1950s and early 1990s due to reservoir development, channelization, spoil disposal, human-induced subsidence, and global sea-level rise (Duke and Kruczynski 1992). Maintenance dredging of navigation channels creates 37M $m^3$ of spoil annually, and reservoir construction has changed the timing of freshwater inflow to critical estuarine habitat. Agricultural, municipal, and industrial runoff is increasing due to population and industrial growth along the Texas coast.

Coastal wetland loss in Texas and in the Galveston Bay system is significant and is a continuing concern because of the essential roles that wetlands perform. Wetland loss in coastal Texas has been rated by the USEPA (1999) as severe. Wetland loss in the Galveston Bay system is greater than in many other areas of the state. The Galveston Bay system lost a net of nearly 141.6 $km^2$ (20%) of its wetlands, and 7.2 $km^2$ (70%) of its seagrasses between the 1950s and 1985 (White et al. 1993). Substantial wetland and associated habitat loss in the Galveston Bay system may have contributed to chronic declines in blue crabs and white shrimp (*Litopenaeus setiferus*), as well as estuarine-dependent bird species, such as tricolored herons (*Egretta tricolor*), snowy egrets (*Egretta thula*), black skimmers (*Rynchops niger*), roseate spoonbills (*Ajaia ajaja*), and great egrets (*Casmerodius albus*) (Shipley and Kiesling, 1994). Recent research indicates and aerial photography demonstrates that wetland loss is continuing at rapid rates.

Many causes have contributed to wetland and seagrass loss in the Galveston Bay system including dredging, stream channelization and filling, subsidence, sediment diversion, saltwater intrusion, erosion, hydrologic alteration (White et al. 1993) and sea level rise. Dredged channels physically displaced many acres of seagrass during the 20-year period between 1956 and 1976. Activities associated with development contributing to seagrass loss include increased boat traffic, channel maintenance, discharges of toxic materials, wastewater discharge, and runoff containing high nutrient levels, herbicides, and pesticides.

Erosion poses a significant threat to the marshes and adjacent habitats within Galveston Bay. In West Galveston Bay, average rates of erosion along shorelines have increased from 0.8 ft/year during the historical period of 1852-1930 to 2.1 ft/year during the recent period of 1930-1982 (Pulich and White 1991). White et al. (2004) mapped the rates of shoreline change and habitat loss within West Galveston Bay. From the mid-1950s to 2002 the amount of estuarine marsh in West Galveston Bay has decreased by 32%. Estuarine tidal flats declined by 61% and palustrine marshes decreased by 50% from the mid-1950s to 2002. Shoreline ridges, vegetated land spits, and other features that once protected intertidal marshes from erosional forces, are disappearing at a more rapid rate than protected inlets. In addition, subsidence of approximately one to two feet between 1906 and 1987 (White et al. 1993) has rendered the marsh systems more vulnerable to erosion during winter, as well as during tropical storms. In addition to subsidence, sea level rise has also contributed to the drowning and fragmentation of the marsh.

## 4.5 Habitat Threats

### 4.5.1 Coastal Development

Increasing human population and coastal development are major threats to estuarine and marine aquatic habitats since urban growth and development in coastal areas of the U.S. are approximately four times greater than that in other areas of the country (Hanson et al. 2003). While the amount of coastal wetlands lost to development has decreased in the last several decades, the rate of loss of coastal wetlands has remained roughly the same. The loss rate was estimated to be 0.2%/year from 1922-1954, while loss rates from 1982-1987 were approximately 0.18%/year (Valiela et al. 2004).

Increasing human populations and development within coastal regions generally leads to an increase in impervious surfaces, including but not limited to roads, residential and commercial development, and parking lots. Impervious surfaces cause greater volumes of runoff and associated contaminants in aquatic and marine waters. The increase of impervious surfaces from construction of urban, suburban, commercial, and industrial centers results in land use conversions that remove vegetation and negatively impact habitat. According to USEPA (1995), impervious surface runoff and storm sewers are the most widespread source of pollution into the nation's waterways. When impervious surfaces exceeded 20-30% of total land cover, Holland et al. (2004) found reduced abundances of stress-sensitive macroinvertebrates and altered food webs in headwater tidal wetlands. Holland et al. (2004) also found measurable adverse changes in the physical and chemical environment when impervious cover exceeded 10-20% land cover.

Non-point and point source pollution discharges may cause organisms to be more susceptible to disease or impair reproductive success (USEPA 2005). While the effects of non-point source pollution can be lower in severity than the effects of point source pollution, non-point source pollution may be more damaging to fish and their habitats. Non-point source pollution may affect sensitive life stages and processes, is often difficult to detect, and its impacts may go unnoticed for years. When population impacts are detected, a single source or event is usually hard to determine and population impacts may be difficult to correct, clean up, or mitigate.

Urban runoff is generally difficult to control because of the intermittent nature of rainfall and the associated runoff, the large variety of pollutant source types, and the variable nature of source loadings. The National Water Quality Inventory (USEPA 2009) reported that runoff from urban areas was the leading source of impairment in surveyed estuaries. Urban areas can have a chronic and insidious pollution potential that onetime events do not. The effects of pollution on coastal fishery resources may not necessarily represent a serious, widespread threat to all species and life history stages, but are dependent upon the type and concentration of the chemical compound and the length of exposure for a particular species and its life history stage. For example, species that spawn in areas that are relatively deep with strong bottom currents and well-mixed water may not be as susceptible to pollution as species that inhabit shallow, inshore areas or enclosed bays and estuaries. Similarly, species whose egg, larval, and juvenile stages utilize shallow, inshore waters and rivers may be more prone to coastal pollution than are species whose early life history stages develop in offshore, pelagic waters.

Urban runoff from coastal development can result in an unnatural influx of suspended particles from soil erosion having negative effects on riverine, nearshore, and estuarine ecosystems. Impacts from this include high turbidity levels, reduced light transmittance, and sedimentation which may lead to the loss of submerged aquatic vegetation and other benthic structure (USEPA 2005, Orth et al. 2006). Developed watersheds tend to have reduced stormwater storage capacity. Other impacts include disruption in the respiration of fishes and other aquatic organisms, reduction in filtering efficiencies and respiration of invertebrates, reduction of egg buoyancy, disruption of ichthyoplankton development, reduction of growth and survival of filter feeders, and decreased foraging efficiency of sight-feeders (Messieh et al. 1991, Wilber and Clarke 2001, USEPA 2005).

Severely eutrophic conditions may adversely affect aquatic systems in a number of ways, including reductions in submerged aquatic vegetation through reduced light transmittance, epiphytic growth, and increased disease susceptibility (Goldsborough 1997); mass mortality of fish and invertebrates through poor water quality; and alterations in long-term natural community dynamics. The environmental effects of excess nutrients and elevated suspended sediments are the most common and significant causes of submerged aquatic vegetation decline worldwide (Orth et al. 2006). There is evidence that nutrient over-enrichment has led to increased incidence, extent, and persistence of harmful algal blooms; increased frequency, severity, spatial extent, and persistence of hypoxia; alterations in the dominant phytoplankton species and size compositions; and greatly increased turbidity of surface waters from planktonic algae (O'Reilly 1994).

Petroleum products consist of thousands of chemical compounds that can be toxic to marine life. Polycyclic aromatic hydrocarbons (PAH) are particularly damaging to marine biota because of their extreme toxicity, rapid uptake, and persistence in the environment (Kennish 1998). Fulton et al. (2003) reported finding significantly higher PAHs in developed watersheds when compared to non-developed watersheds. By far, the largest amount of petroleum released through human activity comes from the use of petroleum products (e.g., cars, boats, paved urban areas, and two-stroke engines) (ASMFC 2004). While most of the activities that use petroleum are based on land, rivers and streams carry the petroleum into nearby estuaries and bays. While individual petroleum product releases are small, they are so ubiquitous that when combined, they contribute nearly 85% of the total petroleum pollution from human activities (ASMFC 2004).

Petroleum products are a major stressor on inshore fish habitats because they can potentially interfere with the reproduction, development, growth, and behavior (e.g., spawning, feeding) of fish, especially early life history stages (Gould et al. 1994). Polycyclic aromatic hydrocarbons can degrade aquatic habitat, consequently interfering with biotic communities and may be discharged into rivers from non-point sources, including municipal runoff and contaminated sediments. Also, oil has been shown to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Although oil is toxic to all marine organisms at high concentrations, certain species are more sensitive than others and generally eggs and larvae of organisms are most sensitive (Gould et al. 1994, Rice et al. 2000).

Although agricultural runoff is a major source of pesticide pollution in aquatic systems, residential areas are also a notable source. Other sources of pesticide discharge into coastal waters include atmospheric deposition and contaminated groundwater (Meyers and Hendricks 1982).

Pesticides may bioaccumulate in the ecosystem by accumulating in sediments and detritus that is then ingested by macroinvertebrates, which in turn are eaten by larger invertebrates and fish.

Hanson et al. (2003) found three basic ways that pesticides can adversely affect fish health and productivity through direct toxicological impact on the health or performance of exposed fish, indirect impairment of the productivity of aquatic ecosystems, and loss or degradation of habitat that provides physical shelter for fish and invertebrates. The majority of effects from pesticide exposures are sublethal. Sublethal effects can impair the physiological or behavioral performance of individual animals in ways that decrease their growth or survival, alter migratory behavior, or reduce reproductive success (Hanson et al. 2003). Early development and growth of organisms involve important physiological processes and include the endocrine, immune, nervous, and reproductive systems. Many pesticides have been shown to impair one or more of these physiological processes in fish (Moore and Waring 2001, Gould et al. 1994). Evidence has shown that DDT (dichloro-diphenyl-trichloroethane) and its chief metabolic by-product, DDE (dichloro-diphenyl-dichloroethylene), can mimic estrogen or inhibit androgen effectiveness. Gould et al. (1994) showed that DDT can cause deformities in winter flounder eggs and Atlantic cod embryos and larvae. Generally, however, the sublethal impacts of pesticides on fish health are poorly understood.

The direct and indirect effects of pesticides on fish and other aquatic organisms can be a key factor in determining the impacts on the structure and function of ecosystems (Preston 2002). This factor includes impacts on primary producers (Hoagland et al. 1996) and aquatic microorganisms (DeLorenzo et al. 2001), as well as macroinvertebrates that are prey species for fish. It is not surprising that pesticides are relatively toxic to insects and crustaceans that inhabit estuaries since they are designed to kill insects. Lee and Oshima (1998) found that pesticides including chlorophyrifos, cypermethrin, fenvalerate, and diflubenzuron all inhibited hatching of blue crab embryos. Horst and Walker (1999) found that methoprene used for mosquito control interrupted chitin production in adult postmolt blue crabs, increased mortality of hatching zoeae, and was toxic to megalopae by delaying molting time.

Herbicides may alter long-term natural community structure by hindering aquatic plant growth or destroying aquatic plants. Hindering plant growth can have notable effects on fish and invertebrate populations by limiting nursery and forage habitat. Chemicals used in herbicides may also be endocrine disrupters, exogenous chemicals that interfere with the normal function of hormones. Coastal development and water diversion projects contribute substantial levels of herbicides into estuaries. A variety of human activities such as noxious weed control in residential development and agricultural lands, right-of-way maintenance, algae control in lakes and irrigation canals, and aquatic habitat restoration results in contamination from these substances.

### 4.5.2 Energy Related Activities

Oil and gas activities can directly and indirectly impact coastal and estuarine habitats through vessel traffic, maintenance dredging of navigational canals, construction and operation of onshore facilities, installation and maintenance of pipelines, expansion of ports and docks, and operation of offshore oil and gas facilities. The potential for impacts is largely influenced by site-specific factors, such as the habitat types and distribution in the vicinity of oil and gas activities. Many of the activities associated with oil and gas development, such as platform construction, would occur in offshore waters.

A variety of contaminants can be discharged into the marine environment as a result of petroleum extraction operations. Waste discharges associated with a petroleum facility include drilling well fluids, produced waters, surface runoff and deck drainage, and drilling mud and cuttings (NMFS 2011). In addition to crude oil spills, chemical, diesel, and other contaminant spills can occur with petroleum-related activities (NMFS 2011). In even moderate quantities, oil discharged into the environment can affect habitats and living marine resources. Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the outer continental shelf and in nearshore coastal areas and can occur from a number of sources, including equipment malfunction, ship collisions, pipeline breaks, other human error, or severe storms (Hanson et al. 2003).

Accidental spills and daily operational discharges are the major sources of oil releases as a result of oil and gas activities. The NRC estimates the largest anthropogenic source of petroleum hydrocarbon releases into the marine environment is from petroleum extraction-related activities. Approximately 2,700 tons per year in North America are introduced to the marine environment as a result of produced waters (NRC 2003). Produced waters are waters that are pumped to the surface from oil reservoirs which cannot be separated from the oil. Produced waters contain finely dispersed oil droplets that can stay suspended in the water column or can settle out into sediments. Produced waters are generally more saline than seawater and contain elevated concentrations of radionuclides, metals, and other contaminants. Produced waters are either injected back into reservoirs or discharged into the marine environment (NRC 2003). Over 90% of the oil released from extraction activities is from produced water discharges which contain dissolved compounds (i.e., PAHs) and dispersed crude oil (NRC 2003). These compounds stay suspended in the water column and undergo microbial degradation or attach to suspended sediments and are deposited on the seabed. Elevated levels of PAH in sediments are typically found up to 300 m from the discharge point (NRC 2003).

Oil spills may cover and degrade coastal habitats and associated benthic communities or may produce a slick on the surface waters which disrupts the pelagic community. The water column may be polluted with oil as a result of wave action and currents dispersing the oil. Benthic habitat and the shoreline can be covered and saturated with oil, leading to the protracted damage of aquatic communities, including the disruption of population dynamics. Oil can persist in sediments for decades after the initial contamination, causing disruption of physiological and metabolic processes of demersal fishes (Vandermeulen and Mossman 1996). These changes may lead to disruption of community organization and dynamics in affected regions and permanently diminish fishery habitat.

The discharge of oil drilling mud can change the chemical and physical characteristics of benthic sediments at the disposal site by introducing toxic chemical constituents. The addition of contaminants can reduce or eliminate the suitability of the water column and substrate as habitat for fish species and their prey. The discharge of oil-based drill cuttings are currently not permitted in

U.S. waters. However, where oil-based drill cuttings have been discharged, there is evidence that sediment contamination and benthic impacts can occur up to 2 km from the production platform (NRC 2003).

Direct loss of marsh habitat can result from pipeline construction through coastal wetlands and impacts depend upon avoidance of wetlands in pipeline route selection and the technique used for laying the pipeline. The use of directional boring under wetlands during pipeline construction can avoid major impacts on wetlands. Trenching results in direct impacts on marsh habitat due to excavating the pipeline right of way. Long-term reduction in vegetation productivity above and adjacent to the pipeline, including backfilled areas, can lead to potential losses of wetland habitat and wetland loss depends on the success of backfilling, time of year, and duration of construction (Turner et al. 1994).

Refining converts crude oil into gasoline, home heating oil, and other refined products. The refining process produces effluents, which can degrade coastal water quality. Oil refinery effluents contain many different chemicals at different concentrations including ammonia, sulphides, phenol, and hydrocarbons. Toxicity tests have shown that most refinery effluents are toxic, but to varying extents. Some species are more sensitive and the toxicity may vary throughout the life cycle. Experiments have shown that not only can the effluents be lethal, but they can often have sublethal effects on growth and reproduction (Wake 2005). Field studies have shown that oil refinery effluents often have an adverse impact on aquatic organisms that is more pronounced in the area closest to the outfall (Wake 2005).

Impacts on coastal marsh vegetation from oil spills could range from a short-term reduction in photosynthesis to extensive mortality and subsequent loss of marsh habitat as a result of substrate erosion and conversion to open water (Hoff 1995, Proffitt 1998). Long-term impacts could include reduced stem density, biomass, and growth (Proffitt 1998). Direct exposure to petroleum can lead to die-off of submerged aquatic vegetation (SAV) in the first year of exposure. Certain species which propagate by lateral root growth rather than seed germination may be less susceptible to oil in the sediment (NRC 2003). Oil has been demonstrated to disrupt the growth of vegetation in estuarine habitats (Lin and Mendelssohn 1996). Mangroves might decrease canopy cover or die over a period of weeks to months (Hoff et al. 2002, Hayes et al. 1992). Other effects of spills could include a change in plant community composition or the displacement of sensitive species by more tolerant species. In locations where soil microbial communities were affected, effects might be long-term, and wetland recovery might be slowed. The degree of impacts on wetlands from spills are related to the oil type and degree of weathering, amount of oil, duration of exposure, season, plant species, percentage of plant surface oiled, substrate type, and oil penetration (Hayes et al. 1992, Hoff 1995, Proffitt 1998, Hoff et al. 2002). Higher mortality and poorer recovery of vegetation generally result from spills of lighter petroleum products (such as diesel fuel), heavy deposits of oil, spills during the active growing period of a plant species, contact with sensitive plant species (especially those located in coastal fresh marsh), completely oiled plants, and deep penetration of oil and accumulation in substrates. Because of the changes in the northern Gulf's barrier island profiles as a result of hurricanes Katrina, Rita, and Ivan, there is a greater potential for oil spill impacts on coastal marshes (MMS 2008).

Many factors determine the degree of damage from a spill, including the composition of the petroleum compound, the size and duration of the spill, the geographic location of the spill, and the weathering process present (NRC 2003). Although oil is toxic to all marine organisms at high concentrations, certain species and life history stages of organisms appear to be more sensitive than others. In general, the early life stages (i.e., eggs and larvae) are most sensitive, juveniles are less sensitive, and adults least so (Rice et al. 2000). Some marine species may be particularly susceptible to hydrocarbon spills if they require specific habitat types in localized areas and utilize enclosed water bodies, like estuaries or bays (Stewart and Arnold 1994).

Disruption of the areas from dredging and sedimentation may cause spawning fish to leave the area for more suitable spawning conditions. Dredging, as well as the equipment used in the process such as pipelines, may damage or destroy other sensitive habitats such as emergent marshes and SAV (Mills and Fonseca 2003) and macroalgae beds. The stabilization and hardening of shorelines for the development of upland facilities can lead to a direct loss of SAV, intertidal mudflats, and salt marshes that serve as important habitat for a variety of living marine resources.

Offshore wind energy facilities have been proposed for the Gulf of Mexico, and these facilities convert wind energy into electricity through the use of turbines that harness the kinetic energy of the moving air. An offshore facility generally consists of a series of wind turbine generators, an array of submarine electric cables that connect each of the turbines, and a single electric service platform (ESP). An ESP is a central offshore platform that provides a common electrical interconnection for all of the wind turbine generators in the array and serves as a substation where the outputs of multiple collection cables are combined, brought into phase, and stepped up further in voltage for transmission to a land-based substation that is connected to the onshore grid (MMS 2007a). Electricity is transmitted from the ESP to an onshore facility through one or a series of submarine cables.

The construction of offshore wind turbines and support structures can result in benthic habitat conversion and loss because of the physical occupation of the natural substrate. Scour protection around the structures, consisting of rock or concrete mattresses, can also lead to a conversion and modification of habitat. The burial and installation of submarine cable arrays can impact the benthic habitat through temporary disturbance from plowing and from barge anchor damage. In some cases, plowing or trenching for cable installation can permanently convert benthic habitats when top layers of sediments are replaced with new material. The installation of cables and associated barge anchor damage can adversely affect SAV, if those resources are present in the project area. Cable maintenance, repairs, and decommissioning can also result in impacts to benthic resources and substrate.

### 4.5.3 Alteration of Freshwater Inflow

Suitable freshwater inflow is necessary to dilute sea water and create salinity gradients for optimum fishery production, transport nutrients to the coast and then distribute them into estuaries, where they fuel production of fish, crustaceans, and other organisms, and distribute sediment into the estuary to keep tidal wetlands from subsiding, and ultimately disappearing. Changes to freshwater inflow affect estuarine habitats and organisms. The effects include mortality, changes in growth and development, and changes in species distributions. Sediment loads, pH, temperature, salinity, turbidity, tidal exchange, and nutrients are affected by any alteration of freshwater inflow.

Freshwater inflow is a critical component in determining suitability of blue crab habitat. In the Gulf of Mexico, climate and hydrology operate to structure available habitat in ways that influence survival of juvenile blue crabs. High river flows in Gulf estuaries have been linked to increased commercial landings of blue crabs in Texas (More 1969), Louisiana (Guillory 2000) and Florida (Wilber 1992 and 1994) and to abundance of juvenile crabs in Louisiana, Mississippi, and Alabama (Guillory 2000, Sanchez-Rubio et al. 2011, Riedel et al. 2010, respectively).

The dredging, damming, and channelization of rivers in the U.S. has greatly altered the sedimentation patterns and the timing and volume of freshwater inflows into bays and estuaries. The result of dam construction, channelization, and deforestation is a decline in base flows to estuaries during critical dry seasons and an increase in extreme freshwater pulses during wet seasons (Browder 1991). In arid areas like southwest Texas, dams are of particular concern due to their relation to significant declines in dry season flows and to ecologically stressed hypersaline coastal lagoons (Browder and Moore 1981). For coastal systems in Texas and Florida, small changes in inflow volumes during the dry season can significantly alter salinity gradients (McPherson and Hammett 1991). However, declines in wet season flows can also impact estuarine biota. The shrimp fishery in Sabine Lake was negatively impacted by the Toledo Bend Dam because heavy summer demand for electricity decreased the formerly high winter water discharges and increased summer discharges. This changed the salinity regime in Sabine Lake by creating a low salinity nursery ground for brown shrimp (*Farfantepenaeus aztecus*) in the spring and a high salinity nursery ground for white shrimp in the summer (White and Perret 1974).

Levee and canal construction can significantly impact coastal wetlands by causing ponding, impoundments, low sedimentation rates, high subsidence, and increased saltwater intrusion. In Louisiana's highly organic soils, these conditions tend to stress plants and cause mortality due to high levels of hydrogen sulfide (Mendelssohn and McKee 1988, Burdick et al. 1989) and salinity (Pezeshki et al. 1987). The loss of plants causes increased erosion and land loss (Scaife et al. 1983). In Florida's oligotrophic marl soils, the network of canals and levees has a different effect. By delivering relatively high nutrient loads and increasing the flooding duration in some areas and decreasing flooding duration in others, these alterations have stimulated primary productivity and the invasion of opportunistic native plants, such as cattail (*Typha domingensis*), and invasive exotic species such as Melaleuca (*Melaleuca quinquenervia*) and Brazilian pepper (*Schinus terebinthifolius*) (Jensen et al. 1995, Wu et al. 1995).

River diversions, channelization, and rainfall runoff within the watershed can affect nutrient distribution to estuaries. Watershed runoff can lead to estuarine eutrophication, while river diversions and channelization can lead to eutrophication or nutrient deprivation. The input of nutrients from freshwater inflow is directly related to estuarine primary production and help form the community structure of the downstream estuary (Odum 1971).

Freshwater inflow helps distribute sediments that shape and maintain river deltas, deposit nutrients, and influence turbidity. These functions are critical to coastal vegetation succession

(Sklar et al. 1985) and act to counter coastal subsidence and sea level rise. Alterations in freshwater inflow can affect sediment loads in differing ways. Deforestation and agriculture usually increase the sediment load of rivers, while dams block sediments from being carried into downstream estuaries. Water management policies need to consider the serious issue of sediment deprivation due to the significant need for sediment in coastal areas. Diverting Mississippi River sediments to offshore water has led to the loss of coastal wetlands in Louisiana (Craig et al. 1979) and cutting off wetlands from other sediment sources through intensive canal dredging for oil exploration (Scaife et al. 1983, Cahoon and Turner 1989).

### 4.5.4 Marine Transportation

As the human population increases, so does the demand for increased marine transportation vessels, facilities, and port infrastructure. Port facility expansion, vessel operations, and commercial and recreational marinas can adversely impact fish habitat through the filling of aquatic habitat and wetlands, dredging activities, and other land use changes. While some impacts related to marine transportation may be minimal and site specific, the cumulative impact of marine transportation activities can have substantial impacts on habitat over time.

#### 4.5.4.1 Ports and Marinas

Most marinas or port facilities will have a footprint that alters the surrounding environment. The construction of ports and marinas can directly fill habitat for port and marine structures or replace wetlands, SAV, and intertidal mud flat habitat with hardened structures such as bulkheads and jetties that provide few ecological services. Port construction usually leads to increased impervious surfaces which exacerbates storm water runoff and can increase the siltation and sedimentation loads in estuarine and marine habitats. Oil and fuel can accumulate on dock surfaces, facilities properties, adjacent parking lots, and roadways and can pollute surrounding waters through storm water runoff. Shoreline armoring is usually associated with ports and marinas. Shoreline armoring is used to prevent erosion due to increased boat traffic. Shoreline armoring reduces habitat complexity and directly reduces intertidal habitat. Installing breakwaters and jetties can lead to community changes as habitat is altered. Jetties and channels for marinas and ports can also lead to increased erosion and changes to sedimentation patterns due to alteration and amplification of tides and currents.

Marinas and docks often contain pilings and docks treated with chemicals such as chromated copper arsenate, ammoniacal copper zinc arsenate, and creosote to help extend their service life in the marine environment. These preservatives can leach harmful chemicals into the water that have been shown to produce toxic effects on fish and other organisms (Weis et al. 1991). The leaching rate and leaching duration of these preservatives after installation are highly variable and dependent on many factors, including the pH, salinity, and the type of compounds used in the preservatives (Hingston et al. 2001). The metals and chemicals in preservatives can become available to marine organisms through uptake by wetland vegetation, adsorption by adjacent sediments, or directly through the water column (Weis and Weis 2002). Weis and Weis (2002) found that chromated copper arsenate can cause reductions in species richness and diversity in localized areas.

Vessel operations can have a wide range of impacts to habitat, ranging from minor to potentially large-scale impacts. Direct disturbance of bottom habitat can result from propeller scarring and vessel wake impacts on SAV and direct contact by groundings. Uhrin and Holmquist (2003) found that propeller scarring can result in a loss of benthic habitat, decreased productivity, potentially fragmented SAV beds, and further erosion and degradation of the habitat. The disturbance of sediments and rooted vegetation decreases habitat suitability for fish and shellfish resources and can affect the spatial distribution and abundance of fauna (Uhrin and Holmquist 2003). Burfeind and Stunz (2007) found that white shrimp showed significantly lower growth in highly scarred areas than in regions of low-level propeller scarring (<15%) and concluded that higher levels of propeller scarring may affect habitat quality.

Wave energy caused by industrial and recreational shipping and transportation can lead to high levels of shoreline erosion and cause additional problems such as damaging vegetation, disturbing substrate, and increasing turbidity. Johnson and Gosselink (1982) measured canal widening rates of over 2.5 m/year in heavily traveled oilfield canals in Louisiana. Size of the vessel, vessel hull configuration, and vessel speed all affect the wave energy and surge produced by vessels. The wave energy and surge, the slope of the shoreline, the shoreline sediment type, and the type of shoreline vegetation, and the depth and bottom topography of the water body affect the degree of shoreline erosion caused by vessels.

#### 4.5.4.2 Navigational Channel Dredging

Around the Gulf of Mexico, dredging usually is required in and around ports, harbors, and marinas. Dredging can often affect the surrounding environment and negatively impact sensitive aquatic habitats. Dredging can be classified as creating new or expanded waterways, maintaining existing waterways, or deepening existing waterways. The increasing size of commercial cargo vessels has led to increased competition among the major coastal ports to provide facilities to accommodate these vessels. Larger vessels mean that ports must continually deepen their navigation channels. Port, harbors, and marina facilities usually require maintenance dredging because of the continuous deposition of sediments.

The location and method of disposal for dredged material depends on the suitability of the material determined through chemical, and often, biological analyses conducted prior to the dredging project. Generally, sediments determined to be unacceptable for open water disposal are placed in confined disposal facilities or contained aquatic disposal sites and capped with uncontaminated sediments. Sediments that are determined to be uncontaminated may be placed in open water disposal sites or used beneficially. Beneficial uses are intended to provide environmental or other benefits to the human environment, such as shoreline stabilization and erosion control, habitat restoration/enhancement, beach nourishment, capping contaminated sediments, parks and recreation, agriculture, strip mining reclamation and landfill cover, and construction and industrial uses. Some open water disposal sites are designed so that the material remains at the disposal site while others are designed for the material to be dispersed by currents and/or wave action. The potential for environmental impacts is dependent upon the type of disposal operation used, the physical characteristics of the material, and the hydrodynamics of the disposal site.

Dredging involves a number of fishery habitat impacts. These include the direct removal or burial of demersal and benthic organisms and aquatic vegetation, alteration of physical habitat features, the disturbance of bottom sediments (resulting in increased turbidity), contaminant releases in the water column, light attenuation, releases of oxygen consuming substances and nutrients, entrainment of living organisms in dredge equipment, noise disturbances, and the alteration of hydrologic and temperature regimes (Johnson et al. 2008). Dredging is often accompanied by a significant decrease in the abundance, diversity, and biomass of benthic organisms in the affected area and an overall reduction in the aquatic productivity of the area (Allen and Hardy 1980, Newell et al. 1998). The rate of recovery of the benthic community is dependent upon an array of environmental variables which reflect interactions between sediment particle mobility at the sediment-water interface and complex associations of chemical and biological factors operating over long time periods (Newell et al. 1998).

Bathymetry alterations, changes to benthic habitat features, and substrate type changes caused by navigational dredging activities may have long-term impacts on the functions of estuarine and other aquatic environments. The impacts of an individual project are proportional to the scale and time required for a project to be completed, with small-scale and short-term dredging activities having less impact on benthic communities than long-term and large-scale dredging projects. Dredging can have cumulative effects on benthic communities, depending upon the dredging interval, the scale of the dredging activities, and the ability of the environment to recover from the impacts. The new exposed substrate in a dredged area may be composed of material containing more fine sediments than before the dredging, which can reduce the recolonization and productivity of the benthos and the species that prey upon them. The impacts to benthic communities vary greatly with the type of sediment, the degree of disturbance to the substrate, the intrinsic rate of reproduction of the species, and the potential for recruitment of adults, juveniles, eggs, and larvae (Newell et al. 1998). Following a dredging event, sediments may be nearly devoid of benthic infauna, and those that are the first to recolonize are typically opportunistic species which may have less nutritional value for consumers (Allen and Hardy 1980, Newell et al. 1998).

In general, dredging can be expected to result in a 30-70% decrease in the benthic species diversity and 40-95% reduction in number of individuals and biomass (Newell et al. 1998). Recovery of the benthic community is generally defined as the establishment of a successional community which progresses towards a community that is similar in species composition, population density, and biomass to that previously present or at nonimpacted reference sites (Newell et al. 1998). The factors which influence the recolonization of disturbed substrates by benthic infauna are complex, but the suitability of the post-dredging sediments for benthic organisms and the availability of adjacent, undisturbed communities which can provide a recruitment source are important (Barr 1987, ICES 1992). Rates of benthic infauna recovery for disturbed habitats may also depend upon the type of habitat being affected and the frequency of natural and anthropogenic disturbances. Benthic infauna recovery rates may be less than one year for some fine-grained mud and clay deposits, where a frequent disturbance regime is common, while gravel and sand substrates, which typically experience more stability, may take many years to recover (Newell et al. 1998). Sheridan (2004) found that recovery from dredged material placement was nearly complete for the water column and sediment components after 1.5-3.0 years, but recovery of the benthos and nekton was predicted to take 4-8 years.

The small, localized disturbance of SAV associated with dredging may be viewed as a significant impact in the context of diminished regional health and distribution resulting from stressors such as poor water quality and cumulative effects such as dredging, prop scarring, and shoreline alteration (Goldsborough 1997, Thayer et al. 1997). In a study of dredging impacts on seagrass in the Laguna Madre in Texas, Onuf (1994) found that off-site dredging effects were detectable for the 15-month study period and noted that resuspension and dispersion events caused by wind-generated waves were responsible for the propagation of dredge-related turbidity over space and time in the system. Also in a study of dredged material placement sites in Laguna Madre, Texas, Sheridan (2004) found that recovery from dredged material placement for seagrass took from 4-8 years. Sheridan (2004) stated that the current two to five year dredging cycle for the area virtually insured that the ecosystem did not recover before being disturbed again.

Dredging degrades habitat quality through the resuspension of sediments which creates turbid conditions and can release contaminants into the water column, in addition to impacting benthic organisms and habitat through sedimentation. Turbidity plumes ranging in the hundreds to thousands of mg/L are created and can be transported with tidal currents to sensitive resource areas. Alterations in bottom sediments, bottom topography, and altered circulation and sedimentation patterns related to dredge activities can lead to shoaling and sediment deposition on benthic resources such as spawning grounds, SAV, and shellfish beds (Wilber et al. 2005, MacKenzie 2007). Early life history stages (eggs, larvae, and juveniles) and sessile organisms are the most sensitive to sedimentation impacts (Barr 1987, Wilber et al. 2005).

Large channel-deepening projects can potentially alter ecological relationships through a change in freshwater inflow, tidal circulation, estuarine flushing, and freshwater and saltwater mixing. Dredging may also modify longshore current patterns by altering the direction or velocity of water flow from adjacent estuaries. These changes in water circulation are often accompanied by changes in the transport of sediments and siltation rates resulting in alteration of local habitats used for spawning and feeding (Messieh et al. 1991).

Maintenance dredging of navigation channels between barrier islands can remove sediments from the longshore sediment drift. Maintained channels intercept and capture sediments, and dredged materials are often discharged to ocean dump sites. Dredging may contribute to the reduction of sediment deposition and affect the stability of barrier landforms (MMS 2007b). Reductions in sediment supply could subsequently contribute to minor local losses of adjacent barrier beach habitat, with impacts over a broader area where the sediment supply is low.

Dredging of navigation channels can contribute to increased flushing and draining of interior marsh areas by tides and storms, which could result in shifts in species composition, habitat deterioration, erosion, and wetland loss. Channels alter the hydrology of coastal marshes by affecting the amount, timing, and pathways of water flow (Day et al. 2000). Hydrologic alterations can result in changes in salinity and inundation, causing a dieback of marsh vegetation and a subsequent loss of substrate and conversion to open water (Day et al. 2000). Saltwater intrusion into brackish and freshwater wetlands further inland could result in mortality of salt-intolerant species and loss of some wetland types such as cypress swamp, or transition of wetland types such as freshwater marsh to brackish and salt marsh or open water (MMS 2007b). The deposition of dredged material onto adjacent disposal banks could potentially result in a localized and minor contribution to ongoing impacts of disposal banks, such as preventing the effective draining of some adjacent areas, resulting in higher water levels or more prolonged tidal inundation, or restricting the movement of water, along with sediments and nutrients, into other marsh areas (Day et al. 2000).

Navigational channels that are substantially deeper than surrounding areas can become anoxic or hypoxic as natural mixing is decreased and detrital material settles out of the water column and accumulates in the channels. This concentration of anoxic or hypoxic water can stress nearshore biota when mixing occurs from a storm event (Allen and Hardy 1980). The potential for anoxic conditions can be reduced in areas that experience strong currents or wave energy, and sediments are more mobile (Barr 1987, Newell et al. 1998).

### 4.5.5 Invasive Species

Effects of invasive species can be devastating on both habitat and native species. Impacts may include a decrease in biological diversity of native ecosystems, a decrease in the quality of important habitats for native fish and invertebrate species, a reduction in habitats needed by threatened and endangered species, and an increase in direct and indirect competition with aquatic plants and animals. Invasive species have been introduced to coastal areas through industrial shipping, recreational boating, and intentional and unintentional human releases. These introductions can be in the form of fouling organisms on the bottoms of vessels as they are transported between water bodies or through the release of ballast water from large commercial vessels. Introductions of non-native invasive species into marine and estuarine waters are a significant threat to living marine resources in the U.S. (Carlton 2001). Hundreds of species have been introduced into U.S. waters from overseas and from other regions around North America, including finfish, shellfish, phytoplankton, bacteria, viruses, and pathogens (Drake et al. 2005). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001).

Invasive species that occur in Gulf of Mexico freshwater, estuarine, and marine environments include 483 aquatic microbes, invertebrates and aquatic vertebrates, and 221 aquatic plants (Battelle 2000). These introduced species have the potential to affect native populations and their habitat. During the summer of 2000, an invasion of Pacific spotted jellyfish (*Phyllorhiza puncata*) covered 150 $km^2$ in the northern Gulf of Mexico. An estimated six million of these jellyfish consumed vast amounts of plankton. The green mussel (*Perna viridis*) found in Tampa Bay, Florida, is well established on hard surfaces in the bay. This species is now being reported attaching to unconsolidated sediments and creating new shellfish communities. Nutria (*Myocastor coypus*) is an invasive species that has had a significant adverse impact on Louisiana marshes. Nutria affect nursery habitat for many estuarine species by undermining and converting tidal emergent marsh habitat to open water.

Since 2009, lionfish, a non-indigenous species from the Indo-Pacific region, have rapidly increased in numbers throughout the coastal waters of the Gulf of Mexico. Lionfish can be found in brackish river mouths, bays, estuaries, and open oceans to a depth of at least 900 ft and are general predators that consume a wide variety of fish and invertebrates posing a large threat to many native marine species. The degree to which these exotic species directly impact blue crab or their habitat is uncertain.

Tiger shrimp (*Penaeus monodon*) and the Bocourt swimming crab (*Callinectes bocourti*) are non-native crustaceans that have been found in the Gulf. Tiger shrimp feed on small crabs and also compete with native blue crab populations for food and habitat. Increasing numbers of tiger shrimp have the potential to threaten population levels of blue crabs in some areas of the Gulf of Mexico.

Invasive species can have severe impacts on the quality of habitat (Deegan and Buchsbaum 2005). Non-native aquatic plant species can infest water bodies, impair water quality, cause anoxic conditions when they die and decompose, and alter predator-prey relationships. Fish may be introduced into an area to graze and biologically control aquatic plant invasions. However, introduced fish may also destroy habitat, which can eliminate nursery areas for native juvenile fish, accelerate eutrophication, and cause bank erosion (Kohler and Courtenay 1986).

Increased competition for food and space between native and non-native species can alter the trophic structure of an ecosystem (Kohler and Courtenay 1986, Caraco et al. 1997, Strayer et al. 2004, Deegan and Buchsbaum 2005) as well as through predation by invasive species on native species (Kohler and Courtenay 1986). Competition may result in the displacement of native species from their habitat or a decline in recruitment, which are factors that can collectively contribute to a decrease in population size (Kohler and Courtenay 1986). Predation on native species by non-native species may increase the mortality of a species. Whether the predation is on the eggs, juveniles, or adults, a decline in native forage species can affect the entire food web (Kohler and Courtenay 1986).

### 4.5.6 Harmful Algal Blooms (HABs)

Harmful algal blooms (HABs) are caused by naturally occurring dinoflagellates and algae. Over 60 species of dinoflagellates that can cause harmful algal blooms are found in the Gulf of Mexico with the most common being *Karenia brevis*. Toxic dinoflagellates such as *Karenia* spp. are common in the Gulf of Mexico all year long at background cell concentrations of approximately 1,000 cells per liter. The harmful impacts caused by these HABs only occur when cell concentrations increase significantly above the low background concentrations. Brown tides have been caused in Texas by blooms of *Aureoumbra*.

In the Gulf of Mexico, HABs occur most commonly in Florida waters with over 60% of the documented events occurring between 1957 and 2005. Louisiana, Mississippi, and Alabama have each experienced at least one red tide event, but Texas has experienced 13 red tide events attributed to *K. brevis* since 1935 (Magana et al. 2003). Most of these HABs have been concentrated along the west Florida shelf from Clearwater to Sanibel Island and the Texas coast between Port Arthur and Galveston Bay. In 1996, red tides occurred in the coastal waters of all five Gulf states. Most blooms occur during late summer to fall (Tester and Steidinger 1997). These blooms can extend for hundreds to thousands of square kilometers and can persist for months. High concentrations of cells are variable due to the influence of currents. Off Florida, harmful algal blooms usually start offshore in oligotrophic waters between 18 and 74 km off central Florida at depths of 12-40 m and can take about a month or so to develop into a fish-killing bloom depending on environmental conditions (Liu et al. 2001). Most harmful algal blooms off Texas occur in inshore or nearshore waters.

Ingestion of brevetoxin, the toxic compound produced and released by red tide cells by fish, paralyzes the respiratory system causing death. The red tide bloom off Texas in 1997 killed a minimum of 22M finfish (McEachron et al. 1998). Clupeids and other schooling fishes were the main species impacted, although about 100 total species were identified, including recreationally and commercially important fish such as spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), flounder (*Paralichthys* sp.), black drum (*Pogonias cromis*), and Atlantic croaker (*Micropogonias undulatus*). Brevetoxin also affects top predators through bioaccumulation of toxin in planktivorous prey fish that ingest the cells or are otherwise exposed to a bloom. Finfish are not the only casualties of harmful algal blooms. In addition, bottlenose dolphins (*Tursiops truncatus*), marine turtles, and the Florida manatee (*Trichechus manatus latirostrus*) have all died as a result of toxins associated with HABs. In 1996, 149 Florida manatees, an endangered species, died and, in 2005, 138 marine turtles died due to HABs in Florida Gulf waters (FWC personal communication).

Unexplained fish kills and other animal mortalities in red tide endemic areas are increasingly linked with post-bloom exposures of biota to brevetoxins (Landsberg et al. 2009). Landsberg et al. (2009) collected animal tissues and environmental samples for brevetoxin analyses after red tide events. They found that a persistence of high concentrations of brevetoxins in various biotic reservoirs can remain a stable source of toxicity, even in the absence of *K. brevis* cells.

A persistent *Aureoumbra* brown tide bloom began in 1990 in the Laguna Madre and Baffin Bay, Texas. The brown tide stopped in 1997, but developed again the following summer (Buskey et al. 2001). Brown tide blooms have occurred intermittently in the Laguna Madre system since then, but have not been as severe. Brown tides affect seagrass due to decreased light penetration and Onuf (1996) recorded a 9.4 $km^2$ loss of seagrass over the course of several years. Ward et al. (2000) found a decrease in the biomass and diversity of benthic invertebrates in the Laguna Madre due to the brown tide bloom.

The dinoflagellate *Gonyaulax monilata* (=*Alexandrium monilatum* (Howell) Balech 1995) has been responsible for fish mortalities across the Gulf of Mexico (Connell and Cross 1950, Gates and Wilson 1960, Williams and Ingle 1972, Wardle et al. 1975). Perry et al. (1979) reported on an extensive outbreak of *G. monilata* in coastal and offshore waters of the northern Gulf in the summer of 1979 with fish kills reported in Alabama and Florida.

### 4.5.7 Climate Change

Climate change could have many consequences for most U.S. coastal and marine ecosystems, and some of the consequences may substantially alter human dependencies and interactions with these complex and linked systems. The climatic effects will be superimposed upon, and interact with, a wide array of current stresses, including excess nutrient loads, overfishing, invasive species, habitat destruction, and toxic chemical contamination. While the ability of these ecosystems to cope with or adapt to climate change or variability is compromised by extant stresses, the inverse is also likely to be true. Ecosystems will be better suited to deal with climate variability and change if other stresses are significantly reduced.

Climate change may result in higher water temperatures, stronger stratification, and increased inflows of freshwater and nutrients to coastal waters in many areas. Both past experience and model forecasts suggest that these changes will result in enhanced primary production, higher phytoplankton and macroalgal standing stocks, and more frequent or severe hypoxia.

Natural biological and geological processes should allow responses to gradual changes, such as transitions from marsh to mangrove swamp as temperatures warm, as long as environmental thresholds for plant survival are not crossed. Accelerated sea level rise also threatens these habitats with inundation, erosion, and saltwater intrusion. Over the last 6,000 years, coastal wetlands expanded inland as low lying areas were submerged, but often did not retreat at the seaward boundary because sediment and peat formation enabled them to keep pace with the slow rate of sea level rise. If landward margins are armored, effectively preventing inland migration, then wetlands could be lost if they are unable to accumulate substrate at a rate adequate to keep pace with future increased rates of sea level rise.

Increased air, soil, and water temperature may also increase growth and distribution of coastal salt marshes and forested wetlands. For many species, including mangroves, the limiting factor for the geographic distribution is not mean temperature, but rather low temperature or freezing events that exceed tolerance limits (McMillan and Sherrod 1986, Snedaker 1995). The Gulf of Mexico is a prime candidate for mangrove expansion to occur because it is located at the northward limit of black mangrove habitat (Comeaux et al. 2012). This may come at the expense of *Spartina* spp. dominated marshes. Historically, small populations of black mangroves have been present in Louisiana in the extreme southern portion of the state. Black mangrove distribution was limited by cold winter temperatures. Black mangrove populations are now expanding in southern Louisiana's *Spartina* dominated marshes (Perry and Mendelssohn 2009). Caudill (2005) found that blue crabs were collected in higher abundances in mangrove areas in south Louisiana sites than at adjacent *Spartina* sites.

Fodrie et al. (2010) sampled seagrass areas in Mississippi, Alabama, and northern Florida previously sampled in the 1970s to compare the ichthyofauna between the two periods. The comparison showed several new species including lane snapper (*Lutjanus synagris*), red grouper (*Epinephelus morio*), and yellowtail snapper (*Ocyurus chrysurus*). Several other species showed large increases in abundance between 1979 and 2006, including gag grouper (*Mycteroperca microlepis*) and mangrove snapper (*Lutjanus griseus*). The researchers also observed increased air and sea surface temperatures, which they theorize have led to northern shifts in the distribution of these warm water fish. Fodrie et al. (2010) found that nearly 20% of the fish species collected in northern Gulf of Mexico seagrass meadows during 2006–2007 were tropical or subtropical, and were either absent, or much less abundant than they were in the 1970s. Fodrie et al. (2010) conclude that the presence of these fish may be an early indicator for the extension of tropical conditions in the northern Gulf of Mexico.

Changes in the timing and volume of freshwater delivery to coastal wetlands will also be critical, yet perhaps the most difficult to assess. In contrast to uncertainties associated with regional impacts of climate change on hydrology, it is clear that increased human population and coastal development will create higher demands for freshwater resources. While increased freshwater is likely to decrease osmotic stress and increase productivity, less freshwater may increase salinity stress. Wetlands may accommodate gradual increases in salinity as salt and brackish marshes replace freshwater marshes and swamps, although sustained or pulsed changes in salinity can have dramatic negative effects. *Panicum hemitomon,* a typical freshwater marsh species, grew at a reduced rate in water of 9‰ salinity in one study (McKee and Mendelssohn 1989) and had reduced carbon assimilation at 5‰ in another (Pezeshki et al. 1987).

Climate change will likely influence the vulnerability of estuaries to eutrophication in several ways, including changes in mixing characteristics caused by alterations in freshwater runoff, and changes in temperature, sea level, and exchange with the coastal ocean (Kennedy 1990, Peterson et al. 1995, Najjar et al. 2000). A direct effect of changes in temperature and salinity may be seen through changes in suspension feeders such as mussels, clams, and oysters. The abundance and distribution of these consumers may change in response to new temperature or salinity regimes and they can significantly alter both phytoplankton abundance and water clarity (Alpine and Cloern 1992, Meeuwig et al. 1998, NRC 2000).

Increased anthropogenic nutrient loading and a changing climate will make coastal ecosystems more susceptible to the development of hypoxia through enhanced stratification, decreased oxygen solubility, increased metabolism and remineralization rates, and increased production of organic matter. All these factors related to global change may progressively result in an onset of hypoxia earlier in the season and possibly an extended duration of hypoxia.

### 4.5.8 Weather-Related Events

Tropical storms generally form from June until October each year in the Gulf of Mexico, and in a typical year, 11 tropical storms will form in the region with approximately six reaching hurricane status (Blake et al. 2007). Hurricanes and tropical storms can increase surface current speeds to between 1 and 2 m/s (3.2 and 6.8 ft/s) in continental shelf regions (Nowlin et al. 1998, Teague et al. 2007). Storm surges can impact coastal areas and have been reported to range between 2 and 8 m for hurricanes reaching the northern coast of the Gulf of Mexico (NOAA 2013). Storms affect estuaries through overwash events and by erosion from wind and waves.

Evidence of an increase in intense tropical cyclone activity in the North Atlantic over the past 40 years (Meehl et al. 2007, Trenberth et al. 2007) supports predictions that the frequency (Holland and Webster 2007, Mann et al. 2007) and intensity (Emanuel 2005, Webster et al. 2005) of extreme weather events have been increasing and will continue to increase with warmer global temperatures. However, these predictions have been challenged by suggestions that the apparent trend in increasing storm frequency is an artifact of improved monitoring (Landsea 2007) and by predictions that increased vertical wind shear could dampen the effects of increasing hurricane intensity (Vecchi and Soden 2007). Meehl et al. (2007) suggest that a warmer climate will increase the overall intensity of tropical cyclones and, whereas the number of storms is expected to decrease globally by the end of the 21st century, the number of storms in the North Atlantic could increase by as much as 34% during this period (Oouchi et al. 2006).

El Niño, also called the El Niño Southern Oscillation (ENSO), is a change in the eastern Pacific Ocean's surface water temperatures that contributes to major changes in global weather. It is a periodic phenomenon that is caused by changes in surface trade wind patterns. The tropical trade winds normally blow east to west, piling up water in the western Pacific and causing upwelling of cooler water along the South American coast. El Niño occurs when this normal wind pattern is disrupted. El Niño generally produces cooler and wetter weather in the southern United States and warmer than normal weather in the northern part of the country. In addition, there seems to be reduced, though no less severe, tropical activity during El Niño years (NAS 2000). The resulting increased summer rainfall can significantly increase river discharge, flow rates, water clarity, and other physical-chemical parameters in estuaries.

The effects of La Niña are nearly opposite to that of El Niño. La Niña is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific Ocean. La Niña periods are characterized by wetter than normal conditions across the Pacific Northwest and very dry and hot conditions in the Southeast. Also, a greater than average number of tropical storms, and possibly hurricanes, are likely in the Gulf from June-October.

Tropical storm and hurricane damage to coastal property is a recognized physical and monetary threat to the states located along the Gulf coast. Costanza et al. (2008) estimated that the coastal wetlands of the United States provide $23.2B/year in storm protection services. Each hectare of coastal wetland lost corresponds to an average of $33,000 of increased damage from specific storms. Louisiana alone lost $816M/year of wetland services prior to Hurricane Katrina and an additional $34M were lost due to Hurricane Katrina. These values emphasize the need to protect and restore coastal wetlands.

# 5.0 FISHERY MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES AFFECTING THE STOCK(S)

Blue crabs are directly and indirectly affected by numerous state and federal management institutions through their administration of state and federal laws, regulations, and policies. The following is a partial list of some of the most important agencies, laws, and regulations that affect blue crabs and their habitat. Each of these management institutions, federal laws, and policies have the potential to affect harvesting, processing, and various aspects of habitat of Gulf of Mexico blue crab. These may change at any time; however, individual Gulf states are directly responsible for the management of blue crab, and they should be contacted for specific and current state laws and regulations.

## 5.1 Management Institutions

### 5.1.1 Federal

#### 5.1.1.1 Regional Fisheries Management Councils

Although blue crabs are found in the exclusive economic zone (EEZ) of the Gulf of Mexico, they are most abundant in state waters. The commercial and recreational fisheries occur almost exclusively in state management jurisdictions. Consequently, laws and regulations of federal agencies primarily influence blue crab abundance by maintaining and enhancing habitat, preserving water quality and food supplies, and abating pollution. Federal laws may also affect consumers through the development of regulations to protect product quality.

With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA) and the subsequent Magnuson-Stevens Conservation and Management Act (Mag-Stevens) of 1996, the federal government assumed responsibility for fishery management within the EEZ, a zone contiguous to the territorial sea and whose inner boundary is the outer boundary of each coastal state. The outer boundary of the EEZ is a line 200 nautical miles from the (inner) baseline of the territorial sea. Management of fisheries in the EEZ is based on fishery management plans (FMPs) developed by regional fishery management councils. Each council prepares plans for each fishery requiring management within its geographical area of authority and amends such plans as necessary. Plans are implemented as federal regulation through the U.S. Department of Commerce (USDOC).

The councils must operate under a set of National Standards and guidelines laid out in the Mag-Stevens, and to the extent practicable, an individual stock of fish must be managed as a unit throughout its range. Management must, where practicable, promote efficiency, minimize costs, and avoid unnecessary duplication (MFCMA Section 301a).

There is no significant fishery for blue crab in the EEZ of the U.S. Gulf of Mexico. Consequently, the Gulf of Mexico Fishery Management Council (GMFMC) has not developed a management plan for blue crab.

#### 5.1.1.2 National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (USDOC)

The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all FMPs prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen. It performs research and conducts management authorized by international treaties. The NMFS has the authority to enforce the Mag-Stevens and the Lacey Act and other federal laws protecting marine organisms, including the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA) and is the federal trustee for living and nonliving natural resources in coastal and marine areas.

The NMFS exercises no management jurisdiction other than enforcement with regard to blue crabs in the Gulf of Mexico. It conducts some research and data collection programs and comments on all projects that affect marine fishery habitats.

The USDOC, in conjunction with coastal states, administers the National Estuarine Research Reserve and National Marine Sanctuaries Programs as authorized under Section 315 of the Coastal Management Act of 1972. Those protected areas serve to provide suitable habitat for a multitude of estuarine and marine species and serve as sites for research and education activities relating to coastal management issues.

### 5.1.2 Treaties and Other International Agreements

There are no treaties or other international agreements that affect the harvesting or processing of blue crabs. No foreign fishing applications to harvest blue crabs have been submitted to the United States.

### 5.1.3 Federal Laws, Regulations, and Policies

The following federal laws, regulations, and policies may directly and indirectly influence the quality, abundance, and ultimately the management of blue crabs.

#### 5.1.3.1 Magnuson Fishery Conservation and Management Act of 1976 (MFCMA); Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Mag-Stevens) also called the Sustainable Fisheries Act (P.L. 104-297)

The MFCMA mandates the preparation of FMPs for important fishery resources within the EEZ. It sets national standards to be met by such plans. Each plan attempts to define, establish, and maintain the optimum yield for a given fishery. The 1996 Mag-Stevens reauthorization included three additional national standards (eight through ten) to the original seven for fishery conservation and management, included a rewording of standard number five, and added a requirement for the description of essential fish habitat and definitions of overfishing.

1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry;
2. Conservation and management measures shall be based on the best scientific information available;
3. To the extent practicable, an individual stock shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or close coordination;
4. Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various U.S. fishermen, such allocations shall be:
    - fair and equitable to all such fishermen;
    - reasonably calculated to promote conservation; and
    - carried out in such a manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.
5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of the resources; except that no such measures shall have economic allocation as its sole purpose.
6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fisheries resources, and catches.
7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.
8. Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to:
    - provide for the sustained participation of such communities, and
    - to the extent practicable, minimize adverse economic impacts on such
    - communities.
9. Conservation and management measures shall, to the extent practicable,
    - minimize bycatch; and
    - to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.
10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

The 2006 reauthorization builds on the country's progress to implement the 2004 Ocean Action Plan which established a date to end over-fishing in America by 2011, use market-based incentives to replenish America's fish stocks, strengthen enforcement of America's fishing laws, and improve information and decisions about the state of ocean ecosystems.

#### 5.1.3.2 Interjurisdictional Fisheries Act (IFA) of 1986 (P.L. 99-659, Title III)

The IFA of 1986 established a program to promote and encourage state activities in the support of management plans and to promote and encourage regional management of state fishery resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

#### 5.1.3.3 Federal Aid in Sport Fish Restoration Act (SFRA); the Wallop-Breaux Amendment of 1984 (P.L. 98-369)

The SFRA, passed in 1950, provides funds to states, the USFWS, and the Gulf States Marine Fisheries Commission to conduct research, planning, and other programs geared at enhancing and restoring marine sportfish populations. The 1984 amendment created the Aquatic Resources Trust Fund which is a 'user pays/user benefits' program. The amendment allows transfer of fishing and boating excise taxes and motorboat gas taxes (user pays) to the improvement of boating and fishing programs (user benefits) and provides equitable distribution of funds between freshwater and saltwater projects in coastal states.

## 5.2 State Authority, Laws, Regulations, and Policies

Table 5.1 outlines the various state management institutions and authorities. Table 5.2 shows a summary of selected regulations for the Gulf states. Unless otherwise specified, these regulations apply to both commercial and recreational fishermen. *These are not exhaustive, and each state should be contacted for a complete and up-to-date list of regulations.*

### 5.2.1 Florida

#### 5.2.1.1 Florida Fish and Wildlife Conservation Commission

Florida Fish and Wildlife Conservation Commission (FWC)
620 South Meridian Street
Tallahassee, Florida 32303
(850) 487-0580

The agency charged with the administration, supervision, development, and conservation of saltwater fisheries, freshwater fisheries, and wildlife is the Florida Fish and Wildlife Conservation Commission (FWC). The administrative head of the FWC is the Executive Director. The Division of Law Enforcement is responsible for enforcement of all marine, freshwater, and wildlife rules and regulations of the FWC.

The FWC, a seven-member board appointed by the Governor and confirmed by the Senate, was created by constitutional amendment effective July 1999.

The FWC was delegated rule-making authority over marine life in the following areas of concern that include but are not limited to: gear specifications, prohibited gear, bag limits, size limits, species that may not be sold, protected species, closed areas, seasons, and quality control codes. The FWC does not have authority over penalty provisions.

**Table 5.1** State management institutions - Gulf of Mexico.

| STATE | ADMINISTRATIVE BODY AND ITS RESPONSIBILITIES | ADMINISTRATIVE POLICY-MAKING BODY AND DECISION RULE | LEGISLATIVE INVOLVEMENT IN MANAGEMENT REGULATIONS |
|---|---|---|---|
| Florida | **FFWCC** | | |
| | • administers management programs<br>• enforcement<br>• conducts research | • creates rules in conjunction with management plans<br>• ten member commission | • responsible for setting fees, licensing, and penalties. |
| Alabama | **ADCNR** | | |
| | • administers management programs<br>• enforcement<br>• conducts research | • Commissioner of department has authority to establish management regulation<br>• Conservation Advisory Board is a thirteen- member board and advises the commissioner has authority to amend and promulgate regulations | • authority for detailed management regulations delegated to commissioner statutes concerned primarily with licensing |
| Mississippi | **MDMR** | **COMMISSION ON MARINE RESOURCES** | |
| | • administers management programs<br>• conducts research<br>• enforcement | • five-member board<br>• establishes regulations on recommendation of executive director (MDMR) | • authority for detailed management regulations delegated to commission statutes concern licenses, taxes and some specific fisheries laws |
| Louisiana | **LDWF** | **WILDLIFE AND FISHERIES COMMISSION** | |
| | • administers management programs<br>• enforcement<br>• conducts research<br>• makes recommendations to legislature | • seven-member board establishes policies and regulations based on majority vote of a quorum (four members constitute a quorum) consistent with statutes | • detailed regulations contained in statutes<br>• authority for detailed management regulations delegated to commission |
| Texas | **TPWD** | **PARKS AND WILDLIFE COMMISSION** | |
| | • administers management programs<br>• enforcement<br>• conducts research<br>• makes recommendations to Texas Parks & Wildlife Commission (TPWC) | • nine-member body<br>• establishes regulations based on majority vote of quorum (five members constitute a quorum)<br>• granted authority to regulate means and methods for taking, seasons, bag limits, size limits and possession | • licensing requirements and penalties are set by legislation |

**Table 5.2** Summary of Gulf States' blue crab regulations. NOTE: These are intended as a quick reference for state specific dimensions but are only current through 2011. See individual state regulations for more detailed and up-to-date information.

| REGULATION | FLORIDA | ALABAMA | MISSISSIPPI | LOUISIANA | TEXAS |
|---|---|---|---|---|---|
| *Size Limits*<br>Commercial<br>Recreational | <br>-5" CW minimum<br>-none | <br>-5" CW minimum<br>-none | <br>-5" CW minimum<br>-5" CW minimum | <br>-5" CW minimum<br>-none | <br>-5" CW minimum<br>-5" CW minimum |
| *Gear Limits*<br>Traps<br>Escape rings<br>Degradable panel<br>Maximum volume<br>Maximum number<br>Identification<br><br>Trawls | <br>-three, 2 3/8" ID<br>-yes, 5 options<br>-8 cubic feet<br>-none (commercial)<br>-five (recreational)<br>-buoy (commercial and recreational)<br><br>-see possession limits | <br>-none<br>-none<br>-27 cubic feet<br>-none<br>-five (recreational)<br>-buoy (commercial)<br><br>-none | <br>-none<br>-none<br>-none<br>-none (commercial)<br>-six (recreational)<br>-buoy/vessel/trap tags<br><br>-must comply with legal shrimp trawl regulations | <br>-two, 2 5/16" ID<br>-none<br>-none<br>-none (commercial)<br>-ten (recreational)<br>-steel tag on trap<br><br>-must comply with legal shrimp trawl regulations | <br>-four, 2 3/8" ID<br>-yes, 2 options<br>-18 cubic feet<br>-200 (commercial)<br>-six (recreational)<br>-buoy (commercial and recreational)<br><br>-must comply with legal shrimp trawl regulations |
| *Possession Limits*<br>Commercial<br><br>Recreational | <br>-none (traps)<br>-200 pounds/trip of shrimp trawl bycatch<br>-10 gallons | <br>-none<br><br>yes* | <br>-none<br><br>-none | <br>-none<br><br>-12 dozen, certain areas | <br>-none<br><br>-none |
| *Closed Areas* | none | yes* | yes* | yes* | yes* |
| *Closed Seasons* | none | none | yes* | none | none |
| *Data Reporting Required* | yes* | yes* | yes* | yes* | yes* |
| *Licenses Required*<br>Commercial<br>Recreational | <br>yes*<br>yes* | <br>yes*<br>none | <br>yes*<br>yes* | <br>yes*<br>yes* | <br>yes*<br>yes* |

Florida has a habitat protection and permitting programs and a federally-approved CZM program (see the Florida Coastal Management Act of 1978).

### 5.2.1.2 Legislative Authorization

Prior to 1983, the Florida Legislature was the primary body that enacted laws regarding management of blue crab. In July 1999 the Florida Marine Fisheries Commission merged with the Florida Game and Freshwater Fish Commission to become the Florida Fish and Wildlife Conservation Commission. The Legislature gave this new commission the authority to promulgate regulations affecting marine fisheries, freshwater fisheries, and wildlife.

#### 5.2.1.3 Reciprocal Agreements and Limited Entry Provisions

##### 5.2.1.3.1 Reciprocal Agreements

Florida statutory authority provides for reciprocal agreements related to fishery access and licenses. Florida has no statutory authority to enter into reciprocal management agreements.

##### 5.2.1.3.2 Limited Entry

Florida has no statutory provisions for limited entry in the blue crab fishery. Blue crabs are designated as a restricted species pursuant to Section 379.101(32) F.S., requiring harvesters to possess a restricted species endorsement to legally fish commercially for blue crabs.

#### 5.2.1.4 Commercial Landings Data Reporting Requirements

On a monthly basis, processors are required to report the volume and price of all saltwater products received and sold. These data are collected and published by the Florida Department of Environmental Protection (FDEP), Marine Fisheries Information System.

#### 5.2.1.5 Penalties for Violations

Penalties for violations of Florida laws and regulations are established in Section 379.407 F.S. Additionally, upon the arrest and conviction for violation of such laws or regulations, the license holder is required to show just cause as to reasons why his saltwater license should not be suspended or revoked.

#### 5.2.1.6 Annual License Fees

| | |
|---|---|
| Resident wholesale seafood dealer | |
| · county | $400.00 |
| · state | 550.00 |
| Nonresident wholesale seafood dealer | |
| · county | 600.00 |
| · state | 1,100.00 |
| Alien wholesale seafood dealer | |
| · county | 1,100.00 |
| · state | 1,600.00 |
| Resident retail seafood dealer | 75.00 |
| Nonresident retail seafood dealer | 250.00 |
| Alien retail seafood dealer | 300.00 |
| Saltwater products license | |
| · resident-individual | 50.00 |
| · resident-vessel | 100.00 |
| · nonresident-individual | 200.00 |
| · nonresident-vessel | 400.00 |

| | |
|---|---|
| · alien-individual | 300.00 |
| · alien-vessel | 600.00 |
| Recreational saltwater fishing license | |
| · resident (annual) | 17.00 |
| · nonresident (three day) | 17.00 |
| · nonresident (seven day) | 30.00 |
| · nonresident (annual) | 47.00 |
| Annual commercial vessel saltwater fishing license (recreational for hire) | |
| · 11 or more customers | 801.50 |
| · five-10 customers | 401.50 |
| · four or less customers | 201.50 |
| Optional pier saltwater fishing license (recreational users exempt from other licenses) | 501.50 |
| Optional recreational vessel license (recreational users exempt from other licenses) | 2,001.50 |

**5.2.1.7 Laws and Regulations**

Florida's laws and regulations regarding the harvest of blue crabs are uniform across the state. The following are general summaries of laws and regulations; the FWC's Bureau of Marine Enforcement should be contacted for more specific information. *The restrictions discussed in this FMP are current to the date of this publication and are subject to change at any time thereafter.*

**5.2.1.7.1 Size Limits**

Except as provided in subsection 68B-45.004(5), F.A.C., for crabs to be used as live bait, no person harvesting for commercial purposes shall possess any blue crabs measuring less than five inches measured from the tip of one lateral spine to the tip of the opposite lateral spine in quantities greater than 5% of the total number in each container in such person's possession. This minimum size limit does not apply to the harvest of peeler crabs.

**5.2.1.7.2 Protection of Female Crabs**

The harvest, possession, purchase, or sale of egg-bearing female crabs is prohibited. Egg-bearing blue crabs found in traps shall be immediately returned to the water free, alive, and unharmed.

**5.2.1.7.3 Gear Restrictions**

Except for harvest of peeler crabs and crabs used for live bait, only the following types of gear shall be used to harvest blue crabs in or from state waters:

- dip or landing net
- drop net
- fold-up trap with a square base panel no larger than one square foot

- hook and line gear
- push scrape
- trotline
- traps meeting the following specifications:
    1) Traps shall be constructed of wire with a minimum mesh size of $1^1/_2$ inches and have throats or entrances located only on a vertical surface. All traps shall have a maximum dimension of 24 x 24 x 24 inches or a volume of 8 cubic feet and a degradable panel that meets the specifications of subsection (7) of this rule.
    2) All traps shall have a buoy or a time release buoy attached to each trap or at each end of a weighted trotline which buoy shall be constructed of styrofoam, cork, molded polyvinyl chloride, or molded polystyrene, be of sufficient strength and buoyancy to float, and be of such color, hue and brilliancy to be easily distinguished, seen, and located. Buoys shall be either spherical in shape with a diameter no smaller than 6 inches or some other shape so long as it is no shorter than 10 inches in the longest dimension and the width at some point exceeds 5 inches. No more than 5 feet of any buoy line attached to a buoy used to mark a blue crab trap or attached to a trotline shall float on the surface of the water.
    3) Each trap used for harvesting blue crab for commercial purposes shall have the harvester's blue crab endorsement number permanently affixed to it. Each buoy attached to such a trap shall have the number permanently affixed to it in legible figures at least 2 inches high. The buoy color and license number shall also be permanently and conspicuously displayed on any vessel used for setting the traps and buoys, so as to be readily identifiable from the air and water, in the following manner:
        a) From the Air - The buoy design approved by the FWC shall be displayed and be permanently affixed to the uppermost structural portion of the vessel and displayed horizontally with the painted design up. If the vessel is an open design (such as a skiff boat), in lieu of a separate display, one seat shall be painted with buoy assigned color with permit numbers, unobstructed and no smaller than 10 inches in height, painted thereon in contrasting color. Otherwise the display shall exhibit the harvester's approved buoy design, unobstructed, on a circle 20 inches in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than 10 inches in height.
        b) From the Water - The buoy design approved by the FWC shall be displayed and be permanently affixed vertically to both the starboard and port sides of the vessel near amidship. The display shall exhibit the harvester's approved buoy design, unobstructed, on a circle 8 inches in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than 4 inches in height.
    4) The buoy attached to each trap used to harvest blue crab, other than those used to harvest for commercial purposes, shall have a legible "R", at least 2 inches high, permanently affixed to it. The trap shall have the harvester's name and address permanently affixed to it in legible letters. The buoy requirements of this subparagraph shall not apply to traps fished from a dock.

5) Each trap with a mesh size of $1^1/_2$ inches or larger shall have at least three unobstructed escape rings installed, each with a minimum inside diameter of $2^3/_8$ inches. One such escape ring shall be located on a vertical outside surface adjacent to each crab retaining chamber.
6) Each throat (entrance) in any trap used to harvest blue crabs shall be horizontally oriented, i.e., the width of the opening where the throat meets the vertical wall of the trap and the opening of the throat at its farthest point from the vertical wall, inside the trap, is greater than the height of any such opening. No such throat shall extend farther than 6 inches into the inside of any trap, measured from the opening where the throat meets the vertical wall of the trap to the opening of the throat at its farthest point from the vertical wall, inside the trap.
7) Subparagraphs one through six shall not apply to any trap used to harvest blue crabs for other than commercial purposes, which trap has a volume of no more than 1 cubic foot and is fished from a vessel, a dock, or from shore.

(1) (a) dip or landing net
(b) drop net
(c) fold-up trap with a square base panel no longer than one square foot
(d) hook and line gear
(e) push scrape
(f) trotline

(2) (a) Peeler crabs may be harvested in traps constructed of wire with a minimum mesh size of 1 inch and with the throats or entrances located only on a vertical surface. Such traps shall have a maximum dimension of 24 x 24 x 24 inches or a volume of 8 cubic feet and a degradable panel.
(b) Each trap used to harvest peeler crabs shall have buoys and be identified as described in subparagraphs (a)2 and (a)3 or (a)4 of this subsection.
(c) All peeler crabs harvested must be kept in a container separate from other blue crabs.
(d) Each trap used to harvest peeler crabs shall only be baited with live male blue crabs. Any trap used to harvest blue crabs that is baited with anything other than live male blue crabs shall meet the requirements of paragraph 1) of this rule.

(3) In addition to the allowable gear provided for in paragraphs 1) and 2) above, blue crabs harvested in fresh water may be harvested with gear permitted by the FWC.

(4) Blue crabs may be harvested as an incidental bycatch of shrimp trawls lawfully harvesting shrimp, provided the amount of blue crabs so harvested does not exceed 200 pounds of blue crabs per vessel per trip.

(5) Blue crabs not meeting size requirements may be harvested as a direct catch by or with a dip or landing net or as bycatch of live bait shrimp trawls, provided that the total amount of blue crab harvested in either case does not exceed ten gallons per person per vessel per day, whichever is less. Undersized blue crabs so harvested shall be maintained alive and shall be sold, bought, bartered, or exchanged solely for use as live bait. Blue crabs harvested as bycatch of live bait shrimp trawls shall be counted for purposes of determining compliance

with paragraphs (4) above and (6) below. No person harvesting blue crabs as a directed catch by or with a dip or landing net shall, on the same trip, harvest blue crabs using any other gear.

(6) Blue crabs may be harvested as an incidental bycatch of other species lawfully harvested with other types of gear so long as the amount does not exceed the bag limit and does not violate any other applicable provision of law.

(7) A trap shall be considered to have a degradable panel if one of the following methods is used in construction of the trap:

(a) The trap lid tie-down strap is secured to the trap at one end by a single loop of untreated jute twine. The trap lid must be secured so that when the jute degrades, the lid will no longer be securely closed.

(b) The trap lid tie-down strap is secured to the trap at one end with a corrodible loop composed of non-coated steel wire measuring 24-gauge or thinner. The trap lid must be secured so that when the loop degrades, the lid will no longer be securely closed.

(c) The trap lid tie-down strap is secured to the trap at one end by an untreated pine dowel no larger than two inches in length by $^3/_8$ inch in diameter. The trap lid must be secured so that when the dowel degrades, the lid will no longer be securely closed.

(d) The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches in height by 3 inches in width. This opening must be laced, sewn, or otherwise obstructed by a single length of untreated jute twine knotted only at each end and not tied or looped more than once around a single mesh bar. When the jute degrades, the opening in the sidewall of the trap will no longer be obstructed.

(e) The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches in height by 3 inches in width. This opening must be obstructed with an untreated pine slat or slats no thicker than $^3/_8$ inches. When the slat degrades, the opening of the sidewall of the trap will no longer be obstructed.

(f) The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches in height by 3 inches in width. The opening may either be laced, sewn, or otherwise obstructed by noncoated steel wire measuring 24-gauge or thinner or be obstructed with a panel of ferrous single-dipped galvanized wire mesh made of 24-gauge or thinner wire. When the wire or wire mesh degrades, the opening in the sidewall of the trap will no longer be obstructed.

(g) The trap contains at least one sidewall with a vertical rectangular opening no smaller in either dimension than 6 inches by 3 inches in width. The opening may be obstructed with a rectangular panel made of any material, fastened to the trap at each of the four corners of the rectangle by rings made of noncoated 24-gauge or thinner wire or single strands of untreated jute twine. When the corner fasteners degrade, the panel will fall away and the opening in the sidewall of the opening in the sidewall of the trap will no longer be obstructed.

(8) No person shall harvest or attempt to harvest blue crabs with any trap seaward of nine nautical miles from shore on the Gulf of Mexico or seaward of three nautical miles from shore on the Atlantic Ocean.
(9) No person shall harvest any blue crabs for commercial purposes with any trap unless such person possesses a valid saltwater products license to which is affixed both a blue crab endorsement and a restricted species endorsement.

**5.2.1.7.4 Closed Areas and Seasons**

Harvesting of blue crabs with any trap seaward of nine nautical miles from shore on the Gulf of Mexico is prohibited.

**5.2.1.7.5 Bag/Possession Limits**

Except for persons possessing a blue crab endorsement and a restricted species endorsement, no person shall harvest in any one day or possess while in or on state waters more than 10 gallons of whole blue crabs. Blue crabs may be harvested as incidental bycatch of shrimp trawls lawfully harvesting shrimp, with a maximum of 200 pounds of blue crabs per vessel per trip. Blue crabs less than 5 inches CW, harvested as a directed catch with a dip or landing net or as bycatch of live bait shrimp trawls, may not exceed 10 gallons per person or per vessel per day, whichever is less.

**5.2.1.7.6 Other Restrictions**

Traps used to harvest blue crabs or peeler crabs may be worked during daylight hours only. The pulling of traps from one hour after official sunset until one hour before official sunrise is prohibited.

It is unlawful for any person to willfully molest any traps, lines, or buoys belonging to another without permission of the license-holder.

**5.2.1.8 Florida Statutes and Programs Relating to Habitat**

**5.2.1.8.1 Land Conservation Act of 1972**

The Florida Legislature passed the Land Conservation Act of 1972, and Florida voters subsequently approved a bond issue of $240M to purchase "those areas of ecological significance the development of which by private or public works would cause the deterioration of submerged lands, inland or coastal water, marshes, or wilderness areas essential to the environmental integrity of adjacent areas."

**5.2.1.8.2 State Parks and Preserves**

Section 258.47, Florida Statutes (F.S.), allows for establishment of aquatic preserves, defined in section 258.37, F.S., as "an exceptional area of submerged lands and its associated waters set aside for being maintained essentially in its natural or existing condition." Aquatic preserves are protected against destruction of bottom or shoreline, except under certain specified conditions which are set forth in Section 258.43. There are 42 aquatic preserves throughout Florida with 37 of these preserves established along estuarine and continental shelf areas. Maintenance of aquatic preserves and attendant rules and regulations are addressed in sections 258.42 and 258.43, F.S.

**5.2.1.8.3 Florida Coastal Zone Management Act of 1978**

Chapter 380, Part II, F.S., authorized the former Department of Environmental Regulation to develop a state coastal management program based on the provisions of existing state law and submit the management program to the USDOC for approval. The 1981 federal approval of the Florida Coastal Management Program (FCMP) provided the state of Florida with annual implementation grants and the authority to renew federal activities that affect any land or water use, or natural resources of the state's coastal zone to ensure consistency with the requirements of the state's coastal management program. All direct and indirect federal actions are subject to state review.

Through the FCMP, the state of Florida reviews activities conducted by or on behalf of federal agencies, federally-funded activities, and federal licenses and permits for activities specified in section 380.23(3)(c), F.S., to ensure consistency with the 23 Florida Statutes and their implementing regulations which are included in the FCMP.

The FCMP, administered by the Department of Community Affairs (DCA), utilizes a network of ten state agencies and five water management districts to ensure the wise use and protection of state's water, cultural, historic, and biological resources; to minimize the state's vulnerability to coastal hazards; to ensure compliance with the state's transportation system; and to protect the state's proprietary interest as the owner of sovereign submerged lands. The DCA shares the responsibility for administering the state's review of federal licenses and permits that require a state license or permit with the state's environmental permitting agencies.

On behalf of the state, the DCA acts in consultation with the Executive Office of the Governor and state agencies charged with the implementation of the 23 statutes included in the FCMP to ensure that federal actions which impact the state of Florida's coastal zone comply with all applicable state requirements.

**5.2.1.8.4 National Estuarine Research Reserves and National Marine Sanctuaries**

Section 315 of the CZM Amendments of 1976 (P.L. 94-370) provided for acquisition, development, or operation of estuarine sanctuaries to serve as natural field laboratories in which to study and gather data on the natural and human processes occurring within the estuaries. Florida has established national estuarine sanctuaries in Rookery and Apalachicola bays and the Florida Keys National Marine Sanctuary. Creation of a fourth reserve on the Florida east coast is also underway.

#### 5.2.1.8.5 Florida Preservation Act 2000

Chapter 259, F.S., created a trust fund for acquisition of sensitive state lands.

#### 5.2.1.8.6 Florida Air and Water Pollution Control Act

Chapter 403, F.S., provides protection for fish and wildlife as well as water quality.

#### 5.2.1.8.7 Ecosystem Management Implementation Strategy

This statute provides the USFWS the authority to protect seagrasses throughout Florida waters.

#### 5.2.1.8.8 Seagrass Protection Zones

Seagrass Protection Zones provide limited entry or no entry zones for boaters in sensitive seagrass areas throughout the state.

#### 5.2.1.8.9 Beach and Shore Preservation

Section 161, F.S., authorizes the Bureau of Beaches and Coastal Systems within the FDEP to regulate construction on or seaward of the state's beaches. A coastal construction control line was established and Section 161, F.S., regulates construction activities located seaward of the mean high water line. Construction activities that occur seaward of the coastal construction control line are required to comply with special siting and structural design requirements which ensure the protection of beach/dune systems.

#### 5.2.1.8.10 Saltwater Fisheries

Section 379, F.S., authorizes the FWC to administer, supervise, develop, and conserve the marine fishery resources in state waters, protect and enhance the marine and estuarine environment, protect marine and estuarine water quality, and protect threatened and endangered marine species. The FWC is charged with the development of regulations governing the taking and use of the state's recreational and commercial marine fishery resources.

#### 5.2.1.8.11 Water Resources

Section 373, F.S., authorizes the FWC and the water management districts to regulate the construction and operation of storm-water management systems and the withdrawal, diversion, storage, and consumption of water. Particularly relevant to marine habitat protection is Part I, which authorizes the development of the State Water Resources Plan and the District Water Management Plans, both of which describe programs related to water supply, water quality, flood management, and natural systems. Section 373.042 establishes criteria for determining minimum flows for surface waters and minimum water levels for groundwater and surface waters, in order to limit withdrawals that would be significantly harmful to the water resources or ecology of the area. Part IV addresses permitting criteria for activities in surface waters and wetlands in order to preserve natural resources, fish, and wildlife.

#### 5.2.1.8.12 Florida Environmental Reorganization Act of 1993

Chapter 93-213, Laws of Florida, Section 2(2) (c) provides several broad guidance statements related to protection of Florida's water resources, including protecting the functions of entire ecological systems through enhanced coordination of public land acquisition, regulatory, and planning programs.

#### 5.2.1.9 Historical Changes to Regulations

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1941: The first blue-crab specific regulation in Florida was enacted included a $5^{1}/_{2}$ inch CW minimum size limit and a May 15 - August 15 prohibition of the possession of egg-bearing females.

1947: Closed season was removed making it legal to harvest egg-bearing females year-round.

1963: The take or possession of egg-bearing females from waters east of the Aucilla River was prohibited.

1973: Requirements for possessing and displaying the number of a current state permit and escape gap regulation were passed. It was also deemed unlawful to offer for sale any egg-bearing females taken from state waters.

1978: Minimum CW size limit was reduced to 5 inches The possession of undersized blue crabs, for the purpose of sale, in quantities greater than 10% of the total catch, was prohibited unless authorized by a special permit for the soft-shell crab or bait trade.

1985: The Marine Fisheries Information System (Trip Ticket) obtained data on number of trips, pounds caught per trip, and number of traps per trip.

1994: The Florida Marine Fisheries Commission designated blue crab as a restricted species, retained the minimum size limit of 5 inches for commercial harvest, repealed the 10% tolerance for undersized crabs, allowed a bycatch possession limit of 200 pounds of blue crabs per trip on shrimp trawls, prohibited all harvest and possession of egg-bearing blue crabs, and established a daily recreational bag limit of ten (10) gallons of blue crabs. There were additional changes to some of these regulations that allowed some retention of undersized crabs and mandated the use of three escape rings larger than $2^3/_8$ inch inside-diameter in each trap; biodegradable trap components were enacted to prevent 'ghost-fishing' by lost traps.

1995: The development of a peeler-trap fishery that used small meshed traps without escape rings led to regulations that only blue crab traps with larger, $1^1/_2$ inch mesh required escape rings and that only live male crab could be used as 'bait' in peeler traps.

1998: The use of blue crab traps to harvest blue crabs in federal waters adjacent to Florida was prohibited, mainly as a way to eliminate the use of these traps to catch finfish. A moratorium was placed on the issuance of new blue crab endorsements beginning in June 1998 and this was extended through June 2007 in preparation for an effort management plan that involves limiting the number of fishers and the number of traps they are allowed to possess.

2004: To eliminate the take of stone crabs in blue crab traps prior to the opening of the stone crab fishery, the waters three to nine nautical miles offshore of the area north of the Suwannee River were closed to blue crab traps during September 20 - October 4 each year.

2005: The closure of waters three to nine nautical miles offshore was extended to all of the Gulf coast of Florida during September 20 - October 4 each year.

2008: The Blue Crab Effort Management Plan (BCEMP) separated the blue crab endorsements by product type: hard shell (VH), soft shell (VS), non-transferable (VN) and incidental catch (VI) along with issuing tags for each trap fished based that was based on where and how the blue crab trap was fished (inshore, offshore, soft shell and hard shell). The BCEMP is structured so fishermen must annually re-qualify with landings in order to renew their endorsements.

2009: Fees for trap tags were implemented.

### 5.2.2 Alabama

#### 5.2.2.1 Alabama Department of Conservation and Natural Resources

Alabama Department of Conservation and Natural Resources (ADCNR)
Marine Resources Division (MRD)
P.O. Box 189
Dauphin Island, Alabama 36528
(251) 861-2882

The Commissioner of the Alabama Department of Conservation and Natural Resources (ADCNR) holds management authority of fishery resources in Alabama. The Commissioner may promulgate rules or regulations designed for the protection, propagation, and conservation of all seafood. He may prescribe the manner of taking, times when fishing may occur, and designate areas where fish may or may not be caught.

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulations other than those of an emergency nature. Among this series of events are: (a) the advertisement of the intent of the regulation; (b) a public hearing for the regulation; (c) a 35-day waiting period following the public hearing to address comments from the hearing; and (d) a final review of the regulation by a Joint House and Senate Review Committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies and regulations of the ADCNR. The board consists of the Governor, the ADCNR Commissioner, the Director of the Auburn University Agriculture and Extension Service, and ten board members.

The MRD has responsibility for enforcing state laws and regulations, for conducting marine biological research, and for serving as the administrative arm of the commissioner with respect to marine resources. The division recommends regulations to the commissioner.

Alabama has a habitat protection and permitting program and a federally-approved CZM program.

#### 5.2.2.2 Legislative Authorization

Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that affect marine fisheries.

#### 5.2.2.3 Reciprocal Agreements and Limited Entry Provisions

##### 5.2.2.3.1 Reciprocal Agreements

Alabama statutory authority provides for reciprocal agreements with regard to access and licenses. Alabama has no statutory authority to enter into reciprocal management agreements.

##### 5.2.2.3.2 Limited Entry

Alabama has no statutory provisions for limited entry.

#### 5.2.2.4 Commercial Landings Data Reporting Requirements

Alabama law requires that wholesale seafood dealers file monthly reports by the tenth of each month for the preceding month. Under a cooperative agreement, records of sales of seafood products are now collected jointly by the NMFS and ADCNR port agents.

#### 5.2.2.5 Penalties for Violations

Violations of the provisions of any statute or regulation are considered Class C misdemeanors and are punishable by fines up to $500 and/or up to three months in jail.

#### 5.2.2.6 Annual License Fees

*The following is a list of license fees current to the date of publication; however, they are subject to change at any time.* Nonresident fees for commercial hook and line licenses, recreational licenses, and seafood dealer licenses may vary based on the charge for similar fishing activities in the applicant's resident state.

| | |
|---|---|
| Commercial trap license (over five traps) | |
| Resident | $51.00 |
| Nonresident FL | $325.00 |
| Nonresident GA | $189.00 |
| Nonresident LA | $660.00 |
| Nonresident MS | $201.00 |
| Nonresident TX | $2,620.00 |
| Nonresident AOS (all other states) | $101.00 |
| Recreational Trap (five traps maximum) | |
| Recreational saltwater fishing license required | $21.20 |
| Seafood dealer | |
| Resident | $201.00 |
| Nonresident | $401.00 |
| Vehicle license | $101.00 |

#### 5.2.2.7 Laws and Regulations

Alabama laws and regulations regarding the harvest of crabs primarily address the type of gear used for the commercial fishery. The following is a general summary of these laws and regulations. *They are current to the date of this publication and are subject to change at any time thereafter. The ADCNR/MRD should be contacted for specific and up-to-date information.*

#### 5.2.2.7.1 Size Limits

It is unlawful to take, possess, transport, or sell blue crabs that are smaller than 5 inches in width as measured across the widest points of the upper shell, except when a commercial crabber takes a soft shell or pre-molt shell solely for the purpose of shedding or if sublegal crabs are held in a maximum of two work boxes aboard the crabber's vessel. Licensed live bait dealers are exempt from the minimum size requirement when the crabs are sold solely for bait. Licensed seafood dealers may possess sub-legal pre-molt crabs solely for processing as soft-shell crabs if they are held separately in a container marked peelers or busters.

#### 5.2.2.7.2 Protection of Female Crabs

None.

#### 5.2.2.7.3 Gear Restrictions

Individuals can use up to, but not more than, five crab traps for taking crabs for personal, noncommercial purposes with a recreational saltwater fishing license in areas open to commercial crabbing. In certain listed closed areas, recreational traps may be placed but be physically attached to a pier, dock, piling, bulkhead, boathouse, other structure or the shoreline by a line and placed no farther than 10 feet away with no more than five traps per property. All recreational crab traps shall be marked with an orange float of not less than 6 inches in diameter with the letter "R" at least 2 inches high permanently affixed.

It is unlawful to set or place any trap used for the taking of crabs in any man-made canal, named waterway, or within 300 feet of any marked navigational channel, public boat launching ramp, or public pier. They also may not be placed in any manner so as to prevent ingress or egress to or from any pier, wharf, dock, marina, or boat launching ramp. Traps shall not exceed 27 cubic feet in volume. It is unlawful to take crabs from traps belonging to another without written authorization. Each commercial crab trap shall be marked with at least one buoy no smaller than 6 inches in diameter, and at least one half of the buoy shall be white. Each buoy shall be marked with the fisherman's identification number. Buoys must be attached to the traps by use of a weighted line. Plastic bottles are prohibited for use as a commercial trap buoy. The owner identification number must be painted or affixed to either side of the vessel used to harvest crabs from said traps. It is unlawful to remove commercial crab traps from the water or remove crabs from commercial crab traps from sunset to one hour before sunrise the following day. Crab traps that are no longer serviceable or in use must be removed from the water by the owner. Any unidentified, improperly marked, or illegally placed trap shall be confiscated.

Recreational crabbers must obtain a saltwater fishing license to engage in the following crabbing activities:

- Recreational crab pots (limited to 5 properly placed and marked pots)
- Trot line with baited hooks (5 hooks maximum)
- Hand line/rope/string with hook
- Rod and reel with baited hook
- Rod and reel with tied bait
- Gigging
- Cast Netting

It is unnecessary for recreational crabbers to have a saltwater fishing license to engage in the following crabbing activities:

- Trot line with tied bait
- Hand line/rope/string with tied bait and dip net

#### 5.2.2.7.4 Closed Areas and Seasons

It is illegal to attempt to take or harvest or to take or harvest crabs by the use of crab traps north of a line described as Interstate Highway 10 eastbound lane (except that portion of Interstate Highway 10 which lies north of State Highway 90 Battleship Parkway, in which case the line follows the Battleship Parkway). It is illegal to take crabs for commercial purpose in certain named rivers, creeks, bayous, or other named water bodies.

#### 5.2.2.7.5 Bag/Possession Limits

Licensed recreational shrimp boats taking crabs in open water are limited to no more than one five-gallon container of legal size crabs per boat. If crabs are taken by recreational shrimp boats for bait, they are restricted to the number of crabs held by a one-gallon container per boat per day but are exempt from the minimum size limit. Licensed commercial shrimpers are limited to one five-gallon container of legal size crab per boat.

#### 5.2.2.7.6 Other Restrictions

All containers of Alabama crabs must be tagged with the crabber's full name, identification number and date harvested. Crabs imported from another state must be taken and marked in accordance with that state's laws and a bill of sale showing the nonresident crabber/dealer name, address, pounds purchased and date of purchase, and records must be kept for one year. Commercial crabbers taking crabs from other states may import the crabs if taken legally and marked with the crabber's full name, license number, and date of harvest. All licenses, tags, invoices, or other information required by law must be immediately available for inspection, upon request, by a conservation enforcement officer or other authorized agent.

### 5.2.2.8 Alabama Statutes and Programs Relating to Habitat

Habitat protection programs in the Alabama estuarine area are provided by local, state, and federal agencies. Federal protective programs are pursuant to Section 10 of the River and Harbor Act of 1899 (33 U.S.C. 403), the Federal Water Pollution Control Act, and the Fish and Wildlife Coordination Act. Each of these acts provides protection to the estuarine area by consideration of fish and wildlife interest for any construction, dredge and fill, channelization, and waste discharge into the environment. Input is requested by the lead agency, usually the USACOE, by circulating the permit request along with a detailed description of requested work among various government agencies (local, state, and federal), as well as private clubs and individuals. The ADCNR/MRD investigates and provides critical review of all USACOE permits in the estuarine area.

State pollution control standards were revised in 1965 (Acts of Alabama, 1965 Regular Session, Act Number 574) strengthening requirements for effluent treatment of industrial and municipal wastes. Standards adopted categorized the Alabama estuarine area with the exception of a few isolated areas as ‘fish and wildlife’ best use classification or better. The Alabama Oil and Gas Board has statutory authority over control and disposal of wastes from oil and gas wells in Alabama, and the board cooperates with the Alabama Department of Environmental Management in controlling related wastes. The adoption of the Water Pollution Control Act with subsequent enactment of water quality standards has reversed water degradation trends of the 1950s and early 1960s.

Additional protection to the Alabama estuarine area was provided in 1976 with the enactment of the Coastal Area Board Act (Act Number 534) by the Alabama Legislature. This act was created to promote, improve, and safeguard lands and waters located in the coastal area of Alabama through a comprehensive and cooperative program designed to preserve, enhance, and develop such valuable resources for the present and future well-being and general welfare of the citizens of Alabama. The director of the MRD is one of nine permanent board members of the Alabama Coastal Area Board.

In 1982, commissions and boards involved with protection of air, land, and water were combined by law in the creation of the Alabama Department of Environmental Management (Acts of Alabama, 1982 Regular Session, Act Number 82-612). This increased the efficiency of habitat protection for Alabama by incorporating all existing regulations and standardizing the philosophy of environmental protection.

The MRD is responsible for inspecting and commenting on any projects within the coastal zone which are being considered for permit to determine what effect those projects would have on the habitat and the marine resources.

Protection to the estuarine area is provided by local county health departments through the frugal issuance of septic tank permits. The primary intent of county health department regulations is public health oriented; however, a secondary benefit is realized by preventing over-enrichment of certain estuarine habitats. Local zoning ordinances have the potential of protecting estuarine areas by either eliminating activities which degrade or minimizing degradation by localizing harmful activities.

#### 5.2.2.9 Historical Changes to Regulations

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1971: Repealed the regulation prohibiting the taking of spawn crabs.

1989: Amendment to regulation 220-3-.03 that stated that it was unlawful to remove commercial crab traps from the water or remove crabs from commercial crab traps during the hours from sunset to one hour before sunrise the following day. Also, this amendment stated each commercial crab trap should be marked with at least one buoy no smaller than 6 inches diameter and at least one-half of the buoy should be white.

1996: Amendment to regulation 220-3-.31 which makes it unlawful to sell for commercial purposes blue crabs that measure less than 5 inches instead of 4 inches found in previous versions of the regulation

1999: Extensive amendments to regulation 220-3-.31 clarifying how buoys, crab pots, crab containers for blue crabs and soft shell crabs should be labeled. Also this amendment allows for the possession of two intermediate 'work boxes' and under what circumstances a container is no longer considered a 'work box'. This amendment details the regulations for the taking of crabs for bait as well as the amount of blue crab by-catch that may be retained by commercial shrimpers. Recreational crabbing (by crab pot) is detailed, including where they are permitted, how they are to be attached and marked. Improperly marked or illegally placed crab traps shall be considered a nuisance and may be confiscated.

2001: Amendments to regulation 220-3-.31 clarifying certain areas prohibited to commercial crabbing. This regulation clarifies proximity to navigational channels, public ramps, and public piers.

2002: Amendments to regulation 220-3-.31 removing the use of the buoy color code system and using identification numbers on buoys to identify commercial crab pots. Clarification of areas prohibited to crabbing. Clarifying that nuisance crab pots may be confiscated by MRD enforcement or other authorized agent of the ADCNR.

2004: Amendments to regulation 220-3-.31 requiring the identification number of the commercial harvester's crab traps to be displayed clearly on the vessel used for harvesting blue crabs. Redefinition and clarification of specific areas prohibited to the taking of blue crab.

2012: Amendments to regulation 220-3-.31 clarifying position of crab trap buoy markings and size of identification numbers so that numbers are easily seen and identified. Redefinition and clarification of specific areas prohibited to the taking of blue crabs.

### 5.2.3 Mississippi

#### 5.2.3.1 Mississippi Department of Marine Resources

Mississippi Department of Marine Resources (MDMR)
1141 Bayview Avenue
Biloxi, Mississippi 39530
(228) 374-5000

The MDMR administers coastal fisheries and habitat protection programs. Authority to promulgate regulations and policies is vested in the Mississippi Commission on Marine Resources (MCMR), the controlling body of the MDMR. The MDMR consists of five members appointed by the Governor. The MDMR has full power to "manage, control, supervise, enforce, and direct any matters pertaining to all saltwater aquatic life and marine resources under the jurisdiction of the commission" (Mississippi Code Annotated 4915-11).

Mississippi has a habitat protection and permitting program and a federally-approved CZM program.

#### 5.2.3.2 Legislative Authorization

Title 49, Chapter 15 of the Mississippi Code of 1972, annotated, contains various restrictions regarding the harvest of marine species. This chapter also authorizes the MDMR to promulgate regulations affecting the harvest of marine fishery resources. Title 49, Chapter 27 contains the Wetlands Protection Act, and its provisions are also administered by the MDMR.

#### 5.2.3.3 Reciprocal Agreements and Limited Entry Provisions

##### 5.2.3.3.1 Reciprocal Agreements

Section 49-15-15 provides statutory authority for the MDMR to enter into advantageous interstate and intrastate agreements with proper officials, which directly or indirectly result in the protection, propagation, and conservation of the seafood of the state of Mississippi, or to continue any such agreement already in existence. This section also gives the MDMR statutory authority to arrange, negotiate, or contract for the use of available federal, state, and local facilities which would aid in protection, propagation, and conservation.

##### 5.2.3.3.2 Limited Entry

Section 49-15-16 provides that the MDMR may develop a limited entry fisheries management program for all resource groups. Section 49-15-31(2) prohibits a nonresident from purchasing a commercial license if the nonresident's state of domicile likewise prohibits the sale of such license to a Mississippi resident.

#### 5.2.3.4 Commercial Landings Data Reporting Requirements

Title 22 Part 9 of the MDMR establishes reporting requirements for various fisheries and types of fishery operations. It also provides for confidentiality of data and penalties for falsifying or refusing to supply such information.

#### 5.2.3.5 Penalties for Violations

Penalties for violations of Mississippi laws and regulations regarding theft of crabs or crab pots are provided for in Section 49-15-92. Every person who shall steal, remove, take or carry away crab pots, the property of another used to catch saltwater crabs from said crab pots, shall be guilty of petit larceny, and on conviction shall be sentenced to serve a term in the county jail not to exceed (3) months or be fined a sum not less than $100.00 or both.

Additional penalties of Mississippi laws and regulations are provided in Section 49-15-63, Mississippi Code of 1972, annotated. Any person, firm, or corporation violating any of the provisions of Chapter 49-15 or any ordinance duly adopted by the MCMR shall on conviction be fined not less than $100 nor more than $500 for the first offense; and not less than $500 nor more than $1,000 for the second offense when such offense is committed within a period of three years from the first offense; and not less than $2,000 nor more than $4,000, or imprisonment in the county jail for a period not exceeding 30 days for any third or subsequent offense when such offense is committed within a period of three years from the first offense and upon conviction of such third or subsequent offense. It shall be the duty of the court to revoke the license of the convicted party and of the boat or vessel used in such offense, and no further license shall be issued to such person, or for said boat to engage in catching or taking of any seafood from the waters of the state of Mississippi for a period of one year following such conviction. Further, upon conviction of such third or subsequent offense committed within a period of three years from the first offense, it shall be the duty of the court to order the forfeiture of any equipment or nets used in such offense. Provided, however, that equipment shall not mean boats or vessels. Any person convicted and sentenced under this section shall not be considered for suspension or other reduction of sentence. Except as provided under subsection (5) of Section 49-15-45, any fines collected under this section shall be paid into the seafood fund.

#### 5.2.3.6 Annual License Fees

The following is a list of license fees for activities related to the capture, sale, or transport of blue crab. *They are current only to the date of publication and may change at any time.* Nonresident fees may vary based on the charge for similar fishing activities in the applicant's state of residence.

| | |
|---|---|
| Recreational | $5.00 |
| Resident commercial crab trap license | 75.00 |
| Resident commercial crab trawl license | 75.00 |
| Nonresident commercial crabbing license | 200.00 |
| Seafood dealer/processor | 100.00 |

#### 5.2.3.7 Laws and Regulations

Section 49-15-84(1) designates that the MDMR shall coordinate with the Gulf Coast Research Laboratory in the development of regulations for the purpose of taking *Callinectes sapidus* (blue crab) or allied species. Title 22 Part 4 of the MDMR contains regulations regarding the taking of crabs from Mississippi territorial and inland waters. The following is a general summary of these laws and regulations. *They are current to the date of this publication and are subject to change at any time thereafter. The MDMR should be contacted for specific and up-to-date information.*

#### 5.2.3.7.1 Size Limits

It is unlawful for any person to catch, destroy, confine, hold, or have in his possession, whether for individual use or for market, any blue crab or allied species of a smaller size than five inches measured from the tip of one lateral spine across the back of the shell to the tip of the opposite lateral spine; provided that peeler crabs and soft-shell crabs are exempt from these limitations. Conservation officers may inspect any catch for violations of any of these provisions.

#### 5.2.3.7.2 Protection of Female Crabs

It is unlawful to catch, have, or have in possession any female sponge crab or any female crab bearing visible eggs at any time within marine waters. It is not unlawful to catch those crabs unintentionally if the crabs are immediately returned to the water.

Any person, firm, or corporation possessing egg-bearing crabs in Mississippi must have a bill of laden or sales receipt from an out of state dealer or harvester from a state where egg-bearing crabs may be legally harvested.

#### 5.2.3.7.3 Gear Restrictions

Sections 49-15-96 and 49-15-46 state that licensed shrimp and oyster vessels, respectively, may keep, in whole, for personal consumption, three dozen blue crabs (portunidae family). This exemption for personal consumption does not apply to crabs that are otherwise illegal to possess or catch. Trawls used for taking crabs must not exceed the maximum allowable dimensions specified for shrimp and must comply with all other regulations governing the use of a trawl.

It is unlawful for any person, firm, or corporation fishing for crabs to be offered for sale by means of crab traps or crab pots to fail to mark each said trap or pot with the corresponding commercial crab license number set out on the trap or pot in such a manner to be clearly visible to an inspecting officer. All crab traps must be permanently marked for ownership by a corrosion resistant metal or plastic tag attached to the trap. The tag must be supplied by the fishermen and must be legibly stamped with license holder's full name.

In lieu of marking said crab traps or pots with corresponding license numbers, any licensed crab fisherman may obtain a registered color code design from the Chief Inspector of the MDMR Law Enforcement Division or his designee. Once obtained, this color code must be placed on each buoy or float and painted or affixed to each side of the vessel used to harvest crabs from said traps or pots. Floats marking crab traps must be at least 6 inches in width, 6 inches in length, 6 inches in height, and be of a highly visible color.

It is unlawful for any person fishing for crabs for personal use or consumption by means of crab traps or crab pots to use in excess of six such traps or pots per household; and each said trap or pot shall be marked with the owner's name in such a manner to be clearly visible to an inspecting officer. Crab trap floats must be visibly marked with corresponding recreational crab license number. In addition, Title 22 Part 4 requires that all crab traps or pots fished from a boat or vessel must also be marked with that boat or vessel's Mississippi registration identification. State statute 49-15-84 permits the taking of crabs with drop nets without a license.

It is unlawful for any person, firm, or corporation to attach any buoy or float to any crab trap with materials other than lines of nylon, hemp, cotton, or woven synthetic materials which can easily be cut with a standard steel knife.

It is unlawful for any person, firm, or corporation to remove crabs from crab traps or pots that are not specifically licensed or permitted to said person, firm, or corporation.

The MCMR may establish a maximum number of crab pots allowable per license.

**5.2.3.7.4 Closed Areas and Seasons**

It is unlawful for any person, firm, or corporation to place or cause to be placed any crab traps or pots north of the Interstate 10 (I-10) in the three coastal counties. It is unlawful for any person, firm, or corporation to commercially take crabs from the marine waters north of the CSX railroad bridge in the three coastal counties in Mississippi (Jackson, Harrison, and Hancock).

It is unlawful for any person, firm, or corporation to place or cause to be placed any crab trap or pot in any marked channel or fairway.

It is unlawful for any person, firm, or corporation to harvest or attempt to harvest or possess any crabs between January 1 and March 31 of each year while trawling within the area bounded by the following line: beginning at a point on the Mississippi-Alabama border due south of the "Intracoastal Waterway Grand Island Channel Light 1," thence running north to said "Light 1," thence running northeasterly along the "Intracoastal Waterway Marianne Channel" through "Buoy 22," "Light 18," "Buoy 12," to "Light 8," thence running northeasterly along the most direct line to "Lighted Buoy 4," thence running southeasterly along the most direct line to "Cat Island Channel Buoy E," thence running due south to a point on the Louisiana-Mississippi border; thence running westerly along the Louisiana-Mississippi border to the point due south of the "Intracoastal Waterway Grand Island Channel Light 1."

It is unlawful to harvest from crab traps from 30 minutes after legal sunset to 30 minutes before legal sunrise the following day. It is not unlawful to remove crab traps from the water if done so unintentionally in legal trawling activities providing traps are immediately returned to the water.

Section 49-15-84.1 allows the MCMR to establish a closed season for the use of crab traps in the public waters of this state. The commission may designate the closed season as not less than 10 days no more than 30 days per year. Any crab trap remaining in the public waters after the expiration to the seventh day of a closed season may be considered as abandoned under the regulations established by the commission.

#### 5.2.3.7.5 Bag/Possession Limits

There are no bag or possession limits in effect for the blue crab fishery in Mississippi. Possession limits apply to licensed commercial shrimp and oyster vessels of three dozen crabs per vessel for personal consumption, not sale (see Section 5.2.3.7.3).

#### 5.2.3.7.6 Other Restrictions

None.

### 5.2.3.8 Mississippi Statutes and Programs Relating to Habitat

Section 3 of the Mississippi Coastal Program (1980) includes three separate objectives for habitat protection. These are habitat degradation which determines safe concentrations of toxicants and regulation of discharge at allowable levels; habitat destruction which includes regulation of ditching and draining, dredging and filling, dam construction, alteration of barrier islands, etc.; and habitat creation which provides for marsh creation from dredged spoils, artificial reef construction, and creation of seagrass beds.

The Mississippi Department of Environmental Quality (MDEQ) is the regulatory agency for the state for all purposes of federal air and water pollution legislation and programs and is also empowered to promulgate standards of water and air quality consistent with existing federal regulations.

Management of the state's marine resources is carried out by the MDMR. The MDMR has the authority to manage, control, supervise, and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency. The MDMR has jurisdiction and control over all marine aquatic life and all public and natural oyster reefs and oyster bottoms of the state of Mississippi. Additionally, the MDMR administers the state CZM program, the Mississippi Wetlands Protection Law of 1973, and regulations pertaining to Marine Litter Title 22 Part 10.

### 5.2.3.9 Historical Changes to Regulations

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1963: Ordinance 21 was the first Ordinance to prohibit catch, sale, or possession of sponge crabs.

1975: Ordinance 68 limited fishing for sponge crabs only within one mile of Horn, Ship or Petit Bois Islands.

1977: Ordinance 73 repealed Ordinance 68 and prohibited fishing for sponge crabs everywhere in Mississippi.

Ordinance 74 repealed Ordinance 73 and prohibited fishing for sponge crabs south of the Intracoastal and east of the Gulfport Ship Channel (later called the sanctuary area).

1978: Ordinance 88 repealed Ordinance 74 and reinstated the complete ban on sponge crab harvest.

1979: Ordinance 92 repealed Ordinance 88 and set a season for the total sponge crab harvest ban from June 15 to August 15. The sanctuary area was reinstated for the entire year.

1981: Ordinance 106 repealed Ordinance 92 and eliminated the sponge crab harvest ban during June through August, but retained the sanctuary area.

1983: The National Park Service prohibited all commercial fishing within one mile of the shoreline of all Gulf Island National Seashore barrier islands through CFR 36 Chapter 1 Part 2 Section 2.3.

1988: Ordinance 4.003 prohibited the placing of recreational or commercial crab traps north of the Interstate 10 (I-10) Highway in the three coastal counties.

1995: Ordinance 4.004 prohibited commercial take of crabs from the marine waters north of the CSX rail road bridge in the three coastal counties of Mississippi.

1996: Ordinance 4.005 prohibited sponge crab harvest in the sanctuary area only.

1997: State Statute 49-15-84 eliminated the legal take of sponge crabs.

### 5.2.4 Louisiana

#### 5.2.4.1 Louisiana Department of Wildlife and Fisheries

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898-9000
(504) 765-2800

The LDWF is one of 21 major administrative units of the Louisiana government. A sevenmember board, the Louisiana Wildlife and Fisheries Commission (LWFC), is appointed by the Governor. Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The LWFC is a policy-making and budgetary-control board with no administrative functions. The Louisiana Legislature has authority to establish management programs and policies; however, the Legislature has delegated certain authority and responsibility to the LWFC and the LDWF. The LWFC may set possession limits, quotas, places, seasons, size limits, and daily take limits based on biological and technical data. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control, and operation of the functions, programs, and affairs of the department. The Secretary is appointed by the Governor with consent of the Senate.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. In this office, a Marine Fisheries Division (headed by the Division Administrator) performs "the functions of the state relating to the administration and operation of programs, including research relating to oysters, waterbottoms, and seafood including, but not limited to, the regulation of oyster, shrimp, and marine fishing industries" (Louisiana Revised Statutes 36:609). The Enforcement Division in the Office of the Secretary is responsible for enforcing all marine fishery statutes and regulations.

Louisiana has habitat protection and permitting programs and a federally-approved CZM program.

#### 5.2.4.2 Legislative Authorization

Title 56, Louisiana Revised Statutes (L.R.S.), contains statutes adopted by the Legislature that govern marine fisheries in the state and that empower LWFC to promulgate rules and regulations regarding fish and wildlife resources of the state. Title 36, L.R.S., creates the LDWF and designates the powers and duties of the department. Title 76 of the Louisiana Administrative Code contains rules and regulations adopted by the LWFC and the LDWF that govern marine fisheries.

Section 2 of Title 56, L.R.S., authorizes the LWFC to promulgate rules for the harvest of blue crab including daily take and possession limits, permits, and other aspects of harvest. Additionally, the LWFC has authority to set possession limits, quotas, locations, seasons, size limits, and daily take limits for all freshwater and saltwater species based upon biological and technical data.

#### 5.2.4.3 Reciprocal Agreements and Limited Entry Provisions

##### 5.2.4.3.1 Reciprocal Agreements

The LWFC is authorized to enter into reciprocal management agreements with the states of Arkansas, Mississippi, and Texas on matters pertaining to aquatic life in bodies of water that form a common boundary. The LWFC is also authorized to enter into reciprocal licensing agreements.

##### 5.2.4.3.2 Limited Entry

There are no provisions for limited entry; however, there was a commercial crab trap license moratorium with qualifying criteria from 1996 to 1998.

#### 5.2.4.4 Commercial Landings Data Reporting Requirements

Any wholesale/retail seafood dealer buying crabs from any commercial crab fisherman and commercial fishermen selling crabs to anyone other than a wholesale/retail seafood dealer is required to fill out a trip ticket for each transaction. The trip ticket includes the following information: fisherman's license number; vessel registration; date; area fished; species; trip time; price/unit; and, total value. The owner or operator of any soft shell crab shedding facility must purchase a wholesale/retail seafood dealer license and shall on or before the tenth of each month file a report to the LDWF detailing the quantity and prices of premolt or buster crabs acquired and soft shell crabs sold. A commercial fisherman with a fresh products license must file a monthly submission report to the LDWF.

### 5.2.4.5 Penalties for Violations

Penalties for blue crab violations are shown below, and class of violation varies by Legislative statute or LWFC promulgation. If a wholesale or retail dealer can identify the commercial fisherman who harvested undersize crabs, only the latter is subject to undersize crab violations.

Class One violations: first offense carries a civil penalty fine of $50; second offense fined $100; third and subsequent offenses are fined $200.

Class Two violations: first offenses are fined $100-$350 or imprisonment of not more than 60 days or both; second offense fined $300-$550 and imprisonment of 30-60 days; third and subsequent offenses fined $500-$750, imprisonment of 60-90 days, and forfeiture of anything seized in connection with the violation.

Class Three violations: first offenses are fines $250-$500 or imprisonment of not more than 90 days or both; second offense fined $500-$800, imprisonment of 60-90 days, and forfeiture of anything seized in connection with the violation; third and subsequent offenses fined $750-$1,000, imprisonment of 90-120 days, and forfeiture of anything seized in connection with the violation. Any person convicted of a class three or greater violation shall be ineligible to hold a commercial fisherman's license for two years.

Class Four violations: first offenses are fined $400-$450 or imprisonment of not more than 120 days or both; second offense fined $750-$3,000 and imprisonment of 90-180 days; third and subsequent offenses fined $1,000-$5,000 and imprisonment of 180 days to two years. In addition, violators (a) must forfeit any blue crabs in connection with the violation, (b) may have their license revoked, (c) may have illegal or improperly tagged fishing gear confiscated, and (d) be liable for civil penalties for the restitution of value. The civil penalty for blue crabs is $0.41 per lb.

Class Five violations: each offense shall have a mandatory jail sentence in two options. For a class 5-A violation, the first offense is $500-$750 and 15-30 days imprisonment. The second offence is $750-$1000 with 60-90 days and a third increases imprisonment to 90-120 days. A class 5-B violoation has slightly lower fines but jail time of 30, 60, and 90 days mandatory for each subsequent offense. Both classes result in forfeiture of license and anything seized in connection with the violation.

Class Six violations: for each offense, the fine shall be $1,000-$2,000 or imprisonment for not more than 120 days or both and the forfeiture of anything seized in connection with the violation. Persons convicted of this violation shall be forever barred from applying for a crab trap gear license.

### 5.2.4.6 Annual License Fees

*The following is a list of license fees that is current to the date of this publication. They are subject to change any time thereafter.* Also, nonresident fees may vary based on the charge for similar fishing activities in the applicant's state of residence. Recreational fishermen using gear other than traps are not required to purchase a license.

**Commercial**

| | |
|---|---|
| Commercial Crab Trap | |
| · resident | $25.00 |
| · nonresident | 100.00 |
| Crab Trap Gear Fee | |
| · resident | 10.00 |
| · nonresident | 40.00 |
| Commercial fisherman license | |
| · resident | 55.00 |
| · nonresident | 460.00 |
| Vessel license | |
| · resident | 15.00 |
| · nonresident | 60.00 |
| Fresh products license | |
| · resident | 20.00 |
| · nonresident | 120.00 |
| · spouse | 5.00 |
| Wholesale/retail seafood dealer (business) | |
| · resident | 250.00 |
| · nonresident | 1,105.00 |
| · resident (4-year) | 1,000.00 |
| · nonresident (4-year) | 4,420.00 |
| Wholesale/retail seafood dealer (vehicle) | |
| · resident | 250.00 |
| · nonresident | 1,105.00 |
| · resident (4-year) | 1,000.00 |
| · nonresident (4-year) | 4,420.00 |
| Seafood Retail Dealer (Business) | |
| · resident | 105.00 |
| · nonresident | 405.00 |
| · resident (4-year) | 420.00 |
| · nonresident (4-year) | 1,620.00 |
| Seafood Retail Dealer (Vehicle) | |

| | | |
|---|---|---|
| · | resident | 105.00 |
| · | nonresident | 405.00 |
| · | resident (4-year) | 420.00 |
| · | nonresident (4-year) | 1,620.00 |
| Seafood Transport Wholesale/retail dealer | | |
| · | resident | 30.00 |
| · | nonresident | 30.00 |
| · | resident (4-year) | 120.00 |
| · | nonresident (4-year) | 120.00 |
| Seafood Transport Retail dealer | | |
| · | resident | 30.00 |
| · | nonresident | 30.00 |
| · | resident (4-year) | 120.00 |
| · | nonresident (4-year) | 120.00 |
| Wholesale Out-of-State Crab Shipping | | |
| · | resident | 100.00 |
| · | nonresident | 100.00 |
| Retail Out-of-State Crab Shipping | | |
| · | resident | 100.00 |
| · | nonresident | 100.00 |
| **Recreational** | | |
| Crab Trap (no more than ten traps) | | |
| · | resident | 15.00 |
| · | nonresident | 600.00 |

#### 5.2.4.7 Laws and Regulations

Louisiana laws and regulations regarding the harvest of blue crab include gear restrictions, seasons, and other provisions. The following is a general summary of these laws and regulations. *They are current to the date of this publication and are subject to change at any time thereafter. The LDWF should be contacted for specific and up-to-date information.*

##### 5.2.4.7.1 Size Limits

The size limit on hardshell commercial crabs is five inches in carapace width, except when held for later processing as soft crabs or sold to a processor for making of soft crabs. Any blue crab less than five inches must be returned immediately to the waters from which taken without avoidable injury. Blue crabs less than five inches may be taken from privately-owned ponds, impoundments, or waters and sold to other persons for purposes of stocking private waters, ponds, or impoundments. There are no minimum size restrictions for recreational crabbers.

Premolt crabs less than five inches in width held by a commercial fisherman for later processing as soft shell crabs must be identifiable as premolt crabs and must be held in a separate container marked ‘peelers’ or ‘busters.’ Pre-molt ‘buster’ or ‘peeler’ stage crabs must be no further from molting than having a white line on the back paddle fin.

If more than 10% of crabs in a 50 crab random sample are less than five inches in width, the entire number of crabs in that crate or group of crabs equivalent to one crate is in violation. Crabs in a work box are not subject to the minimum commercial size limits for hardshell crabs while held aboard the vessel. Each fisherman may have one work box, if not using a grader, or two work boxes under the grader, if using a grader.

Wholesale and retail dealers, as well as commercial fishermen, are subject to penalties for possession of undersized crabs. If the dealer can identify the commercial fisherman who harvested the undersize crabs, the dealer shall not be subject to the penalties. A person possessing more than 20% undersize crabs shall be subjected to additional penalties: first offense, license suspended for six months; second offense within a five-year period, license suspended for 12 months; third offense within a five-year period, license revoked permanently.

### 5.2.4.7.2 Protection of Female Crabs

No person can keep or sell adult female crabs in the berry (egg) stage. All crabs in the berry stage taken by any means must be returned immediately to the waters. However, a legally licensed commercial crab fisherman may have in his workbox an incidental take of crabs in the berry stage in an amount equal to not more than 2% of the total number of crabs in his possession.

### 5.2.4.7.3 Gear Restrictions

Crabs may be taken with any legal crab trap, crab dropnet, trawl, skimmer net, butterfly net, trotline, handline, bushline, dipnet, or cast net. Dredges cannot be used for the intentional taking of crabs. Harvest of crabs by trawls in inside waters is permitted only during the open season for shrimp and with a legal commercial mesh size. A legal trap must have a solid float (6 inches minimum diameter), a non-floating buoy line ($^1/_4$ inch minimum diameter), be marked, and have escape rings. Crab traps located in areas north of the northern bank of the Intracoastal Waterway and west of Louisiana Highway 70 and those areas located on the eastern side of the Mississippi River and inland from the saltwater line are not required to be marked with a float and float line, unless the trap is placed in a lake.

Each crab trap shall be marked with a $^1/_2$ inch stainless steel self-locking tag containing the commercial fisherman's license number attached to the center of the trap ceiling. Crab fishers may also utilize a plastic bait box cover containing the commercial fisherman's license number to mark trap ownership.

Each crab trap shall have a minimum of two escape rings placed on the vertical, outside walls flush with the trap floor or baffle with at least one ring located in each chamber of the trap. The minimum size of the rings shall be $2^5/_{16}$ inch inside diameter, not including the ring material. The rings shall be rigid and attached to the trap with material of a smaller diameter than the wire strands of the trap. Except from March 1-June 30 and from September 1-October 31, escape ring openings shall not be obstructed with any material that prevents or hampers exit of crabs. Crab traps placed in Lake Pontchartrain are exempt from escape ring requirements.

Traps which are no longer serviceable or in use shall be removed from the water by the owner and properly disposed of or stored by him. A serviceable crab trap means any crab trap of legal construction and condition maintained in such a manner with the potential to harvest crabs. Except as provided in R.S. 56:320(B)(3), maintained condition shall include being legally tagged, legally marked with float and float line attached and two escapement rings affixed whether obstructed or not.

A fisherman with a crab trap license may raise and check any trap with a common float to determine ownership. Shrimp fishermen who catch an otherwise serviceable crab trap without a float shall return the trap to the water with a common float (an all-white, plastic, one-gallon or larger bleach bottle); unserviceable traps must be retained for proper disposal. The owner of the trap shall return the common float to any shrimper for reuse.

For the purpose of taking crabs as bait, seines of 1/4 inch bar and ½ inch stretched mesh or less and measuring 30 feet or less in length, cast nets, dip nets, minnow traps, or any other devices approved by the Commission may be utilized.

**5.2.4.7.4 Closed Areas and Seasons**

Crab traps cannot be set in navigable channels or entrances to streams. A fisherman must place traps so vessels can safely navigate. The use of crab traps is prohibited in certain areas of the Calcasieu River system, the Tchefuncte River, Vermilion Bay, Sabine Lake, the Grand Isle shoreline, or on the following wildlife management areas or refuges: Rockefeller Wildlife Refuge, Marsh Island Wildlife Refuge, Pointe-au-Chien Wildlife Management Area (with the exception of Wonder Lake and Cut Off Canal), and Salvador Wildlife Management Area.

**5.2.4.7.5 Bag/Possession Limits**

Except for certain refuges or wildlife management areas, a recreational limit is twelve dozen daily and in possession. Twelve dozen crabs per boat or vehicle per day are allowed in Rockefeller Wildlife Refuge, Marsh Island Wildlife Refuge, Pointe-au-Chien Wildlife Management Area, and Salvador Wildlife Management Area.

**5.2.4.7.6 Other Restrictions**

No person may take diamond-back terrapins by traps of any kind. No person may intentionally damage or destroy crab traps, floats or lines, or remove the contents thereof, other than the licensee or his agent. No person shall disturb any fisherman who is engaged in the lawful taking of fish. Commercial fishermen must tag or mark any crabs sold with their commercial fisherman's license number, name, and date harvested.

A licensed commercial fisherman may retain for personal consumption finfish caught as bycatch in crab traps up to an aggregate of 25 finfish per vessel per day. No freshwater game fish, no red drum, and no spotted seatrout may be kept as a part of this aggregate. Any fish retained are subject to recreational size and possession limits. In addition, any licensed commercial fisherman holding a Gear License which allows him to take finfish for commercial purposes, may possess any finfish caught under that Gear License up to the commercial possession limit allowable for such finfish and such fish shall not be required to be separated from the bycatch allowed above.

#### 5.2.4.8 Louisiana Statutes and Programs Relating to Habitat

The state and local Coastal Resources Management Act was passed in 1979 by the Louisiana Legislature. The Louisiana Department of Natural Resources (LDNR) is charged with coastal zone management and overseeing permit activities. In addition, several coastal parishes have developed their own CZM programs. In 1981, Act 41 of the 1981 Extraordinary Session of the Louisiana Legislature created a Coastal Environmental Protection Trust Fund and appointed the Governor's Task Force on Coastal Erosion. Act 5 of the 1988 First Extraordinary Session in effect abolished the Trust Fund. In the 1989 Second Extraordinary Session, Senate Bill Number 26 created an office of Coastal Restoration and Management in LDNR, a Wetlands Conservation and Restoration Authority in the Governor's Office and a Wetlands Conservation and Restoration Fund.

The Louisiana Department of Environmental Quality (LDEQ) has the responsibility of setting and monitoring pollution standards for all waters of the state, including the Gulf of Mexico. The state of Louisiana is also pursuing protection of its estuarine habitats through the acquisition of land for the establishment of over 1,800,000 acres of wildlife management areas and refuges.

#### 5.2.4.9 Historical Changes to Regulations

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1974: Established a 5 inch carapace width minimum size limit for hard crabs.

Established the law that made it illegal to retain sponge crabs.

1977: Required commercial license and tagging of traps and fishermen could not have more than 300 total traps.

Made it illegal to set traps in navigable channels or entrances to streams.

Allowed recreational fishermen to use up to 5 traps without a license and a maximum of 10 if they obtained a recreational crab trap license.

1979: Allowed trawls as a legal gear for taking blue crabs in inside waters during the open shrimp season.

1986: Removed the maximum number of crab traps for commercial crab fishermen.

1987: Made it illegal to bait, tend, check or remove crab traps from ½ hour after legal sunset to $^{1}/_{2}$ hour before legal sunrise.

Recreational crab trap license required for recreational fisherman using up to 10 traps.

1988: Established a 5% of a 50 crab sample to contain undersized crabs excluding crabs held for shedding.

1989: Raised the 5% tolerance for undersized crabs to 10%.

1991: Made dredges illegal for the intentional taking of crabs.

1995: Established that crabs in 'work boxes' not subject to minimum commercial size limits.

1997: Established rules that required two escape rings per trap minimum. Minimum size of rings required to be $2^{5}/_{16}$ inches inside diameter.

1999: Recreational take of blue crabs limited to 12 dozen daily.

2001: Louisiana Crab Task Force was created.

2003: Allowed for a closure period between February 1st and March 31st and allowed the removal of 'abandoned' traps inside the closure areas.

Established a maximum height of crab traps to be 30 inches.

2005: Established a one year moratorium on commercial crab trap license gear sales.

Crab Promotion and Marketing Account was created.

Derelict Crab Trap Removal Program Account was created.

### 5.2.5 Texas

#### 5.2.5.1 Texas Parks and Wildlife Department

Texas Parks and Wildlife Department (TPWD)
Coastal Fisheries Division
4200 Smith School Road
Austin, Texas 78744
(512) 389-4864

The Texas Parks and Wildlife Department is the administrative unit of the state charged with management of the coastal fishery resources and enforcement of legislative and regulatory procedures under the policy direction of the Texas Parks and Wildlife Commission (TPWC). The TPWC consists of nine members appointed by the Governor for six-year terms. The TPWC selects an Executive Director who serves as the administrative officer of the department. Directors of Coastal Fisheries, Inland Fisheries, Wildlife, Resource Protection, and Law Enforcement are named by the Executive Director. The Coastal Fisheries Division, headed by a Division Director, is under the supervision of the Executive Director.

Texas has habitat protection and permitting programs and a federally-approved CZM program.

#### 5.2.5.2 Legislative Authorization

Chapter 11, Texas Parks and Wildlife Code, establishes the TPWC and provides for its makeup and appointment. Chapter 12 establishes the powers and duties of the TPWC, and Chapter 61 provides the commission with responsibility for marine fishery management and authority to promulgate regulations. All regulations adopted by the TPWC are included in the *Texas Statewide Hunting and Fishing Proclamations*.

#### 5.2.5.3 Reciprocal Agreements and Limited Entry Provisions

##### 5.2.5.3.1 Reciprocal Agreements

Texas statutory authority allows the TPWC to enter into reciprocal licensing agreements in waters that form a common boundary, i.e., the Sabine River area between Texas and Louisiana. Texas has no statutory authority to enter into reciprocal management agreements.

##### 5.2.5.3.2 Limited Entry

Texas Senate Bill 750 and Texas Parks and Wildlife Code Subchapter B, Section 78.101, provides statutory authority for TPWD to implement a Crab License Management Program. This program shall promote efficiency and economic stability in the crabbing industry and shall conserve economically-important crab resources. This program shall be administered by TPWD Executive Director and includes the components below.

###### 5.2.5.3.2.1 Licensing

No person shall engage in commercial crab fishing without a commercial crab fisherman license. This license replaced the crab trap tag, general commercial fishing license, and commercial fishing boat license.

###### 5.2.5.3.2.2 License Display

The commercial crab fisherman license plate must be prominently displayed and clearly visible from both sides of the boat. No more than one set of plates may be displayed at one time.

**5.2.5.3.2.3 Eligibility and License Renewal**

Commercial crab fisherman licenses will only be issued to persons concurrently holding the following licenses and tags during the period September 1, 1995 through November 13, 1996:

- General commercial fisherman's license
- Commercial fishing boat license; and
- Commercial crab trap tags.

After August 31, 1999, licenses will only be renewed by persons licensed the previous year. Those who do not meet these requirements may appeal to the Crab License Management Review Board.

**5.2.5.3.2.4 License Transfer**

Prior to September 1, 2001, no license may be transferred from one person to another except to an heir or devisee of a deceased holder of a commercial crab fisherman license.

**5.2.5.3.2.5 License Limit, Designated License Holder**

A commercial crab fisherman license must be issued to an individual, and no person may hold more than three licenses.

**5.2.5.3.2.6 License Suspension and Revocation**

Licenses may be suspended or revoked if the license holder is convicted of two or more flagrant offenses, which include:

- Retaining undersized or left claws of a stone crab,
- Possessing egg-bearing crabs or female crabs with its abdominal apron detached,
- Removing crabs or crab traps 30 minutes before or after legal crabbing hours,
- Fishing crab traps in restricted areas,
- Fishing crab traps in excess of legal trap numbers,
- Fishing for crabs without the appropriate license, or
- Theft of crabs or crab traps.

**5.2.5.3.2.7 License Buyback Program**

Twenty percent of commercial crab fisherman license and license transfer fees shall be set aside to be used only for the purpose of buying back licenses from willing license holders. Specific crab license buyback criteria are available from TPWD.

#### 5.2.5.3.2.8 Crab License Management Review Board

License holders under this chapter shall elect a review board composed of five to eleven members. Members of the review board must be crab license holders or wholesale fish dealers with knowledge of the commercial crab fishing industry. The review board shall advise the TPWC and TPWD and make recommendations concerning the administrative aspects of the crab licensing program including the definition of flagrant offenses and hardship appeal cases concerning eligibility, license transfer, license renewal, license suspension, and license revocation.

### 5.2.5.4 Commercial Landings Data Reporting Requirements

All seafood dealers in aquatic products who purchase directly from fishermen, or fishermen that do not sell to dealers, are required to file monthly aquatic products reports with the TPWD by the tenth of each month. These reports must include species, poundage, gear utilized, and location of fishing activities.

### 5.2.5.5 Penalties for Violations

Penalties for violations of Texas proclamations regarding blue crabs are provided in Chapter 61, Texas Parks and Wildlife Code, and most are Class C misdemeanors punishable by fines ranging from $25-$500.

### 5.2.5.6 Annual License Fees

The following is a list of licenses and fees that are applicable to blue crab harvest in Texas. *They are current to the date of this publication and are subject to change at any time thereafter.*

**Commercial**

| | |
|---|---|
| Commercial crab fisherman's license | |
| • Resident | $630.00 |
| • Non-resident | 2,520.00 |
| Commercial finfish fisherman's license | |
| • Resident | 360.00 |
| • Non-resident | 1,440.00 |
| Wholesale fish dealer (business) | 825.00 |
| Wholesale fish dealer (truck)* | 590.00 |
| Retail fish dealer (business) | 92.40 |
| Retail fish dealer (truck)* | 171.60 |

*Refers to the use of a truck as a place of business.

**Recreational**

For the recreational harvest of blue crab a valid recreational fishing license and a saltwater fishing stamp endorsement are required unless otherwise exempt.

Resident:

| | |
|---|---|
| • Freshwater Package | $30.00 |
| • Saltwater Package | 35.00 |
| • All-Water Package | 40.00 |
| • Senior Freshwater Package | 12.00 |
| • Senior Saltwater Package | 17.00 |
| • Senior All-Water Package | 22.00 |
| • Special Resident All-Water License (Legally Blind) | 7.00 |
| • Year-from-Purchase All-Water Package | 47.00 |
| • One-Day All-Water License | 11.00 |
| • Lifetime Resident Fishing License | 1000.00 |
| • Saltwater Fishing Stamp[1] | 5.00 |
| • Freshwater Fishing Stamp[2] | 10.00 |
| • Super Combo[3] | 68.00 |
| • Combo[4] | 16.00-60.00 |

Non-Resident:

| | |
|---|---|
| • Freshwater Package | 58.00 |
| • Saltwater Package | 63.00 |
| • All-Water Package | 68.00 |
| • One-Day All-Water License | 16.00 |

[1] Required in addition to recreational licenses when fishing in saltwater.
[2] Required in addition to recreational licenses when fishing in freshwater.
[3] Package includes Resident Combination Hunting and Fishing License and five state stamp fees (three hunting, two fishing) at a discount price (Up to $18 savings).
[4] Package includes a resident hunting license, a resident fishing license and either saltwater stamp endorsement (with a red drum tag), freshwater stamp endorsement, or both, depending on package purchased.

#### 5.2.5.7 Laws and Regulations

Various statewide hunting and fishing proclamations affect the harvest and use of blue crabs in Texas. The following is a general summary of these laws and regulations. *They are current to the date of this publication and are subject to change at any time thereafter. The TPWD should be contacted for specific and up-to-date information.*

##### 5.2.5.7.1 Size Limits

No hard-shell crab less than five inches in carapace width (measured from tip of spine to tip of spine) may be possessed except not more than 5% by number may be possessed for bait purposes only, if placed in a separate container at the time of taking. All other crabs less than five inches shall be returned immediately to the waters from which taken.

#### 5.2.5.7.2 Protection of Female Crabs

It is unlawful to possess egg-bearing female crabs (sponge crabs). No person may possess a female crab that has its abdominal apron detached and was taken from coastal waters.

#### 5.2.5.7.3 Gear Restrictions

Crabs may be taken in any number by crab line, crab trap, and other devices (handline, gig, trotline, trawl) legally used for taking finfish or shrimp if operated in legal places and times.

No more than 200 crab traps per person while fishing with a commercial crab fisherman's license, no more than 20 crab traps per person while fishing with a commercial finfish license, or no more than six crab traps per person for non-commercial purposes may be fished at one time. Crab traps may not be removed from the water or crabs may not be removed from crab traps during the period from 30 minutes after sunset to 30 minutes before sunrise. Crab traps may not be placed closer to 100 feet from any other crab trap, except when traps are secured to a pier or dock. A crab trap may not be fished in fresh waters.

A crab trap may not exceed 18 cubic feet in volume and must be equipped with at least two escape vents (minimum $2^3/_8$ inches inside diameter) in each crab-retaining chamber and located on the lower edge of the outside trap walls. Traps must be equipped with a degradable panel constructed on the trap in one of the following methods:

1) The trap tie-down strap is secured to the trap by a loop of untreated jute twine (comparable to Lehigh brand #530), untreated sisal twine (comparable to Lehigh brand #390), or untreated steel wire with a diameter of no larger than 20-gauge. The trap lid must be secured so that when the twine or wire degrades, the lid will no longer be securely closed; or
2) The trap contains at least one sidewall, not including the bottom panel, with a rectangular opening no smaller than 3 x 6 inches. Any obstruction placed in this opening may not be secured in any manner, except:

    a) It may be laced, sewn, or otherwise obstructed by a single length of untreated jute twine (comparable to Lehigh brand #530), untreated sisal twine (comparable to Lehigh brand #390) knotted only at each end and not tied or looped more than once around a single mesh bar, or untreated steel wire with a diameter of no larger than 20-gauge. When the twine or wire degrades, the opening in the sidewall of the trap will no longer be obstructed; or
    b) The obstruction may be loosely hinged at the bottom of the opening by no more than two untreated steel hog rings and secured at the top of the obstruction in no more than one place by a single length of untreated sisal twine (comparable to Lehigh brand #390), or untreated steel wire with a diameter of no larger than 20-gauge. When the twine or wire degrades, the obstruction will hinge downward and the opening in the sidewall of the trap will no longer be obstructed.

Traps must be marked with a valid gear tag attached within six inches of the buoy and contain the name and address of the fisherman and the date the trap was set out. The gear tag is valid for 30 days after the date set out. Crab traps and crab lines must be marked with a floating white buoy not less than 6 inches in height, 6 inches in length, and 6 inches in width bearing the commercial crab fisherman license plate number in letters of a contrasting color at least two inches high attached to the trap or end fixtures of crab line. The license number on the trap buoy must match the license number displayed on the crab fishing boat. Crab traps fished by commercial finfish fishermen must have similarly marked buoys with the commercial finfish fisherman's license plate number preceded with the letter F.

#### 5.2.5.7.4 Closed Areas and Seasons

No nets, traps, longlines, trotlines, juglines, seines, or any other device for capturing sea life shall be used or possessed in the spoil areas on Pleasure Island in Port Arthur; provided, however, that crabs and fish can be taken by a hand-held crab net, landing net, or casting net. No more than three crab traps may be used or placed in the public waters of the San Bernard River north of a line marked by the boat access channel at Bernard Acres or in waters north and west of Highway 146 where it crosses the Houston Ship Channel in Harris County.

It is unlawful to fish a crab trap within 200 feet of a marked navigable channel in Aransas County and in the water area of Aransas Bay within $^1/_2$ mile of a line from Hail Point on the Lamar Peninsula, then direct to the eastern end of Goose Island, then along the southern shore of Goose Island, then along the eastern shoreline of the Live Oak Peninsula past the town of Fulton, past NineMile Point, past the town of Rockport to a point at the east end of Talley Island including that part of Copano Bay within 1,000 feet of the causeway between Lamar and Live Oak peninsulas.

#### 5.2.5.7.5 Bag/Possession Limits

Texas has not established any statewide bag/possession limits for blue crabs except possession of crabs under five inches for bait purposes, as specified in Section 5.2.5.7.1. The City of Port Arthur has set a daily bag limit of 24 crabs/person or 48 crabs/vehicle for crabs taken from the spoil areas in the city limits of Port Arthur.

#### 5.2.5.7.6 Other Restrictions

None.

### 5.2.5.8 Texas Statutes and Programs Relating to Habitat

The Coastal Coordination Act passed by the Texas Legislature in 1991 and amended in 1995 directed development of a long-term plan for management of uses affecting coastal natural resource areas such as Gulf beaches and critical dune areas, submerged lands, coastal historic areas, coastal preserves, and the water and submerged land of the open Gulf of Mexico within the jurisdiction of the state of Texas (Texas General Land Office 1995). The Coastal Coordination Council is an eleven-member policy-making and review body created by the Coastal Coordination

Act to oversee decisions affecting coastal and natural resources. Members of this council include chairmen (or designees) of the Texas General Land Office, Texas Natural Resource Conservation Commission, Texas Parks and Wildlife Commission, Railroad Commission of Texas, Texas Water Development Board, Texas Transportation Commission, Texas State Soil and Water Conservation Board, and four other coastal zone residents with coastal management interests, appointed by the governor for twoyear terms.

The Texas Coastal Management Program received federal approval in 1997. The principle issues of concern addressed by this program are coastal erosion, protection of living resources, protection of coastal wetlands and other important habitats, water supply and water quality, dune protection, shoreline access, and institutional impediments to effective and efficient management, chiefly the fragmentation of coastal regulatory authority among hundreds of state, federal, and local governmental entities.

The Inland Fisheries Division of the TPWD, working with other divisions and agencies, assesses the impact of construction and development on the estuarine environment and fish and wildlife resources. This division also investigates fish kills and pollution complaints and issues various permits including those for removal of sand, shell, and gravel from state-owned water bottoms. The Coastal Fisheries Division monitors fish and shellfish populations as well as hydrological parameters that might affect their abundance.

#### 5.2.5.9 Historical Changes to Regulations

The following regulatory changes may have notably influenced the landings during a particular year and are summarized here for interpretive purposes.

1980: 300 trap limit; 5-inch minimum size limit, 5% tolerance for undersize, exception for bait crabs; Illegal to retain sponge crabs

1984: Three trap maximum in specified waters in Harris County

1986: Closed area in specified waters in Aransas County; No traps within 200 feet of marked navigable channel in Aransas County

1988: Crab trap size maximum of 18 cubic feet

1991: Crab trap tag issued by state ($1.50/tag) mandated to be attached to each trap

1993: Harvest of crabs from traps legal during daylight hours only; Escape rings mandated, minimum $2^3/_8$ inches internal diameter

1994: Crab trap limit reduced to 200 traps; Minimum spacing of 100 feet between traps; except when secured to a pier or dock; Three trap maximum in specified waters of San Bernard River in Brazoria County

1997: House Bill 2542 created the Crab License Management Program (limited entry), with provisions for a commercial crab fishing license, license transfer, license suspensions, license review board, and a voluntary license buyback program; Gear tag attached to float replaces crab trap tag

1998: All crab limited entry license requirements and provisions take effect September 1; Degradable panels mandated for all traps

2000: 20 trap limit while fishing under Commercial Finfish Fisherman's License

2002: Closed season beginning on the third Friday in February and running for ten consecutive days; all traps must be removed from coastal waters and remaining traps are considered 'litter' and subject to removal by public (Abandoned Crab Trap Removal Program).

## 5.3 Regional/Interstate

### 5.3.1 Gulf States Marine Fisheries Compact (P.L. 81-66)

The Gulf States Marine Fisheries Commission (GSMFC) was established by an act of Congress (P.L. 81-66) in 1949 as a compact of the five Gulf States. Its charge is

> "to promote better utilization of the fisheries, marine, shell and anadromous, of the seaboard of the Gulf of Mexico, by the development of a joint program for the promotion and protection of such fisheries and the prevention of the physical waste of the fisheries from any cause."

The GSMFC is composed of three members from each of the five Gulf States. The head of the marine resource agency of each state is an ex-officio member, the second is a member of the legislature, and the third, a citizen who shall have knowledge of and interest in marine fisheries, is appointed by the governor. The chairman, vice chairman, and second vice chairman of the GSMFC are rotated annually among the states.

The GSMFC is empowered to make recommendations to the governors and legislatures of the five Gulf States on action regarding programs helpful to the management of the fisheries. The states do not relinquish any of their rights or responsibilities in regulating their own fisheries by being members of the GSMFC.

Recommendations to the states are based on scientific studies made by experts employed by state and federal resource agencies and advice from law enforcement officials and the commercial and recreational fishing industries. The GSMFC is also authorized to consult with and advise the proper administrative agencies of the member states regarding fishery conservation problems. In addition, the GSMFC advises the U.S. Congress and may testify on legislation and marine policies that affect the Gulf States. One of the most important functions of the GSMFC is to serve as a forum for the discussion of various problems, issues, and programs concerning marine management.

### 5.3.2 Technical Coordinating Committee (TCC) Crab Subcommittee

The TCC's Crab Subcommittee is made up of the crab experts in each of the five state agencies and includes all crab species of concern in the Gulf of Mexico, not just blue crabs (*Callinectes sapidus*). The Crab Subcommittee's mission is to discuss crab related management, research, issues, and activities among the five Gulf states and make recommendations to the TCC and the GSMFC on all crab populations and fisheries. These include stone, red, golden, horseshoe and any other commercially or recreationally exploited crab population. The Crab Subcommittee meets in conjunction with the GSMFC's annual spring and fall meetings although there is no programmatic support for their travel or routine activities.

In addition, the Crab Subcommittee also forms the base of the Blue Crab Technical Task Force (TTF) for the purposes of revising the Blue Crab FMP and the Derelict Trap Task Force which is responsible for developing and coordinating recovery programs in each of the five Gulf states for lost or abandoned crab traps. While serving as the Blue Crab TTF, there are travel funds available through the IJF Program for FMP development.

### 5.3.3 Interjurisdictional Fisheries Act (IFA) of 1986 (P.L. 99-659, Title III)

The IFA of 1986 established a program to promote and encourage state activities in the support of management plans and to promote and encourage regional management of state fishery resources throughout their range. The enactment of this legislation repealed the Commercial Fisheries Research and Development Act (P.L. 88-309).

#### 5.3.3.1 Development of Management Plans [Title III, Section 308(c)]

Through P.L. 99-659, Congress authorized the USDOC to appropriate funding in support of state research and management projects that were consistent with the intent of the IFA. Additional funds were authorized to support the development of interstate fishery management plans (FMP) by the Gulf, Atlantic, and Pacific States Marine Fisheries Commissions.

## 6.0 DESCRIPTION OF THE FISHERY

There have been significant changes in the Gulf of Mexico blue crab fishery since the publication of the first regional FMP (Steele and Perry 1990) and its 2001 revision (Guillory et al. 2001). Problems identified by Steele and Perry (1990) included economic overcapitalization, habitat loss and/or degradation, and competition from imported crab products. Guillory et al. (1998) noted effort had increased significantly while harvest levels stabilized or decreased, and new management regulations were implemented. Additional management considerations reported in the 2001 regional FMP included inadequate fishery-dependent (FDD) and fishery-independent data (FID), ghost fishing, and biologically unnecessary harvest prohibition of egg-bearing females. While programs have been instituted to manage many of these issues, man-made and natural disaster events in the Gulf of Mexico since 2004 have presented challenges not readily addressed by management.

The blue crab is an abundant, environmentally tolerant estuarine organism with yearround accessibility to the fishery. The fishery has three basic components: commercial, recreational, and incidental. The commercial hard crab fishery is comprised of licensed fishermen associated with wholesale dealers or immediate commercial buyers. The catch is generally sold for processing or to the live crab market. The commercial soft crab fishery is primarily dependent upon the incidental catch of premolt crabs (peelers) by hard crab fishermen, although directed premolt crab fisheries exist in some states. Individual fishermen may shed their own crabs or provide premolt crabs to shedding facilities. The final product is usually marketed through nontraditional, poorly documented channels. Recreational fishery effort and harvest are substantial, although inadequately documented. High numbers of crabs are taken as incidental catch in other fisheries, although most are not kept.

### 6.1 Gulf Commercial Hard Crab Fishery

#### 6.1.1 Development and History

Little is known of the early history of the commercial blue crab fishery in the Gulf of Mexico (Steele and Perry 1990). Commercial landing statistics were first collected in 1880. In the 1800s, crab fishermen waded in shallow water at night and used handheld dip nets with lanterns or torches to harvest crabs. Dip nets were longhandled and fashioned with a metal ring to which shallow webbing was attached to facilitate removal of the crabs with a quick shake (Perry et al. 1984). Crabs were scooped up and dropped into towed skiffs, tubs, halfbarrels, or burlap sacks. Crab fishermen also used drop nets consisting of a netcovered metal frame, with bait fastened in the middle, attached to a buoy line. The uniqueness and perishability of the product probably hampered early development of the fishery (Perry et al. 1984). Steele and Bert (1998) noted that during the 1890s in the Florida panhandle fishermen caught crabs with trotlines and bartered the product with local consumers. One of the first commercial crab fisheries in the Gulf developed near New Orleans to supply the French Market and local restaurants (Perry et al. 1984). The first processing plant for Louisiana crab meat was constructed in 1924 at Morgan City, and by 1931 there were seven additional plants in the Morgan CityBerwick area. This period also coincided with the first crab processing operations in other Gulf states. Although there were several smallscale processing plants in Florida by 1897 that handled a variety of seafood products, the first fullscale crab meat processing plant was started in the Apalachicola area in 1930 (Steele and Bert 1998). Hardcrab fishing for commercial processing did not become significant until World War II. Landings increased gradually though erratically during the 1950s, 1960s, and 1970s and then increased dramatically during the mid-1980s. This increased harvest is thought to reflect economic difficulties in oilproducing states, economic overfishing in interdependent fisheries, and political refugees from Southeastern Asia moving into the fishery. With the exception of Mississippi, highest recorded landings in all Gulf states occurred during this time period.

### 6.1.2 Methods/Gear/Vessels

Probably more commercial gears have been used to harvest blue crabs than any other crab species (Haefner 1985). The primary post-1950 gears used to harvest blue crabs in the Gulf states were hard crab traps, trotlines, drop nets, and otter trawls. Other miscellaneous gears included gill nets, brails or scoops, fyke nets, pound nets, beam trawls, brush traps, dredge, and wing nets; landings from many of these gears were either very limited or confidential and were combined with otter trawl landings. During the 1950s and 1960s the Gulf commercial blue crab fishery evolved from a trotline to a trotline-drop net and finally to a trap-based fishery (Guillory and Perret 1998). Blue crabs are currently harvested almost exclusively with wire traps.

Trotlines were described in detail by Andrews (1948) and Floyd (1968). A trotline consisted of a length of rope or mainline, short (10 inch) drop lines (called snoods, drops, or stagings) placed at approximately two foot intervals, and bait. Trotline orientation within the estuary was dependent upon tide, season, and geographic location (Van Engel 1962, Jaworski 1972). Beef lips, ears, and tripe were preferred baits because they were tough and durable. Fishermen pulled their skiff downwind or down current along the trotline and netted the feeding crabs with a long-handled dip net as the trotline was lifted from the water by rollers or spools extending outward from the vessel side. In 1950, trotline landings comprised 97.2% of the total; after 1950, trotline landings declined gradually and were recorded in only one year (1985) after 1978. Drop net landings were highest from 1956-1965, and then drastically declined.

Otter trawls used in the shrimp fishery generally harvest blue crabs as incidental catch, although directed trawl fisheries have existed in some years (Steele and Bert 1998, Floyd personal communication). Gulf-wide, trawl landings were highest during the 1960s and early 1970s; trawls were the only gear, other than traps, with consistent reported landings during the 1980s, although they accounted for less than 0.5% of 1980 to 1989 landings. Since the early 1990s, regulations imposed by the states related to bycatch in the shrimp trawl fishery have reduced the number of crabs retained by commercial shrimpers in the Gulf region. Since 1994, crab landings from the commercial shrimp trawl fishery have been less than 1% of the total hard crab landings in the region (NOAA personal communication).

Crab traps (also referred to as ‘pots’), the dominant gear currently used in the Gulf fishery, were first introduced into the Chesapeake Bay blue crab fishery in 1927 and in the Gulf of Mexico in the early 1950s (Gowanloch 1952, Steele and Bert 1998). Trap-caught crabs began to influence

Florida landings in 1954 and Texas landings as early as 1952. Traps used prior to the early 1970s were similar to the early Chesapeake Bay design (Adkins 1972a) described by Andrews (1947), Van Engel (1962), Green (1952), Isaacson (1962), and Steele and Perry (1990). Traps constructed of vinylcoated wire were widespread by the mid-1970s because of their resistance to corrosion.

Crab traps consist of the following: a floor and ceiling; two to four tapered conical entrance funnels located one mesh above the floor; an arched or gull wing shaped apron, which separates the inner and outer chambers and serves as an effective means of crab retention; and an inner cylindrical shaped bait chamber fastened to the center of the floor and containing an exterior door. Bait chambers are usually constructed of smaller $^1/_2$ x 1 inch vinyl-coated mesh. Trap size, number of funnels, size of inner chamber relative to outer chamber and bait chamber (presence or absence) varies to yield a wide variety of trap sizes and configurations. The number of entrance funnels may range from two to four. Although dimensions may vary from less than 24 inches to more than 36 inches in length and width, most traps average 24 inches wide and deep and $14^1/_2$ inches high. The inner chamber may occupy the entire floor of the trap, half of the floor, or even be absent in some traps. Traps are usually constructed of $1^1/_2$ inch hexagonal, black vinylcoated mesh, although $1^1/_2$ inch square mesh and different colors (green, orange, red) have become increasingly popular. Some blue crab fishermen weight their traps by attaching $^1/_2$ - $^3/_4$ inch diameter reinforcing iron bars (rebar) or bricks to the trap base. Lines of varying length, depending upon water depth, are attached to the top corner of the trap and lead to a buoy generally made of polystyrene or plastic. Traps are usually set in a line and baited with fish; the preferred bait is Gulf menhaden (*Brevoortia patronus*) or striped mullet (*Mugil cephalus*).

Vessels engaged in the trap fishery range from small outboard powered flats to large inboard powered skiffs. Fishermen fish alone or may employ one to two deck hands depending upon the number of traps fished, the proportion of undersized crabs, and whether premolt crabs are separated from the catch. Some vessels may utilize a 'rake,' a rectangular metal (usually aluminum) frame or boom to assist in retrieving trap buoys. Rakes are generally mounted to the starboard aft onethird of the vessel and are deployed to allow the bottom toothed bar to fall just below the water surface and grab the buoy. Traps retrieved with rakes must have reinforced buoys and trap corners where the buoy lines are tied.

Crab dredges, a controversial gear used in the Chesapeake Bay fishery since 1900, were introduced in Louisiana in late 1990 and used by a few fishermen in near shore Gulf waters (Caillou Bay) and in Vermilion Bay. Legislation introduced during the 1991 legislative session has specifically prohibited the use of dredges to harvest blue crabs in Louisiana. Dredges are illegal gear in other Gulf states.

### 6.1.3 Crab Trap Development and Research

The use of crab traps as a commercial gear was evaluated in several studies. The influence of various factors on crab catch rates in traps was documented by Green (1952), Isaacson (1962), and Castro and DeAlteris (1990). Miller (1986, 1990) and Krouse (1989) discussed and reviewed performance and selectivity of decapod traps.

B.F. Lewis of Harryhogan, Virginia, patented different versions of the crab pot in 1928 and 1938 (Wharton 1956). Early traps were cubical in shape, with 2 foot square sides, and made of 18gauge galvanized poultry wire with 1 - $1^1/_2$ inch hexagonal mesh. Only minor improvements to the basic Lewis crab pot design were implemented during the 1940s and 1950s (Van Engel 1962).

Retention of sublegal (<127 mm CW) blue crabs in traps has been recognized since the introduction of the gear (Davis 1942, Green 1952). Although the concept of selfculling blue crab traps originated many years ago when large mesh panels (Cronin 1950) and entire traps made of larger mesh (Van Engel 1962) were evaluated, gear research was not a high priority for many years. Subsequent research documented adverse effects of injuries and exposure during trap confinement or culling operations (Murphy and Kruse 1995) and contributed to the development of gear innovations to reduce sublegal catch.

Several studies have evaluated the use of escape rings in blue crab traps (Whitaker 1978 and 1980, Eldridge et al. 1979, Guillory 1989, 1990, Casey and Daugherty 1990, Casey et al. 1992, Arcement and Guillory 1993, Guillory and Merrell 1993, Casey and Doctor 1996, Guillory and Hein 1998a, 1998b). Guillory and Hein (1998a) experimentally determined the optimum escape ring size and reviewed research data and management regulations associated with escape rings in blue crab traps. To minimize sublegal crab catches and maximize escape ring benefits, circular 6.03 cm rings were recommended for general use. The escapement of sublegal crabs from the 6.03 cm ring is high with only a moderate escapement of 127136 mm legal crabs. In areas with high densities of sublegal sized crabs, escapement may still not meet legal allowable tolerances but will significantly reduce the catch of undersized crabs. Escape rings or vents in crab traps are currently required in Florida, Louisiana, and Texas (Section 5.2.1.7.3, 5.2.1.9, 5.2.4.7.3, 5.2.5.7.3, and 5.2.5.9).

Guillory and Hein (1998a) listed the possible advantages of escape rings in blue crab traps:

a) an immediate increase in catch rate of legal crabs because of trap saturation effects associated with large numbers of sublegal crabs in unringed traps;
b) a future increase in catch rate of legal crabs associated with reduced harvest of sublegal crabs and decreased mortality associated with stress and injuries on undersized crabs returned to the water;
c) a reduction in undersized crab injuries or stress that occur in the trap or during culling operations;
d) a reduction in ghost fishing mortality in traps because of fewer overall numbers of crabs retained in traps;
e) a reduction in culling/sorting time of the catch;
f) a reduction in law enforcement problems associated with possession of sublegal crabs, allowing additional time to enforce other fishing regulations; and
g) a reduction in sublegal crabs delivered to crab processors who cannot profitably process these small crabs.

The primary disadvantage of escape rings is an approximate 70% reduction in catches of pinkline and redline premolt crabs (Guillory 1990). Most premolt crabs are obtained from hard crab trap fishermen. Reductions in premolt crab catches in traps with escapement rings limit the availability of peeler crab, thus impacting the soft crab industry.

Guillory and Prejean (1997), Guillory and Hein (1998b), and Prejean and Guillory (1998) evaluated the effects of mesh size and configuration on blue crab trap catches. Traps with 3.81 cm hexagonal mesh had significantly lower catches of sublegal blue crabs and had either equal or greater catches of legal crabs than did traps with 3.81 cm square mesh.

To determine the optimum square mesh size, Guillory (1998a) manually inserted blue crabs through various sized openings to determine the percent escapement by size group. Based upon minimal retention rates of sublegal crabs and maximal retention rates of legal crabs, the $1^3/_4$ inch square was superior to other tested squares and to the commercially available $1^1/_2$ inch square and hexagonal mesh wire.

In recent years, there has been increased concern over the mortality of diamondback terrapins (*Malaclemys terrapin*) in crab traps across the southeastern U.S. Diamondback terrapin excluder devices placed in the entrance funnels of crab traps have been evaluated in several studies (Wood 1992 and 1994, Guillory and Prejean 1998, Stehlik et al. 1998). Use of turtle excluder devices in crab traps have reduced the catch of diamondback terrapins and maintained and, in some cases, increased the catch of legal blue crabs. On-going derelict crab trap cleanup efforts, which began in 1999, have resulted in the successful removal of over 75,000 lost traps from marine habitats across the Gulf, thus reducing potential threat to diamondback terrapins and other incidentally captured species.

The impacts of ghost fishing in blue crab traps were evaluated by Guillory (1993), Arcement and Guillory (1993), and Casey and Daugherty (1989). Guillory (1993) concluded that substantial numbers (25/trap/year) of crabs died in each trap and that unbaited traps continued to attract crabs (35/trap/year). Arcement and Guillory (1993) found that mortality of blue crabs was significantly less in traps with escape rings (5.3/trap) than in unvented (17.3/trap) traps because of significantly lower numbers of sublegal blue crabs. In Chesapeake Bay ghost traps, average mortalities of 100% (7.7 crabs/trap) after three months and 33% (7.5 crabs/trap) after two months were found (Casey and Daugherty 1989).

Time-release mechanisms or degradable panels have been introduced into trap fisheries to reduce ghost fishing mortality. Casey (1994) evaluated several twines (jute, cotton, sisal, polyester, and manila) and wire (aluminum hobby, annealed iron) that might be used as a patch material. Only the jute (either twoply #18 or threeply #30) decomposed fairly quickly; the number of days to decomposition ranged from 5159 days for a jute panel and from 3036 days for a jute tiedown strap. Degradation rates of six types of natural twine and three types of escapement mechanisms (twine attached to lid closure strap, escapement door or escape ring) were evaluated by McKenna (personal communication) of the North Carolina Division of Marine Fisheries. His study found that decomposition times for jute and sisal twines ranged from 28-63 days (0 = 48) and 35-77 days (0 = 54), respectively. After the twine closure strap or attachment strap degraded, all trap lids snapped open, and 80% of escapement doors fell open. Shively (1997) determined the average degradability of four materials used as attachments for trap panels: sisal, 39 days; jute, 45 days; medium cotton cord, 70 days; and cotton cable cord, 125 days. Degradability time for these twines used with the tiedown strap was significantly longer than those used to attach panels. Blott (1978) evaluated several time-release mechanisms and recommended the use of hinged doors with a biodegradable attachment made of jute or manila. Degradable panels in crab traps are currently required in Florida and Texas (Sections 5.2.1.7.3, 5.2.1.9, 5.2.5.7.3, and 5.2.5.9).

### 6.1.4 Effort

The number of commercial blue crab fishermen and percent contribution by gear type for the Gulf states are presented in Table 6.1. The NMFS data on fishermen by gear type and number of traps are not available after 1993. Fishermen who incidentally caught blue crabs while targeting other species in gears such as trawls, gill nets, wing nets, and small local directed fisheries were not included. The dominant gear type as measured by the number of fishermen shifted from trotline to trotlinedrop net and finally to trap. The only other gears used specifically to harvest blue crabs were pound nets and trawls in the state of Florida. During the 1980s and 1990s trap fishermen comprised 99% and 100% of the total, respectively.

**Table 6.1** Number and percent contribution of commercial hard crab fishermen by gear and overall number of fishermen, Gulf of Mexico from 1950-1993 (NOAA personal communication). NA indicates data not available. 'Full' represents full time fishermen, 'Part' represents part time fishermen.

| YEAR | TRAP | | TROTLINE | | DROP NET | | OTHER | | OVERALL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO. | % | NO. | % | NO. | % | NO. | % | FULL | PART | TOTAL | PART% |
| 1950 | 67 | 4.6 | 1,316 | 89.8 | 83 | 5.7 | 0 | 0.0 | 1,192 | 274 | 1,466 | 18.7 |
| 1951 | 153 | 10.6 | 1,199 | 82.9 | 94 | 6.5 | 0 | 0.0 | 1,152 | 294 | 1,446 | 20.3 |
| 1952 | 184 | 12.8 | 1,109 | 77.0 | 146 | 10.1 | 0 | 0.0 | 1,109 | 330 | 1,439 | 22.9 |
| 1953 | 126 | 9.4 | 986 | 73.7 | 226 | 16.9 | 0 | 0.0 | 1,051 | 386 | 1,338 | 28.8 |
| 1954 | 196 | 15.0 | 895 | 68.3 | 220 | 16.8 | 0 | 0.0 | 1,049 | 257 | 1,311 | 19.6 |
| 1955 | 223 | 17.8 | 896 | 71.5 | 134 | 10.7 | 0 | 0.0 | 978 | 227 | 1,253 | 18.1 |
| 1956 | 246 | 21.7 | 708 | 62.5 | 178 | 15.7 | 0 | 0.0 | 921 | 213 | 1,132 | 18.8 |
| 1957 | 321 | 28.3 | 629 | 55.5 | 184 | 16.2 | 0 | 0.0 | 915 | 219 | 1,134 | 19.3 |
| 1958 | 287 | 24.7 | 674 | 58.1 | 199 | 17.2 | 0 | 0.0 | 968 | 192 | 1,160 | 16.6 |
| 1959 | 439 | 32.5 | 708 | 52.4 | 203 | 15.0 | 0 | 0.0 | 1,147 | 203 | 1,350 | 15.0 |
| 1960 | 453 | 32.1 | 753 | 53.4 | 204 | 14.5 | 0 | 0.0 | 1,207 | 203 | 1,410 | 14.4 |
| 1961 | 430 | 30.0 | 720 | 50.3 | 281 | 19.6 | 0 | 0.0 | 1,216 | 215 | 1,431 | 15.0 |
| 1962 | 444 | 30.2 | 683 | 46.4 | 344 | 23.3 | 0 | 0.0 | 1,240 | 231 | 1,471 | 15.7 |
| 1963 | 419 | 27.6 | 743 | 49.0 | 344 | 22.7 | 10 [1] | 0.6 | 1,292 | 224 | 1,516 | 14.8 |
| 1964 | 511 | 30.2 | 748 | 44.3 | 420 | 24.9 | 10 [1] | 0.6 | 1,512 | 177 | 1,689 | 10.5 |
| 1965 | 629 | 35.1 | 760 | 42.4 | 403 | 22.5 | 2 [1] | 0.1 | 1,551 | 243 | 1,794 | 13.5 |
| 1966 | 894 | 52.2 | 691 | 40.4 | 127 | 7.4 | 0 | 0.0 | 1,433 | 292 | 1,712 | 17.0 |
| 1967 | 1,072 | 62.4 | 519 | 30.2 | 128 | 7.4 | 0 | 0.0 | 1,438 | 283 | 1,721 | 16.4 |
| 1968 | 1,013 | 59.2 | 566 | 33.1 | 132 | 7.7 | 0 | 0.0 | 1,387 | 324 | 1,711 | 18.9 |

| YEAR | TRAP | | TROTLINE | | DROP NET | | OTHER | | OVERALL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NO. | % | NO. | % | NO. | % | NO. | % | FULL | PART | TOTAL | PART% |
| 1969 | 1,089 | 60.6 | 575 | 32.0 | 133 | 7.4 | 0 | 0.0 | 1,385 | 412 | 1,797 | 22.9 |
| 1970 | 1,092 | 69.1 | 346 | 21.9 | 142 | 9.0 | 0 | 0.0 | 1,292 | 288 | 1,580 | 18.2 |
| 1971 | 1,172 | 73.5 | 343 | 21.5 | 80 | 5.0 | 0 | 0.0 | 1,248 | 347 | 1,595 | 21.8 |
| 1972 | 1,147 | 75.4 | 333 | 21.9 | 41 | 2.7 | 0 | 0.0 | 1,244 | 277 | 1,521 | 18.2 |
| 1973 | 1,250 | 86.1 | 201 | 13.8 | 0 | 0.0 | 0 | 0.0 | 1,167 | 284 | 1,451 | 19.6 |
| 1974 | 1,278 | 88.8 | 162 | 11.2 | 0 | 0.0 | 0 | 0.0 | 1,153 | 277 | 1,440 | 19.2 |
| 1975 | 1,381 | 91.3 | 132 | 8.7 | 0 | 0.0 | 0 | 0.0 | 1,196 | 317 | 1,513 | 20.9 |
| 1976 | 1,500 | 94.0 | 95 | 6.0 | 0 | 0.0 | 0 | 0.0 | 1,285 | 310 | 1,595 | 19.4 |
| 1977 | 1,492 | 95.8 | 65 | 4.2 | 0 | 0.0 | 0 | 0.0 | 1,224 | 333 | 1,557 | 21.4 |
| 1978 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1979 | 1,653 | 100 | 0 | 0.0 | 0 | 0.0 | 0 [2] | 0.0 | 153 | 500 | 1,653 | 30.2 |
| 1980 | 1,513 | 99.8 | 1 | 0.1 | 0 | 0.0 | 2 [2] | 0.1 | 1,041 | 475 | 1,516 | 31.3 |
| 1981 | 1,969 | 99.4 | 10 | 0.5 | 0 | 0.0 | 2 [2] | 0.1 | 1,063 | 468 | 1,981 | 23.6 |
| 1982 | 1,653 | 99.5 | 4 | 0.2 | 0 | 0.0 | 4 [2] | 0.2 | 1,161 | 499 | 1,661 | 30.0 |
| 1983 | 1,580 | 99.0 | 6 | 0.4 | 0 | 0.0 | 10 [2] | 0.6 | 1,136 | 460 | 1,596 | 28.8 |
| 1984 | 1,928 | 99.2 | 6 | 0.3 | 0 | 0.0 | 10 [2] | 0.5 | 1,331 | 613 | 1,944 | 31.5 |
| 1985 | 1,898 | 99.4 | 0 | 0.0 | 0 | 0.0 | 12 [2] | 0.6 | 1,300 | 610 | 1,910 | 31.9 |
| 1986 | 1,847 | 99.2 | 1 | 0.1 | 0 | 0.0 | 14 [2] | 0.8 | 1,445 | 417 | 1,862 | 22.4 |
| 1987 | 2,339 | 99.2 | 1 | 0.1 | 0 | 0.0 | 18 [2] | 0.8 | 1,999 | 359 | 2,358 | 15.2 |
| 1988 | 2,357 | 99.8 | 4 | 0.2 | 0 | 0.0 | 0 | 0.0 | 1,794 | 458 | 2,361 | 19.4 |
| 1989 | 2,853 | 100 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2,425 | 428 | 2,853 | 15.0 |
| 1990 | 3,292 | 100 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 2,806 | 486 | 3,292 | 14.8 |
| 1991 | 4,028 | 100 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3,155 | 873 | 4,028 | 21.7 |
| 1992 | 3,780 | 100 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3,080 | 700 | 3,780 | 18.5 |
| 1993[3] | 3,877 | 100 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 3,017 | 860 | 3,877 | 22.1 |

[1]trawl; [2]poundnet; [3]Texas excluded.

The total number of commercial blue crab fishermen in the Gulf states steadily increased from 1950 through the early 1980s, after which there was a marked increase in numbers of fishermen Gulf-wide through the 1990s (Table 6.2); the increase between 1980 (1,516 fishermen) and 1991 (4,028 fishermen) was 166%. Earlier fluctuations resulted in peaks in the early 1950s and mid to late 1960s.

Increased numbers of fishermen during the 1980s were attributed to several interrelated factors: relatively low fixed investment requirements and high resource abundance, economic difficulties of individuals previously employed in the depressed oil and gas industry, economic overfishing in other fisheries, and a sudden influx of Indochinese into the fishery (Roberts and Thompson 1982, Keithly et al. 1988, Steele and Perry 1990). Guillory et al. (1996) suggested that an improving economy, increased operating costs, increased number of traps-per-fishermen, declining catch rates, and other factors may have provided incentives for fishermen to leave the Louisiana fishery in the 1990s or disincentives not to enter the fishery; however, the overall numbers of fishermen Gulf-wide increased through the 1990s.

**Table 6.2** Number of resident crab fishermen in the Gulf of Mexico commercial trap fishery based on state license sales from 1994-2011 (includes latent licenses in all states).

| YEAR | FL | AL | MS | LA | TX | GULF |
|---|---|---|---|---|---|---|
| 1994 | 4,933 | 115 | 148 | 2,498 | 345 | 8,039 |
| 1995 | 6,082 | 150 | 148 | 3,423 | 327 | 10,130 |
| 1996 | 5,519 | 220 | 143 | 2,904 | 335 | 9,121 |
| 1997 | 5,737 | 177 | 194 | 2,529 | 345 | 8,982 |
| 1998 | 5,920 | 176 | 230 | 2,331 | 318 | 8,975 |
| 1999 | 5,297 | 169 | 213 | 3,533 | 287 | 9,499 |
| 2000 | 4,784 | 176 | 208 | 3,561 | 265 | 8,994 |
| 2001 | 4,376 | 174 | 217 | 3,228 | 244 | 8,239 |
| 2002 | 3,435 | 169 | 253 | 3,342 | 231 | 7,430 |
| 2003 | 3,222 | 158 | 262 | 3,386 | 234 | 7,262 |
| 2004 | 2,931 | 170 | 189 | 3,421 | 229 | 6,940 |
| 2005 | 2,798 | 157 | 122 | 2,996 | 224 | 6,297 |
| 2006 | 2,579 | 120 | 110 | 3,230 | 222 | 6,261 |
| 2007 | 2,283 | 148 | 138 | 3,125 | 221 | 5,915 |
| 2008 | 1,190 | 188 | 155 | 3,006 | 216 | 4,755 |
| 2009 | 1,021 | 183 | 138 | 3,107 | 211 | 4,660 |
| 2010 | 1,035 | 327 | 291 | 3,523 | 206 | 5,382 |
| 2011 | 950 | 338 | 223 | 3,631 | 195 | 5,337 |

The percentage of parttime fishermen peaked from 1979-1985 with an average of 29.6% (Table 6.1); the overall percentage from 1950-1993 was 18.5%. Crabbing for many fishermen was a seasonal or secondary activity that supplemented other fisheries or employment income.

Except for Mississippi, the numbers of fishermen per state increased erratically over time until peaking in the late 1980s or 1990s (Table 6.3). In the early 1950s, Mississippi ranked second with 17% and 18% of the total, but then declined to 25% through the 1980s and to 1% or less since 1990. Louisiana led the Gulf in numbers of fishermen, with percentages generally ranging between 55-70%. By the 1960s, Florida and Texas were usually ranked second and third, respectively; Alabama and Mississippi had the fewest numbers of fishermen.

Number of vessels, fishermen, total number of traps, and average number of traps in the Gulf commercial trap fishery through 1993 are shown in Tables 6.3 and 6.4. The number of traps increased dramatically from 4,480 in 1950 to more than 600,000 in 1993. Numbers of fishermen also increased during this period. Although the average number of traps-per-fishermen has declined, this decline is offset by the increase in numbers of fishermen resulting in an increase in the total number of traps. The number of traps-per-fishermen (especially after 1988) and the total number of traps is probably underestimated (Guillory and Perret 1998).

Collection of Gulf-wide effort data (Tables 6.1-6.3) is currently undergoing a transition from the NMFS port agent collections to individual state effort estimates. Though accurate measures

**Table 6.3** Number and overall percent contribution of commercial hard crab fishermen by state, 1950-1993 (NOAA personal communication). NA indicates not available.

| YEAR | FL | | AL | | MS | | LA | | TX | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1950 | 58 | 3.9 | 130 | 8.9 | 264 | 18.0 | 954 | 65.1 | 60 | 4.1 |
| 1951 | 125 | 8.6 | 123 | 8.5 | 250 | 17.3 | 902 | 62.4 | 46 | 3.2 |
| 1952 | 136 | 9.4 | 74 | 5.1 | 254 | 17.6 | 926 | 64.3 | 49 | 3.4 |
| 1953 | 176 | 12.2 | 94 | 6.5 | 96 | 6.7 | 1,007 | 70.1 | 64 | 4.4 |
| 1954 | 286 | 21.9 | 109 | 8.3 | 62 | 4.7 | 815 | 62.4 | 34 | 2.6 |
| 1955 | 250 | 20.7 | 127 | 10.5 | 66 | 5.5 | 737 | 61.2 | 25 | 2.1 |
| 1956 | 265 | 23.4 | 68 | 6.0 | 62 | 5.5 | 716 | 63.1 | 23 | 2.0 |
| 1957 | 279 | 24.6 | 58 | 5.1 | 64 | 5.6 | 704 | 62.1 | 29 | 2.6 |
| 1958 | 254 | 21.9 | 73 | 6.3 | 62 | 5.3 | 734 | 63.3 | 37 | 3.2 |
| 1959 | 415 | 30.7 | 81 | 6.0 | 79 | 5.8 | 744 | 55.1 | 31 | 2.3 |
| 1960 | 377 | 26.7 | 76 | 5.4 | 83 | 5.9 | 803 | 57.0 | 71 | 5.0 |
| 1961 | 280 | 19.6 | 78 | 5.4 | 74 | 5.2 | 923 | 64.5 | 76 | 5.3 |
| 1962 | 261 | 17.7 | 47 | 3.2 | 62 | 4.2 | 1,012 | 68.8 | 89 | 6.0 |
| 1963 | 247 | 16.3 | 68 | 4.5 | 33 | 2.2 | 1,086 | 71.6 | 82 | 5.4 |
| 1964 | 330 | 19.5 | 84 | 5.0 | 40 | 2.4 | 1,148 | 68.0 | 87 | 5.2 |
| 1965 | 376 | 21.0 | 74 | 4.1 | 49 | 2.7 | 1,225 | 68.3 | 70 | 3.9 |
| 1966 | 357 | 20.7 | 75 | 4.3 | 48 | 2.8 | 1,173 | 68.0 | 72 | 4.2 |
| 1967 | 335 | 19.5 | 85 | 4.9 | 49 | 2.3 | 1,195 | 69.4 | 66 | 3.8 |
| 1968 | 210 | 12.3 | 104 | 6.1 | 45 | 2.6 | 1,271 | 74.3 | 81 | 4.7 |
| 1969 | 244 | 13.6 | 85 | 4.7 | 75 | 4.2 | 1,298 | 72.2 | 95 | 5.3 |
| 1970 | 270 | 17.0 | 94 | 5.9 | 73 | 4.6 | 1,041 | 65.9 | 102 | 6.4 |
| 1971 | 265 | 16.6 | 88 | 5.5 | 65 | 4.1 | 1,087 | 68.2 | 90 | 5.6 |
| 1972 | 190 | 12.5 | 106 | 7.0 | 62 | 4.1 | 1,068 | 70.2 | 95 | 6.2 |
| 1973 | 204 | 14.1 | 95 | 6.5 | 68 | 4.7 | 958 | 66.0 | 126 | 8.7 |
| 1974 | 193 | 13.5 | 85 | 5.9 | 61 | 4.3 | 971 | 67.9 | 120 | 8.4 |
| 1975 | 192 | 12.7 | 75 | 5.0 | 63 | 4.2 | 1,031 | 68.1 | 152 | 10.0 |
| 1976 | 198 | 12.4 | 65 | 4.1 | 43 | 2.7 | 1,110 | 70.0 | 179 | 11.2 |
| 1977 | 222 | 14.3 | 76 | 4.9 | 66 | 4.2 | 1,026 | 65.9 | 167 | 10.7 |
| 1978 | NA | NA | NA | NA | NA | NA | 1,067 | NA | NA | NA |
| 1979 | 308 | 18.6 | 98 | 5.9 | 65 | 3.9 | 1,085 | 65.6 | 97 | 5.9 |
| 1980 | 322 | 21.2 | 135 | 8.9 | 63 | 4.2 | 885 | 58.4 | 111 | 7.3 |
| 1981 | 340 | 22.2 | 127 | 8.3 | 61 | 4.0 | 891 | 58.2 | 112 | 7.3 |
| 1982 | 385 | 23.2 | 93 | 5.6 | 66 | 4.0 | 975 | 58.7 | 141 | 8.5 |
| 1983 | 473 | 29.6 | 111 | 7.0 | 55 | 3.4 | 826 | 51.8 | 131 | 8.2 |
| 1984 | 505 | 26.0 | 133 | 6.8 | 60 | 3.1 | 1,019 | 52.4 | 227 | 11.7 |
| 1985 | 508 | 26.6 | 113 | 5.9 | 64 | 3.4 | 1,030 | 53.9 | 195 | 10.2 |
| 1986 | 518 | 27.8 | 137 | 7.4 | 68 | 3.6 | 916 | 49.2 | 223 | 12.0 |
| 1987 | 587 | 24.9 | 157 | 6.7 | 66 | 2.8 | 1,231 | 52.2 | 317 | 13.4 |
| 1988 | 480 | 20.3 | 215 | 9.1 | 56 | 2.4 | 1,343 | 56.7 | 273 | 11.5 |
| 1989 | 391 | 13.7 | 221 | 7.7 | 44 | 1.5 | 1,892 | 66.3 | 305 | 10.7 |
| 1990 | 467 | 14.2 | 178 | 5.4 | 33 | 1.0 | 2,303 | 70.0 | 311 | 9.4 |
| 1991 | 566 | 14.0 | 193 | 4.8 | 34 | 0.8 | 3,020 | 75.0 | 215 | 5.3 |
| 1992 | 806 | 21.7 | 175 | 4.7 | 37 | 1.0 | 2,602 | 70.2 | 160 | 4.3 |
| 1993 | 913 | -- | 188 | -- | 65 | -- | 2,711 | -- | NA | -- |

**Table 6.4** Number of vessels, fishermen, total number of traps, average number of traps, and landings in the Gulf of Mexico commercial trap fishery, 1950-1993 (NOAA personal communication). NA indicates not available. 'Full' represents full time fishermen, 'Part' represents part time fishermen.

| YEARS | VESSELS | NO. OF FISHERMEN | | | TOTAL TRAPS | AVERAGE TRAPS PER | | TRAP LANDINGS (X1000 lbs) |
|---|---|---|---|---|---|---|---|---|
| | | FULL | PART | TOTAL | | FISHERMEN | VESSEL | |
| 1950 | 63 | 64 | 3 | 67 | 4,480 | 67 | 71 | 384 |
| 1951 | 142 | 133 | 20 | 153 | 10,860 | 71 | 76 | 1,220 |
| 1952 | 174 | 156 | 28 | 184 | 17,300 | 94 | 99 | 1,875 |
| 1953 | 214 | 195 | 31 | 226 | 20,071 | 89 | 94 | 1,878 |
| 1954 | 186 | 180 | 16 | 196 | 20,779 | 106 | 112 | 1,733 |
| 1955 | 204 | 201 | 22 | 223 | 24,276 | 109 | 119 | 3,946 |
| 1956 | 235 | 226 | 22 | 246 | 27,303 | 111 | 116 | 3,883 |
| 1957 | 288 | 282 | 39 | 321 | 33,680 | 105 | 117 | 6,398 |
| 1958 | 264 | 249 | 38 | 287 | 32,741 | 114 | 124 | 9,733 |
| 1959 | 392 | 397 | 42 | 439 | 49,225 | 112 | 126 | 16,830 |
| 1960 | 404 | 419 | 34 | 453 | 49,849 | 110 | 123 | 22,912 |
| 1961 | 388 | 407 | 23 | 430 | 49,318 | 115 | 127 | 21,602 |
| 1962 | 392 | 411 | 33 | 444 | 52,354 | 118 | 134 | 15,740 |
| 1963 | 388 | 378 | 41 | 419 | 51,978 | 124 | 134 | 18,013 |
| 1964 | 458 | 476 | 35 | 511 | 70,145 | 137 | 153 | 18,844 |
| 1965 | 580 | 558 | 71 | 629 | 90,085 | 143 | 155 | 27,478 |
| 1966 | 744 | 765 | 129 | 894 | 115,010 | 129 | 154 | 25,352 |
| 1967 | 845 | 943 | 129 | 1,072 | 129,705 | 121 | 153 | 23,877 |
| 1968 | 785 | 873 | 140 | 1,013 | 125,611 | 124 | 160 | 21,180 |
| 1969 | 928 | 891 | 198 | 1,089 | 129,021 | 118 | 139 | 27,718 |
| 1970 | 1,012 | 922 | 170 | 1,092 | 139,700 | 128 | 138 | 29,009 |
| 1971 | 1,055 | 924 | 248 | 1,172 | 151,240 | 129 | 143 | 29,898 |
| 1972 | 1,072 | 941 | 206 | 1,147 | 151,222 | 132 | 141 | 30,887 |
| 1973 | 1,208 | 1,016 | 234 | 1,250 | 158,480 | 127 | 132 | 38,943 |
| 1974 | 1,231 | 1,021 | 257 | 1,278 | 170,345 | 133 | 138 | 38,580 |
| 1975 | 1,348 | 1,094 | 287 | 1,381 | 194,330 | 141 | 144 | 38,875 |
| 1976 | 1,467 | 1,210 | 290 | 1,500 | 219,919 | 147 | 150 | 35,579 |
| 1977 | 1,446 | 1,169 | 323 | 1,492 | 215,575 | 144 | 149 | 43,588 |
| 1978 | NA | NA | NA | NA | NA | NA | NA | 37,739 |
| 1979 | 1,481 | 1,153 | 500 | 1,653 | 223,001 | 135 | 150 | 43,000 |
| 1980 | 1,372 | 1,038 | 475 | 1,513 | 233,670 | 154 | 170 | 41,531 |
| 1981 | 1,363 | 1,052 | 467 | 1,519 | 238,270 | 157 | 175 | 41,873 |
| 1982 | 1,449 | 1,154 | 499 | 1,653 | 254,104 | 154 | 175 | 36,474 |
| 1983 | 1,398 | 1,121 | 459 | 1,580 | 237,749 | 150 | 170 | 40,051 |
| 1984 | 1,723 | 1,317 | 611 | 1,928 | 298,833 | 155 | 173 | 55,342 |
| 1985 | 1,647 | 1,290 | 608 | 1,898 | 320,577 | 169 | 195 | 55,438 |
| 1986 | 1,716 | 1,432 | 415 | 1,847 | 333,304 | 180 | 194 | 52,700 |
| 1987 | 1,777 | 1,983 | 356 | 2,339 | 446,076 | 191 | 251 | 77,768 |
| 1988 | 1,904 | 1,784 | 573 | 2,357 | 460,931 | 196 | 242 | 77,778 |
| 1989 | 2,093 | 2,425 | 428 | 2,853 | 440,912 | 154 | 211 | 78,936 |
| 1990 | 2,767 | 2,806 | 486 | 3,292 | 447,432 | 136 | 162 | 55,301 [1] |
| 1991 | 3,314 | 3,155 | 873 | 4,028 | 558,958 | 139 | 169 | 57,997 [1] |
| 1992 | 3,419 | 3,080 | 700 | 3,780 | 556,575 | 147 | 163 | 65,468 [1] |
| 1993 | 3,510 [2] | 3,017 [2] | 860 [2] | 3,877 [2] | 604,700 [2] | 156 | 172 | 69,570 [1] |

[1] 99.4% of total assumed to be trap landings
[2] excludes Texas

for calculating catch-per-unit-effort have been difficult since the data collection transition, there were indications throughout the 1990s of an overall decline in catch per fisherman. As of the late 1990s, Florida and Texas effort estimates are substantially higher than previously reported by the NMFS. As a result, in some states effort reduction programs were initiated to prevent more traps being fished than necessary (Sections 6.6.1 and 6.6.5). Several options have been used to prevent overcapitalization of the fishery including license moratoriums, qualifying income and license criteria, license buyback programs, trap limitations, and trip quotas. However, many traditional commercial fishing families depend on multiple fisheries, such as shrimp and oyster, and rotate seasonally and annually as abundance and market conditions dictate. Annual limited entry requirements may permanently force historical fishermen out of the crab fishery. Frequent derelict crab trap removal programs have also been instituted Gulf-wide as a means of reducing latent effort.

In Florida there was a significant increase in the number of blue crab endorsements sold in 1995. During this period a statewide ban on net fishing was implemented and many commercial finfish fishermen entered the blue crab fishery. The statewide number of licenses increased from 4,933 in 1994 to 6,082 in 1995. After the increase in 1995, a steady decrease in endorsements followed as spectator (lesser utilized or unused) licenses were slowly eliminated over time. Florida's Blue Crab Effort Management Plan (BCEMP) was enacted in 2007 to further decrease effort to address socio-economic issues of seasonal crowding of traps in confined waterways, lost traps, bycatch, overcapitalization, latent endorsements and conflicts between hard shell blue crab fishermen and soft shell blue crab fishermen.

According to the TPWD, the number of Texas crab fishermen peaked in 1994 at 345 fishermen and has since declined to 196 fishermen in 2011. Texas' Crab License Management Program passed by the legislature in 1997 and issuing a limited entry and a crab license buyback program have played a major role in facilitating this decline.

In the last decade Gulf-wide license sales for resident commercial crab trap fishermen have remained steady, averaging 4,282 per year (Table 6.2). Decreases in licenses sales were evident in all Gulf states in part as a result from vessel, gear and infrastructure devastation following the 2004-2005 hurricane seasons and in 2008 for Louisiana and Texas following additional hurricanes. Commercial licenses were required for participation in recovery programs offered by British Petroleum in the wake of the DWH disaster and this resulted in an increase in license sales in the northern Gulf during 2010-2011.

### 6.1.5 Landings

Unreported hard crab landings in the Gulf of Mexico are a serious problem (Adkins 1972a, Moss 1982, Roberts and Thompson 1982, Keithly et al. 1988, Steele and Perry 1990). Although the fishery is characterized by year-to-year fluctuations in reported landings and there are acknowledged limitations associated with use of NMFS statistical data, long-term trends and cycles in the landings can be identified.

Total reported landings in the Gulf increased from less than 1.0M pounds in the late 1800s to approximately 18M pounds prior to World War II (Table 6.5). Landings increased markedly in the late 1950s with introduction of the wire trap (Table 6.6 and 6.7 and Figure 6.1). The increased availability of raw product associated with adoption of the wire trap stimulated processing capacity and market development, and landings continued to rise through the 1980s. Record landings of 78M and 79M pounds occurred in 1987 and 1988, respectively. The dramatic increase in landings during the 1980s can be attributed to increased fishing effort and increased processing capacity in some states. Landings declined slightly after 1988 and ranged from approximately 50M-70M pounds and except for 1989, 1990, 1994, and 1995 remained above the 15 year (1983-1997) average of 60.7M pounds.

While landings continued to fluctuate widely, there has been a general downward trend Gulf-wide over the last decade (2000-2010). Several events led to the decline in landings including the hurricanes of 2004-2005 that displaced fishermen and gear and prevented harvest in the northern Gulf in 2005 and 2006. Two additional storms impacted Louisiana and Texas directly in 2008. In April 2010, the DWH disaster led to the closing of most of the north-central Gulf during the peak of the fishing season. These events reduced fishing effort for extended periods of time. Effort reduction management in Texas (1997) and Florida (2007) may have reduced landings in those states.

Blue crab fisheries are characterized by seasonal, annual, and geographic fluctuations in landings. Gulf landings increased 48.0% from 1986-1987 but declined 29.8% from 1988-1989. Fluctuations in landings have become more pronounced in recent years (Figure 6.2). Sources of this variability in annual landings include economic factors related to market demand and processing capacity (Lyles 1976, Moss 1982); economic interdependency with other fisheries (Steele and Perry 1990); changes in fishing effort (Guillory et al. 1996); and variability in year-class strength (Steele and Perry 1990).

During the 1950s and 1960s the fishery gradually evolved from a trotline to trotlinedrop net to a trap dominated fishery (Table 6.7 and Figure 6.1). Trotline landings comprised 95.9% of all landings in 1950 and at least 75% of the total through 1955 but then began a gradual decline until landings were <0.1% during the early 1980s; trotline landings were not recorded after 1984. Although used only in Louisiana, drop nets averaged 6.9% of annual Gulf landings from 1954-1965 with a peak of 12.7% in 1956. Drop net landings gradually declined and were last recorded in 1972. The introduction and widespread adoption of the wire crab trap had a pronounced effect on the commercial fishery (Steele and Perry 1990). The NMFS statistics show that crab traps were used in Louisiana and Texas as early as 1948 with wide acceptance beginning in Florida in the middle 1950s. The Gulf-wide contribution of trap landings steadily increased from 2% in 1950 to 99% in 1979 (Figure 6.1). In 1959, traps became the dominant gear in terms of Gulf landings. By 1960, trap landings in every state except Louisiana and Alabama exceeded landings from any other gear. From the late 1970s through the 1990s, trap landings contributed 98-99% of total landings. Reported landings of blue crabs taken in trawls have fluctuated widely. Although directed trawl fisheries exist, the fishing is seasonal and related to economic conditions in other fisheries. Trawl landings were highest in the 1960s and early 1970s, averaging 3.8% of the total; for the 19851994 period trawl landings were <1% of the total. Trawl landings declined steadily since the early

**Table 6.5** Historical Gulf of Mexico hard-shell blue crab landing statistics, 1880-1950 (quantity [Q] X1000 lbs; value [V] X1000 dollars). NA indicates data not available; (1) Less than 500 lbs or $500 reported.

| YEAR | FLW | | AL | | MS | | LA | | TX | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q | V | Q | V | Q | V | Q | V | Q | V | Q | V |
| 1880 | -- | -- | -- | -- | -- | -- | 288 | 7 | 36 | 1 | 324 | 8 |
| 1887 | NA | NA | NA | NA | 38 | 1 | 837 | 13 | 111 | 4 | NA | NA |
| 1888 | 3 | (1) | 96 | 6 | 16 | (1) | 851 | 13 | 115 | 4 | 1,081 | 23 |
| 1889 | -- | -- | -- | -- | 48 | 1 | 842 | 14 | 189 | 5 | 1,079 | 20 |
| 1890 | -- | -- | -- | -- | 33 | 1 | 851 | 13 | 191 | 5 | 1,075 | 19 |
| 1891 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1892 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1895 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1897 | 6 | (1) | 24 | 1 | 132 | 3 | 1,459 | 13 | 138 | 4 | 1,759 | 21 |
| 1898 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1899 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1901 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1902 | 1 | (1) | 75 | 2 | 235 | 5 | 312 | 16 | 43 | 2 | 666 | 25 |
| 1904 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1905 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1908 | 2 | (1) | 246 | 6 | 380 | 10 | 244 | 8 | 199 | 5 | 1,071 | 29 |
| 1915 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1918 | -- | -- | 96 | 3 | 216 | 6 | 282 | 10 | 193 | 11 | 787 | 30 |
| 1919 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1920 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1921 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1922 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1923 | -- | -- | 84 | 3 | 435 | 11 | 312 | 8 | 109 | 9 | 940 | 31 |
| 1924 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1925 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1926 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1927 | 12 | 1 | 32 | 1 | 2,426 | 62 | 1,091 | 51 | 121 | 9 | 3,682 | 124 |
| 1928 | 7 | 1 | 102 | 4 | 1,518 | 40 | 2,320 | 78 | 300 | 12 | 4,247 | 135 |
| 1929 | 2 | (1) | 103 | 3 | 1,247 | 33 | 2,675 | 78 | 163 | 11 | 4,190 | 125 |
| 1930 | 4 | (1) | 80 | 1 | 673 | 11 | 4,186 | 63 | 29 | 1 | 4,972 | 76 |
| 1931 | 4 | (1) | 78 | 1 | 454 | 7 | 4,985 | 53 | 49 | 1 | 5,570 | 62 |
| 1932 | 4 | (1) | 70 | 1 | 320 | 5 | 5,878 | 57 | 45 | 1 | 6,317 | 64 |
| 1933 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1934 | 49 | 1 | 257 | 4 | 603 | 7 | 11,676 | 164 | 258 | 13 | 12,843 | 189 |
| 1935 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1936 | 821 | 12 | 997 | 14 | 2,011 | 30 | 12,576 | 168 | 320 | 8 | 16,725 | 232 |
| 1937 | 775 | 12 | 756 | 11 | 1,435 | 25 | 14,717 | 195 | 922 | 24 | 18,605 | 267 |
| 1938 | 1,104 | 16 | 511 | 8 | 1,016 | 17 | 10,533 | 106 | 971 | 24 | 14,135 | 171 |
| 1939 | 722 | 11 | 558 | 8 | 1,469 | 25 | 11,228 | 129 | 406 | 8 | 14,383 | 181 |

| YEAR | FLW | | AL | | MS | | LA | | TX | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q | V | Q | V | Q | V | Q | V | Q | V | Q | V |
| 1940 | 1,170 | 16 | 1,381 | 28 | 1,488 | 26 | 14,062 | 172 | 252 | 6 | 18,353 | 248 |
| 1941 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1942 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1943 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1944 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1945 | 1,092 | 54 | 2,207 | 110 | 5,639 | 282 | 31,280 | 1,418 | 339 | 39 | 40,557 | 1,903 |
| 1946 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1947 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| 1948 | NA | NA | 2,373 | 119 | 5,503 | 275 | 21,110 | 608 | 526 | 34 | NA | NA |
| 1949 | 2,056 | 91 | 2,128 | 106 | 4,163 | 208 | 17,874 | 555 | 374 | 22 | 26,595 | 982 |
| 1950 | 684 | 27 | 599 | 26 | 4,040 | 202 | 13,106 | 599 | 387 | 30 | 18,816 | 884 |

* Partial surveys were done prior to 1912 and in 1934, 1936 through 1940, 1945, 1948 and 1949 and 1951.

1990s as states imposed greater restrictions on bycatch in the shrimp fishery. Trap landings since 2000 have provided over 99% of the total Gulf landings for the states that identify contributions by gear (Figure 6.1).

Percentage of Gulf landings to total U.S. landings ranged from 12.0% to 38.9% in 1952 and 1987, respectively (Table 6.8). From 1962-1967, the Gulf states generally contributed less than 20% of total U.S. landings. The total Gulf contribution increased gradually to 34.5% in 1977 and then declined to 18.8% in 1982. With the increase in Louisiana landings in the middle 1980s, Gulf

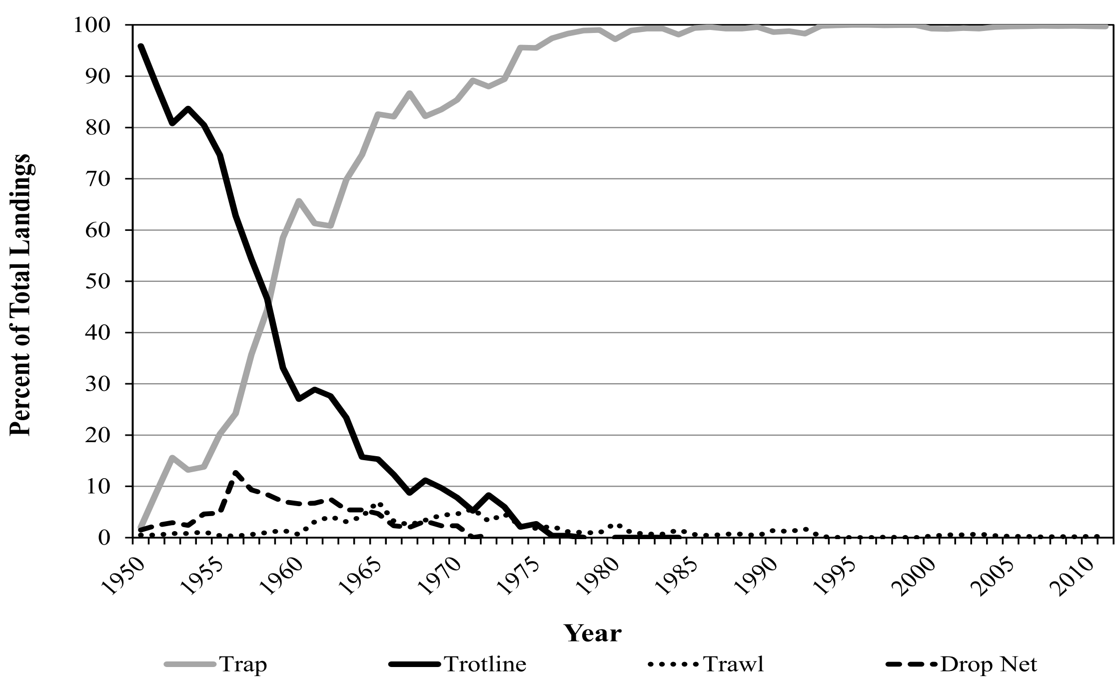



**Figure 6.1** Percent of total Gulf of Mexico blue crab commercial landings by gear from 1950-2011 (NOAA personal communication).

**Table 6.6** Hard crab landings (X1000 lbs) by state, 1950-2011 (NOAA personal communication).

| YEAR | FL | AL | MS | LA | TX | TOTAL |
|---|---|---|---|---|---|---|
| 1950 | 684 | 599 | 4,040 | 13,106 | 387 | 18,816 |
| 1951 | 2,076 | 1,109 | 1,623 | 8,710 | 280 | 13,798 |
| 1952 | 1,984 | 655 | 1,726 | 7,334 | 338 | 12,037 |
| 1953 | 3,153 | 1,087 | 1,412 | 8,131 | 432 | 14,215 |
| 1954 | 2,903 | 972 | 1,256 | 7,085 | 379 | 12,595 |
| 1955 | 4,954 | 1,613 | 1,763 | 10,811 | 356 | 19,497 |
| 1956 | 3,728 | 725 | 1,979 | 9,402 | 195 | 16,029 |
| 1957 | 5,302 | 1,462 | 2,400 | 8,559 | 201 | 17,924 |
| 1958 | 8,693 | 1,182 | 2,124 | 9,336 | 570 | 21,905 |
| 1959 | 13,895 | 1,093 | 3,003 | 9,570 | 1,192 | 28,753 |
| 1960 | 18,648 | 499 | 2,812 | 10,050 | 2,867 | 34,876 |
| 1961 | 17,130 | 838 | 2,505 | 11,910 | 2,875 | 35,258 |
| 1962 | 10,356 | 634 | 907 | 9,523 | 4,473 | 25,893 |
| 1963 | 13,148 | 1,297 | 1,112 | 7,982 | 2,980 | 26,519 |
| 1964 | 14,068 | 1,762 | 1,286 | 5,692 | 2,484 | 25,292 |
| 1965 | 20,598 | 1,812 | 1,692 | 9,284 | 3,622 | 37,008 |
| 1966 | 16,547 | 2,183 | 1,457 | 7,986 | 2,778 | 30,951 |
| 1967 | 13,976 | 2,353 | 1,015 | 7,559 | 2,625 | 27,528 |
| 1968 | 9,008 | 1,980 | 1,136 | 9,551 | 4,084 | 25,759 |
| 1969 | 11,584 | 1,920 | 1,740 | 11,602 | 6,343 | 33,189 |
| 1970 | 14,786 | 1,407 | 2,027 | 10,254 | 5,525 | 33,999 |
| 1971 | 12,279 | 1,997 | 1,259 | 12,186 | 5,810 | 33,531 |
| 1972 | 10,673 | 1,612 | 1,362 | 15,083 | 6,464 | 35,194 |
| 1973 | 9,599 | 2,098 | 1,814 | 23,080 | 6,881 | 43,472 |
| 1974 | 10,134 | 1,826 | 1,167 | 20,639 | 6,088 | 39,854 |
| 1975 | 12,807 | 1,639 | 1,137 | 17,144 | 5,992 | 38,719 |
| 1976 | 12,049 | 1,299 | 1,334 | 15,211 | 6,668 | 36,561 |
| 1977 | 15,832 | 2,174 | 1,919 | 16,154 | 8,249 | 44,328 |
| 1978 | 11,679 | 2,009 | 1,940 | 15,074 | 7,470 | 38,172 |
| 1979 | 11,198 | 1,341 | 1,313 | 21,334 | 8,312 | 43,498 |
| 1980 | 11,276 | 1,557 | 2,760 | 18,183 | 8,953 | 42,729 |
| 1981 | 14,788 | 2,462 | 1,867 | 16,237 | 6,952 | 42,306 |
| 1982 | 8,871 | 1,266 | 1,297 | 17,284 | 8,010 | 36,728 |
| 1983 | 9,337 | 1,412 | 1,140 | 19,616 | 8,829 | 40,334 |
| 1984 | 12,912 | 4,216 | 2,250 | 29,617 | 7,229 | 56,224 |
| 1985 | 12,273 | 2,261 | 1,649 | 29,848 | 9,722 | 55,753 |
| 1986 | 7,644 | 2,886 | 1,303 | 31,611 | 9,482 | 52,926 |
| 1987 | 10,425 | 2,507 | 1,374 | 52,345 | 11,688 | 78,339 |
| 1988 | 10,403 | 3,869 | 863 | 53,554 | 10,428 | 79,117 |
| 1989 | 8,197 | 4,090 | 651 | 33,390 | 9,066 | 55,394 |

| YEAR | FL | AL | MS | LA | TX | TOTAL |
|---|---|---|---|---|---|---|
| 1990 | 6,915 | 3,302 | 390 | 39,135 | 8,599 | 58,341 |
| 1991 | 5,235 | 2,731 | 454 | 51,987 | 6,137 | 66,538 |
| 1992 | 7,654 | 3,550 | 443 | 51,744 | 6,135 | 69,578 |
| 1993 | 8,459 | 2,554 | 230 | 45,847 | 8,288 | 65,378 |
| 1994 | 8,458 | 2,744 | 171 | 36,664 | 5,154 | 53,891 |
| 1995 | 8,725 | 2,520 | 321 | 36,914 | 5,787 | 53,925 |
| 1996 | 11,140 | 3,219 | 407 | 39,902 | 6,310 | 62,250 |
| 1997 | 9,246 | 3,476 | 683 | 43,440 | 5,739 | 62,584 |
| 1998 | 12,771 | 3,478 | 592 | 43,480 | 6,989 | 67,309 |
| 1999 | 11,047 | 3,768 | 920 | 46,328 | 6,472 | 68,534 |
| 2000 | 6,413 | 4,780 | 839 | 51,446 | 4,653 | 68,131 |
| 2001 | 4,548 | 2,457 | 432 | 41,398 | 5,163 | 53,998 |
| 2002 | 5,489 | 2,575 | 716 | 49,751 | 7,037 | 65,568 |
| 2003 | 7,141 | 2,957 | 875 | 47,705 | 4,811 | 63,489 |
| 2004 | 8,008 | 3,329 | 811 | 44,069 | 3,961 | 60,177 |
| 2005 | 7,312 | 1,024 | 429 | 37,880 | 3,119 | 49,763 |
| 2006 | 8,565 | 2,384 | 1,127 | 53,252 | 1,966 | 67,294 |
| 2007 | 6,074 | 2,554 | 737 | 44,902 | 3,454 | 57,722 |
| 2008 | 2,627 | 1,799 | 450 | 41,617 | 2,635 | 49,128 |
| 2009 | 3,313 | 1,458 | 545 | 52,848 | 2,844 | 61,010 |
| 2010 | 5,709 | 927 | 366 | 30,599 | 3,436 | 41,037 |
| 2011 | 1,616 | 1,616 | 370 | 43,698 | 2,893 | 50,192 |

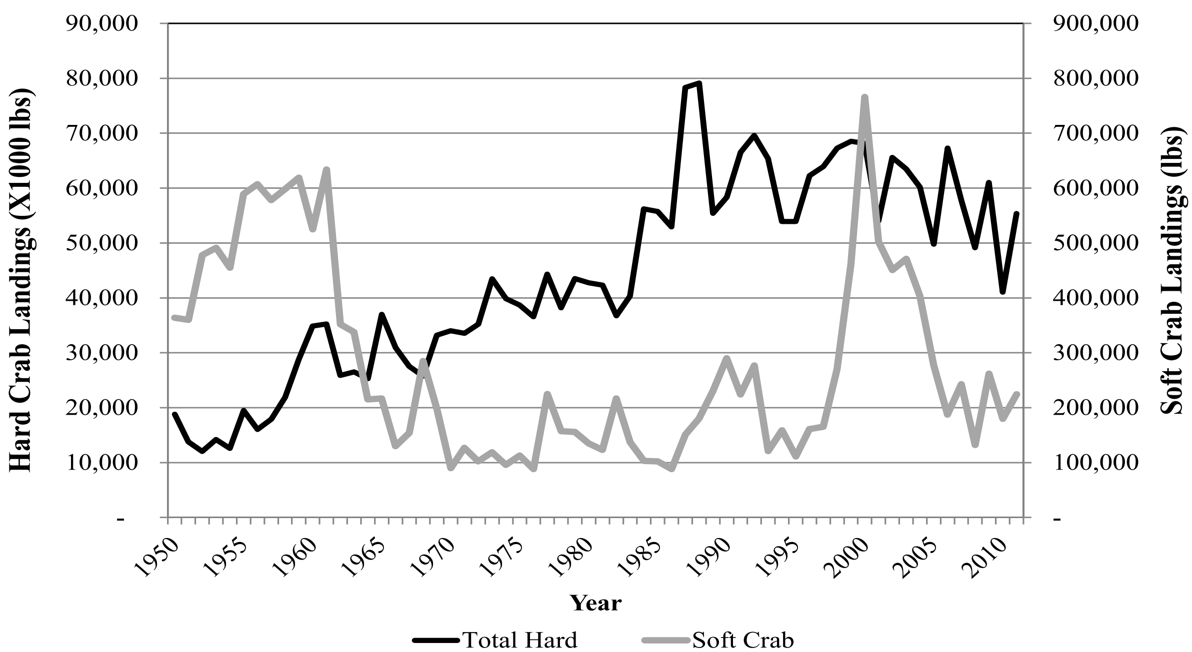



**Figure 6.2** Total landings of hard and soft crabs in the Gulf of Mexico from 1950-2011 (NOAA personal communication).

production increased to 38.9% of total U.S. landings in 1987. Gulf production averaged 26.8% of U.S. landings for hard crabs during the 1990s but, since 2000, has averaged around 34%, despite the reduction in effort for several of those years. In 2006, immediately after hurricanes Katrina, Rita, and Wilma of 2005, the Gulf's contribution reached an all-time high of 41.3% of the total U.S. hard crab landings.

Landings by state are listed in Table 6.6. The percent contribution of each Gulf state to total Gulf landings is shown in Table 6.8. For hard and soft crabs combined, Louisiana ranked first

**Table 6.7** Percent contribution by gear of Gulf of Mexico hard crab landings, 1950-1994 (NOAA personal communication).

| YEAR | TRAP | TROTLINE | TRAWL | DROP NET |
|---|---|---|---|---|
| 1950 | 2.0 | 95.9 | 0.5 | 1.5 |
| 1951 | 8.9 | 88.2 | 0.5 | 2.4 |
| 1952 | 15.6 | 80.8 | 0.8 | 2.9 |
| 1953 | 13.2 | 83.7 | 0.8 | 2.4 |
| 1954 | 13.8 | 80.5 | 1.1 | 4.6 |
| 1955 | 20.2 | 74.6 | 0.4 | 4.8 |
| 1956 | 24.2 | 62.8 | 0.3 | 12.7 |
| 1957 | 35.7 | 54.3 | 0.6 | 9.3 |
| 1958 | 44.4 | 46.6 | 1.0 | 8.4 |
| 1959 | 58.5 | 33.1 | 1.4 | 7.0 |
| 1960 | 65.7 | 27.0 | 0.6 | 6.6 |
| 1961 | 61.3 | 28.9 | 3.1 | 6.7 |
| 1962 | 60.8 | 27.6 | 4.1 | 7.5 |
| 1963 | 69.8 | 23.4 | 3.1 | 5.4 |
| 1964 | 74.7 | 15.7 | 4.1 | 5.4 |
| 1965 | 82.6 | 15.3 | 7.0 | 4.7 |
| 1966 | 82.1 | 12.3 | 3.2 | 2.3 |
| 1967 | 86.7 | 8.7 | 2.5 | 2.0 |
| 1968 | 82.2 | 11.2 | 3.4 | 3.2 |
| 1969 | 83.5 | 9.7 | 4.4 | 2.3 |
| 1970 | 85.4 | 7.8 | 4.6 | 2.3 |
| 1971 | 89.2 | 5.2 | 5.6 | <0.1 |
| 1972 | 88.0 | 8.3 | 3.2 | 0.5 |
| 1973 | 89.4 | 6.0 | 4.6 | 0.0 |
| 1974 | 95.6 | 2.1 | 2.3 | 0.0 |
| 1975 | 95.5 | 2.7 | 1.8 | 0.0 |
| 1976 | 97.4 | 0.4 | 2.2 | 0.0 |
| 1977 | 98.3 | 0.4 | 1.2 | 0.0 |
| 1978 | 98.9 | <0.1 | 1.0 | 0.0 |

| YEAR | TRAP | TROTLINE | TRAWL | DROP NET |
|---|---|---|---|---|
| 1979 | 99.0 | 0.0 | 0.9 | 0.0 |
| 1980 | 97.2 | <0.1 | 2.8 | 0.0 |
| 1981 | 98.9 | <0.1 | 1.0 | 0.0 |
| 1982 | 99.3 | <0.1 | 0.7 | 0.0 |
| 1983 | 99.3 | <0.1 | 0.7 | 0.0 |
| 1984 | 98.1 | <0.1 | 1.5 | 0.0 |
| 1985 | 99.4 | 0.0 | 0.6 | 0.0 |
| 1986 | 99.6 | 0.0 | 0.4 | 0.0 |
| 1987 | 99.3 | 0.0 | 0.7 | 0.0 |
| 1988 | 99.3 | 0.0 | 0.7 | 0.0 |
| 1989 | 99.6 | 0.0 | 0.4 | 0.0 |
| 1990 | 98.6 | 0.0 | 1.4 | 0.0 |
| 1991 | 98.8 | 0.0 | 1.2 | 0.0 |
| 1992 | 98.3 | 0.0 | 1.7 | 0.0 |
| 1993 | 99.8 | 0.0 | 0.2 | 0.0 |
| 1994 | 98.9 | 0.0 | 1.1 | 0.0 |

in landings throughout most of the 1950s, with Florida replacing Louisiana during the early and mid-1960s, and Louisiana again dominating Gulf landings after 1971. Louisiana's contribution gradually increased with time, and by the mid-1980s, more than 50% of total Gulf landings were from Louisiana. In 1987, Louisiana produced 66.8% of the total Gulf catch.

Florida generally ranked second to Louisiana, although Texas had higher landings for the 19861991 period. Florida's contribution to total Gulf landings decreased from 35.0% in 1981 to 13.3% in 1987. The percent contribution of Texas to Gulf landings increased through the early 1980s, dropped to 12.9% from 21.9% in 1984, and then rose again to 17.9% in 1986. On a percentage basis, Alabama landings have remained fairly consistent over time, usually ranging from 3% to 8%. Mississippi landings averaged 12.2% of the total during the 1950s but then gradually declined; by the 1990s Mississippi landings decreased to 0.6% of the total. The average percent contribution by state during the 1980s and 1990s were: Louisiana, 60.9%; Florida, 17.7%; Texas, 14.3%; Alabama, 4.9%; and, Mississippi, 1.9%. In the last decade, Louisiana has continued to dominate the blue crab landings for hard and soft crabs in the Gulf, increasing from 75.5% of the total Gulf landings in 2000 to 86.6% by 2009. Landings in Florida averaged around 10%, Alabama 4%, Mississippi 1%, and Texas 7% of the Gulf region total harvest.

In addition to interstate differences, blue crab landings also varied within states. Steele (1982) reported that more than 50% of the blue crabs landed from Florida's west coast were from Apalachicola Bay south to Waccasassa Bay. Steele and Bert (1998) reported that Florida west coast blue crab landings were highest north of Hillsborough and Pinellas counties and south of Cape San Blas. In Alabama, the bulk of production comes from Mississippi Sound (57%) with

**Table 6.8** Percent contribution by state to Gulf of Mexico hard crab landings and Gulf to the total U.S. landings, 1950-2011.

| YEAR | FL | AL | MS | LA | TX | % TOTAL U.S. |
|---|---|---|---|---|---|---|
| 1950 | 3.6 | 3.2 | 21.5 | 69.6 | 2.0 | 15.8 |
| 1951 | 15.0 | 8.0 | 11.7 | 63.1 | 2.0 | 12.8 |
| 1952 | 16.5 | 5.4 | 14.3 | 60.9 | 2.8 | 12.0 |
| 1953 | 22.2 | 7.6 | 9.9 | 57.2 | 3.0 | 13.5 |
| 1954 | 23.0 | 7.7 | 10.0 | 56.2 | 3.0 | 12.9 |
| 1955 | 25.4 | 8.3 | 9.0 | 55.4 | 1.8 | 20.0 |
| 1956 | 23.2 | 4.5 | 12.3 | 58.6 | 1.2 | 17.0 |
| 1957 | 29.6 | 8.2 | 13.4 | 47.8 | 1.1 | 16.6 |
| 1958 | 40.0 | 5.4 | 9.7 | 42.6 | 2.6 | 20.7 |
| 1959 | 48.3 | 3.8 | 10.4 | 33.5 | 4.1 | 25.6 |
| 1960 | 53.5 | 1.4 | 8.1 | 28.8 | 8.2 | 23.3 |
| 1961 | 48.6 | 2.4 | 7.1 | 33.8 | 8.2 | 23.9 |
| 1962 | 40.0 | 2.4 | 3.5 | 36.8 | 17.3 | 17.3 |
| 1963 | 49.6 | 4.9 | 4.2 | 30.1 | 11.2 | 18.7 |
| 1964 | 55.6 | 7.0 | 5.1 | 22.5 | 9.8 | 16.6 |
| 1965 | 55.7 | 4.9 | 4.6 | 25.1 | 9.8 | 22.2 |
| 1966 | 53.5 | 7.1 | 4.7 | 25.8 | 9.0 | 18.6 |
| 1967 | 30.8 | 8.5 | 3.7 | 27.5 | 9.5 | 19.0 |
| 1968 | 35.0 | 7.7 | 4.4 | 37.1 | 15.9 | 22.7 |
| 1969 | 34.9 | 5.8 | 5.2 | 35.0 | 19.1 | 25.1 |
| 1970 | 43.5 | 4.1 | 6.0 | 30.2 | 16.3 | 23.4 |
| 1971 | 36.6 | 6.0 | 3.8 | 36.3 | 17.3 | 22.5 |
| 1972 | 30.3 | 4.6 | 3.9 | 42.9 | 18.4 | 23.9 |
| 1973 | 22.1 | 4.8 | 4.2 | 53.1 | 15.8 | 31.8 |
| 1974 | 25.1 | 4.5 | 4.1 | 51.1 | 15.1 | 27.1 |
| 1975 | 33.1 | 4.2 | 2.9 | 48.3 | 15.5 | 28.7 |
| 1976 | 33.0 | 3.6 | 3.6 | 41.6 | 18.2 | 31.7 |
| 1977 | 35.7 | 4.9 | 4.3 | 36.4 | 18.6 | 34.5 |
| 1978 | 30.6 | 5.3 | 5.1 | 39.5 | 19.6 | 27.6 |
| 1979 | 25.7 | 3.1 | 3.0 | 49.0 | 19.1 | 28.5 |
| 1980 | 26.4 | 3.6 | 6.5 | 42.6 | 21.0 | 26.2 |
| 1981 | 35.0 | 5.8 | 4.4 | 38.4 | 16.4 | 21.7 |
| 1982 | 24.2 | 3.4 | 3.5 | 47.1 | 21.8 | 18.8 |
| 1983 | 23.1 | 3.5 | 2.8 | 48.6 | 21.9 | 21.0 |
| 1984 | 23.0 | 7.5 | 4.0 | 52.7 | 12.9 | 27.9 |
| 1985 | 22.0 | 4.1 | 3.0 | 53.5 | 17.4 | 29.3 |
| 1986 | 14.4 | 5.5 | 2.5 | 59.7 | 17.9 | 31.0 |
| 1987 | 13.3 | 3.2 | 1.8 | 66.8 | 14.9 | 38.9 |

| YEAR | FL | AL | MS | LA | TX | % TOTAL U.S. |
|---|---|---|---|---|---|---|
| 1988 | 13.1 | 4.9 | 1.1 | 67.7 | 13.2 | 35.8 |
| 1989 | 14.7 | 7.4 | 1.2 | 60.3 | 16.4 | 38.2 |
| 1990 | 11.8 | 5.7 | 0.7 | 67.1 | 14.7 | 27.6 |
| 1991 | 7.9 | 4.1 | 0.7 | 77.9 | 9.3 | 26.3 |
| 1992 | 10.9 | 5.3 | 0.6 | 74.3 | 8.8 | 35.4 |
| 1993 | 13.0 | 3.9 | 0.4 | 70.4 | 12.4 | 25.9 |
| 1994 | 15.7 | 5.1 | 0.3 | 68.0 | 9.6 | 24.3 |
| 1995 | 16.2 | 4.6 | 0.6 | 68.4 | 10.1 | 25.9 |
| 1996 | 19.9 | 5.2 | 0.6 | 64.1 | 10.1 | 27.8 |
| 1997 | 14.8 | 5.6 | 1.1 | 69.4 | 9.2 | 21.6 |
| 1998 | 19.0 | 5.2 | 0.9 | 64.6 | 10.4 | 31.0 |
| 1999 | 16.1 | 5.5 | 1.3 | 67.6 | 9.4 | 32.0 |
| 2000 | 9.4 | 7.0 | 1.2 | 75.5 | 6.8 | 38.0 |
| 2001 | 8.4 | 4.6 | 0.8 | 76.7 | 9.6 | 35.6 |
| 2002 | 8.4 | 3.9 | 1.1 | 75.9 | 10.7 | 38.6 |
| 2003 | 11.2 | 4.7 | 1.4 | 75.1 | 7.6 | 38.3 |
| 2004 | 13.3 | 5.5 | 1.3 | 73.2 | 6.6 | 35.6 |
| 2005 | 14.7 | 2.1 | 0.9 | 76.1 | 6.3 | 32.3 |
| 2006 | 12.7 | 3.5 | 1.7 | 79.1 | 2.9 | 41.4 |
| 2007 | 10.5 | 4.4 | 1.3 | 77.8 | 6.0 | 37.4 |
| 2008 | 5.3 | 3.7 | 0.9 | 84.7 | 5.4 | 30.7 |
| 2009 | 5.4 | 2.4 | 0.9 | 86.6 | 4.7 | 35.1 |
| 2010 | 13.9 | 2.3 | 0.9 | 74.6 | 8.4 | 20.8 |
| 2011 | 12.3 | 2.9 | 0.7 | 78.9 | 5.2 | 28.1 |

20% of the landings taken from Mobile Bay (Swingle 1971). No information on catch by estuarine system is available for Mississippi, although the majority of the catch probably comes from Mississippi Sound proper (Perry et al. 1984). The area between the Mississippi and Atchafalaya rivers contributed 67.9% of Louisiana's blue crab landings since 1979 (Guillory et al. 1996). From 1972-1997, 48% of Texas commercial hard crab landings came from the Galveston Bay and San Antonio Bay systems (Robinson et al. 1998).

Seasonal fluctuations in reported commercial landings are similar among Gulf states. Commercial crab fishing generally begins in March or April as water temperatures rise above 15EC. Greatest commercial catches usually occur from May through August with peak catches in June or July. A secondary peak may occur in October, after which landings abruptly decline with water temperature. These general trends may shift slightly from month to month depending upon prevailing environmental and/or market conditions.

### 6.1.6 Aquaculture

Early blue crab aquaculture was developed as a way to describe early life history stages and to distinguish *Callinectes sapidus* larvae from the larvae of its congeners. Early studies (Brooks 1882, Paulmier 1903, Hay 1905, Binford 1911, Robertson 1938, Churchill 1942, Lochhead et al. 1942, Hopkins 1943, Hopkins 1944, Sandoz and Hopkins 1944, and Sandoz and Rogers 1944) were not successful in rearing larvae through all zoeal stages and the megalopal instar. Costlow and Bookhout (1959) successfully reared blue crabs from eggs to juveniles under controlled laboratory conditions and fully described the larvae from Atlantic coast specimens. Early life history stages of blue crabs from the Gulf of Mexico were described by Stuck et al. (2009) who noted that size and setation varied from Atlantic coast descriptions of the species.

Culture from egg to adult crab has not been practiced in a commercial setting. Although blue crabs can reach maturity and market size in less than one year under optimal rearing conditions, high mortality rates, high labor demands associated with larval rearing, a prolonged larval life, cannibalism, and the relatively low market value for hard crabs were considered impediments to successful aquaculture (Oesterling and Provenzano 1985, Lunz 1968). Leary (1967) suggested that blue crabs could be raised in ponds or artificial impoundments; however, he provided no documentation. In saltwater ponds used for aquaculture experiments, blue crabs yielded about 112 kg/ha in South Carolina (Lunz 1968) and 79.1 kg/ha in Louisiana shrimp ponds (Rose et al. 1975).

Declining blue crab populations in Chesapeake Bay and the Gulf of Mexico stimulated interest in the development of blue crab aquaculture technology for mass production. While recruitment rates of blue crabs in the northern Gulf of Mexico have been adequate but variable, the abundance of juvenile crabs in fishery-independent surveys in Louisiana, Mississippi, and Alabama has declined significantly suggesting post-settlement mortality is increasing (Perry et al. 2009, Riedel et al. 2010, Sanchez-Rubio et al. 2011). Continued significant downward trends in juvenile abundances of blue crabs suggest that a critical threshold in sustainability of some fisheries resources in the northern Gulf of Mexico may be reached (Riedel et al. 2010). Blue crab aquaculture has the potential to supplement fishery resources with negligible impact to wild stocks.

Mass production technology was developed by Zmora et al. (2005) in Maryland. Two blue crab hatcheries currently exist in the U.S., one at the University of Maryland Baltimore County and one at the University of Southern Mississippi's Gulf Coast Research Laboratory. Blue crab hatchery operations have survival rates ranging from 23-74% (Zmora et al. 2005), up to 80% (Zmora et al. 2011), and 15-51% (Graham et al. 2012). Juvenile production rates in closed-recirculating systems ranged from 5.7-19.9% (Zmora et al. 2005), up to 35% (Zmora et al. 2011) and up to 29% (Graham et al. 2012). Mortality is high at the early juvenile grow out stage, due to cannibalism. Adding substrate to culture tanks where juvenile densities are high mitigates the effects of cannibalism but does not eliminate the problem (Zmora et al. 2005).

Pond aquaculture of blue crabs has shown commercial potential. Survival of crabs in ponds has been as high as 25.1% in North Carolina (Eggleston et al. 2007) and 28% in Mississippi (Graham et al. 2012) and is dependent on many factors including stocking density, substrate availability, periodic harvest methods, and long residence time in ponds. The ability to reliably produce cultured crabs has great potential to expand the soft crab fishery in the Gulf of Mexico. The softshell crab fishery in the Gulf has been and continues to be limited by the lack of supply of peeler crabs (Perry et al. 1982) and the demand for softshells continues to exceed domestic supply (McDonald and DuPaul 1986). Pond culture of peeler crabs would greatly reduce pressure on natural populations and would allow for expansion of the fishery independent of wild stocks. Cultured blue crabs can also support a bait crab industry in the Gulf of Mexico. Bait crabs were provided to recreational fisherman participating in local fishing tournaments in Mississippi (Graham et al. 2012) with the anglers successfully catching red drum, cobia, red snapper, gag grouper, and black drum.

Taste (organoleptic) tests between wild-caught and pond reared hard shell crabs were conducted in Mississippi, with the greatest percentage of participants selecting pond-reared crabs over wild-caught (Graham et al. 2012). Pond raised softshell crabs were highlighted during a public taste test at a local restaurant on the Mississippi Gulf coast, with a positive response from participants (Perry et al. 2010). Taste testing in North Carolina has yielded similar positive results (Eggleston et al. 2004) with the exception of one test (Eggleston et al. 2007).

### 6.2 Gulf Commercial Soft Crab Fishery

Across the U.S., total production of soft crab/peelers has ranged from around 4-5 million pounds throughout most of the 1950s and 1960s, to 2.0M on average in the 1970s, and 5.0M until 2005. During that time, the Gulf production ranged from 10-12% of the total U.S. production in the mid to late 1950s, down to 4% in the early 1970s, to about 5% in the late 1980s and early 1990s. Production in the last decade varied widely, averaging around 8% of the total U.S. soft crab production. There were a number of punctuated spikes over the years following the peak in the 1950s; 1967 (10.5%), 1977 (10.6%), 2000 (11.5%), and 2009 (12.6%). With the exception of an unusually high production in the Gulf in 2000 (766,138 pounds), it appears that the Atlantic Coast production of soft shells was lower than usual in the late 2000s contributing to the higher, recent Gulf contribution.

General overviews and/or reviews of the soft crab fishery are contained in Jaworski (1982), Perry et al. (1982), Otwell and Cato (1982), and Perry and Malone (1989) and in two symposium proceedings edited by Cupka and Van Engel (1979) and Perry and Malone (1985). These papers provide information on harvesting, shedding, and marketing of soft crabs.

#### 6.2.1 History and Development

The first record of soft crab production in the Gulf dates back to 1887 when 133,000 pounds valued at $7,000 were harvested in Louisiana, and 15,000 pounds worth $1,000 were recorded from Mississippi. Recorded production in Texas, Florida, and Alabama began much later with landings rarely exceeding 10,000 pounds. Although landings have varied, Louisiana has historically been the major producer and supplier of soft crabs in the Gulf of Mexico (Perry et al. 1982).

Louisiana, unlike the other Gulf states, has a long and successful history of commercial soft crab production. Due to market demands generated by the city of New Orleans, the Louisiana soft crab fishery initially developed along the northern shore of Lake Pontchartrain and the Rigolets in the late 1800s (Jaworski 1971, 1972, 1982). Terminology and shedding techniques were borrowed from Chesapeake Bay where the soft crab fishery began. Fishermen commonly held peelers in wooden floats that were tethered along shorelines. With the discovery that peeler or premolt crabs could be harvested using fresh willow (*Salix nigra*) and wax myrtle (*Myrica cerifera*) branches, the fishery later expanded in the 1930s into the Barataria estuary around Lafitte, Bayou Des Allemands, Lake Salvador, and Bayou Barataria. Crab fishermen in these areas use in-water floats called 'live cars' to shed peelers.

Crab shedding houses with flow-through circulating systems were built during the 1960s to replace passive float or live car operations (Jaworski 1982), and fishermen from parishes bordering Lake Pontchartrain began to increasingly rely on these systems. More advanced, closed-recirculating systems were introduced in the early 1980s and by 1985 had become increasingly important because of deteriorating water quality, expensive waterfront property, and the desire to move shedding operations close to home (Horst 1985). Approximately 50% of Lake Pontchartrain crab shedders abandoned floats by 1985, with the fishermen choosing closed and open systems in equal numbers. With the development of the closed-recirculating system, the soft crab industry expanded geographically to the central coast of the state and eventually expanded to areas west of the Atchafalaya River; however, the majority of producers are still located in parishes bordering Lake Pontchartrain and within 50 miles of New Orleans (Caffey et al. 1993).

### 6.2.2 Capture of Peelers

Historically, a variety of gears have been used to collect peeler and soft crabs in the Gulf of Mexico, including bush lines, standard hard crab traps, dirty traps, scrapes, push nets, dip nets, drop nets, trawls, trotlines, haul seine, and wing nets (Otwell and Cato 1982, Steele and Perry 1990, Guillory et al. 1996). The current peeler crab supply along the Gulf of Mexico is largely dependent on incidental catch in hard crab traps, although peeler traps are important in Florida and dirty traps, trawls, and skimmer nets are sometimes used in Louisiana. Brush traps, trotlines, and drop nets accounted for most of the peeler/soft crab landings prior to 1970 (Steele and Perry 1990). Catch of peeler crabs from hard crab traps has become increasingly important since 1964 and now accounts for the greatest portion of annual catches among all gears used in the fishery.

Harvest rates of peeler crabs are affected by season, lunar stage, and water conditions. Ryer et al. (1990) found a lunar rhythm of molting activity with peak molting on full moons. The shedding season generally extends from March-October with the primary peak in April or May and a smaller peak in September or October (Caffey et al. 1993).

Fishing methods, identification of peelers, and techniques for handling soft crabs were described by Haefner and Garten (1974), Bearden et al. (1979), Cupka and Van Engel (1979), Otwell (1980), Otwell et al. (1980), Perry et al. (1982), Springborn (1984), Oesterling (1984, 1988), Wescott (1984), Oesterling and Provenzano (1985), Whitaker et al. (1987), Perry and

Malone (1989), and Hines (1991). Bishop et al. (1983, 1984), Christian et al. (1987), and Prejean and Guillory (1998) evaluated the efficiency and compared design techniques of various gears used to harvest premolt crabs. Springborn (1984) reported on the production and harvest of peeler and soft crabs in ponds.

The standard baited hard crab trap is the most important gear used to capture peeler crabs for soft crab shedding operations. Some dealers sort through hard crab catches for peelers, but most peeler crabs are sold directly by hard crab fishermen to soft crab shedders. 'Dirty traps,' which attract premolt crabs in much the same fashion as the artificial habitat pot described by Bishop et al. (1983, 1984) and Christian et al. (1987) are also used. 'Dirty traps' are standard unbaited crab traps fouled with marine growth that are used to target premolts near grass beds and shorelines by providing dark havens for shedding crabs. These traps are left unbaited intentionally to decrease catch of intermolt hard crabs whose presence may repel peeler crabs.

Bush lines became popular in the early 1930s after fishermen in upper Barataria Bay discovered that peeler crabs were attracted to fresh willow branches used to catch river shrimp (*Macrobrachium ohione*) and eels (*Anguilla rostrata*) (Jaworski 1972). Bush lines are typically anchored between large poles in slowmoving water three to six feet deep and suspended just above the water's surface, with 10-100 bundles of brush, preferably wax myrtle, tied to the line with snoods or ganglions (Horst 1982).

Handheld crab scrapes consisting of a metal frame, plastic handle, and fiberglass blade are used to harvest premolt and soft crabs from eelgrass (*Vallisneria spiralis*) beds along the northshore of Lake Pontchartrain. Push nets, a large mouth net with a flat wooden blade or metal roller attached to a two-inch mesh bag, are used in a similar manner.

Otter trawls, wing nets, and skimmer nets are other gears that may be used to harvest soft and premolt crabs, although crabs are generally of poorer quality for shedding because of injuries received during capture. Some fishermen may shed busters in pails of water. Horst (1982) and Supan et al. (1986) described the use and effectiveness of flowthrough shedding systems onboard large shrimp vessels operating on a seven or eight day trip schedule.

### 6.2.3 Shedding Techniques

Currently three types of soft crab shedding systems exist: float (also referred to as floating box, float car, or live car), *flow-through*, and *closed-recirculating* systems. Caffey et al. (1993) reported that during 1991 in Louisiana, 44.6% of producers used closed-recirculating systems with basic shell filters, 32.2% used flow-through systems, 15.4% used float cars, and 6.2% used closed systems with pressurized sand filter systems. However, some producers operate more than one type of system, including holding white-line peelers in float cars during periods when peeler crabs are abundant and space is limited.

The passive flow float system was described by Haefner and Garten (1974), Horst (1982), Otwell et al. (1980), Jaworski (1982), and Perry et al. (1982). Float culture is currently one of the least favored methods used due to periodic rapid changes in water quality, susceptibility to predation, and labor demands. Caffey et al. (1993) noted that floats ranked third in terms of annual productivity among the four systems used by surveyed producers and had the highest average levels of mortality.

Land-based flow-through shedding systems were developed for convenience. Flow-through systems circulate water from a natural water body through trays or troughs (Horst 1982, Otwell and Cato 1982, Jaworski 1982, Perry et al. 1982). Flow-through systems are susceptible to water quality problems but are still favored by some soft crab producers. Flow-through systems were the most productive system in Louisiana but had the second highest mortality (Caffey et al. 1993).

Perry et al. (1982) described the development and theory of operation of a closed-recirculating shedding system. Further review, development, and design of closed-recirculating shedding systems were outlined by Malone and Burden (1988), Perry and Malone (1989), and Oesterling (1988). Malone and Burden (1988) provided the most current design recommendations in recirculating shedding systems, including upflow sand and fluidized bed biological filters. Caffey et al. (1993) reported that 50% of interviewed Louisiana shedders used closed (recirculating) systems. Of those using closed-recirculating systems, 90% relied on basic shell filtration units and the remainder used pressurized sand filters. Closed systems with sand filters had the lowest mortality rate and were followed by systems with shell filters. Closed-recirculating shedding systems consist of five distinct functional elements: pump, sump, reservoir, biological filter, and holding trays. The pump and sump provide circulation and aeration of the system's water; the reservoir and filter work to maintain suitable water quality in the system; and the trays hold the peeler crabs through the shedding process. Closed-recirculating systems eliminate the need for access to natural water of good quality by reusing synthetic seawater.

General reviews are available on water quality and other problems in shedding systems. For public education purposes, water quality concerns (Perry and Wallace 1985), conversion tables (Hochheimer 1985), and methodology for artificial seawater preparation (Perry 1983) have been published. Oesterling (1982) and Manthe et al. (1984) reported on sources of crab mortality and their elimination and examined the carrying capacity in closed shedding systems that used various filter systems. Bacterial and viral diseases in shedding operations were reviewed by Johnson (1985) and Sizemore (1985).

Literature concerning soft crab production under restricted conditions or techniques include: in heated power plant effluents (Reimer and Strawn 1973, Parker et al. 1976, Biever 1981, Wang 1982); on vessels (Supan et al. 1986); in artificially heated systems (Oesterling 1990); in ponds (Springborn 1984); in low calcium water (Freeman et al. 1986); through the use of hormones (Gillies 1975, Freeman and Perry 1985); or eye stalk ablation (Wang 1982) to initiate ecdysis.

### 6.2.4 Production

Reported values of Gulf of Mexico soft crab production are poor estimates of actual production because: 1) soft crab production from small 'cottage' type shedding operations often goes unreported (Guillory and Perret 1998), 2) soft crab production data are combined with hard crab data in Texas, and 3) confidential data are not included in the NMFS estimates. In Louisiana, Caffey et al. (1993) and Supan (unpublished data) estimated that actual soft crab production in some areas may be 1419 times greater than reported landings. Because of recognized limitations in soft crab production data, trends will be emphasized.

Annual Gulf soft crab production from 19502011 is reported in Table 6.9; historic landings (1880-1949) are located in Table 6.5. Soft crab production peaked from 1955 to 1961, when annual production was at least 525,000 pounds (Table 6.9). Despite year-to-year fluctuations, Gulf production displayed a long-term decline until 1986 when 88,000 pounds were recorded. Production increased to a peak of 290,000 pounds in 1990, but declined thereafter. During the 1990s, production ranged from 111,000290,000 pounds and averaged 188,000 pounds (Figure 6.2).

Annual soft crab production by state (Table 6.9) shows that, until recently, Gulf soft crab production was largely from Louisiana. Louisiana averaged 97.8% of Gulf production from 1950-1977. In the late 1970s and 1980s, Florida soft crab production increased, and from 1978-1986, Florida contributed 17.6% of the total while Louisiana dropped to 81.9%. During the 1990s, Florida soft crab production comprised 23.0% of the total, and Louisiana averaged 74.6% of the total. Only six states (New Jersey, Delaware, Maryland, Virginia, North Carolina, and Louisiana) have recorded substantial soft crab production numbers (Otwell and Cato 1982).

Prior to the 1990s, Gulf production was influenced by the same factors driving the fishery in Louisiana. The downward trend in soft crab production from the 1960s through the early 1980s was partially attributed to water quality problems in floats and flowthrough systems and the lack of a reliable source of peeler crabs (Jaworski 1971, 1982, Perry et al. 1982, Guillory and Perret 1998). Increased soft crab production in the late 1980s was due to development and widespread adoption of closedrecirculating systems, promotional and extension efforts, increased trap fishing effort and recognition of peeler crab bycatch value, and potential economic return to the shedder (Sholar 1985, Guillory and Perret 1998). Reasons for the decline in soft crab production during the 1990s are unknown.

The Gulf soft crab fishery is characterized by high annual producer turnover rates and seasonal operations. In Louisiana, a 50% turnover rate between 1985 and 1991 was documented by Caffey et al. (1993). They further reported that nearly 50% of all producers surveyed had been in soft crab production for only one to five years, and 34% were full time producers or operated more than six months per year. The majority of soft crab producers (80%) were commercial crab fishermen, and over half of the producers (53%) also participated in the commercial shrimp fishery.

### 6.2.5 Non-U.S. Gulf of Mexico Blue Crab Production

Data related to non-U.S. (Mexico and Cuba) Gulf of Mexico blue crab harvest and production is limited. However, annual landings records from Mexico's National Aquaculture and Fishing Commission (Comisión Nacional de Acuacultura y Pesca - CONAPESCA) for 2006-2011 are available for the coastal states (CONAPESCA personal communication). In 2010, CONAPESCA reported on four Mexican states with 'blue crab' landings: Campeche 2.5M pounds valued at

**Table 6.9** Soft crab landings (X1000 lbs) by state, 1950-2011 (NOAA personal communication). Landings not recorded or zero indicated by A--@. Most Texas landings are not identified as soft or hard so few values are provided here. (1) indicates less than 1,000 lbs reported.

| YEAR | FL | AL | MS | LA | TX | TOTAL |
|---|---|---|---|---|---|---|
| 1950 | (1) | (1) | -- | 364 | -- | 364 |
| 1951 | 4 | (1) | 6 | 350 | -- | 360 |
| 1952 | 15 | -- | 15 | 448 | -- | 478 |
| 1953 | 3 | -- | (1) | 488 | -- | 491 |
| 1954 | (1) | -- | -- | 455 | -- | 455 |
| 1955 | 1 | -- | 7 | 581 | -- | 589 |
| 1956 | 1 | -- | 6 | 600 | -- | 607 |
| 1957 | 10 | -- | 17 | 551 | -- | 578 |
| 1958 | 1 | -- | 20 | 577 | -- | 598 |
| 1959 | 3 | -- | 11 | 605 | -- | 619 |
| 1960 | 4 | -- | 5 | 514 | 2 | 525 |
| 1961 | 5 | -- | 7 | 620 | 2 | 634 |
| 1962 | (1) | -- | 2 | 344 | 6 | 352 |
| 1963 | 4 | -- | 3 | 329 | 2 | 338 |
| 1964 | 13 | -- | 2 | 200 | (1) | 215 |
| 1965 | 12 | -- | 1 | 204 | -- | 217 |
| 1966 | 1 | -- | 1 | 128 | -- | 130 |
| 1967 | 7 | -- | 1 | 146 | -- | 154 |
| 1968 | -- | -- | 1 | 284 | -- | 285 |
| 1969 | (1) | -- | (1) | 197 | -- | 197 |
| 1970 | (1) | -- | -- | 90 | -- | 90 |
| 1971 | -- | -- | -- | 127 | -- | 127 |
| 1972 | (1) | -- | -- | 102 | -- | 102 |
| 1973 | -- | -- | -- | 119 | -- | 119 |
| 1974 | (1) | -- | -- | 96 | -- | 96 |
| 1975 | 2 | -- | -- | 111 | -- | 113 |
| 1976 | -- | -- | (1) | 88 | -- | 88 |
| 1977 | -- | -- | -- | 225 | -- | 225 |
| 1978 | 22 | -- | 2 | 133 | -- | 157 |
| 1979 | 9 | -- | -- | 147 | -- | 156 |
| 1980 | 17 | -- | -- | 118 | -- | 135 |
| 1981 | 23 | -- | -- | 100 | -- | 123 |
| 1982 | 53 | (1) | -- | 164 | -- | 217 |
| 1983 | 36 | (1) | -- | 101 | -- | 137 |
| 1984 | 28 | (1) | (1) | 75 | -- | 103 |
| 1985 | 17 | 3 | -- | 82 | -- | 102 |
| 1986 | 9 | (1) | -- | 79 | -- | 88 |
| 1987 | 12 | -- | -- | 139 | -- | 151 |

| YEAR | FL | AL | MS | LA | TX | TOTAL |
|---|---|---|---|---|---|---|
| 1988 | 17 | -- | -- | 162 | -- | 180 |
| 1989 | 39 | -- | 19 | 172 | 13 | 230 |
| 1990 | 37 | -- | 4 | 249 | -- | 290 |
| 1991 | 22 | -- | 2 | 200 | (1) | 224 |
| 1992 | 35 | 1 | 2 | 240 | -- | 277 |
| 1993 | 21 | -- | (1) | 99 | -- | 121 |
| 1994 | 52 | -- | 1 | 100 | -- | 159 |
| 1995 | 52 | -- | 2 | 52 | -- | 111 |
| 1996 | 61 | 0 | 1 | 99 | -- | 161 |
| 1997 | 66 | 10 | 2 | 86 | -- | 164 |
| 1998 | 92 | 1 | 1 | 177 | -- | 271 |
| 1999 | 123 | -- | 2 | 336 | -- | 461 |
| 2000 | 160 | 3 | 1 | 602 | -- | 766 |
| 2001 | 99 | -- | 1 | 402 | -- | 502 |
| 2002 | 78 | -- | 1 | 372 | -- | 451 |
| 2003 | 85 | 1 | 1 | 384 | -- | 471 |
| 2004 | 75 | -- | -- | 328 | -- | 404 |
| 2005 | 58 | -- | -- | 220 | -- | 278 |
| 2006 | 45 | -- | -- | 142 | -- | 188 |
| 2007 | 35 | 3 | -- | 205 | -- | 243 |
| 2008 | 36 | -- | -- | 96 | -- | 132 |
| 2009 | 50 | -- | -- | 212 | -- | 262 |
| 2010 | 49 | -- | -- | 131 | -- | 180 |
| 2011 | 37 | -- | -- | 187 | -- | 224 |

$951,444 (U.S. dollars), Tabasco 1.6M pounds valued at $678,380 (U.S. dollars), Veracruz 4.3M pounds valued at $2.36M (U.S. dollars), and Tamaulipas 9.9M pounds valued at $3.59M (U.S. dollars). Gulf blue crab landings from all coastal states in Mexico in 2010 totaled 18.3M pounds valued at $7.57M (U.S. dollars). While reported as 'blue crab', it is not clear if all the landings were in fact *Callinectes sapidus* or if there were other swimming crab species included.

*Callinectes sapidus* have been landed in Cuban waters since at least the 1930s with a peak occurring from 1987-1991 at a 5-year average of 2.7M pounds. In 1995, Cuba recorded a total of 1.6M pounds of blue crabs from their waters (Baisre 2000).

In addition, significant 'crab' fisheries occur throughout the Central and South American countries bordering the Caribbean Sea (Honduras, Nicaragua, Costa Rica, Columbia, and especially Venezuela). While relatively large quantities of 'crab' are imported into the U.S. markets (Capo personal communication), the species identity of the processed product is unknown.

## 6.3 Recreational Fishery

### 6.3.1 Hard Crabs

Recreational crabbing is a relatively inexpensive, low key, familyoriented activity (Guillory 1998b). It occurs yearround, but peaks in late spring and summer when crabs migrate into more accessible habitats and become more active. Recreational fishermen harvest crabs with a variety of gears including crab traps, hand lines, trotlines, drop nets, dip nets, bait seines, and rod and reel. Crabs are also taken as incidental bycatch by recreational fishermen using shrimp trawls. The greatest effort is expended in areas accessible by roads such as canals, bays, bayous, beaches, jetties, seawalls, piers, wharfs, docks, and bridges (Adkins 1972a). Crabs are harvested from boats in lakes, bays, bayous, and canals, as well as behind dams, weirs, and water control structures. Favorite baits include beef, fish, and chicken and turkey necks.

Quantitative data on Gulf-wide recreational blue crab catch and effort are lacking. The sport fishery is thought to contribute significantly to total fishing pressure, though estimates of the impact of recreational fishing on the resource vary widely. Louisiana and Florida recreational fishermen using traps are required to purchase a trap license, and a general sportfishing license is required in some states to crab recreationally. Recreational crabbing has probably increased Gulf-wide, as suggested by recreational crab trap gear licenses in Louisiana, which increased dramatically from 224 in the 1988/1989 license year to 3,328 in the 1995/1996 license year. Guillory (1998b) suggested increased recreational crabbing has probably resulted from a marked increase in coastal populations, mobility, leisure time, and discretionary income.

Several marine recreational surveys (Benefield 1968, Herring and Christmas 1974, Davidson and Chabreck 1983, Titre et al. 1988, Guillory 1998b) have provided important information on the Gulf recreational fishery; however, no long-term recreational surveys have been conducted which may be used to analyze historic changes in effort and harvest in the fishery.

A survey of the recreational blue crab fishery in Mississippi was conducted in 1971/1972 (Perry unpublished data, Herring and Christmas 1974). Parties were interviewed at 28 fishing locations and were asked questions about recreational fishing preferences. Biological data on the catch was recorded for most participants. The average fishing party consisted of three individuals (two males, one female) and the largest fishing party was thirteen individuals. The average age of recreational harvesters was 28, but ranged from 1-74 years of age. Most individuals were local and traveled an average of 20 miles to fish. Common fishing structures included piers (35.4%), bridges (31.3%), and seawalls (24.3%). The average number of recreational fishing trips a year was 17 days, with a maximum of 200 days. The mean units of gear fished was five and regular drop nets made up 79.2% of the gear types used. Other gear used included dip nets, strings, commercial wire traps, folding wire traps, and hook-and-line. Dominant type of bait used was poultry (49.8%) and fish (20.8%), but beef, pork, and a combination of bait types were used. More than half of the parties interviewed had no bait preference. While some participants preferred to fish during high tide (26.5%), the majority had no preference (55.5%). Some parties preferred to fish in the early morning (daylight to 0900 hours, 28.2%), but 60.8% had no preference on fishing time. Sex composition of the catch included males (56.9%), mature females (25.2%), immature females

(17.8%), and sponge crabs (0.1%), with 99.4% of the catch as hard crabs. Overall mean CW was 134 mm (males, 130 mm; mature females, 160 mm; immature females, 110 mm; sponge crab, 160 mm).

Guillory (1998b) provided several statewide estimates of recreational harvest in Louisiana. An estimated annual harvest of 1.8M pounds for 1990-1994 can be generated if recreational harvest is assumed equal to 4.1% of reported commercial production. Effort and harvest for recreational trap fishermen can be estimated for 1990/1991 to 1994/1995 by the product of the average number of recreational crab trap fishermen, average harvest per set, and average number of trap sets per year (Guillory 1998b). Annual statewide effort and harvest estimates for trap fishermen were 29,200 trap sets and 1.75M crabs or 463,100 pounds.

In a creel and mail survey in Terrebonne Parish, Louisiana, Guillory (1998b) found that approximately onethird of saltwater fishing license holders participated in recreational crabbing. Recreational crab fishermen using gear other than traps, averaged 5.8-7.9 trips/year and a harvest of 34.7-83.8 crabs/trip while recreational fishermen using traditional crab traps averaged 11.6 trap sets and 60.7 crabs/set. Titre et al. (1988) reported 42.7% of interviewed boaters in southeast Louisiana participated in recreational crabbing, and all respondents averaged 1.3-1.7 trips/year. The Texas recreational fishery comprised 0.3%1.7% of all fishing activities in 1990 (Cody et al. 1992) and showed no discernible pattern in catch rates from 1983-1994 (Hammerschmidt et al. 1998).

The Gulf of Mexico blue crab recreational fishery is substantial and may be equivalent to as much as 5% of commercial harvest, although data are not available to analyze historic changes in effort and harvest (Guillory et al. 1998). Several surveys, however, have estimated recreational catch as a percentage of commercial landings in different areas or estuaries: 5.9% in Galveston Bay, Texas (Benefield 1968), less than 4% in Mississippi (Herring and Christmas 1974), 20% in Alabama (Tatum 1982), and 4.1% in Terrebone Parish, Louisiana (Guillory and Perret 1998). The recreational harvest from a small area (Rockefeller Refuge) in Louisiana (Davidson and Chabreack 1983) was about 0.3% of statewide commercial landings.

Survey data from Louisiana and Texas provide information on participation in the recreational blue crab fishery. Approximately 40% of interviewed boaters in southeast Louisiana (Titre et al. 1988) and one-third of saltwater fishing license holders in Terrebone Parish, Louisiana (Guillory and Perret 1998) participated in recreational crabbing.

### 6.3.2 Soft Crabs

The recreational fishery for soft crabs is very limited in the Gulf. Fishermen wading in shallows at night along vegetated shorelines or along beaches may occasionally harvest soft crabs with dip nets or flounder gigs (Guillory et al. 1996). Soft crabs are harvested incidentally with hard crabs by crab traps, shrimp trawls, hand lines, trotlines, and drop nets. Guillory (1998b) reported that recreational shrimp trawlers averaged 7.9 trips/year and incidentally harvested an average of 0.2 soft crabs/trip.

### 6.4 Incidental Catch/Bycatch and Impingement

#### 6.4.1 Incidental Catch of Crabs in Shrimp Trawls

Blue crabs are captured in large numbers in gear used in the shrimp fishery. Hammerschmidt et al. (1998) estimated that an average of around 80M individual blue crabs may have been captured annually in the Texas inshore shrimp fishery from 1990-1994. Based upon an estimated 1989 bycatch of 227.8M pounds in the Louisiana shrimp fishery and the percentage by weight (9%) of blue crab (Adkins 1993), the annual Louisiana blue crab bycatch would have been approximately 20.5M pounds; considering that much smaller individuals are captured in trawls, skimmer nets, and wingnets than in crab traps, the number of blue crabs captured in the shrimp fishery exceeds the number harvested by commercial crab fishermen.

Since the early 1990s, regulations imposed by the states related to bycatch in the shrimp trawl fishery have reduced the number of crabs retained by commercial shrimpers in the Gulf region. Since 1994, crab landings from the commercial trawl fishery have been less than 1% of the total hard crab landings in the region (NOAA personal communication).

Research has indicated that capture in shrimp gear and subsequent culling may have significant effects on blue crab survival (Murphy and Kruse 1995). The average mortality rate of blue crabs captured in trawls was 36% overall; 6% during the winter months and 80% during the summer (McKenna and Camp 1992). Delayed mortalities of trawl bycatch may vary because of differences in temperature, exposure time, amount and level of physical injury, and total catch biomass (Smith and Howell 1987, Wassenberg and Hill 1989). The use of salt boxes to separate bycatch from the shrimp may also contribute to juvenile crab mortality. Although survival of crabs subjected to salt box separation is more affected by tow and culling time than by immersion in the brine solution (TPWD and ADCNR unpublished data), increases in delayed mortality may result from prolonged exposure and repeated dippings.

#### 6.4.2 Crab Trap Bycatch

In the commercial blue crab trap fishery, circular $2^3/_8$ inch 'escape' rings have been found to minimize sublegal crab catches. In areas with high densities of sublegal sized crabs, escapement may not meet legal allowable tolerances but will significantly reduce the catch of undersized crabs. Escape rings in crab traps are currently required in Florida, Louisiana, and Texas.

Based on Mississippi commercial crab fishery data covering the period May 2007 to December 2011 (Graham et al. 2012), the amount of bycatch typically follows a seasonal pattern, with more caught during warm months. Overall, nearly 70 different bycatch species have been collected in Mississippi commercial crab traps. While bycatch mortality occurs (0.5%), the vast majority of bycatch species are released alive.

Incidental capture of diamondback terrapin (*Malaclemys terrapin*) in crab traps has been documented in Chesapeake Bay (Roosenburg et al. 1997), South Carolina (Bishop 1983, Dorcas et al. 2007), Georgia (Grosse et al. 2011) and Texas (Hogan 2003). Their drowning after capture is considered to be a major threat to terrapin populations (Seigel and Gibbons 1995). However, many factors contribute to terrapin capture rates, including trap design, distance from shoreline, habitat, and season (Hart and Crowder 2011).

Bycatch reduction devices (BRDs) ranging in size from 4-5 cm (height) by 10-12 cm (width) have been found to be effective at reducing incidental catches of terrapin. Butler and Heinrich (2007) reported a 73.2% reduction in Florida. Coleman et al. 2011 reported a 90% reduction in an Alabama salt marsh. Hart and Crowder (2011) reported significant reductions using BRDs in North Carolina, as did Wood (1997) in New Jersey and Roosenburg and Green (2000) in Chesapeake Bay. Morris et al. (2011) found BRDs in a Virginia tidal marsh to be highly effective in reducing both bycatch of terrapin and finfish.

Studies of BRDs have shown varying effects on catch rates of blue crab. Several studies using traps fitted with and without BRDs showed no significant differences in catch rate or size of crabs caught (Cuevas et al. 2000, Morris et al. 2011, Rook et al. 2010). Others reported an increase in legal-sized crab catch (Guillory and Prejean 1998, Wood 1997). Only Hart and Crowder (2011) reported a reduction in legal-size crab catch using BRDs in North Carolina.

### 6.4.3 Derelict Trap Removal Programs

Numerous species are caught in derelict crab traps. Guillory (1993) and Whitaker (1979) documented 11 and 13 species in monitored ghost traps in Louisiana and South Carolina, respectively. Guillory (1993) evaluated retention, escapement, and mortality of blue crabs encountered in derelict traps. In addition to blue crabs, the most common species found in Louisiana traps were sheepshead *Archosargus probatocephalus* (73.7%), spot *Leiostomus xanthurus* (5.3%), southern flounder *Paralichthys lethostigma* (4.7%), and Atlantic spadefish *Chaetodipterus faber* (4.7%). Other species included pinfish *Lagodon rhomboides,* hardhead catfish *Ariopsis felis*, gulf toadfish *Opsanus beta*, Atlantic croaker *Micropogonias undulatus,* spotted gar *Lepisosteus oculatus,* black drum *Pogonias cromis,* and striped mullet *Mugil cephalus.* Escapement and mortality rates of dead fish were not assessed because they were consumed quickly by entrapped blue crab, leaving only bones and fins. Diamondback terrapin remains were found in derelict traps in Texas (Wagner and Morris 2008). Otters (*Lutra canadensis*) have drowned in crab traps (Holder personal communication). Also, manatees (*Trichechus manatus*) in Florida (Steele personal communication) have been injured after becoming entangled in crab trap buoy lines.

Traps that are lost are termed derelict and can continue to fish despite being fouled or even damaged. 'Ghost fishing' (lost traps that continue to fish) was evaluated by Guillory (1993) who concluded that substantial numbers (25/trap/year) of crabs died in each trap and that unbaited traps continued to attract crabs (35/trap/year). Arcement and Guillory (1993) found that mortality of blue crabs was significantly less in traps with escape rings (5.3/trap) than in unvented (17.3/trap) traps because of significantly lower numbers of sublegal blue crabs. In addition to mortality to blue crabs, ghost fishing can also result in finfish deaths. Organisms become entrapped and die with a lack of food, effectively rebaiting the trap to continue attracting additional organisms.

Ongoing derelict crab trap removal efforts in the five Gulf states since 1999 have reduced the potential threat to diamondback terrapins and other incidentally captured species. Time release mechanisms or degradable panels have been introduced into trap fisheries to reduce ghost fishing mortality. Materials used in the panels include untreated steel wire, jute and sisal twine and were found to decompose fairly quickly, ranging from 28-77 days for a panel or tie-down strap. Blott (1978) evaluated several time-release mechanisms and recommended the use of hinged doors with a biodegradable attachment made of jute or manila. Degradable panels in crab traps are currently required in Florida and Texas.

Derelict traps in the Gulf of Mexico do not pose the same problem today that they did historically. In the five Gulf states, the removal programs have resulted in a great reduction in the number of traps remaining in the water annually. In addition, effort limitation programs have reduced the number of active traps fishing at any given time, further reducing the risk of trap loss. Since the start of the Gulf-wide cleanup efforts in 2002, over 75,000 derelict traps have been removed from our coastal waters (Table 6.10). Alabama and Mississippi now operate their cleanups on an as-needed basis, rather than annually, due to the reduction of problematic traps.

## 6.5 User Group Conflicts

As crab fishing effort and other water related activities increased, user group conflicts escalated. Conflicts in the Gulf blue crab fishery were addressed in a symposium sponsored by the GSMFC (1995). The increased number of traps coupled with the tendency of crab fishermen to saturate prime crabbing areas with gear results in conflicts between users and creates navigational hazards. Conflicts have occurred between commercial trap fishermen and waterfowl hunters, recreational finfish fishermen, pleasure boat operators, recreational crab fishermen, and waterfront property owners. One of the more volatile issues has been the conflict between shrimp and crab

**Table 6.10** Total Gulf of Mexico derelict crab trap removals from 1999-2011 (**Bold** indicates the first year with volunteers; NP = no program in place; - indicates no cleanup in that year).

| YEAR | FL | AL | MS | LA | TX | TOTAL |
|---|---|---|---|---|---|---|
| 1999 | NP | NP | 352 | NP | NP | 352 |
| 2000 | NP | NP | 1,097 | NP | NP | 1,097 |
| 2001 | NP | NP | 393 | NP | NP | 393 |
| 2002 | NP | **438** | **605** | NP | **8,070** | 9,113 |
| 2003 | NP | 1,084 | 1,818 | NP | 3,858 | 6,760 |
| 2004 | 138[1] | 418 | 856 | **6,894** | 3,571 | 11,877 |
| 2005 | 288 | - | - | 4,623 | 2,509 | 7,420 |
| 2006 | 879 | 346 | - | 2,935 | 1,922 | 6,082 |
| 2007 | - | 154 | 11,150 | 1,498 | 2,816 | 15,618 |
| 2008 | - | 356 | 1,259 | 1,234 | 1,301 | 4,150 |
| 2009 | 4,189 | - | 478 | 788 | 1,927 | 7,382 |
| 2010 | 2 | 287 | 349 | 477 | 1,582 | 2,697 |
| 2011 | 1,479 | - | 108 | 1,100 | - | 2,687 |
| Total | 6,975 | 3,083 | 18,465 | 19,549 | 27,556 | 75,628 |

[1] no state-run program, but NGOs held small cleanups

fishermen. Crab fishermen have seen increased numbers of traps lost, damaged, or misplaced due to shrimping activities. Conversely, crab traps caught in shrimp gear can cause damage and loss of catch. Reports of friction and conflicts between these two commercial user groups escalated until the last decade, when the number of shrimp fishermen in the Gulf declined by 75%, due in part to high fuel costs, competition from cheap foreign imported shrimp, as well as natural and man-made disasters (Section 8.3.12).

Theft of traps or their contents has always been a problem in the fishery. This problem escalated when the fishery expanded during the mid-1980s and resulted in conflicts and additional economic loss to the fishermen at a time when net profits were declining. Trap and/or crab theft violations are difficult to enforce because visual verification is needed, often requiring a substantial investment of time by enforcement agents.

## 6.6 Commercial Fishery

### 6.6.1 Florida West Coast

Historical literature on the blue crab fishery in Florida include Landrum and Prochaska (1980), Prochaska and Taylor (1982), and Steele (1982). See Section 5.2.1.9 for regulatory changes that affected the commercial and recreational fisheries.

After World War II, hard shell blue crab landings increased until peaking at 20M pounds in 1965 after the introduction and wide-spread acceptance of the crab trap. Landings for hard shell blue crabs subsequently declined; during 19871997, annual landings averaged 8.6M pounds and ranged from 5-10M pounds (Table 6.6). The landings and the trip ticket program, enacted in 1986, provide a mechanism for tracking effort on the west coast of Florida, through the Marine Fisheries Information System. Since 1996, landings have continued to decline through 2010. The annual landings since 2000 averaged 5.9M pounds and ranging from 2.6-6.1M pounds (Table 6.6). The low landings of 2008 and 2009, 2.6 and 3.1M pounds respectively, represent the reduced demand during the height of the economic recession.

Since 1985, the Marine Fisheries Information System obtained data on number of trips, pounds caught per trip, and number of traps-per-trip. Number of trips increased 63% from 22,596 in 1986 to 36,847 in 1995. Since 1985 landings have been relatively stable, but pounds per trip decreased from 384 in 1986 to 235 in 1995. The catch per hard shell crab trip from 1995 through present has ranged from 187-302 pounds; averaging 263 pounds/trip over the period.

Soft crab production remained low until the 1950s when production began to increase, although very erratically. Production declined in the early and mid-1970s and then increased sharply to 22,000 pounds in 1978. During the 1990s, soft shell production ranged from 21,000-66,000 pounds and averaged 45,000 pounds. Since 2000, the production of soft shell blue crabs has ranged from 35,296 pounds to 158,942 pounds (Table 6.9). Peak soft shell production was realized in 2000 with the harvest of 158,942 pounds. Following the peak in soft shell landings they have steadily declined to present. The catch per soft shell crab trip from 1994 through present ranged from 28.6-61.8 pounds/trip; averaging 44.4 pounds/trip over the period. Soft crab shedding facilities in Florida have diversified levels of intensification which range from small 'Mom and Pop' operations to large commercial facilities that deal in high volume. Despite increased demand for soft crabs, production has remained low.

The Florida blue crab fishery is highly mobile (Gandy personal communication). Many fishermen with blue crab endorsements fish for blue crabs in both the Gulf of Mexico and Atlantic Ocean. The separation of the licenses based on the coast fished is not achievable using licenses. The licensing data presented here illustrate the overall changes within the Florida fishery.

In 1995, there was a significant increase in the number of blue crab endorsements sold in Florida (statewide) (Table 6.11). During this period a statewide ban on net fishing was implemented and many commercial finfish fishermen entered the blue crab fishery. The statewide number of endorsements increased from 4,933 to 6,082 in 1994 and 1995, respectively but steadily declined after. In 2011, the total number of endorsements [hard shell (VH), soft shell (VS), non-transferable (VN) and incidental catch (VI)] for blue crab fishing (950) were a fraction (15.6%) of the endorsements issued in 1995. The decrease in endorsements over the period was steady and was enhanced by the BCEMP in 2007. The BCEMP was enacted to address the problems of seasonal crowding of traps in confined waterways, lost traps, bycatch, overcapitalization, latent endorsements, and conflicts between hard shell and soft shell blue crab fishermen.

On July 1, 2008 the BCEMP separated the blue crab endorsements by product type: VH, VS, VN, and VI along with issuing tags for each trap fished based that was based on where and how the blue crab trap was fished (inshore, offshore, soft shell and hard shell). The high number of traps for 2008 represents when there was no charge for trap fees (year-1 of BCEMP) and the fishers ordered the maximum allowable number of their allotment of traps, the majority of which were not fished. Fees for trap tags were implemented in 2009 and the number more accurately reflects traps that are potentially used by the fishery. The BCEMP is structured so fishermen must annually re-qualify with landings in order to renew their endorsements. Non-renewals may appeal if there were extenuating circumstances that prevented them from renewing on time or attaining the minimum volume of landings for requalification. Otherwise, those non-renewal endorsements were lost, permanently decreasing the number of endorsements in the fishery.

### 6.6.2 Alabama

Historical literature on the blue crab fishery in Alabama include Tatum (1980, 1982). See Section 5.2.3 for regulatory changes that affected the commercial and recreational fisheries.

Hard crab landings remained below 1.0M pounds until 1940. The early increases in production were probably associated with the development of improved transport systems. Landings ranged from 0.6-2.4M pounds during the 1940s through the 1970s. Landings peaked in 1984 at 4.2M pounds (Table 6.6). The sharp increase in production during the 1980s was attributed to an increase in processing capacity due to an influx of Southeast Asians into south Alabama. During the 1990s average annual hard crab landings were 3.1M pounds, which decreased to an average of 2.3M pounds per year since 2000.

**Table 6.11** Total Florida crab endorsements sold from 1991-2011. Endorsements were subdivided into categories after 2007 as part of the Blue Crab Effort Management Plan (BCEMP) to reduce latent licenses (FWC unpublished data). Endorsements represent hard shell (VH), soft shell (VS), non-transferable (VN) and incidental catch (VI).

| YEAR | TOTAL BLUE CRAB LICENSES SOLD | ACTIVE LICENSES (NON LATENT) | SUB-DIVISIONS OF ENDORSEMENTS | | | | TOTAL TRAPS | SUB-DIVISIONS OF TRAP TAGS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | VH | VS | VN | VI | | INSHORE TRAP TAGS | OFFSHORE TRAP TAGS | SOFTSHELL TRAP TAGS | NON-TRANSFERABLE TRAP TAGS |
| 2011 | 950 | 374 | 700 | 87 | 47 | 116 | 251,950 | 193,150 | 36,650 | 16,750 | 5,400 |
| 2010 | 1,035 | 391 | 727 | 95 | 103 | 110 | 257,050 | 192,850 | 38,550 | 17,700 | 7,950 |
| 2009 [3] | 1,021 | 325 | 768 | 112 | 141 | - | 290,599 | 213,550 | 50,100 | 17,749 | 9,200 |
| 2008 [2] | 1,190 | 307 | 832 | 157 | 182 | 19 | 822,750 | 450,000 | 299,600 | 54,950 | 18,200 |
| 2007 | 2,283 | 366 | | | | | | | | | |
| 2006 | 2,579 | 393 | | | | | | | | | |
| 2005 | 2,798 | 427 | | | | | | | | | |
| 2004 | 2,931 | 474 | | | | | | | | | |
| 2003 | 3,222 | 478 | | | | | | | | | |
| 2002 | 3,435 | 490 | | | | | | | | | |
| 2001 | 4,376 | 560 | | | | | | | | | |
| 2000 | 4,784 | 596 | | | | | | | | | |
| 1999 | 5,297 | 698 | | | | | | | | | |
| 1998 | 5,920 | 741 | | | | | | | | | |
| 1997 | 5,737 | 824 | | | | | | | | | |
| 1996 | 5,519 | 822 | | | | | | | | | |
| 1995 [1] | 6,082 | 732 | | | | | | | | | |
| 1994 | 4,933 | 822 | | | | | | | | | |
| 1993 | 4,491 | 913 | | | | | | | | | |
| 1992 | 4,491 | 806 | | | | | | | | | |
| 1991 | 4,558 | 566 | | | | | | | | | |

[1] Net Ban; [2] Effort Management Plan; [3] Trap Tag Fee

The number of trap fishermen according to NMFS data increased steadily from 1976 to a peak of 221 in 1989; thereafter, the number of fishermen declined to a low of 150 in 1995. The number of traps-per-fisherman averaged near 150 until the 1980s when the average peaked at approximately 350. The number of traps-per-fishermen decreased gradually to 250 in 1993. Catch-per-trap declined from 1980 to the early 1990s. In the last decade (Table 6.2), the average number of resident commercial trap fishermen has been 196, with the low in 2006 of 120 and the high of 338 in 2011.

The soft crab fishery is minimal and is based upon commercial hard crab fishermen shedding their own crabs (Table 6.9). Annual soft crab production was less than 500 pounds prior to the 1990s. After 1990 soft crab production has been sporadic with less than 20,000 pounds total reported through 2011 and production occurring in only six years within the last two decades.

### 6.6.3 Mississippi

Historical literature on the blue crab fishery in Mississippi was summarized in Perry (1975) and Perry et al. (1998). See Section 5.2.3.9 for regulatory changes that affected the commercial and recreational fisheries.

With the exception of the post-World War II period when over 5M pounds were landed, landings were stable and generally fluctuated between one to 2.0M pounds until 1987 (Table 6.6). From 1970-1989, Mississippi's crab landings averaged 1.5M pounds. Reported landings declined in 1988 and continued to decrease; harvest during the 1990s averaged 397,400 pounds. Reduced landings were attributed to social, economic, and regulatory changes that have taken place in the fishery and not to major declines in stock abundance.

According to NMFS estimates, the number of fishermen using traps in Mississippi was stable through the 1970s and 1980s averaging 61 participants and ranging between 43 and 73. During the 1990s, the average number of trap fishermen was 42. In the last decade (Table 6.2), resident commercial crab trap licenses averaged 188 annually with a low of 110 in 2006 following Hurricane Katrina and a high of 291 in 2010. Based on voluntary trip ticket harvest data collected by the MDMR during the Hurricane Katrina Emergency Disaster Recovery Program from 2006-2008, the average number of fishermen actively participating in the fishery was 52. The average number of traps-per-fisherman was 107 with an average catch 126 pounds/trip.

Blue crab commercial landings in Mississippi have fluctuated considerably from 2001-2011, ranging from 433,656 pounds to 1.1M pounds in 2001 and 2006 respectively (Table 6.6). Events occurring during this period that have contributed to the variation include Hurricane Katrina in 2005, the opening of the Bonne Carre' Spillway in 2008 and 2011, and the DWH disaster in 2010 which resulted in precautionary fishery closures. Highest landings occur May through August, with the peak in July averaging 87,273 pounds for the last ten years (excluding 2010 due to precautionary fishery closures). All other months for this period averaged 50,000 to 60,000 pounds, with the exception of March, which averaged only 34,270 pounds. A loss of seafood industry infrastructure is evident following Hurricane Katrina and it is estimated that a considerable portion of Mississippi blue crabs are sold to out-of-state dealers and processors.

Since 2005, the MDMR and the University of Southern Mississippi's Gulf Coast Research Laboratory have implemented and maintained a fishery-dependent survey of the blue crab fishery that is unique to the state. Sampling was conducted June 2005-October 2006, but was severely compromised by Hurricane Katrina. Current sampling has been continuous since May 2007. Biologists make bi-monthly trips with contracted commercial fishermen to collect data on catch. In addition to providing valuable information on status of blue crab stocks in Mississippi, other important biological and fisheries data are collected as a part of the project. Data on fishing effort, CW-weight relationships, gonadal conditions, parasite identification and prevalence, spawning period, maturity, fecundity, molt cycles, effect of bycatch reduction devices, and identification and enumeration of trap bycatch have all been collected in conjunction with the study.

Female blue crabs dominated the commercial catch in Mississippi (Graham and Perry 2010, Graham 2011a, 2011b, 2012), while males were more prevalent during colder months (Perry et al. 2006). Catch of ovigerous females were periodically high, up to 79% (Graham and Perry 2010). Two spawning peaks were evident in the data; one in the late spring/early summer followed by another peak in the late summer/early fall (Perry et al. 2006, Graham and Perry 2010). In general, CPUE is highest during the summer and lowest during the winter (Graham and Perry 2010). The CPUE data from the current fishery-dependent survey (Graham and Perry 2010, Graham 2011a, 2011b, 2012) yield substantially lower CPUE values than those reported in the early 1970s by Perry (1975). The dramatic decrease in catch rates requires continued investigation to determine the causes, impacts, and implications they have on the current status of the Mississippi blue crab fishery.

It is evident that changes have occurred in the blue crab fishery in Mississippi due to a number of recent events. In 2005, Hurricane Katrina caused significant impacts that resulted in loss of processing infrastructure, vessels, and gear. During 2010, the DWH disaster resulted in the closure of the fishery during peak months of harvest. In 2011, freshwater flooding due to the opening of the Bonnet Carre' Spillway may have caused increased adversity on the fishery. As a result, the USDOC declared the 2011 Mississippi blue crab fishery a commercial fishery failure.

The soft crab fishery is a small cottage-type industry and is based upon commercial hard crab fishermen shedding their own crabs (Table 6.9). Annual soft crab production averaged less than 2,000 pounds prior to and during the 1990s. NOAA reported Mississippi produced less than 5,000 pounds of soft crab from 2000-2003 (the last year soft crab numbers are documented for the state).

### 6.6.4 Louisiana

Historical literature on the blue crab fishery in Louisiana was summarized in Adkins (1972a), Jaworski (1971, 1972, 1982), and Keithly et al. (1988). See Section 5.2.4.9 for regulatory changes that affected the commercial and recreational fisheries.

Landings increased gradually but erratically through the early 1980s from the late 1960s average of 11.6M pounds. A sharp increase was documented in the mid-1980s when landings averaged 39.4M pounds landed from 1984-1988 when several record highs were attained. Landings stabilized by 1988, and relatively low landings were documented in 1989, 1990, 1994 and 1995 (Table 6.6). Landings averaged 43.5M pounds during the 1990s. Landings still averaged 45.3M pounds from 2000-2010 although there were two years with poor landings. Physical infrastructure and the commercial fleet were negatively impacted in 2005 by hurricanes Katrina and Rita; fishing effort and landings were subsequently suppressed. In 2010, the DWH disaster occurred and landings were the lowest in 28 years.

Since the 1960s, fishing effort has increased both in number of fishermen and units of gear. The number of LDWF crab trap licenses increased from 751 in 1979 to 3,019 in 1989; decreased slightly and stabilized (2,503-2,807) from 1990-1994; increased sharply to 3,482 in 1995 and fell to 2,948 in 1996. In 1995, the increase was probably associated with speculative license purchases prior to a three-year license moratorium. The number of LDWF crab trap licenses rose to 3,533 in 1999 and has remained above 3,000 each year since (Table 6.2). In 1999, LDWF began tracking commercial landings and effort in all fisheries using a trip ticket system, which provided more accurate information. For instance, 3,533 commercial crab trap licenses were sold in 1999, but the actual number of commercial crab fishermen that sold crabs was 2,277. Based on the trip ticket data, there was a decline in the number of active commercial crabbers from 1999-2006 (2,156-1,317). There has been an increase in the number of active commercial crabbers since 2006 with 1,773 participants recording landings in 2011.

The estimated number of traps-per-fisherman increased from 25 in 1957 to 228 in 1987 and then decreased to between 129 and 163 in the 1990s. The total number of traps used in Louisiana waters ranged from 75,760-139,044 from 1970-1983 but then increased dramatically during the mid and late 1980s to 441,710 by 1993. Based upon a 2006 LDWF Crab Fishing Effort Survey, the total number of traps-per-fishermen was 335, although fishermen actually only fished an average of 266 traps/trip. Using the number of active commercial crab trap fishermen and the average number of traps from the pilot study, the estimated number of traps in use in 2006 was 441,195.

Soft crab production in Louisiana (Table 6.9) varied between 350,000 and 605,000 pounds during the 1950s, peaked at 620,000 pounds in 1961, and then declined to a low of 75,000 pounds in 1984. Production increased after 1984 with more than 200,000 pounds reported from 1990-1992. Annual production was 100,000 pounds or less from 1993 to 1997. Beginning in 1998, soft crab production doubled each year until the year 2000 when production increased to 601,515 pounds. The soft crab production from 1999 to 2005 equaled that during the late 1950s and early 1960s. Several estimates of the number of Louisiana soft crab shedders exist; Manthe (1985) estimated that there were 425 in 1985, and Caffey et al. (1993) estimated that there were between 228 and 300 in 1991. A total of 185 shedder's licenses were sold by the LDWF in 1996 but that number declined to 81 in 2006 (a shedder's license was no longer sold after 2006). The high production in the 1950s and 1960s was due to better water quality in the upper estuaries as well as the peeler fishermen using 'bush lines'. A steady decline in soft crab production was seen until 1985 when better shedding systems were developed and the production increased. The increase in soft crab production after 1998 was probably due to the more accurate trip ticket system.

### 6.6.5 Texas

Historical literature on the blue crab fishery in Texas was summarized in Leary (1967), More (1969), Miller and Nichols (1985), Cody et al. (1992), Sutton and Wagner (2007). See Section 5.2.5.9 for regulatory changes that affected the commercial and recreational fisheries.

Total blue crab landings (hard and soft crabs combined) have followed roughly a parabolic trend since 1950, steadily increasing to a maxima of 11.7M pounds in 1987, and then dropping to 1.9M pounds in 2006, after which a slight recovery pushed them back to ~ 3M pounds/year from 2007-2011 (Table 6.6). Peak landings in 1987 correspond to the relatively high number of fishermen (317) operating in Texas that year.

The number of crab fishermen operating in Texas has been estimated from several sources; NMFS port agents (1950-1993; Table 6.4), TPWD crab trap tag sales (1992-1998), and commercial license sales since 1999 (Table 6.2). The number of crab fishermen peaked in 1994 at 345 and has since declined to 196 in 2011. TPWD's Crab License Management Program (a limited entry and a crab license buyback program), which was passed by the legislature in 1997, contributed to the decline in participation over the last decade.

Catch-per-fisherman indices peaked in 1979 at 85,600 pounds/fisherman and then dropped to 8,800 pounds/fisherman by 2006. Similar to the landings, catches increased slightly after 2006 with average values of 14,400 pounds/fishermen from 2007-2011 but additional analysis of trip ticket data suggest that number may be low. Data available after implementation of trip tickets show high latency in the fishery with numerous license holders failing to report any landings. Those 'latent' license holders may be holding on to their licenses in speculation of appreciating monetary values since the beginning of the limited entry program. These data allow a distinction to be made between the total number of licensed crab fishermen and the number of 'active' crab fishermen in Texas which is about half. The latent fishermen issue is explored further in Section 8.0.

It should be noted that the number of traps being used by each fisherman, although initially reported by NMFS port agents through 1992, has not been monitored; however, the average number of traps deployed by each fisherman has been estimated to be around 150 (TPWD unpublished data). A limit of 200 traps per crab fisherman license was set by TPWD in 1994.

## 7.0 ECONOMIC CHARACTERISTICS OF THE COMMERCIAL BLUE CRAB FISHERY

Throughout this section, commercial 'dockside' value represents the total amount paid by the first receiver to the harvester during the initial off-loading of crabs. Annual dockside values will be discussed for each state and the Gulf region in general. Prices and dockside value provide a measure of the economic importance and performance of the commercial harvesting sector. Landings and value data throughout this section were obtained from the NOAA Fisheries Office of Science and Technology (NOAA personal communication). The sources and product form of blue crab by wholesale distributors and processors in the Gulf provide insight into the importance of the stocks to crab purveyors in the region, as compared to crabs obtained from other domestic sources and foreign suppliers.

### 7.1 Domestic Harvesting Sector

#### 7.1.1 Annual Landings and Value

Reported 1962-2011 Gulf-wide blue crab landings, expressed in terms of pounds, value (dollars), and price per pound are provided in Tables 7.1-7.3 and Figure 7.1. Average five-year landings peaked in the Gulf of Mexico in the late 1980s and early 1990s at over 67M pounds. Since the early 1990s, production has decreased based on five-year averages. Annual landings from 2007-2011 averaged ~53M pounds. Closure of waters to fishing associated with the DWH disaster greatly reduced landings in 2010. The 41M pounds harvested in that year were the lowest Gulf landings in 28 years. While average landings have declined over the last few decades, when compared to historical data they increased approximately 81% from reported five-year average landings of 29.1M pounds in the 1960s.

Blue crab values in the Gulf region have followed a similar trend to the landings and increased over the last 49 years. The five-year dockside average of $1.7M in the 1960s rose to a five-year average dockside value of $43M from 2007-2011 (Table 7.2 and Figure 7.1). These dollars represent 'nominal dollars' or dollars in a particular year. This increase can be attributed to two factors, the quantity and price of the product. A sharp decline in production in the Chesapeake Bay production during this period further contributed to the increase in the 1990s (Section 7.1.4).

The rise in the value and price for crab products since 1962 reflected an overall increase in the price for goods and services across the entire U.S. economy. When adjusted for inflation, the average crab price increased from ~$0.43-$0.87/lb landed between 1962 and 2011, using five-year averages (Table 7.3 and Figure 7.1). These dollars are presented as 'real dollars', or inflation-adjusted dollars. Adjusted, crab prices were based on the 1982-1984 Consumer Price Index (CPI) (BLS 2012) with a base year of 2011 and represented a real price increase of about 103% over the last 49 years using five-year averages, with the five-year average peak in the late 1990s at $0.91/lb.

The real ($2011) dockside value of crab landings increased from an average of $12.5M in the 1960s to $45.2M from 2007-2011, based on five-year averages. This nearly fourfold increase

**Table 7.1** Hard crab landings (lbsX1,000) for the Florida West Coast, Alabama, Mississippi, Louisiana, Texas, and the Gulf-wide total from 1962-2011 (NOAA personal communication).

| YEAR | FWC | AL | MS | LA | TX | GULF |
|---|---|---|---|---|---|---|
| 1962 | 10,356 | 634 | 907 | 9,523 | 4,473 | 25,894 |
| 1963 | 13,148 | 1,297 | 1,112 | 7,982 | 2,980 | 26,520 |
| 1964 | 14,069 | 1,762 | 1,286 | 5,692 | 2,484 | 25,292 |
| 1965 | 20,598 | 1,812 | 1,692 | 9,284 | 3,622 | 37,008 |
| 1966 | 16,547 | 2,183 | 1,458 | 7,986 | 2,778 | 30,951 |
| Average | 14,944 | 1,538 | 1,291 | 8,093 | 3,267 | 29,133 |
| 1967 | 13,976 | 2,353 | 1,015 | 7,559 | 2,625 | 27,528 |
| 1968 | 9,008 | 1,980 | 1,136 | 9,551 | 4,084 | 25,759 |
| 1969 | 11,584 | 1,920 | 1,740 | 11,602 | 6,343 | 33,189 |
| 1970 | 14,786 | 1,407 | 2,027 | 10,254 | 5,525 | 34,001 |
| 1971 | 12,279 | 1,997 | 1,259 | 12,186 | 5,810 | 33,531 |
| Average | 12,327 | 1,932 | 1,436 | 10,230 | 4,877 | 30,801 |
| 1972 | 10,673 | 1,613 | 1,362 | 15,083 | 6,464 | 35,195 |
| 1973 | 9,599 | 2,099 | 1,815 | 23,080 | 6,881 | 43,473 |
| 1974 | 10,134 | 1,826 | 1,667 | 20,640 | 6,088 | 40,354 |
| 1975 | 12,807 | 1,640 | 1,137 | 17,144 | 5,992 | 38,718 |
| 1976 | 12,049 | 1,299 | 1,335 | 15,211 | 6,668 | 36,561 |
| Average | 11,052 | 1,695 | 1,463 | 18,231 | 6,419 | 38,860 |
| 1977 | 15,832 | 2,174 | 1,919 | 16,154 | 8,249 | 44,328 |
| 1978 | 11,679 | 2,009 | 1,940 | 15,074 | 7,470 | 38,171 |
| 1979 | 11,198 | 1,341 | 1,313 | 21,334 | 8,312 | 43,497 |
| 1980 | 11,276 | 1,557 | 2,760 | 18,183 | 8,953 | 42,728 |
| 1981 | 14,788 | 2,462 | 1,867 | 16,237 | 6,952 | 42,305 |
| Average | 12,955 | 1,909 | 1,960 | 17,396 | 7,987 | 42,206 |
| 1982 | 8,871 | 1,266 | 1,297 | 17,284 | 8,010 | 36,728 |
| 1983 | 9,337 | 1,412 | 1,140 | 19,616 | 8,829 | 40,334 |
| 1984 | 12,912 | 4,216 | 2,250 | 29,617 | 7,229 | 56,225 |
| 1985 | 12,273 | 2,261 | 1,649 | 29,848 | 9,722 | 55,753 |
| 1986 | 7,644 | 2,886 | 1,303 | 31,611 | 9,482 | 52,926 |
| Average | 10,208 | 2,408 | 1,528 | 25,595 | 8,654 | 48,393 |
| 1987 | 10,413 | 2,496 | 1,374 | 52,345 | 11,688 | 78,315 |
| 1988 | 10,386 | 3,869 | 863 | 53,554 | 10,428 | 79,101 |
| 1989 | 8,159 | 4,090 | 651 | 33,390 | 9,123 | 55,413 |
| 1990 | 6,878 | 3,303 | 390 | 38,886 | 8,599 | 58,056 |
| 1991 | 5,213 | 2,731 | 454 | 51,088 | 6,123 | 65,609 |
| Average | 8,210 | 3,298 | 746 | 45,853 | 9,192 | 67,299 |
| 1992 | 7,619 | 3,550 | 443 | 51,744 | 6,161 | 69,516 |
| 1993 | 8,502 | 2,554 | 253 | 45,847 | 8,286 | 65,442 |
| 1994 | 8,407 | 2,688 | 171 | 36,665 | 5,154 | 53,084 |
| 1995 | 8,725 | 2,520 | 319 | 36,914 | 5,787 | 54,265 |
| 1996 | 12,414 | 3,219 | 407 | 39,902 | 6,311 | 62,253 |
| Average | 9,133 | 2,906 | 319 | 42,214 | 6,340 | 60,912 |

| YEAR | FWC | AL | MS | LA | TX | GULF |
|---|---|---|---|---|---|---|
| 1997 | 9,255 | 3,476 | 683 | 43,440 | 7,084 | 63,937 |
| 1998 | 12,771 | 3,478 | 592 | 43,480 | 6,989 | 67,309 |
| 1999 | 11,047 | 3,768 | 920 | 46,328 | 6,472 | 68,534 |
| 2000 | 6,413 | 4,780 | 839 | 51,446 | 4,653 | 68,131 |
| 2001 | 4,548 | 2,457 | 432 | 41,398 | 5,163 | 53,998 |
| Average | 8,807 | 3,592 | 693 | 45,218 | 6,072 | 64,382 |
| 2002 | 5,489 | 2,575 | 716 | 49,751 | 7,037 | 65,568 |
| 2003 | 7,141 | 2,957 | 875 | 47,705 | 4,811 | 63,489 |
| 2004 | 8,008 | 3,329 | 811 | 44,069 | 3,961 | 60,177 |
| 2005 | 7,312 | 1,024 | 429 | 37,880 | 3,119 | 49,763 |
| 2006 | 8,565 | 2,384 | 1,127 | 53,252 | 1,966 | 67,294 |
| Average | 7,303 | 2,454 | 792 | 46,531 | 4,179 | 61,258 |
| 2007 | 6,074 | 2,554 | 737 | 44,902 | 3,454 | 57,722 |
| 2008 | 2,627 | 1,799 | 450 | 41,617 | 2,635 | 49,128 |
| 2009 | 3,314 | 1,458 | 545 | 52,848 | 2,844 | 61,010 |
| 2010 | 5,710 | 927 | 366 | 30,621 | 3,436 | 41,060 |
| 2011 | 6,626 | 1,617 | 370 | 43,706 | 2,893 | 55,212 |
| Average | 4,870 | 1,671 | 494 | 42,739 | 3,052 | 52,826 |

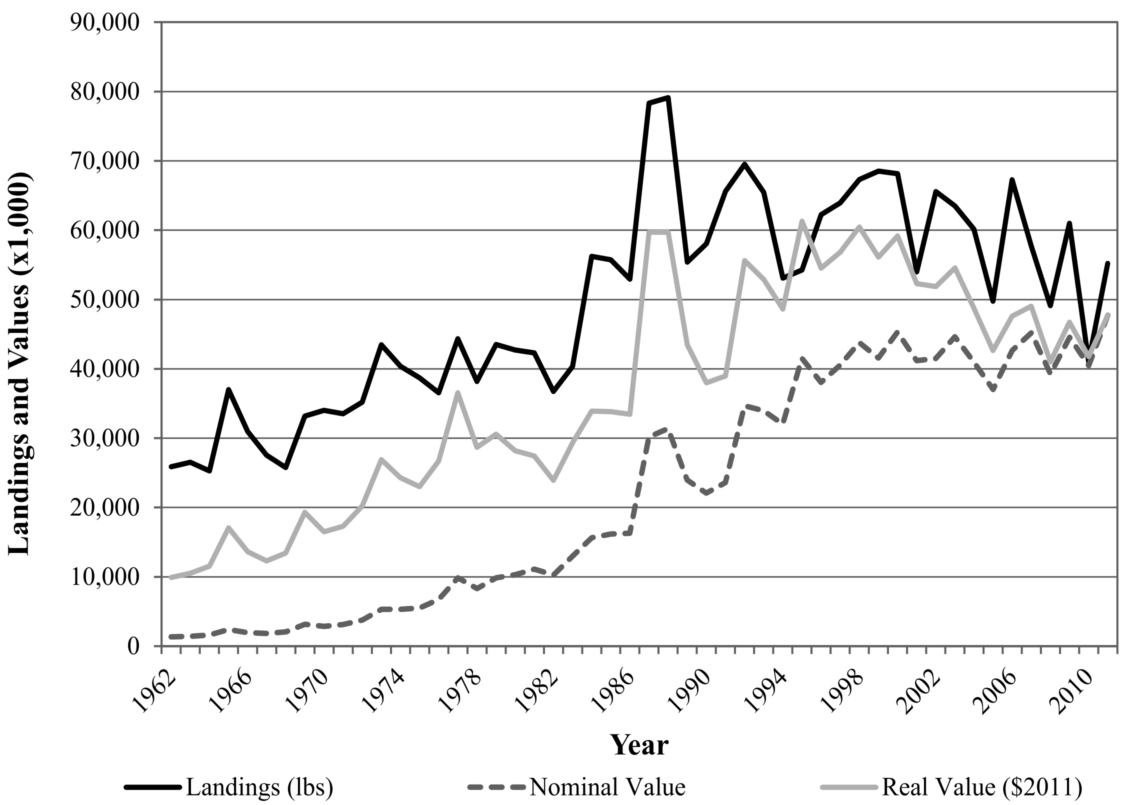



**Figure 7.1** Selected statistics pertaining to Gulf-wide hard crab landings (lbsX1,000) from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

**Table 7.2** Value (dollars) of hard crab landings for Florida West Coast, Alabama, Mississippi, Louisiana, Texas, and the Gulf-wide total from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | FWC | | AL | | MS | | LA | | TX | | GULF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | |
| | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 1962 | 487 | 3,625 | 35 | 262 | 55 | 412 | 462 | 3,445 | 289 | 2,152 | 1,329 | 9,896 |
| 1963 | 644 | 4,736 | 75 | 549 | 64 | 468 | 447 | 3,287 | 200 | 1,467 | 1,429 | 10,507 |
| 1964 | 843 | 6,115 | 110 | 801 | 82 | 592 | 379 | 2,752 | 175 | 1,273 | 1,589 | 11,532 |
| 1965 | 1,184 | 8,458 | 153 | 1,095 | 131 | 933 | 635 | 4,537 | 286 | 2,043 | 2,390 | 17,066 |
| 1966 | 912 | 6,330 | 182 | 1,265 | 105 | 726 | 537 | 3,731 | 228 | 1,581 | 1,964 | 13,633 |
| Average | 814 | 5,853 | 111 | 795 | 87 | 626 | 492 | 3,550 | 236 | 1,703 | 1,740 | 12,527 |
| 1967 | 817 | 5,500 | 188 | 1,268 | 79 | 532 | 520 | 3,500 | 223 | 1,500 | 1,826 | 12,300 |
| 1968 | 674 | 4,356 | 159 | 1,026 | 108 | 700 | 807 | 5,218 | 329 | 2,128 | 2,077 | 13,428 |
| 1969 | 1,074 | 6,583 | 224 | 1,370 | 177 | 1,085 | 1,072 | 6,571 | 600 | 3,676 | 3,146 | 19,285 |
| 1970 | 1,073 | 6,220 | 144 | 835 | 193 | 1,119 | 928 | 5,380 | 509 | 2,950 | 2,847 | 16,505 |
| 1971 | 952 | 5,287 | 212 | 1,176 | 126 | 699 | 1,256 | 6,975 | 567 | 3,150 | 3,113 | 17,288 |
| Average | 918 | 5,589 | 185 | 1,135 | 137 | 827 | 917 | 5,529 | 446 | 2,681 | 2,602 | 15,761 |
| 1972 | 959 | 5,159 | 195 | 1,050 | 169 | 907 | 1,777 | 9,562 | 653 | 3,512 | 3,752 | 20,191 |
| 1973 | 1,147 | 5,811 | 294 | 1,491 | 231 | 1,169 | 2,811 | 14,242 | 830 | 4,207 | 5,314 | 26,919 |
| 1974 | 1,280 | 5,842 | 283 | 1,294 | 227 | 1,034 | 2,701 | 12,326 | 832 | 3,798 | 5,324 | 24,293 |
| 1975 | 1,585 | 6,626 | 283 | 1,184 | 177 | 739 | 2,510 | 10,495 | 948 | 3,962 | 5,503 | 23,006 |
| 1976 | 1,966 | 7,770 | 281 | 1,111 | 268 | 1,058 | 3,061 | 12,099 | 1,179 | 4,662 | 6,754 | 26,701 |
| Average | 1,387 | 6,242 | 267 | 1,226 | 214 | 981 | 2,572 | 11,745 | 888 | 4,028 | 5,329 | 24,222 |
| 1977 | 3,119 | 11,577 | 548 | 2,033 | 473 | 1,756 | 3,765 | 13,976 | 1,947 | 7,226 | 9,852 | 36,568 |
| 1978 | 2,235 | 7,712 | 458 | 1,581 | 422 | 1,456 | 3,189 | 11,004 | 2,004 | 6,913 | 8,309 | 28,665 |
| 1979 | 2,235 | 6,923 | 391 | 1,211 | 316 | 980 | 4,776 | 14,799 | 2,146 | 6,649 | 9,864 | 30,563 |
| 1980 | 2,387 | 6,515 | 465 | 1,268 | 693 | 1,892 | 4,327 | 11,813 | 2,456 | 6,704 | 10,327 | 28,192 |
| 1981 | 3,327 | 8,232 | 850 | 2,103 | 519 | 1,283 | 4,469 | 11,059 | 1,928 | 4,772 | 11,092 | 27,449 |
| Average | 2,660 | 8,192 | 542 | 1,639 | 485 | 1,473 | 4,105 | 12,530 | 2,096 | 6,453 | 9,889 | 30,287 |
| 1982 | 2,209 | 5,149 | 479 | 1,117 | 348 | 810 | 4,843 | 11,290 | 2,375 | 5,536 | 10,254 | 23,902 |
| 1983 | 2,524 | 5,699 | 514 | 1,162 | 332 | 749 | 6,366 | 14,378 | 3,250 | 7,340 | 12,986 | 29,328 |
| 1984 | 3,197 | 6,921 | 1,374 | 2,974 | 640 | 1,385 | 8,192 | 17,735 | 2,252 | 4,876 | 15,654 | 33,891 |
| 1985 | 3,113 | 6,507 | 830 | 1,735 | 538 | 1,125 | 8,387 | 17,533 | 3,309 | 6,918 | 16,177 | 33,818 |
| 1986 | 2,414 | 4,955 | 950 | 1,949 | 470 | 964 | 9,301 | 19,089 | 3,170 | 6,507 | 16,305 | 33,464 |

| YEAR | FWC | | AL | | MS | | LA | | TX | | GULF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | | Value (x$1,000) | |
| | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) |
| Average | 2,691 | 5,846 | 829 | 1,787 | 465 | 1,007 | 7,418 | 16,005 | 2,871 | 6,235 | 14,275 | 30,881 |
| 1987 | 4,068 | 8,055 | 1,005 | 1,990 | 480 | 950 | 20,134 | 39,867 | 4,471 | 8,853 | 30,158 | 59,715 |
| 1988 | 3,751 | 7,132 | 1,551 | 2,950 | 327 | 622 | 21,447 | 40,781 | 4,326 | 8,225 | 31,402 | 59,709 |
| 1989 | 3,183 | 5,774 | 1,735 | 3,147 | 287 | 522 | 14,781 | 26,813 | 3,972 | 7,206 | 23,959 | 43,462 |
| 1990 | 3,139 | 5,402 | 1,265 | 2,176 | 169 | 291 | 14,209 | 24,455 | 3,295 | 5,671 | 22,077 | 37,995 |
| 1991 | 2,763 | 4,564 | 942 | 1,556 | 160 | 265 | 17,468 | 28,849 | 2,271 | 3,751 | 23,605 | 38,985 |
| Average | 3,381 | 6,185 | 1,300 | 2,364 | 285 | 530 | 17,608 | 32,153 | 3,667 | 6,741 | 26,240 | 47,973 |
| 1992 | 3,571 | 5,725 | 1,465 | 2,349 | 207 | 332 | 26,666 | 42,753 | 2,784 | 4,464 | 34,693 | 55,623 |
| 1993 | 4,660 | 7,254 | 1,186 | 1,845 | 133 | 207 | 24,039 | 37,421 | 3,960 | 6,164 | 33,977 | 52,891 |
| 1994 | 5,334 | 8,096 | 1,474 | 2,237 | 89 | 135 | 22,090 | 33,529 | 3,057 | 4,639 | 32,044 | 48,636 |
| 1995 | 6,466 | 9,544 | 1,712 | 2,527 | 229 | 338 | 29,055 | 42,884 | 4,062 | 5,996 | 41,524 | 61,288 |
| 1996 | 7,770 | 11,139 | 1,822 | 2,612 | 262 | 376 | 23,965 | 34,357 | 4,212 | 6,038 | 38,030 | 54,521 |
| Average | 5,560 | 8,351 | 1,532 | 2,314 | 184 | 277 | 25,163 | 38,189 | 3,615 | 5,460 | 36,053 | 54,592 |
| 1997 | 6,543 | 9,170 | 2,053 | 2,878 | 457 | 640 | 27,144 | 38,042 | 4,347 | 6,093 | 40,544 | 56,823 |
| 1998 | 7,548 | 10,416 | 1,947 | 2,687 | 426 | 588 | 29,345 | 40,496 | 4,549 | 6,278 | 43,815 | 60,465 |
| 1999 | 7,144 | 9,646 | 2,079 | 2,806 | 673 | 908 | 27,377 | 36,964 | 4,295 | 5,799 | 41,567 | 56,123 |
| 2000 | 5,041 | 6,585 | 3,083 | 4,027 | 631 | 825 | 33,241 | 43,422 | 3,301 | 4,312 | 45,297 | 59,171 |
| 2001 | 4,213 | 5,351 | 1,744 | 2,215 | 385 | 489 | 30,924 | 39,277 | 3,905 | 4,960 | 41,171 | 52,292 |
| Average | 6,098 | 8,234 | 2,181 | 2,923 | 514 | 690 | 29,606 | 39,640 | 4,079 | 5,488 | 42,479 | 56,975 |
| 2002 | 5,142 | 6,430 | 1,490 | 1,863 | 568 | 711 | 29,762 | 37,214 | 4,523 | 5,655 | 41,486 | 51,872 |
| 2003 | 6,486 | 7,929 | 1,714 | 2,096 | 681 | 832 | 32,596 | 39,849 | 3,157 | 3,859 | 44,634 | 54,565 |
| 2004 | 6,839 | 8,143 | 1,774 | 2,112 | 658 | 783 | 29,019 | 34,555 | 2,663 | 3,171 | 40,951 | 48,764 |
| 2005 | 6,684 | 7,698 | 663 | 764 | 433 | 499 | 26,842 | 30,916 | 2,410 | 2,776 | 37,032 | 42,652 |
| 2006 | 6,739 | 7,520 | 1,319 | 1,472 | 928 | 1,035 | 32,202 | 35,930 | 1,459 | 1,628 | 42,648 | 47,585 |
| Average | 6,378 | 7,544 | 1,392 | 1,661 | 653 | 772 | 30,084 | 35,693 | 2,842 | 3,418 | 41,350 | 49,088 |
| 2007 | 5,486 | 5,951 | 1,710 | 1,855 | 741 | 804 | 34,489 | 37,416 | 2,763 | 2,997 | 45,189 | 49,024 |
| 2008 | 2,999 | 3,133 | 1,533 | 1,601 | 447 | 467 | 31,928 | 33,357 | 2,342 | 2,446 | 39,248 | 41,004 |
| 2009 | 3,823 | 4,009 | 961 | 1,007 | 573 | 601 | 36,757 | 38,540 | 2,454 | 2,573 | 44,569 | 46,730 |
| 2010 | 6,310 | 6,510 | 732 | 756 | 366 | 378 | 29,939 | 30,884 | 3,134 | 3,233 | 40,482 | 41,760 |
| 2011 | 7,239 | 7,239 | 1,128 | 1,128 | 318 | 318 | 36,199 | 36,199 | 2,845 | 2,845 | 47,730 | 47,730 |
| Average | 5,172 | 5,368 | 1,213 | 1,269 | 489 | 513 | 33,863 | 35,279 | 2,708 | 2,819 | 43,443 | 45,250 |

**Table 7.3** Dollars per pound (price) of hard crab landings for the Florida West Coast, Alabama, Mississippi, Louisiana, Texas, and the Gulf-wide total from 1962-2011 (NOAA personal communication). Adjusted (real $2011) prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | FWC | | AL | | MS | | LA | | TX | | GULF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | |
| | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 1962 | 0.05 | 0.35 | 0.06 | 0.41 | 0.06 | 0.45 | 0.05 | 0.36 | 0.06 | 0.48 | 0.05 | 0.38 |
| 1963 | 0.05 | 0.36 | 0.06 | 0.42 | 0.06 | 0.42 | 0.06 | 0.41 | 0.07 | 0.49 | 0.05 | 0.40 |
| 1964 | 0.06 | 0.43 | 0.06 | 0.45 | 0.06 | 0.46 | 0.07 | 0.48 | 0.07 | 0.51 | 0.06 | 0.46 |
| 1965 | 0.06 | 0.41 | 0.08 | 0.60 | 0.08 | 0.55 | 0.07 | 0.49 | 0.08 | 0.56 | 0.06 | 0.46 |
| 1966 | 0.06 | 0.38 | 0.08 | 0.58 | 0.07 | 0.50 | 0.07 | 0.47 | 0.08 | 0.57 | 0.06 | 0.44 |
| Average | 0.05 | 0.39 | 0.07 | 0.50 | 0.07 | 0.48 | 0.06 | 0.44 | 0.07 | 0.52 | 0.06 | 0.43 |
| 1967 | 0.06 | 0.39 | 0.08 | 0.54 | 0.08 | 0.52 | 0.07 | 0.46 | 0.08 | 0.57 | 0.07 | 0.45 |
| 1968 | 0.07 | 0.48 | 0.08 | 0.52 | 0.10 | 0.62 | 0.08 | 0.55 | 0.08 | 0.52 | 0.08 | 0.52 |
| 1969 | 0.09 | 0.57 | 0.12 | 0.71 | 0.10 | 0.62 | 0.09 | 0.57 | 0.09 | 0.58 | 0.09 | 0.58 |
| 1970 | 0.07 | 0.42 | 0.10 | 0.59 | 0.10 | 0.55 | 0.09 | 0.52 | 0.09 | 0.53 | 0.08 | 0.49 |
| 1971 | 0.08 | 0.43 | 0.11 | 0.59 | 0.10 | 0.56 | 0.10 | 0.57 | 0.10 | 0.54 | 0.09 | 0.52 |
| Average | 0.08 | 0.46 | 0.10 | 0.59 | 0.09 | 0.57 | 0.09 | 0.53 | 0.09 | 0.55 | 0.08 | 0.51 |
| 1972 | 0.09 | 0.48 | 0.12 | 0.65 | 0.12 | 0.67 | 0.12 | 0.63 | 0.10 | 0.54 | 0.11 | 0.57 |
| 1973 | 0.12 | 0.61 | 0.14 | 0.71 | 0.13 | 0.64 | 0.12 | 0.62 | 0.12 | 0.61 | 0.12 | 0.62 |
| 1974 | 0.13 | 0.58 | 0.16 | 0.71 | 0.14 | 0.62 | 0.13 | 0.60 | 0.14 | 0.62 | 0.13 | 0.60 |
| 1975 | 0.12 | 0.52 | 0.17 | 0.72 | 0.16 | 0.65 | 0.15 | 0.61 | 0.16 | 0.66 | 0.14 | 0.59 |
| 1976 | 0.16 | 0.64 | 0.22 | 0.86 | 0.20 | 0.79 | 0.20 | 0.80 | 0.18 | 0.70 | 0.18 | 0.73 |
| Average | 0.12 | 0.57 | 0.16 | 0.73 | 0.15 | 0.67 | 0.14 | 0.65 | 0.14 | 0.63 | 0.14 | 0.62 |
| 1977 | 0.20 | 0.73 | 0.25 | 0.94 | 0.25 | 0.92 | 0.23 | 0.87 | 0.24 | 0.88 | 0.22 | 0.82 |
| 1978 | 0.19 | 0.66 | 0.23 | 0.79 | 0.22 | 0.75 | 0.21 | 0.73 | 0.27 | 0.93 | 0.22 | 0.75 |
| 1979 | 0.20 | 0.62 | 0.29 | 0.90 | 0.24 | 0.75 | 0.22 | 0.69 | 0.26 | 0.80 | 0.23 | 0.70 |
| 1980 | 0.21 | 0.58 | 0.30 | 0.81 | 0.25 | 0.69 | 0.24 | 0.65 | 0.27 | 0.75 | 0.24 | 0.66 |
| 1981 | 0.22 | 0.56 | 0.35 | 0.85 | 0.28 | 0.69 | 0.28 | 0.68 | 0.28 | 0.69 | 0.26 | 0.65 |
| Average | 0.20 | 0.63 | 0.28 | 0.86 | 0.25 | 0.76 | 0.24 | 0.72 | 0.26 | 0.81 | 0.23 | 0.72 |
| 1982 | 0.25 | 0.58 | 0.38 | 0.88 | 0.27 | 0.62 | 0.28 | 0.65 | 0.30 | 0.69 | 0.28 | 0.65 |
| 1983 | 0.27 | 0.61 | 0.36 | 0.82 | 0.29 | 0.66 | 0.32 | 0.73 | 0.37 | 0.83 | 0.32 | 0.73 |
| 1984 | 0.25 | 0.54 | 0.33 | 0.71 | 0.28 | 0.62 | 0.28 | 0.60 | 0.31 | 0.67 | 0.28 | 0.60 |
| 1985 | 0.25 | 0.53 | 0.37 | 0.77 | 0.33 | 0.68 | 0.28 | 0.59 | 0.34 | 0.71 | 0.29 | 0.61 |

| YEAR | FWC | | AL | | MS | | LA | | TX | | GULF | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | | Price ($/lb) | |
| | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 1986 | 0.32 | 0.65 | 0.33 | 0.68 | 0.36 | 0.74 | 0.29 | 0.60 | 0.33 | 0.69 | 0.31 | 0.63 |
| Average | 0.27 | 0.58 | 0.35 | 0.77 | 0.31 | 0.66 | 0.29 | 0.64 | 0.33 | 0.72 | 0.30 | 0.64 |
| 1987 | 0.39 | 0.77 | 0.40 | 0.80 | 0.35 | 0.69 | 0.38 | 0.76 | 0.38 | 0.76 | 0.39 | 0.76 |
| 1988 | 0.36 | 0.69 | 0.40 | 0.76 | 0.38 | 0.72 | 0.40 | 0.76 | 0.41 | 0.79 | 0.40 | 0.75 |
| 1989 | 0.39 | 0.71 | 0.42 | 0.77 | 0.44 | 0.80 | 0.44 | 0.80 | 0.44 | 0.79 | 0.43 | 0.78 |
| 1990 | 0.46 | 0.79 | 0.38 | 0.66 | 0.43 | 0.75 | 0.37 | 0.63 | 0.38 | 0.66 | 0.38 | 0.65 |
| 1991 | 0.53 | 0.88 | 0.35 | 0.57 | 0.35 | 0.58 | 0.34 | 0.56 | 0.37 | 0.61 | 0.36 | 0.59 |
| Average | 0.43 | 0.77 | 0.39 | 0.71 | 0.39 | 0.71 | 0.39 | 0.70 | 0.40 | 0.72 | 0.39 | 0.71 |
| 1992 | 0.47 | 0.75 | 0.41 | 0.66 | 0.47 | 0.75 | 0.52 | 0.83 | 0.45 | 0.72 | 0.50 | 0.80 |
| 1993 | 0.55 | 0.85 | 0.46 | 0.72 | 0.53 | 0.82 | 0.52 | 0.82 | 0.48 | 0.74 | 0.52 | 0.81 |
| 1994 | 0.63 | 0.96 | 0.55 | 0.83 | 0.52 | 0.79 | 0.60 | 0.91 | 0.59 | 0.90 | 0.60 | 0.92 |
| 1995 | 0.74 | 1.09 | 0.68 | 1.00 | 0.72 | 1.06 | 0.79 | 1.16 | 0.70 | 1.04 | 0.77 | 1.13 |
| 1996 | 0.63 | 0.90 | 0.57 | 0.81 | 0.64 | 0.92 | 0.60 | 0.86 | 0.67 | 0.96 | 0.61 | 0.88 |
| Average | 0.60 | 0.91 | 0.53 | 0.81 | 0.58 | 0.87 | 0.61 | 0.92 | 0.58 | 0.87 | 0.60 | 0.91 |
| 1997 | 0.71 | 0.99 | 0.59 | 0.83 | 0.67 | 0.94 | 0.62 | 0.88 | 0.61 | 0.86 | 0.63 | 0.89 |
| 1998 | 0.59 | 0.82 | 0.56 | 0.77 | 0.72 | 0.99 | 0.67 | 0.93 | 0.65 | 0.90 | 0.65 | 0.90 |
| 1999 | 0.65 | 0.87 | 0.55 | 0.74 | 0.73 | 0.99 | 0.59 | 0.80 | 0.66 | 0.90 | 0.61 | 0.82 |
| 2000 | 0.79 | 1.03 | 0.64 | 0.84 | 0.75 | 0.98 | 0.65 | 0.84 | 0.71 | 0.93 | 0.66 | 0.87 |
| 2001 | 0.93 | 1.18 | 0.71 | 0.90 | 0.89 | 1.13 | 0.75 | 0.95 | 0.76 | 0.96 | 0.76 | 0.97 |
| Average | 0.73 | 0.98 | 0.61 | 0.82 | 0.75 | 1.01 | 0.66 | 0.88 | 0.68 | 0.91 | 0.66 | 0.89 |
| 2002 | 0.94 | 1.17 | 0.58 | 0.72 | 0.79 | 0.99 | 0.60 | 0.75 | 0.64 | 0.80 | 0.63 | 0.79 |
| 2003 | 0.91 | 1.11 | 0.58 | 0.71 | 0.78 | 0.95 | 0.68 | 0.84 | 0.66 | 0.80 | 0.70 | 0.86 |
| 2004 | 0.85 | 1.02 | 0.53 | 0.63 | 0.81 | 0.97 | 0.66 | 0.78 | 0.67 | 0.80 | 0.68 | 0.81 |
| 2005 | 0.91 | 1.05 | 0.65 | 0.75 | 1.01 | 1.16 | 0.71 | 0.82 | 0.77 | 0.89 | 0.74 | 0.86 |
| 2006 | 0.79 | 0.88 | 0.55 | 0.62 | 0.82 | 0.92 | 0.60 | 0.67 | 0.74 | 0.83 | 0.63 | 0.71 |
| Average | 0.88 | 1.05 | 0.58 | 0.69 | 0.84 | 1.00 | 0.65 | 0.77 | 0.70 | 0.82 | 0.68 | 0.81 |
| 2007 | 0.90 | 0.98 | 0.67 | 0.73 | 1.01 | 1.09 | 0.77 | 0.83 | 0.80 | 0.87 | 0.78 | 0.85 |
| 2008 | 1.14 | 1.19 | 0.85 | 0.89 | 0.99 | 1.04 | 0.77 | 0.80 | 0.89 | 0.93 | 0.80 | 0.83 |
| 2009 | 1.15 | 1.21 | 0.66 | 0.69 | 1.05 | 1.10 | 0.70 | 0.73 | 0.86 | 0.90 | 0.73 | 0.77 |
| 2010 | 1.11 | 1.14 | 0.79 | 0.82 | 1.00 | 1.03 | 0.98 | 1.01 | 0.91 | 0.94 | 0.99 | 1.02 |
| 2011 | 1.09 | 1.09 | 0.70 | 0.70 | 0.86 | 0.86 | 0.83 | 0.83 | 0.98 | 0.98 | 0.86 | 0.86 |
| Average | 1.08 | 1.12 | 0.73 | 0.76 | 0.98 | 1.02 | 0.81 | 0.84 | 0.89 | 0.93 | 0.83 | 0.87 |

in dockside value was paralleled by an almost doubling of the average number of pounds landed in the Gulf of Mexico over the same time period.

The relative contribution of each Gulf state to the region in terms of hard crab landings and value, are presented in Table 7.4 and Figures 7.2 and 7.3. Louisiana has steadily increased its relative contribution to the Gulf from the 1960s to 2007-2011 in both landings and value. In the 1960s, Louisiana contributed 28% of the landings and value in the Gulf of Mexico. Louisiana's relative contribution in recent years (2007-2011) has risen to ~80% of the total Gulf production.

### 7.1.2 Annual Landings and Value by State

Landings, value, and price of crab landings for each of the Gulf states from 1962-2011 are presented in Tables 7.1-7.3. The value and price of crab landings for the Gulf region from 1962-2011 are presented in both nominal and real ($2011) terms. In addition, summary statistics for each Gulf state are presented in Figures 7.4-7.8.

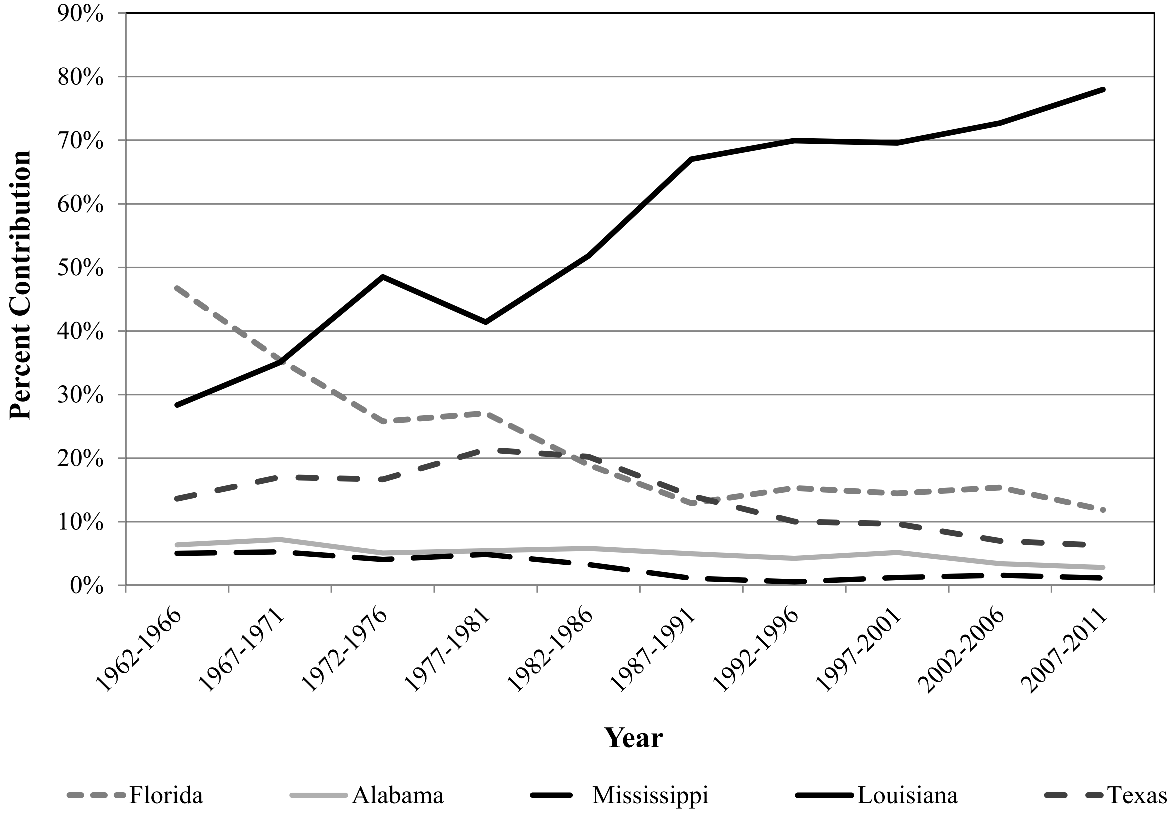
#### 7.1.2.1 Florida West Coast

Reported production of crabs along the Florida West Coast in the early 1960s averaged slightly less than 15.0M pounds (Table 7.1 and Figure 7.4A). In general, Florida's landings (based on five-year averages) declined over the last 49 years from 14.9-4.8M pounds. While average landings reached a low in 2008 at 2.6M pounds, Florida landings began an increasing trend from 2009-2011. This represents only 53% of their 49-year average for those years on average however. Florida's crab production in the early 1960s represented 51% of the total landings in the Gulf (Table 7.4 and Figure 7.3). By 2002-2006, the proportion of the total Gulf landings contributed by Florida had fallen to 12%. The recent contribution to total Gulf landings was about 9%.

**Table 7.4** Relative contribution to Gulf-wide reported hard crab landings (Q) and value (V) by state from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012). Note: Totals may not sum to 100 due to rounding.

| YEARS | FWC | | AL | | MS | | LA | | TX | |
|---|---|---|---|---|---|---|---|---|---|---|
| | % Q | % V | % Q | % V | % Q | % V | % Q | % V | % Q | % V |
| 1962-1966 | 51 | 47 | 5 | 6 | 4 | 5 | 28 | 28 | 11 | 14 |
| 1967-1971 | 40 | 35 | 6 | 7 | 5 | 5 | 33 | 35 | 16 | 17 |
| 1972-1976 | 28 | 26 | 4 | 5 | 4 | 4 | 47 | 48 | 17 | 17 |
| 1977-1981 | 31 | 27 | 5 | 5 | 5 | 5 | 41 | 41 | 19 | 21 |
| 1982-1986 | 21 | 19 | 5 | 6 | 3 | 3 | 53 | 52 | 18 | 20 |
| 1987-1991 | 12 | 13 | 5 | 5 | 1 | 1 | 68 | 67 | 14 | 14 |
| 1992-1996 | 15 | 15 | 5 | 4 | 1 | 1 | 69 | 70 | 10 | 10 |
| 1997-2001 | 14 | 14 | 6 | 5 | 1 | 1 | 70 | 70 | 9 | 10 |
| 2002-2006 | 12 | 15 | 4 | 3 | 1 | 2 | 76 | 73 | 7 | 7 |
| 2007-2011 | 9 | 12 | 3 | 3 | 1 | 1 | 81 | 78 | 6 | 6 |

**Figure 7.2** Relative contribution to Gulf reported hard crab values (V) by state from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).




The average nominal value of Florida's reported crab landings over the last 49 years has increased from about $0.8-$5.1M (Table 7.2 and Figure 7.4A), based on five-year averages. However, the five-year real ($2011) value average of Florida's crab landings only changed by 8%, falling from $5.8M to $5.3M. Considering the general decline in Florida landings overall, the minimal change in the inflation-adjusted value was attributed to an increase in the real ($2011) price of the landed product which increased from $0.39 to $1.12/lb in the early 1960s to the early 2010s, respectively, based on five-year averages. This represents an increase of about 190% (Table 7.3 and Figure 7.4A). Florida's contribution to the total Gulf real value was generally less than the state's contribution to total Gulf landings through the late 1980s (Table 7.4 and Figure 7.2). From the early 1960s to the late 1980s, the real price for Florida product was less than that of the total Gulf average. From about 1990-2011, the Florida dockside price has generally exceeded the Gulf price on average.

### 7.1.2.2 Alabama

Alabama's reported five-year crab landings from 2007-2011 averaged 1.7M pounds, which is similar to the five-year average landings in the early 1960s of 1.5M pounds (Table 7.1 and Figure 7.4B). While highly variable (based on five-year averages), there was a general trend of increased landings in the state from the 1960s to the early 2000s. However, from 2002-2011 blue crab

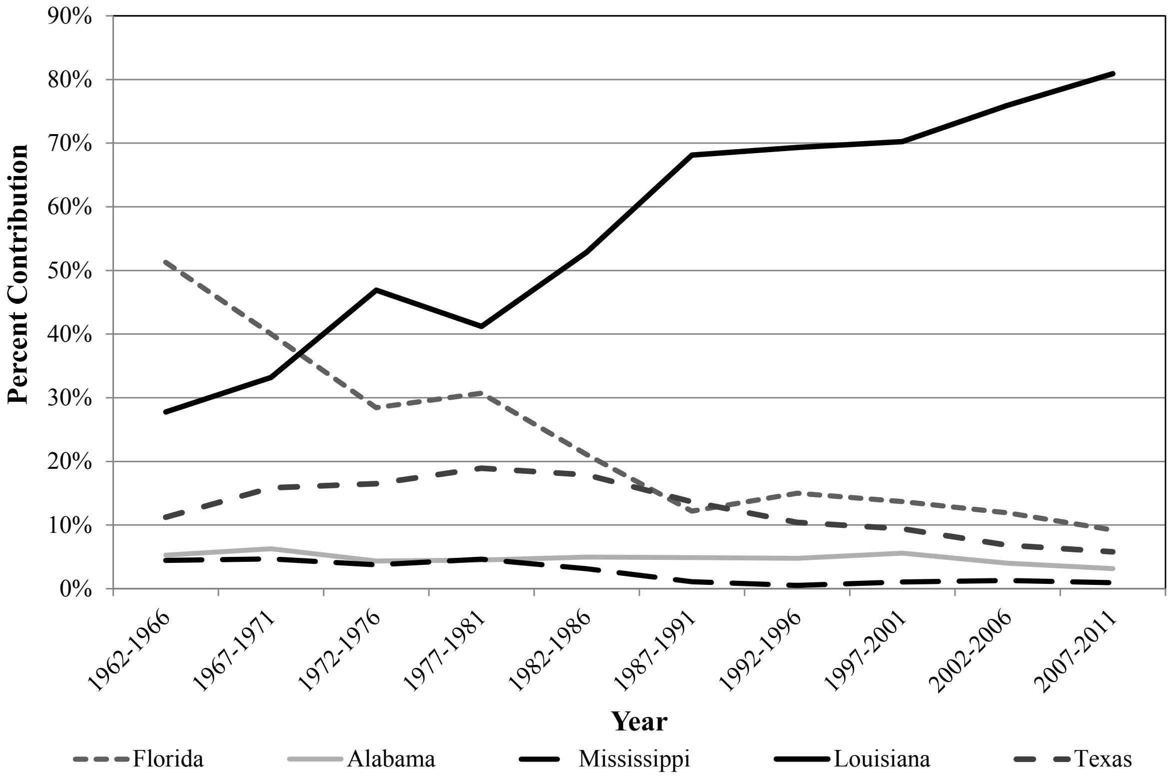



**Figure 7.3** Relative contribution to Gulf reported hard crab landings (Q) in pounds by state from 1962-2011 (NOAA personal communication).

landings in Alabama decreased more than 32%, using five-year averages. Alabama's contribution to total Gulf landings (Table 7.4B and Figure 7.3) increased in the late 1960s to 6%, fell to 4% in the early 1970s, and remained steady at around 5% until the late 2010s when it fell to 3%. The nominal value of Alabama's reported crab landings increased from a five-year average of $111,183 in the 1960s to roughly $2.2M around the 2000s (Table 7.2 and Figure 7.4B). The real ($2011) value of Alabama's landings also increased from about $0.8M in the early 1960s to about $2.9M around the early 2000s, based on five-year averages.

### 7.1.2.3 Mississippi

Landings and value have declined in the Mississippi crab fishery over the 49-year period presented in Tables 7.1-7.2 and Figure 7.4C. In the late 1960s, Mississippi contributed 5% to the total Gulf landings and 5% to the total Gulf value (Table 7.4 and Figures 7.2-7.3). Mississippi's contributions to the total Gulf landings and value have averaged about 1% since 1987. Since the 1960s, Mississippi's landings declined from 1.3M pounds to about 0.5M pounds in the late 2000s, based on five-year averages (Table 7.1 and Figure 7.4C). The average real ($2011) value of Mississippi's reported crab landings fell approximately 18% over the last 49 years from $626,000 to $513,000, based on five-year averages (Table 7.2 and Figure 7.4C).

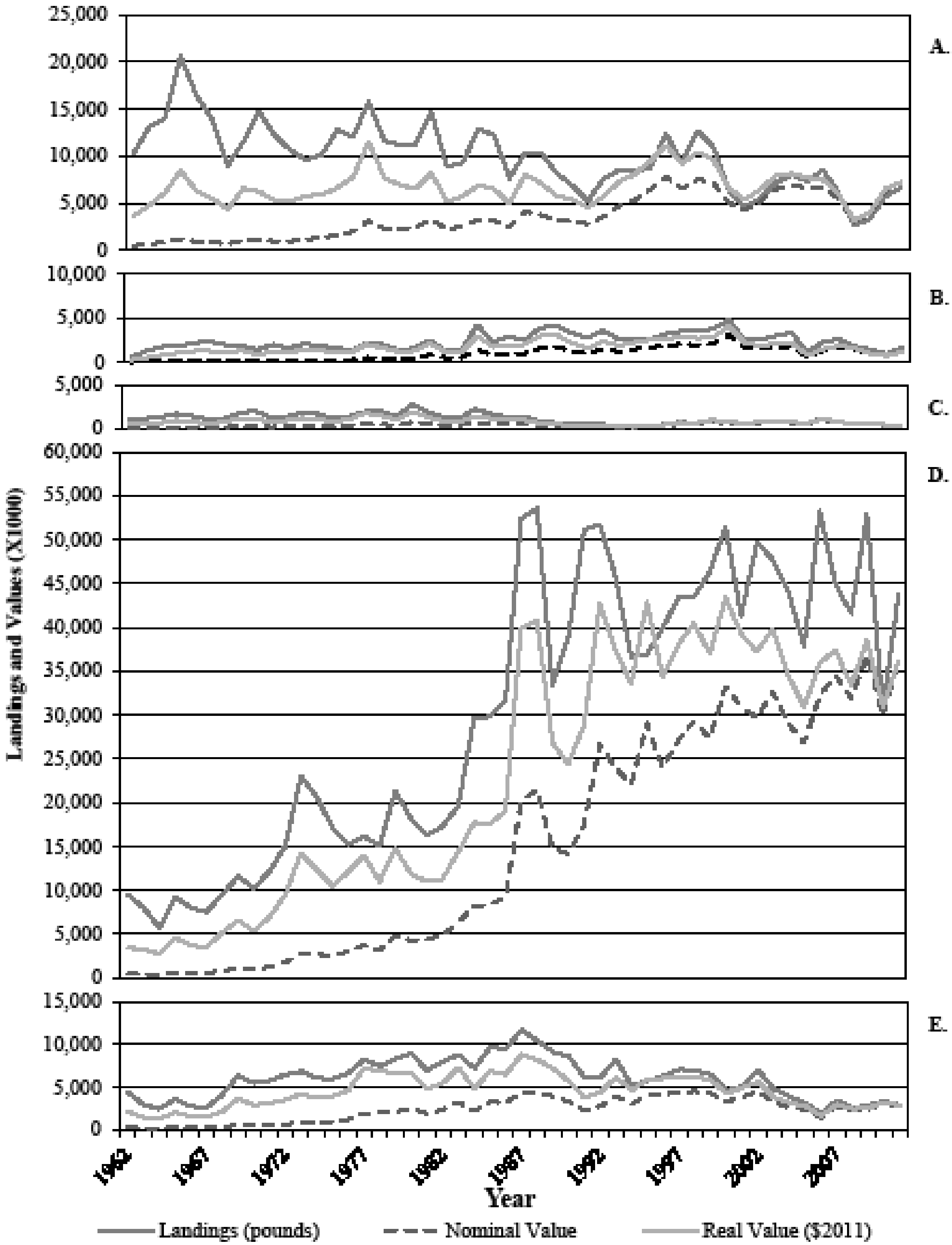



**Figure 7.4** Selected statistics pertaining to hard crab landings (pounds) in A) Florida West Coast, B) Alabama, C) Mississippi, D) Louisiana, and E) Texas from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

#### 7.1.2.4 Louisiana

The reported annual landings of crabs in Louisiana averaged just over 8.0M pounds in the 1960s (Table 7.1 and Figure 7.4D), and the state's contribution to the Gulf total averaged about 28% (Table 7.4 and Figure 7.3). By the mid-1970s, annual production had increased to over 18.0M pounds, based on five-year averages, and the state's contribution to the Gulf total increased to over 45%. A large increase in production began in the mid to late 1980s. Since 1987, five-year average production has been in excess of 42.0M pounds, and the state's contribution to total Gulf production since about the 1990s has been approximately 70% or greater. Most notably, from 2007-2011, Louisiana's contribution to Gulf landings was 81%. Overall, the recent average production of 43.0M pounds from 2007-2011 exceeded the average mid-1960s production of 8.0M pounds by more than 400%.

The annual nominal value of crab landings increased from less than $1.0M in the 1960s to more than $36.0 M during the late 2000s (Table 7.2 and Figure 7.4D). When adjusted for inflation, the real dockside value ($2011), increased by a factor of more than ten from an annual average of $3.5 to $35.0M. The substantial increase in the inflation-adjusted dockside value reflects both a large increase in quantity of product and a large increase in the inflation-adjusted price of the landed product. Overall, Louisiana's contribution to the total Gulf value (real $2011) is similar to the state's contribution by weight from 1962-2011 (Table 7.4 and Figure 7.2).

#### 7.1.2.5 Texas

Reported crab landings in Texas increased from an average of 3.3M pounds in the 1960s to 9.2M pounds in the late 1980s and early 1990s and declined sharply thereafter to 3.0M pounds from 2007-2011. (Table 7.1 and Figure 7.4E). Similarly, the real ($2011) dockside value of these landings peaked at an average of $6.7M in the late 1980s and early 1990s, representing a four-fold increase since the 1960s (Table 7.2 and Figure 7.4E). Since the late 1980s and early 1990s, the average real value ($2011) declined 58% to roughly $2.8M in the late 2000s and early 2010s.

Overall, the contribution of crab landings from Texas to the total for the Gulf peaked at 19% from 1977-1981 and declined to 6% from 2007-2011 (Table 7.4 and Figure 7.3). The contribution to the total Gulf-wide value (real $2011) by Texas nearly paralleled the landings contribution.

### 7.1.3 Seasonal Landings and Value

The average 1990-2011 monthly landings and dockside values associated with Gulf crab harvest are presented in Table 7.5 and Figure 7.5. Peak landings occurred from May through August and averaged 7.0M pounds/month during that time period. The value of landings for this four-month period averaged $4.3M/month in nominal dollars and $5.6M/month in real $2011. Lowest landings occurred from December through March and averaged 3.0M pounds/month, worth $2.3M/month in nominal dollars, and $2.9M in real $2011. Average December-March landings were approximately one-half of the reported value of landings for May-August. While dockside value tended to be positively correlated with volume landed, there existed a strong inverse correlation between price/lb and landings. During the four months when the quantity

**Table 7.5** Average monthly reported hard crab harvest (pounds) and value from the Gulf, 1990-2011, nominal and real (NOAA personal communication). Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| MONTH | HARVEST (lbsX1,000) | VALUE (X$1,000) | | PRICE ($/lb) | |
|---|---|---|---|---|---|
| | | Nominal | Real ($2011) | Nominal | Real ($2011) |
| January | 2,959 | 2,215 | 2,834 | 0.76 | 0.97 |
| February | 2,571 | 2,082 | 2,661 | 0.83 | 1.06 |
| March | 2,713 | 2,229 | 2,880 | 0.86 | 1.09 |
| April | 4,147 | 3,225 | 4,152 | 0.80 | 1.02 |
| May | 6,197 | 4,277 | 5,477 | 0.72 | 0.91 |
| June | 7,597 | 4,688 | 5,960 | 0.64 | 0.80 |
| July | 7,856 | 4,462 | 5,709 | 0.58 | 0.74 |
| August | 6,583 | 4,015 | 5,123 | 0.62 | 0.78 |
| September | 5,127 | 3,245 | 4,211 | 0.65 | 0.82 |
| October | 5,434 | 3,229 | 4,191 | 0.60 | 0.77 |
| November | 4,905 | 3,025 | 3,963 | 0.62 | 0.80 |
| December | 3,935 | 2,506 | 3,229 | 0.64 | 0.83 |

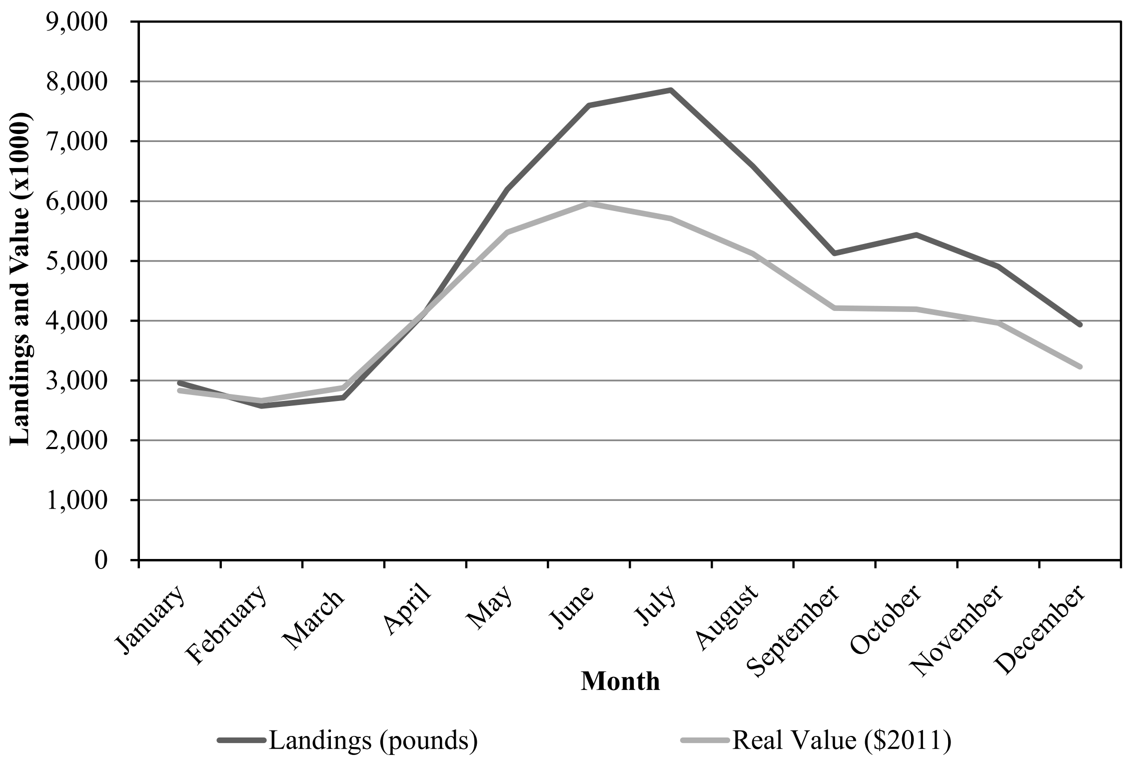



**Figure 7.5** Average monthly (1990-2011) reported hard crab harvest (pounds) and value from the Gulf (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

produced was high (May-August), the dockside price averaged $0.64/lb, expressed on a nominal dollar basis. By comparison, from December-March, price/lb averaged $0.77, or around 20% more than when seasonal landings were at a maximum.

### 7.1.4 Gulf Production in Relation to the Chesapeake Bay and the U.S.

The production of crabs in the U.S. increased during the 49-year analysis (Table 7.6 and Figure 7.6). The 177.0M pounds reported for the last five years represents an increase of about 21.0M pounds, on average, when compared to the reported total production for 1962-1966 of 155.0M pounds. This is a decline of 43.0M pounds; however, when comparing peak U.S. production of crabs in 1992-1996 with production in 2007-2011.

The Gulf contribution to total U.S. crab landings ranged from about 20-40%, with the average being 28% (Table 7.6). The Chesapeake Bay's share to the total U.S. landings declined from roughly 50% on average in the 1960s to around 42% from 2007-2011. Overall, 2007-2011 average production in the Chesapeake Bay region represented a reduction of almost 17.0M

**Table 7.6** Summary statistics pertaining to hard crab landings (pounds) and real $2011 for the Gulf of Mexico, Chesapeake Bay, and U.S. from 1962-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012). Note: Percentages represent contribution to U.S. total by respective regions.

| YEARS | GULF (X1,000) | | CHESAPEAKE BAY (X1,000) | | U.S. (X1,000) | |
|---|---|---|---|---|---|---|
| | Pounds | Real ($2011) | Pounds | Real ($2011) | Pounds | Real ($2011) |
| 1962-1966 | 29,133<br>19% | 12,527<br>19% | 79,036<br>51% | 36,113<br>55% | 155,443<br>100% | 65,906<br>100% |
| 1967-1971 | 30,801<br>22% | 15,761<br>23% | 66,297<br>48% | 32,698<br>48% | 137,079<br>100% | 67,582<br>100% |
| 1972-1976 | 38,860<br>28% | 24,222<br>28% | 59,621<br>44% | 36,715<br>42% | 136,666<br>100% | 86,867<br>100% |
| 1977-1981 | 42,206<br>26% | 30,287<br>29% | 67,408<br>42% | 42,448<br>41% | 160,350<br>100% | 103,691<br>100% |
| 1982-1986 | 48,393<br>25% | 30,881<br>26% | 91,614<br>47% | 56,866<br>49% | 195,472<br>100% | 117,190<br>100% |
| 1987-1991 | 67,299<br>31% | 47,973<br>33% | 87,700<br>40% | 58,861<br>41% | 220,000<br>100% | 144,927<br>100% |
| 1992-1996 | 60,912<br>28% | 54,592<br>28% | 77,125<br>35% | 74,446<br>38% | 220,009<br>100% | 195,791<br>100% |
| 1997-2001 | 64,382<br>32% | 56,975<br>29% | 60,185<br>30% | 66,599<br>34% | 198,168<br>100% | 194,783<br>100% |
| 2002-2006 | 61,258<br>37% | 49,088<br>33% | 52,950<br>32% | 53,766<br>36% | 164,560<br>100% | 150,886<br>100% |
| 2007-2011 | 52,826<br>30% | 45,250<br>26% | 74,699<br>42% | 79,446<br>46% | 176,662<br>100% | 172,320<br>100% |

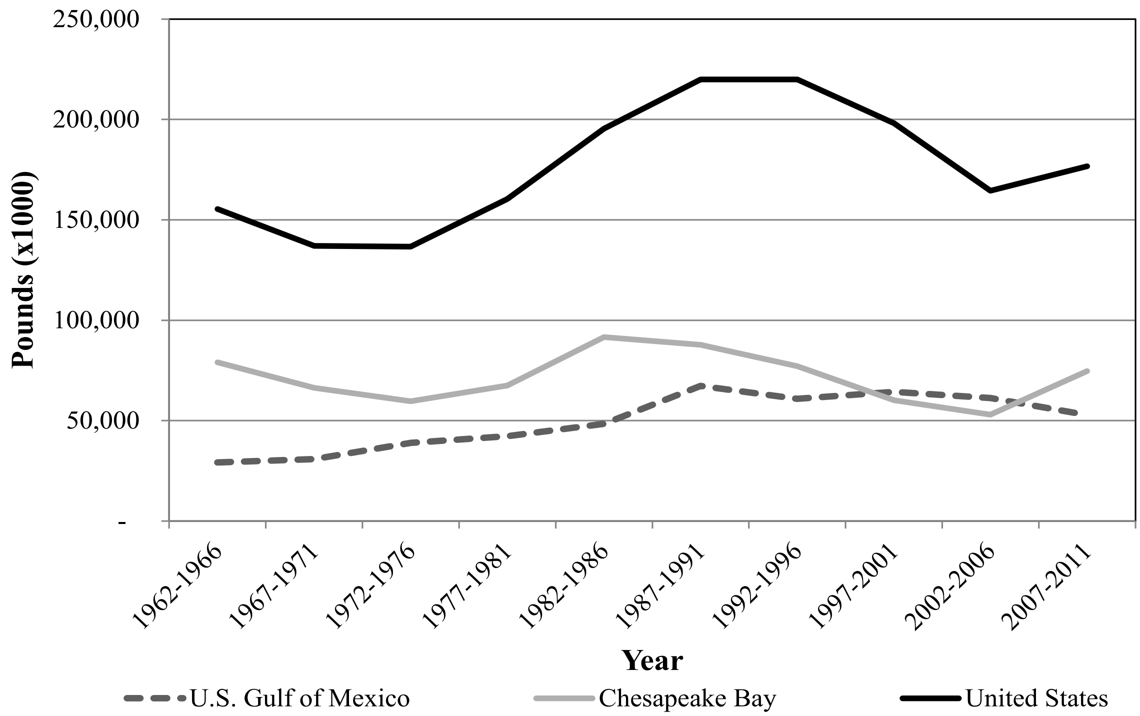



**Figure 7.6** Five-year average hard crab landings (pounds) for the U.S. Gulf of Mexico, Chesapeake Bay, and total U.S. from 1962-2011 (NOAA personal communication).

pounds annually when compared to peak average landings from 1982-1986 at 92.0M pounds. This reduction may explain, in part, the increase in the Gulf dockside price per pound in recent years (Table 7.3).

## 7.2 Crab Harvester Business Characteristics

Similar to other seafood harvesters and businesses, crab harvesters operate on the inflow of sales from crab landings and non-crab landings and the outflow or expenses from variable and fixed costs. Sales occur when crab and other types of seafood are sold to downstream businesses such as dealers and processing plants. Variable costs are incurred when a crab harvester is actively harvesting crab and often includes fuel, oil, bait, groceries, etc. Fixed costs do not change as a function of whether or not a harvester is fishing and include insurance, maintenance and repair, overhead, interest payments, and principal payments.

To better understand the business characteristics of Gulf of Mexico crab harvesters, a socioeconomic survey was administered Gulf-wide by the GMSFC in March 2013 (see Section 8.2 for methodology and Appendix 13.2 for survey instrument). The survey was made available to all commercial blue crab license holders from Florida to Texas (4,549 total). Of the 478 responses received, 180 respondents provided complete responses needed to describe the general business characteristics of crab harvesters and are used herein for analysis and summary statistics. Social characteristics such as the age, education levels, and other occupations are included in Section 8.3 and following.

The survey found an interdependency of the crab fishery with other fisheries. Respondents included in the analysis indicated that, on average, a little more than 70% of their harvesting income came from harvesting crab, followed by shrimp, other, soft crab, finfish, and oysters. Commercial seafood harvesting of any seafood type was often only one component of total income for respondents included in the analysis and, on average, about 70% of their total income came from commercial seafood harvesting. Crab harvester survey respondents included in the analysis were likely supplementing their crab and seafood harvesting income with additional revenue from other occupations.

The 2013 survey also contained questions related to crab harvesting effort. The number of trips a crab fisherman took in a year directly influenced the total cash inflow or revenue received by the crab harvester. Additional research is needed, however, to better understand the relationship between total harvesting revenue and the number of trips a harvester takes in a year. For crab harvesters who responded to the survey, and were included in the analysis, the average number of trips taken was 141. About 21% of respondents included in the analysis took a total of 101-150 trips per year followed by 19% taking 151-200 trips, 19% taking 1-50 trips, 16% taking 51-100, 11% taking 201-250, 9% taking between 251-300, and 4% taking 301-365 (Figure 7.7). In Florida, Gandy (2012) observed that 22% of crab harvesters, or the largest number of survey respondents, fished for crabs 151-200 days/year.

The crab fishing vessel appears to, on average, be operated by one harvester at a time. Given the responses used in the analysis, about 60% of crab fishermen indicated that they did not

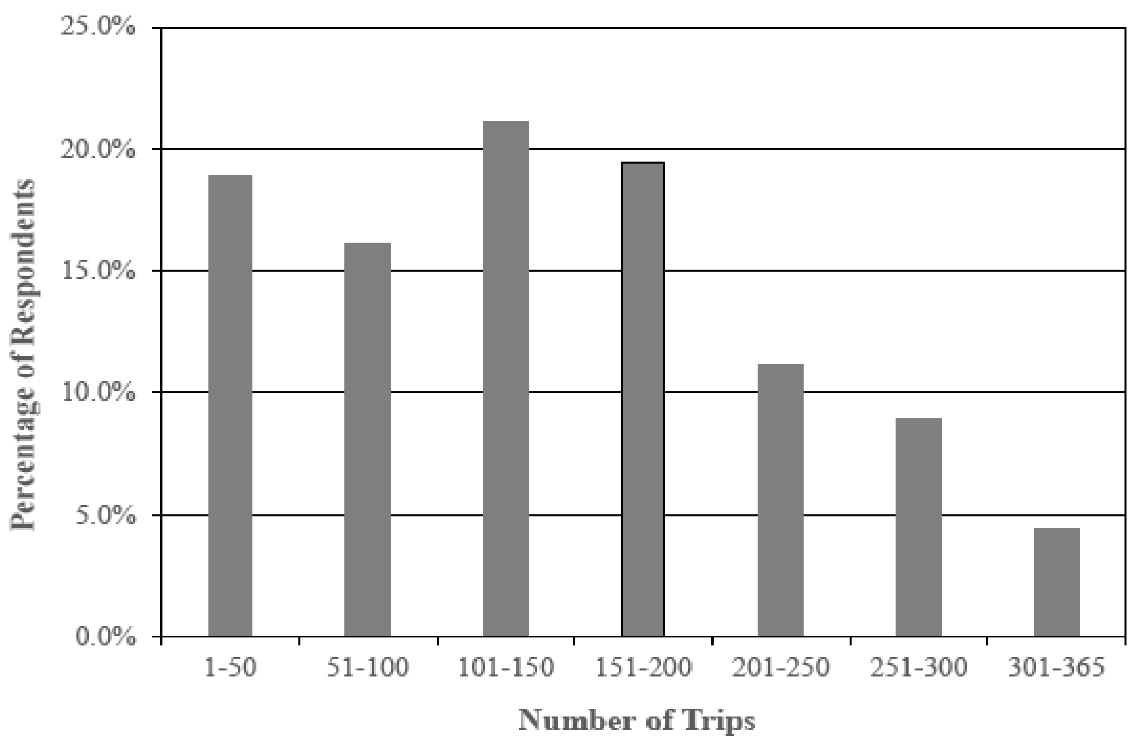



**Figure 7.7** The number of crab harvesting trips per year for respondents included in the 2013 socioeconomic survey of the commercial blue crab fishery in the Gulf of Mexico.

hire any crew to work on their primary crabbing vessel. For the crab harvesters that hired crew, the average number of hired crew onboard the vessel was 1.4. This finding is similar to Gandy (2012) who found that crab fishermen in Florida typically fish crab traps alone, and that if they do have others onboard, they only have one other person working with them.

Insurance for a crab harvesting business, or any businesses, allows the proprietor to hedge against unforeseen events such as a hurricane, theft, or fire. Given the responses used in the analysis, only 16% of crab harvesters carried insurance on their primary crabbing vessel over the course of the prior year. Using the inshore shrimp industry as a reference point, this represents more than double the percentage of shrimp harvesters who carried vessel insurance on the vessel used most frequently for shrimp harvesting in 2008 (Miller and Isaacs 2011).

As a measure of indebtedness among crab harvesters, respondents were asked whether or not they had loan obligations in the previous year for their primary crab harvesting vessel. Less than one-fifth (14%) of the respondents included in the analysis indicated having loans on their primary crabbing vessel at any time during the last year. The percentage of crab harvesters having loans on their primary vessel is similar to the 19% of inshore shrimp harvesters who had loans on their primary shrimp harvesting vessel in 2008 (Miller and Isaacs 2011).

Respondents were asked about their total cash outflow (variable and fixed costs) as it pertained to expenditures during the last year on trip-related operating expenditures (fuel, oil, ice, bait, groceries, other supplies, and hired crew and captain,) and non-trip-related expenses (maintenance, repair, and gear expenditures, insurance premiums, overhead expenditures, and loan interest and principal payments). For responses used within the analysis, the expense category percentages were as follows: bait (20%), fuel (17%), overhead (14%), maintenance, repair, and gear (12%), hired crew and captain (12%), other suppliers (8%), oil (6%), groceries (5%), ice (4%), interest and principal payments (2%), and insurance (<1%) (Figure 7.8). This is similar to crab harvester respondents in Florida who reported that their major expense categories were also bait, fuel, gear, and maintenance (Gandy 2012).

Crab harvesters responding to the survey were also asked about gross revenues from harvesting crab as well as total revenue received from other sources for the last year for their primary crab harvesting vessel. Total revenue received from non-crab sales included gross revenue from other seafood types (shrimp, crab, oysters, fish, etc.), government payments, grant money, and disaster assistance for the primary crab harvesting vessel. Respondents included within the analysis indicated that about 66% of their gross revenues came from crab landings while about 34% came from non-crab landings. This result is similar to results of the question concerning the percentage of annual harvesting income from different seafood types which indicated that 70% of harvester income for respondents used within the analysis came from crab.

Having a buyer for a fisherman's catch is an important component to any seafood harvesting business, and for respondents included in the analysis, 67% of a crab harvester's catch was, on average, sold to dealers (first receivers) followed by wholesalers, the public, processing plants, other, and restaurants. Gandy (2012) found a similar result where a majority of crab harvesters sold their catch to wholesalers in Florida.

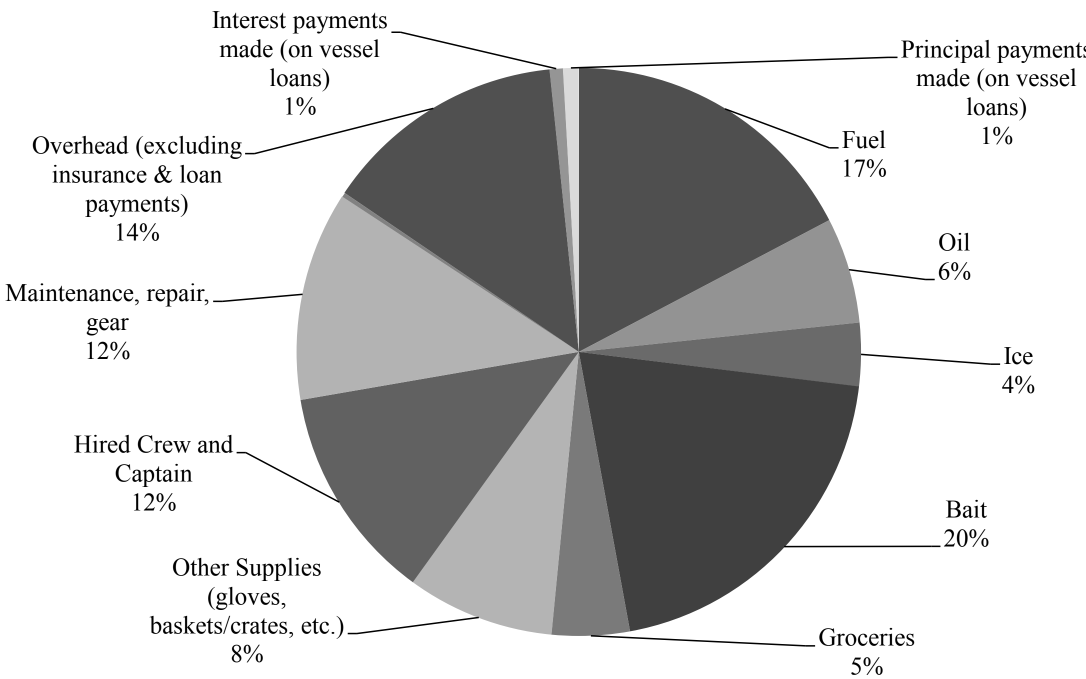



**Figure 7.8** Percentage of total cash outflow by expenditure category for crab harvester survey respondents in the 2013 socioeconomic survey of the commercial blue crab fishery in the Gulf of Mexico.

## 7.3 Blue Crab Marketing

In the aftermath of recent natural and manmade disasters in the Gulf region, coupled with an effort to combat rising foreign imports, a number of blue crab 'marketing' initiatives have developed. These initiatives have included attempts to separate the domestic blue crab market from the global commodity crab market and efforts to communicate the sustainability of the fishery to seafood buyers and consumers. A number of organizations have delved into these activities, including the LDWF Blue Crab Task Force, the Louisiana Seafood Marketing and Promotion Board, Louisiana Direct Seafood, Mississippi Gulf Fresh Seafood, Alabama Gulf Seafood, Fresh from Florida Gulf Seafood, and the Gulf Seafood Marketing Coalition.

The aforementioned marketing organizations have routinely sponsored traditional and non-traditional advertisements, retail and foodservice promotions, and regional cooking competitions for crab and other types of Gulf seafood. Through their websites and creative material, they have provided information about their seafood products, recipes, news, transparency and accountability information, where-to-buy guides, supplier resources, handbooks, how-to guides, sponsorship opportunities, and information concerning the local culture and local marine resource. Specific organizations and crab businesses in the Gulf have also developed innovative initiatives to separate Gulf crab products from other regions and imports. Examples include the Louisiana Seafood Direct program where customers buy crab directly from the boat through electronic web-based notifications.

Efforts to differentiate Gulf crab, typically by individual crab processors, have also included innovative technologies such as electronic traceability, provided by the Gulf Seafood Trace program via Trace Register, which shows retail and foodservice buyers and consumers exactly where crabs were harvested and the steps taken to reach final sale. Source and geographic certifications have also accompanied electronic traceability information or purchase orders and product labels. One such example is the Certified Louisiana Seafood program where the product is labeled as having been landed, caught, or processed in Louisiana. Similar efforts to communicate the source of blue crabs have been implemented in the Chesapeake Bay region through a program called 'True Blue', which is an initiative of the Maryland Seafood marketing program.

A seafood sustainability certification for crab has been employed in Louisiana to market and communicate the status of the crab stock to the global seafood industry. Certified in March of 2012, the Marine Stewardship Council (MSC) certification for Louisiana blue crabs is the first blue crab fishery in the world to earn the MSC certification from the independent non-profit organization. The MSC sets standards for sustainable fishing that are used by a certification body, which is independent of the fishery and the MSC, to certify it. It is assumed that achieving MSC certification will appeal to domestic major retailers, as well as markets overseas in the United Kingdom and Europe that require sustainability certifications such as the MSC label.

## 7.4. Procurement

Dealers who do not process raw crab product are typically referred to as wholesalers, docks, or first receivers. In many states in the Gulf, the aforementioned businesses usually procured raw product directly from local harvesters through the point of first sale. Through a survey effort conducted by GSMFC and LDWF to collect economic data from dealers (first receivers), approximately 97% of seafood procured by Gulf dealers (first receivers), who handled crab, was sourced from independent domestic Gulf harvesters (derived from Miller et al. 2014a). About 3% of seafood from Gulf dealers (first receivers), who handled crab, came from vessels owned by dealers (first receivers).

Because processors often require very large raw product supplies, procurement tends to engage a variety of sources that include other processors, independent harvesters, domestic dealers (first receivers) or distributors, and processor-employed harvesters. Approximately 50% of raw crab product was secured by processors purchasing from domestic dealers (first receivers) or distributors while 22% of the product supply among processors were direct purchases from independent crab harvesters (Figure 7.9) (derived from Miller et al. 2014b). About 11% of the raw crab product supply was derived from the processor-employed harvesters. About 2% was procured via sales from other domestic crab processors, while importers accounted for 15% and other accounted for < 1%.

## 7.5 Sales, Distribution, and Utilization

Unpublished crab dealer (first receiver) data collected by GSMFC and LDWF, indicated that approximately 60% of cumulative seafood sales from dealers (first receivers) came from other dealers or distributors, while 29% was sold to processors, and 11% was sold to retailers (Figure

7.10) (derived from Miller et al. 2014a). Sales from dealers (first receivers) to the public and other sources represented less than 1%.

Moving down the supply chain, approximately 58% of cumulative crab processor seafood sales were sold to seafood distributors and dealers, while almost 30% was sold to seafood retailers (Figure 7.11). The remaining 13% and 1% where sold to other processors and the public, respectively (derived from Miller et al. 2014b).

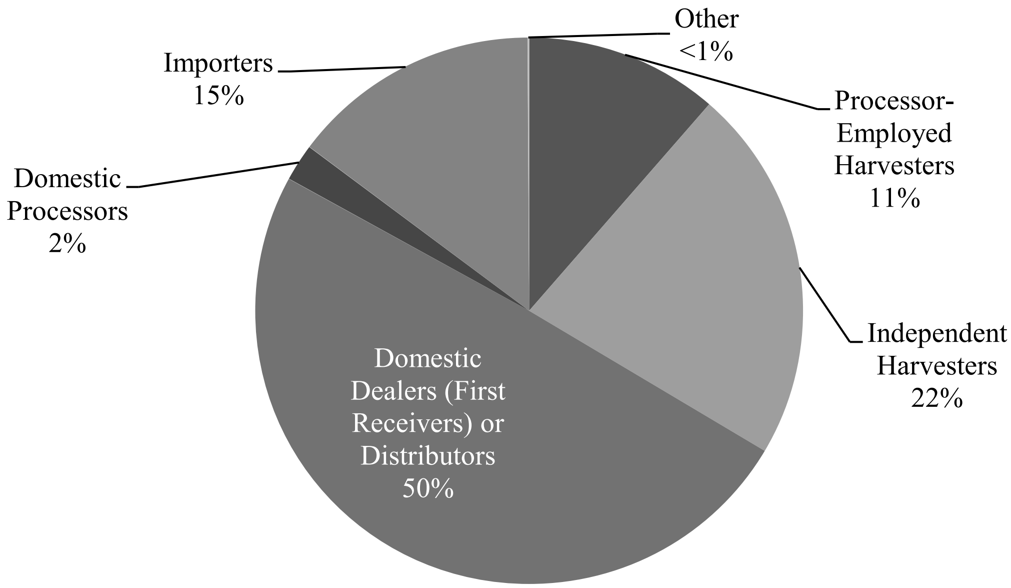



**Figure 7.9** Percentage of cumulative seafood procured from a variety of sources by Gulf crab processors (derived from Miller et al. 2014a).

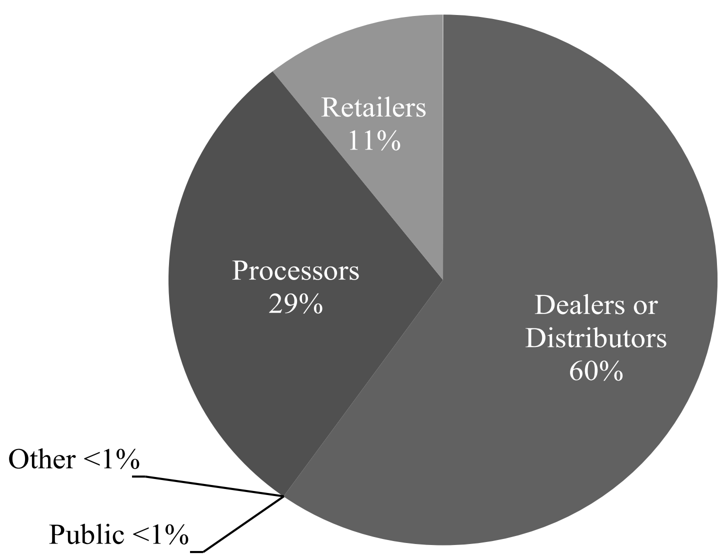



**Figure 7.10** Percentage of cumulative seafood sales sold to the following customer types by Gulf crab dealers (first receivers) (derived from Miller et al. 2014a).

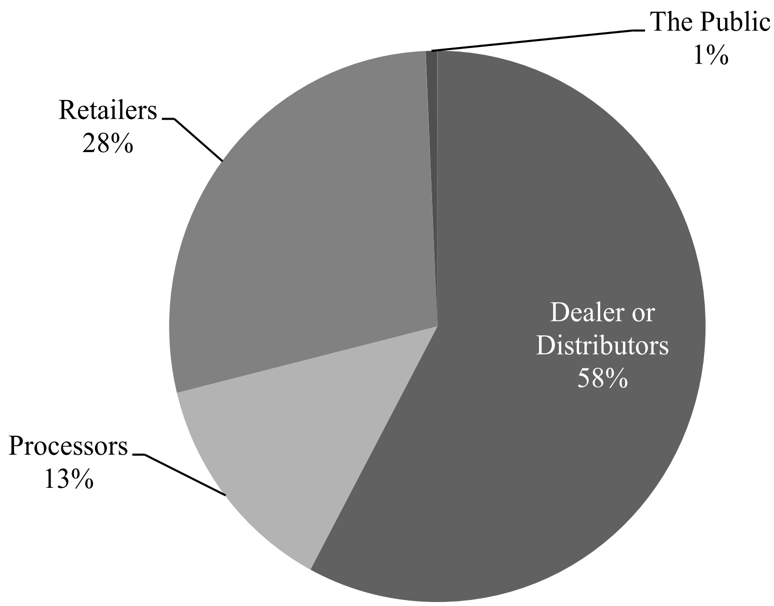



**Figure 7.11** Percentage of cumulative Gulf crab processor seafood sales sold to the following customer types (derived from Miller et al. 2014a).

Crab product sold to various processor customer types, derived from Miller et al. 2014b, included cooked crab meat, live crabs, soft shell crab, and other. Cooked crab meat represented the largest category for processors by product form at approximately 82%, while live crabs accounted for about 16% of crab processor sales (Figure 7.12). Soft shell crabs and other product forms were 0.5% and 1.7% of crab processor sales, respectively.

Through the crab processing and distribution process, waste products such as picked crab shells and claws accumulate and are often an expensive businesses expense. In recent years, picked crab shells and claws have been used through a number of different commercial applications through post processing applications that offer an additional revenue stream and eliminate waste. Crab shells and claws contain chitin, a structure component of the exoskeleton that is used to produce chitosan for commercial and biomedical uses. Chitosan is produced by treating crab shells with alkali sodium hydroxide to deacetylate chitin. Both chitin and chitosan have been used in research and commercial applications that include the following:

- Making new battery materials (Boerner 2013)
- Producing more affordable and innovative pharmaceuticals (Coxworth 2013, Real 2012)
- Improving wastewater treatment (Belsie 1991, FoxNews.com 2005)
- Improving clothing treatments (Belsie 1991)
- Developing new cosmetic and medical creams and lotions (Belsie 1991)
- Enhancing agricultural growth yields (Wikipedia 2013)
- Preserving the flavor and shelf life of meat, fruits, and vegetables (Belsie 1991)
- Creating mold and mildew inhibitors (Marketwire 2012, Mother Nature Network 2013)

- Removing high concentrations of phosphate (Jeon and Yeom 2009)
- Producing agricultural fertilizer and compost (The City of Bayou La Batre: News 2012)
- Developing car coatings that repair scratches (LiveLeak.com 2009)
- Engineering biodegradable sutures or second skins for burn victims (Block 2000)
- Creating new blood clotting technologies (Celox 2013)
- Enhancing biological denitrification (Robinson-Lora and Brennan 2008)

The geographic distribution of crab dealer (first receiver) sales by sales volume, as indicated through unpublished GSMFC and LDWF crab data, indicated that sales primarily stayed within the Gulf region (Figure 7.13) (derived from Miller et al. 2014a). Sales to other states within the Gulf region accounted for 28%, while sales within the respondents' base state accounted for 52%. Sales from dealers (first receivers) to US states outside the Gulf accounted for 20%.

As derived from Miller et al. 2014b, sales for Gulf crab processors were different than those of dealers (first receivers) and showed that crab processor sales were mostly made throughout the rest of the U.S. and not within the Gulf region. Sales to U.S. states outside the Gulf region were almost half or 46% (Figure 7.14). Sales to other states within the Gulf region accounted for 27%, while sales within the respondent's base state also accounted for 27%.

### 7.6 Domestic Processing Sector

The majority of blue crab landings are processed upon arrival at the processor. Picking crab meat is generally done by hand and is labor intensive. Upon picking, the product may be pasteurized, breaded, or prepared as stuffed crabs, gumbos, or soups. The annual processed

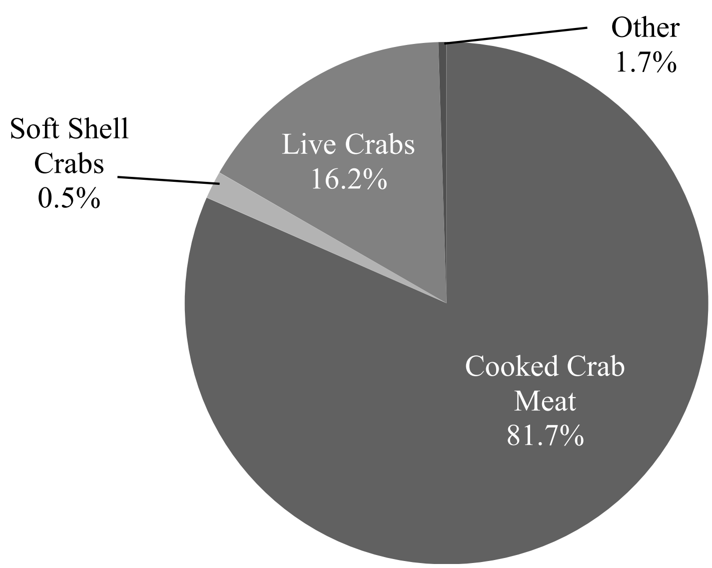



**Figure 7.12** Distribution of Gulf crab processor sales by crab product form (by sales value) (derived from Miller et al. 2014a).

product survey, conducted by NOAA Fisheries (personal communication), indicates that the five largest Gulf crab processors historically (1973-2011) accounted for about 26% of total processed crab sales. The 10 largest crab processors accounted for 37% of total processed crab sales, and the 20 largest processors comprised 51%. According to unpublished GSMFC and LDWF crab processing data (derived from Miller et al. 2014b), of the firms identified as crab processors, 30% said that their seafood business started handling seafood at its present location prior to 1980. Thirty-nine percent said their business started processing seafood at the current location between 1980 and 1994. About 30% said their business started processing seafood at the current location

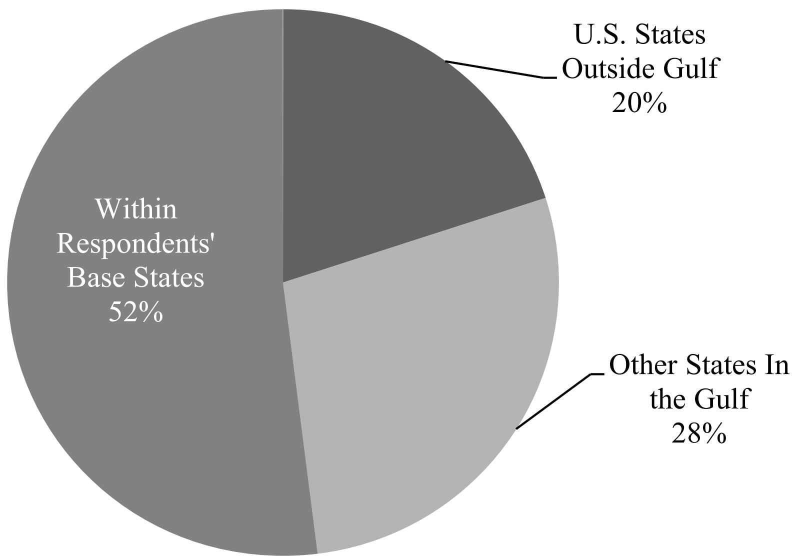



**Figure 7.13** Geographic distribution of Gulf crab dealers' crab sales by sales volume (derived from Miller et al. 2014a).

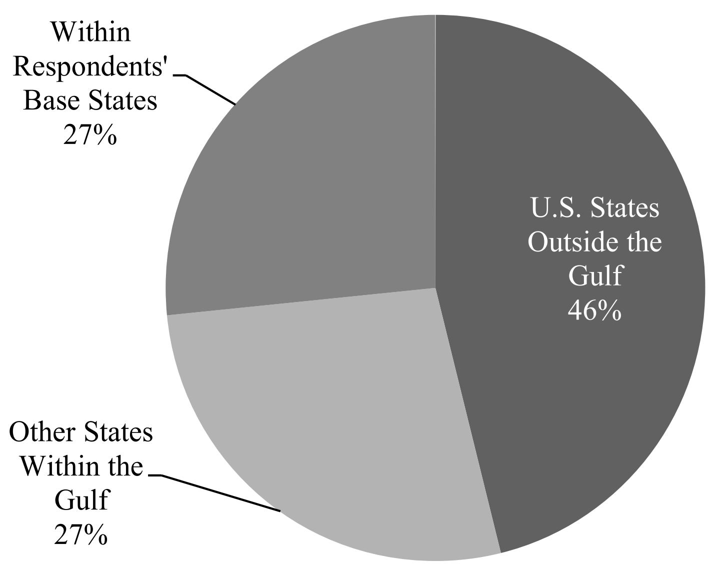



**Figure 7.14** Geographic distribution of Gulf crab processor product sales by sales volume (derived from Miller et al. 2014a).

after 1995. Additional processing statistics for Gulf blue crab are presented below for 1973-2011, using data from the NOAA Fisheries annual survey of seafood processors.

### 7.6.1 Aggregate Processing Activities

The number of Gulf crab processors increased from a three-year average of 84 in the mid-1970s to 107 in the early 1990s (Table 7.7). Since the early 1990s, however, a sharp decline in the number of processors has occurred. From 2009-2011, only 31 crab processors, on average, were in operation in the Gulf. This represents the lowest three-year average in the last 38 years. Processed poundage and real product value ($2011) has also decreased over the last four decades (Table 7.7, Figure 7.15).

The quantity processed (pounds) is reported in three categories: product-weight, estimated edible meat weight, and estimated live-weight (Table 7.7). Processed crab may be sourced from the Gulf states, other regions of the U.S., or from other countries. The product weight includes the meat weight of crabs plus any additional ingredients such as the breading materials and the shell weight, if appropriate (i.e., stuffed crabs and cocktail claws). The estimated (approximate) meat-weight basis is expressed in terms of pounds of crab meat. The live weight has been estimated based on conversion factors provided by NOAA Fisheries and is used to express the estimated pounds of live crabs used in processing activities. Since both the meat and the live weight figures are estimates based on conversion factors, some error may be introduced. Because live weight estimates may include different product forms (i.e., body weight and claw weight), some products may be counted twice.

The total processed quantity, expressed on a product weight basis, increased from 1973-1991 (Table 7.7 and Figure 7.15). Since about 1992, however, the processed quantity fell sharply. The average annual reported processed weight of 17.9M pounds (product weight) in the early 1990s, for example, declined to 5.6M pounds in 2009-2011, representing about a three-fold decrease. The 3.0M pounds reported in 2007 was the lowest quantity reported for the 38 years of data included. While undocumented, at least some of the decline in processing activities in the Gulf from the 1990s into the 2000s may be attributable to the general reduction of production (dockside landings) in the Chesapeake Bay (Table 7.6, Figure 7.6). Shipments of live Gulf crab to the Chesapeake may have increased to meet local and regional demand in the mid-Atlantic and Chesapeake Bay region.

The nominal annual value of crab processing activities in the Gulf expanded from an average of $17.6M in the mid-1970s to approximately $61.0M in the mid-1990s (Table 7.7 and Figure 7.15). However, no long-term increase in nominal value has been evident since the mid-1990s, on average. The real annual value ($2011) of crab processing activities increased by almost 43% from $80.7M in the mid-1970s to $115.0M in the mid-1980s, on average. Since the mid-1980s, however, the real value ($2011) of processing activities has fallen sharply, on average. The most recent (2009-2011) average annual real ($2011) processed value of $34.0M was only about 30% of what the value was more than 20 years ago. This represents a 70% decrease in processed activities in the Gulf from the peak in the 1980s to the 2010s. The $34.0M value (real $2011) in the 2010s was lower than that estimated for almost all but one of the three-year averages dating

**Table 7.7** Production of processed crab (pounds) in the Gulf, 1973-2011, nominal and real ($2011) (NOAA personal communication). Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012). Note: Product weight and number of firms were derived from the NOAA Fisheries annual survey of seafood processors.

| YEAR | NO. OF FIRMS | PROCESSED POUNDAGE (x1,000) | | | POUNDS LANDED (x1,000) | PRODUCT VALUE (x$1,000) | | PRODUCT PRICE ($/lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 1973 | 85 | 9,657 | 6,827 | 48,723 | 43,473 | 16,890 | 85,569 | 1.75 | 8.86 |
| 1974 | 86 | 9,431 | 6,667 | 47,582 | 40,354 | 17,621 | 80,397 | 1.87 | 8.52 |
| 1975 | 82 | 9,088 | 6,424 | 45,850 | 38,718 | 18,232 | 76,227 | 2.01 | 8.39 |
| Average | 84 | 9,392 | 6,639 | 47,385 | 40,848 | 17,581 | 80,731 | 1.87 | 8.59 |
| 1976 | 91 | 9,629 | 6,807 | 48,579 | 36,561 | 22,938 | 90,679 | 2.38 | 9.42 |
| 1977 | 85 | 10,579 | 7,479 | 53,375 | 44,328 | 24,972 | 92,691 | 2.36 | 8.76 |
| 1978 | 84 | 11,094 | 7,842 | 55,971 | 38,171 | 23,989 | 82,762 | 2.16 | 7.46 |
| Average | 87 | 10,434 | 7,376 | 52,642 | 39,687 | 23,966 | 88,711 | 2.30 | 8.55 |
| 1979 | 75 | 10,993 | 7,771 | 55,464 | 43,497 | 24,706 | 76,546 | 2.25 | 6.96 |
| 1980 | 77 | 10,220 | 7,225 | 51,564 | 42,728 | 28,614 | 78,111 | 2.80 | 7.64 |
| 1981 | 81 | 9,445 | 6,677 | 47,651 | 42,305 | 29,120 | 72,060 | 3.08 | 7.63 |
| Average | 78 | 10,219 | 7,224 | 51,560 | 42,843 | 27,480 | 75,572 | 2.71 | 7.41 |
| 1982 | 88 | 10,813 | 7,644 | 54,557 | 36,728 | 31,186 | 72,693 | 2.88 | 6.72 |
| 1983 | 98 | 12,557 | 8,877 | 63,354 | 40,334 | 41,386 | 93,467 | 3.30 | 7.44 |
| 1984 | 97 | 16,233 | 11,476 | 81,900 | 56,225 | 55,295 | 119,711 | 3.41 | 7.37 |
| Average | 94 | 13,201 | 9,332 | 66,604 | 44,429 | 42,622 | 95,290 | 3.20 | 7.18 |
| 1985 | 94 | 18,271 | 12,916 | 92,183 | 55,753 | 50,978 | 106,571 | 2.79 | 5.83 |
| 1986 | 96 | 17,741 | 12,542 | 89,511 | 52,926 | 60,526 | 124,221 | 3.41 | 7.00 |
| 1987 | 98 | 16,629 | 11,756 | 83,898 | 78,315 | 58,319 | 115,477 | 3.51 | 6.94 |
| Average | 96 | 17,547 | 12,405 | 88,531 | 62,332 | 56,608 | 115,423 | 3.24 | 6.59 |
| 1988 | 103 | 16,286 | 11,513 | 82,168 | 79,101 | 54,816 | 104,229 | 3.37 | 6.40 |
| 1989 | 105 | 15,131 | 10,697 | 76,343 | 55,413 | 64,564 | 117,120 | 4.27 | 7.74 |
| 1990 | 94 | 16,527 | 11,683 | 83,382 | 58,056 | 61,769 | 106,307 | 3.74 | 6.43 |
| Average | 101 | 15,981 | 11,298 | 80,631 | 64,190 | 60,383 | 109,219 | 3.79 | 6.86 |
| 1991 | 107 | 18,482 | 13,066 | 93,247 | 65,609 | 54,569 | 90,122 | 2.95 | 4.88 |
| 1992 | 110 | 18,449 | 13,042 | 93,081 | 69,516 | 62,604 | 100,372 | 3.39 | 5.44 |
| 1993 | 103 | 16,781 | 11,863 | 84,667 | 65,442 | 48,682 | 75,782 | 2.90 | 4.52 |
| Average | 107 | 17,904 | 12,657 | 90,332 | 66,856 | 55,285 | 88,758 | 3.08 | 4.94 |
| 1994 | 96 | 16,095 | 11,378 | 81,204 | 53,084 | 46,316 | 70,299 | 2.88 | 4.37 |
| 1995 | 90 | 15,544 | 10,988 | 78,422 | 54,265 | 76,243 | 112,533 | 4.91 | 7.24 |
| 1996 | 88 | 13,822 | 9,771 | 69,737 | 62,253 | 60,726 | 87,060 | 4.39 | 6.30 |
| Average | 91 | 15,154 | 10,713 | 76,455 | 56,534 | 61,095 | 89,964 | 4.06 | 5.97 |
| 1997 | 81 | 11,814 | 8,352 | 59,606 | 63,937 | 48,720 | 68,281 | 4.12 | 5.78 |
| 1998 | 76 | 10,924 | 7,722 | 55,115 | 67,309 | 38,137 | 52,628 | 3.49 | 4.82 |
| 1999 | 72 | 11,479 | 8,115 | 57,913 | 68,534 | 40,849 | 55,153 | 3.56 | 4.80 |
| Average | 76 | 11,406 | 8,063 | 57,545 | 66,594 | 42,569 | 58,687 | 3.72 | 5.13 |
| 2000 | 67 | 11,416 | 8,071 | 57,600 | 68,131 | 39,191 | 51,194 | 3.43 | 4.48 |
| 2001 | 61 | 8,790 | 6,214 | 44,348 | 53,998 | 29,229 | 37,124 | 3.33 | 4.22 |

| YEAR | NO. OF FIRMS | PROCESSED POUNDAGE (x1,000) | | | POUNDS LANDED (x1,000) | PRODUCT VALUE (x$1,000) | | PRODUCT PRICE ($/lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 2002 | 59 | 7,968 | 5,633 | 40,201 | 65,568 | 28,876 | 36,106 | 3.62 | 4.53 |
| Average | 62 | 9,391 | 6,639 | 47,383 | 62,566 | 32,432 | 41,475 | 3.46 | 4.41 |
| 2003 | 58 | 11,352 | 8,025 | 57,273 | 63,489 | 33,163 | 40,541 | 2.92 | 3.57 |
| 2004 | 47 | 8,003 | 5,658 | 40,378 | 60,177 | 27,985 | 33,324 | 3.50 | 4.16 |
| 2005 | 42 | 7,601 | 5,373 | 38,349 | 49,763 | 24,563 | 28,291 | 3.23 | 3.72 |
| Average | 49 | 8,985 | 6,352 | 45,333 | 57,810 | 28,570 | 34,052 | 3.22 | 3.82 |
| 2006 | 35 | 7,080 | 5,005 | 35,720 | 67,294 | 21,754 | 24,272 | 3.07 | 3.43 |
| 2007 | 33 | 3,052 | 2,158 | 15,398 | 57,722 | 14,783 | 16,038 | 4.84 | 5.25 |
| 2008 | 35 | 5,849 | 4,135 | 29,512 | 49,128 | 25,429 | 26,567 | 4.35 | 4.54 |
| Average | 34 | 5,327 | 3,766 | 26,877 | 58,048 | 20,655 | 22,292 | 4.09 | 4.41 |
| 2009 | 30 | 6,131 | 4,334 | 30,932 | 61,010 | 32,258 | 33,822 | 5.26 | 5.52 |
| 2010 | 33 | 6,277 | 4,438 | 31,670 | 41,060 | 34,145 | 35,223 | 5.44 | 5.61 |
| 2011 | 30 | 4,515 | 3,192 | 22,781 | 55,212 | 31,693 | 31,693 | 7.02 | 7.02 |
| Average | 31 | 5,641 | 3,988 | 28,461 | 52,427 | 32,699 | 33,579 | 5.91 | 6.05 |

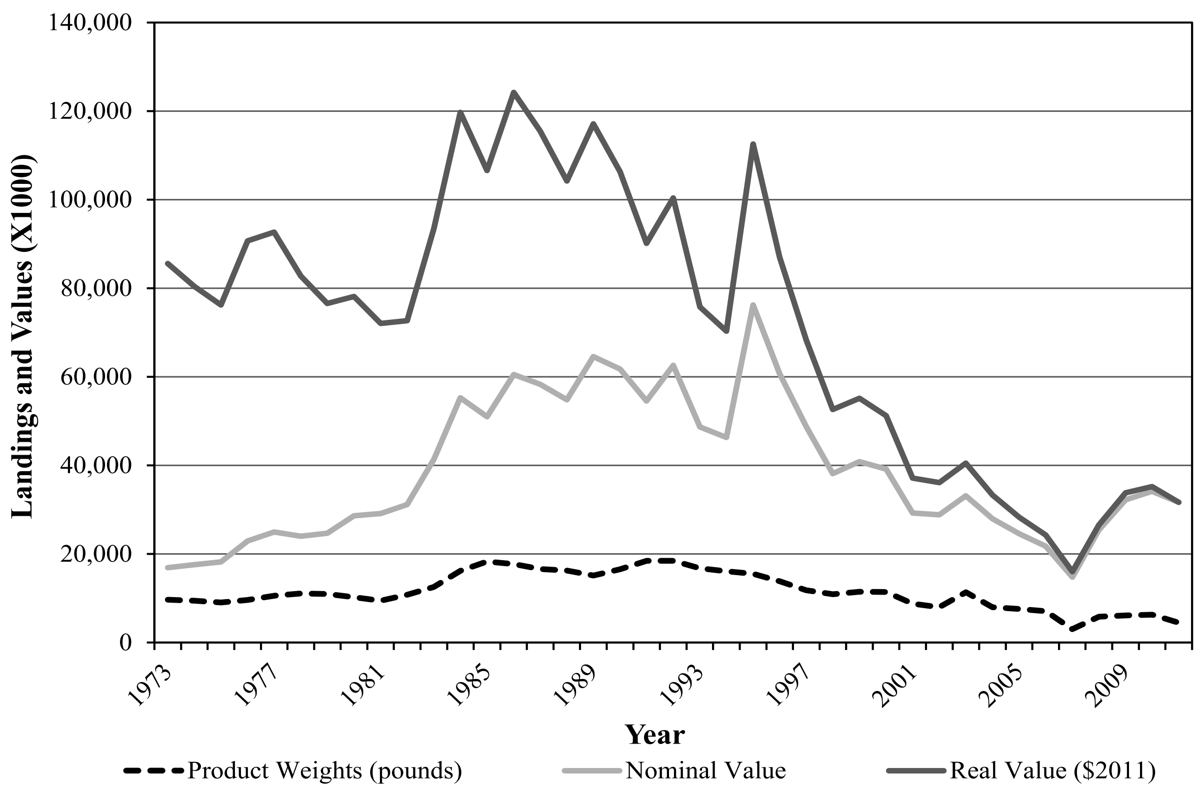



**Figure 7.15** Production of processed crab (pounds) in the Gulf from 1973-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

back to 1973. This decline in the real value was primarily in response to a reduction in processed quantity rather than a significant decline in the real price ($2011) per processed pound (Table 7.7). The real ($2011) price of the processed crab product, which fell throughout the early 1990s and early 2000s, increased significantly from 2006-2011.

The Gulf processed crab quantity, expressed on a live-weight basis, exceeded pounds landed from the early 1970s to the mid-1990s (Table 7.7). In recent years, however, the reported landings exceeded the estimated live weight of processed blue crabs. From 2009-2011, the estimated weight of live crabs used in processing activities equaled only about one-half of the landings, on average. Increased demand for Gulf harvested crab product in the Chesapeake Bay may be responsible for much of the increasing difference in recent years.

### 7.6.2 Processing Activities by Product Form

For purposes of discussion, Gulf processed crab activities were segmented into three primary categories: 1) meat products, 2) breaded products, and 3) 'other' products (which include claws, soups, gumbos, etc.). Some of the relevant information pertaining to this exercise is presented in Table 7.8.

#### 7.6.2.1 Meat Products

In the Gulf region, 24-85 processors were responsible for crab meat production from 1973-2011 which averaged 4.4M pounds over that time period. When examined in three-year average

**Table 7.8** Proportion of Gulf processed crab poundage [%Q = product weight basis (PW) and live weight basis (LW)] and percent value (%V) contributed by individual Gulf states from 1973-2011 on a three-year average. Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

| YEARS | FL | | | AL | | | MS | | | LA | | | TX | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | %Q | | | %Q | | | %Q | | | %Q | | | %Q | | |
| | PW | LW | %V | PW | LW | %V | PW | LW | %V | PW | LW | %V | PW | LW | %V |
| 1973-75 | 25 | 25 | 27 | 35 | 35 | 25 | 9 | 9 | 11 | 22 | 22 | 22 | 9 | 9 | 14 |
| 1976-78 | 24 | 24 | 25 | 51 | 51 | 34 | 4 | 4 | 5 | 15 | 15 | 24 | 6 | 6 | 12 |
| 1979-81 | 19 | 19 | 23 | 59 | 59 | 42 | 3 | 3 | 5 | 12 | 12 | 18 | 6 | 6 | 12 |
| 1982-84 | 20 | 20 | 24 | 60 | 60 | 43 | 2 | 2 | 3 | 12 | 12 | 20 | 6 | 6 | 10 |
| 1985-87 | 20 | 20 | 20 | 53 | 53 | 39 | 2 | 2 | 3 | 18 | 18 | 32 | 7 | 7 | 5 |
| 1988-90 | 22 | 22 | 16 | 44 | 44 | 31 | 1 | 1 | 1 | 24 | 24 | 37 | 10 | 10 | 14 |
| 1991-93 | 11 | 11 | 9 | 57 | 57 | 37 | 2 | 2 | 3 | 27 | 27 | 48 | 2 | 2 | 4 |
| 1994-96 | 12 | 12 | 9 | 54 | 54 | 36 | 2 | 2 | 2 | 28 | 28 | 48 | 4 | 4 | 5 |
| 1997-99 | 14 | 14 | 13 | 68 | 68 | 54 | 2 | 2 | 2 | 12 | 12 | 22 | 5 | 5 | 9 |
| 2000-02 | 24 | 24 | 22 | 63 | 63 | 51 | 2 | 2 | 2 | 9 | 9 | 22 | 2 | 2 | 3 |
| 2003-05 | 27 | 27 | 27 | 62 | 62 | 47 | 1 | 1 | 2 | 6 | 6 | 18 | 4 | 4 | 7 |
| 2006-08 | 2 | 2 | 4 | 82 | 82 | 67 | 0 | 0 | 0 | 9 | 9 | 21 | 7 | 7 | 9 |
| 2009-11 | 5 | 5 | 5 | 79 | 79 | 77 | 0 | 0 | 0 | 6 | 6 | 10 | 9 | 9 | 7 |

intervals, the processed weight of meat ranged from a low of ~1.1M pounds during the early 2010s to an average of more than 7.8M pounds in the mid to late 1980s. After peaking in the late 1980s, production has gradually decreased to 1.1M pounds in the 2010s, using three-year averages.

The nominal value of 2009-2011 processed meat products in the Gulf averaged $11.6M (Table 7.9). The inflation-adjusted (real $2011) value of the processed meat products, after peaking at about $86.0M annually during the late 1980s, gradually decreased to coincide with the decrease in quantity of meats products produced. The most recent (2009-2011) average real ($2011) price of $10.44 per product weight pound was, however, relatively low when compared to the peak of $15.02/lb (real $2011) in the late 1970s. The real ($2011) average price of $10.44/lb from 2009-2011 is the lowest price per pound received for crab meat product from the Gulf in the last 38 years.

Meat products accounted for slightly more than one-half of the total processed product weight in the mid-1970s but slightly more than three-quarters of the total nominal value (Tables 7.9 and 7.7). In recent years (2009-2011), processed meat products accounted for about 20% of the total processing activities by product weight and more than 35% of total Gulf crab processing activities by nominal value, on average.

#### 7.6.2.2 Breaded Products

The number of firms that processed breaded crab products in the Gulf ranged from four firms in the late 2000s to 14 in the 1970s and 1980s (Table 7.9). Average production of breaded products equaled about 5.0M product weight pounds. Pounds processed exhibited substantial variation ranging from 2.2M pounds in the late 1990s to 7.5M pounds in the mid-1980s, on average. A clear decline in breaded processing activities occurred after the late 1980s. The 2009 production of 4.2M pounds was half of the peak production year of the 1985 production when 8.5M pounds of breaded crab product was produced.

The real ($2011) value of processed breaded crab products increased from an average of $16.6M in the mid-1970s to $28.2M in the mid-1980s. Since the mid-1980s, however, the inflation-adjusted price has fallen. The real ($2011) value in 2009, at $17.6M, was approximately one-half of the value at the peak in the mid-1980s. In general, the increase in the real ($2011) value during the 1970s and early 1980s can be attributed to an increase in processed poundage since the inflation-adjusted price during the period fell by almost 20%. The decline in the real ($2011) value after about 1984 until about the late 1990s reflects a general decline in both the processed quantity and the real ($2011) price of the processed product for that period. The average annual real ($2011) value of breaded products ($13.2M) in recent years (2003-2005) was about 25% less than the available 38-year average of $18.0M.

During the mid-1970s, breading activities accounted for approximately 40% of the total Gulf crab processing activities by product weight but only about 20% of the total by nominal value. In the late 1990s, breaded products fell to about 20% on the basis of quantity and just slightly more than 10% when expressed on a nominal value basis. In the mid-2000s, this increased

**Table 7.9** Gulf processed crab production (pounds) by product form, 1973-2011, nominal and real ($2011) (NOAA personal communication). Confidential and unavailable data is presented as N/A. Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | MEAT | | | | | BREADED | | | | | OTHER (CLAWS, SOUPS, GUMBOS, ETC.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/lbs) | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/lbs) | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/ lbs) |
| | | | Nominal | Real ($2011) | Real ($2011) | | | Nominal | Real ($2011) | Real ($2011) | | | Nominal | Real ($2011) | Real ($2011) |
| 1973 | 65 | 4,958 | 12,666 | 64,168 | 12.94 | 14 | 3,866 | 3,581 | 18,143 | 4.69 | 6 | 833 | 643 | 3,259 | 3.91 |
| 1974 | 67 | 5,341 | 13,568 | 61,908 | 11.59 | 13 | 3,550 | 3,511 | 16,020 | 4.51 | 6 | 539 | 541 | 2,469 | 4.58 |
| 1975 | 64 | 4,301 | 13,811 | 57,743 | 13.43 | 13 | 3,324 | 3,730 | 15,597 | 4.69 | 5 | 1,463 | 690 | 2,887 | 1.97 |
| Ave. | 65 | 4,867 | 13,348 | 61,273 | 12.65 | 13 | 3,580 | 3,608 | 16,587 | 4.63 | 6 | 945 | 625 | 2,871 | 3.49 |
| 1976 | 71 | 4,126 | 16,575 | 65,526 | 15.88 | 14 | 4,984 | 6,158 | 24,344 | 4.88 | 6 | 518 | 205 | 809 | 1.56 |
| 1977 | 68 | 4,178 | 17,505 | 64,976 | 15.55 | 10 | 5,589 | 7,171 | 26,619 | 4.76 | 7 | 812 | 295 | 1,095 | 1.35 |
| 1978 | 70 | 3,930 | 15,513 | 53,521 | 13.62 | 11 | 6,477 | 8,282 | 28,572 | 4.41 | NA | NA | NA | NA | NA |
| Ave. | 70 | 4,078 | 16,531 | 61,341 | 15.02 | 12 | 5,683 | 7,204 | 26,512 | 4.69 | 7 | 665 | 250 | 952 | 1.45 |
| 1979 | 65 | 3,666 | 14,650 | 45,390 | 12.38 | 8 | 6,747 | 9,858 | 30,544 | 4.53 | NA | NA | NA | NA | NA |
| 1980 | 68 | 3,923 | 17,868 | 48,776 | 12.43 | 7 | 6,221 | 10,605 | 28,949 | 4.65 | NA | NA | NA | NA | NA |
| 1981 | 67 | 4,466 | 21,967 | 54,359 | 12.17 | 11 | 4,871 | 6,681 | 16,533 | 3.39 | NA | NA | NA | NA | NA |
| Ave. | 67 | 4,018 | 18,161 | 49,508 | 12.33 | 9 | 5,946 | 9,048 | 25,342 | 4.19 | NA | NA | NA | NA | NA |
| 1982 | 73 | 3,792 | 19,975 | 46,562 | 12.28 | 12 | 6,974 | 10,397 | 24,234 | 3.47 | NA | NA | NA | NA | NA |
| 1983 | 82 | 5,168 | 28,596 | 64,583 | 12.50 | 14 | 7,316 | 11,873 | 26,814 | 3.67 | NA | NA | NA | NA | NA |
| 1984 | 82 | 6,962 | 37,749 | 81,725 | 11.74 | 13 | 8,375 | 15,496 | 33,549 | 4.01 | NA | NA | NA | NA | NA |
| Ave. | 79 | 5,307 | 28,774 | 64,290 | 12.17 | 13 | 7,555 | 12,589 | 28,199 | 3.72 | NA | NA | NA | NA | NA |
| 1985 | 77 | 5,813 | 32,970 | 68,924 | 11.86 | 12 | 8,531 | 15,480 | 32,361 | 3.79 | 5 | 3,927 | 2,529 | 5,286 | 1.35 |
| 1986 | 80 | 7,898 | 46,314 | 95,052 | 12.04 | 13 | 8,009 | 12,452 | 25,557 | 3.19 | NA | NA | NA | NA | NA |
| 1987 | 81 | 9,634 | 47,516 | 94,086 | 9.77 | 13 | 6,011 | 8,849 | 17,522 | 2.91 | 4 | 984 | 1,954 | 3,870 | 3.93 |
| Ave. | 79 | 7,782 | 42,266 | 86,021 | 11.22 | 13 | 7,517 | 12,260 | 25,147 | 3.30 | 5 | 2,455 | 2,241 | 4,578 | 2.64 |
| 1988 | 85 | 6,956 | 41,514 | 78,936 | 11.35 | 12 | 8,311 | 12,009 | 22,834 | 2.75 | 6 | 1,019 | 1,293 | 2,459 | 2.41 |
| 1989 | 81 | 8,496 | 52,748 | 95,687 | 11.26 | 13 | 4,888 | 9,993 | 18,128 | 3.71 | 11 | 1,747 | 1,822 | 3,306 | 1.89 |
| 1990 | 71 | 7,892 | 48,782 | 83,955 | 10.64 | 11 | 6,858 | 10,728 | 18,463 | 2.69 | 12 | 1,777 | 2,260 | 3,889 | 2.19 |
| Ave. | 79 | 7,781 | 47,681 | 86,193 | 11.08 | 12 | 6,686 | 10,910 | 19,808 | 3.05 | 10 | 1,514 | 1,792 | 3,218 | 2.16 |
| 1991 | 83 | 6,776 | 43,504 | 71,848 | 10.60 | 10 | 5,877 | 9,344 | 15,432 | 2.63 | 14 | 5,828 | 1,721 | 2,842 | 0.49 |
| 1992 | 85 | 7,680 | 53,151 | 85,216 | 11.10 | 11 | 3,977 | 7,322 | 11,740 | 2.95 | 14 | 6,792 | 2,131 | 3,416 | 0.50 |

| YEAR | MEAT | | | | | BREADED | | | | | OTHER (CLAWS, SOUPS, GUMBOS, ETC.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/lbs) | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/lbs) | No. of Firms | lbs (x1000) | Value (x$1000) | | Price ($/ lbs) |
| | | | Nominal | Real ($2011) | Real ($2011) | | | Nominal | Real ($2011) | Real ($2011) | | | Nominal | Real ($2011) | Real ($2011) |
| 1993 | 78 | 5,309 | 38,821 | 60,431 | 11.38 | 10 | 3,771 | 6,180 | 9,620 | 2.55 | 15 | 7,701 | 3,681 | 5,731 | 0.74 |
| Ave. | 82 | 6,588 | 45,158 | 72,498 | 11.03 | 10 | 4,542 | 7,616 | 12,264 | 2.71 | 14 | 6,774 | 2,511 | 3,996 | 0.58 |
| 1994 | 70 | 4,828 | 34,874 | 52,931 | 10.96 | 11 | 4,325 | 7,678 | 11,653 | 2.69 | 15 | 6,942 | 3,765 | 5,714 | 0.82 |
| 1995 | 68 | 6,404 | 65,566 | 96,774 | 15.11 | 10 | 3,261 | 7,731 | 11,411 | 3.50 | 12 | 5,878 | 2,946 | 4,349 | 0.74 |
| 1996 | 66 | 5,846 | 53,909 | 77,286 | 13.22 | 9 | 2,098 | 4,427 | 6,346 | 3.02 | 13 | 5,878 | 2,390 | 3,427 | 0.58 |
| Ave. | 68 | 5,692 | 51,449 | 75,664 | 13.10 | 10 | 3,228 | 6,612 | 9,804 | 3.07 | 13 | 6,233 | 3,034 | 4,497 | 0.72 |
| 1997 | 61 | 5,054 | 42,487 | 59,545 | 11.78 | 9 | 1,662 | 3,611 | 5,060 | 3.04 | 11 | 5,098 | 2,622 | 3,675 | 0.72 |
| 1998 | 57 | 3,584 | 31,685 | 43,724 | 12.20 | 8 | 1,557 | 3,340 | 4,609 | 2.96 | 11 | 5,783 | 3,113 | 4,295 | 0.74 |
| 1999 | 54 | 3,498 | 30,196 | 40,769 | 11.65 | 6 | 3,503 | 8,065 | 10,889 | 3.11 | 12 | 4,477 | 2,589 | 3,495 | 0.78 |
| Ave. | 57 | 4,045 | 34,789 | 48,013 | 11.88 | 8 | 2,241 | 5,005 | 6,852 | 3.04 | 11 | 5,119 | 2,775 | 3,822 | 0.75 |
| 2000 | 50 | 3,101 | 27,590 | 36,040 | 11.62 | 5 | 3,501 | 9,003 | 11,761 | 3.36 | 12 | 4,814 | 2,597 | 3,393 | 0.70 |
| 2001 | 46 | 1,992 | 18,983 | 24,111 | 12.10 | 6 | 3,250 | 8,254 | 10,484 | 3.23 | 9 | 3,548 | 1,992 | 2,530 | 0.71 |
| 2002 | 44 | 2,181 | 19,149 | 23,943 | 10.98 | 6 | 2,822 | 7,368 | 9,213 | 3.26 | 9 | 2,964 | 2,359 | 2,950 | 1.00 |
| Ave. | 47 | 2,425 | 21,907 | 28,031 | 11.57 | 6 | 3,191 | 8,209 | 10,486 | 3.28 | 10 | 3,776 | 2,316 | 2,958 | 0.80 |
| 2003 | 43 | 2,004 | 18,413 | 22,510 | 11.23 | 6 | 5,045 | 12,573 | 15,370 | 3.05 | 9 | 4,302 | 2,177 | 2,661 | 0.62 |
| 2004 | 35 | 1,621 | 15,512 | 18,471 | 11.40 | NA | NA | NA | NA | NA | 9 | 2,523 | 2,073 | 2,469 | 0.98 |
| 2005 | 31 | 1,385 | 13,190 | 15,192 | 10.97 | 4 | 3,828 | 9,679 | 11,148 | 2.91 | 7 | 2,388 | 1,694 | 1,951 | 0.82 |
| Ave. | 36 | 1,670 | 15,705 | 18,724 | 11.20 | 5 | 4,437 | 11,126 | 13,259 | 2.98 | 8 | 3,071 | 1,981 | 2,360 | 0.80 |
| 2006 | 26 | 1,580 | 15,016 | 16,755 | 10.60 | NA | NA | NA | NA | NA | 7 | 2,935 | 1,183 | 1,320 | 0.45 |
| 2007 | 26 | 1,301 | 13,492 | 14,637 | 11.25 | NA | NA | NA | NA | NA | 6 | 1,584 | 949 | 1,030 | 0.65 |
| 2008 | 30 | 1,563 | 16,708 | 17,455 | 11.17 | NA | NA | NA | NA | NA | 4 | 438 | 1,035 | 1,082 | 2.47 |
| Ave. | 27 | 1,482 | 15,072 | 16,282 | 11.01 | NA | NA | NA | NA | NA | 6 | 1,652 | 1,056 | 1,144 | 1.19 |
| 2009 | 24 | 1,493 | 14,869 | 15,589 | 10.44 | 4 | 4,233 | 16,821 | 17,637 | 4.17 | NA | NA | NA | NA | NA |
| 2010 | 26 | 892 | 9,213 | 9,504 | 10.65 | NA | NA | NA | NA | NA | 4 | 438 | 1,580 | 1,630 | 3.72 |
| 2011 | 24 | 1,055 | 10,801 | 10,801 | 10.24 | NA | NA | NA | NA | NA | 4 | 490 | 1,964 | 1,964 | 4.01 |
| Ave. | 25 | 1,147 | 11,628 | 11,965 | 10.44 | 4 | 4,233 | 16,821 | 17,637 | 4.17 | 4 | 464 | 1,772 | 1,797 | 3.86 |

to about 47% in terms of quantity and about 40% in terms of nominal value as the seafood industry generally moved towards value-added products.

#### 7.6.2.3 'Other' Products

Production of 'other' crab processed products (e.g., claws, soups, gumbos, etc.) has traditionally been less than meat and breaded crab products in the Gulf. When examined in three-year average intervals, production ranged from a low of about 464,000 pounds in the early 2010s to a little more than 6.7M pounds in the early 1990s (Table 7.9). The real ($2011) price of 'other' processed crab products varied considerably and ranged from $0.58 per product-weight pound during the early 1990s to $3.86 per product-weight pound in the early 2010s, on average. For years 2006-2008, the real ($2011) price per pound averaged $1.19. Much of the variation in the price per pound may likely reflect the wide variety of products included in this category with each of the individual products exhibiting significant price differentials. To the extent that the relative shares of the different products have varied during the period of analysis, the price will vary accordingly.

### 7.6.3 Processing Activities by State

Crab processing activities by the individual states in the Gulf are briefly examined in this section. As a result of confidentiality concerns, only the aggregate processing activities by state, rather than activities by product form, are presented.

#### 7.6.3.1 Florida West Coast

The number of reported crab processors along Florida's West Coast peaked at 32 during the mid-1980s followed by a sharp decline thereafter to a low of four in the 2000s and 2010s (Table 7.10). Overall, Florida crab processors represented 28% of the Gulf total population in the mid-1970s but only 15% by the early 2010s, on average (Table 7.10).

Until 2006, annual Florida production of processed crab products ranged from approximately 1.6M pounds in the late 1990s to 3.5M pounds in the late 1980s, when examined in three-year average intervals. Recent three-year average production for 2006-2008 and 2009-20011 was 108,000 and 296,000 pounds, respectively. When converted to a live-weight basis, pounds of crabs used in processing generally coincided with reported landings in the state. A sharp decline in processing activities was apparent in the 1990s and 2000s and reported landings exceeded processing activities, expressed on a live-weight basis, during a number of years.

Florida accounted for approximately 25% of the Gulf crab processing activities on the basis of both quantity and value during the mid-1970s (Table 7.8 and Figure 7.16). The state's share, however, declined considerably over the last 38 years. By the mid-1990s, Florida's share had fallen to 12% on the basis of product weight and to only 9% when expressed on a value basis. In recent years, from 2009-2011, Florida has fallen to only 5% of total processed quantity contributed and 5% of value contributed to the Gulf.

**Table 7.10** Production (pounds) of processed crab from Florida's West Coast, 1973-2011, nominal and real $2011 (NOAA personal communication). Confidential and unavailable data are presented as N/A. Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 1973 | 23 | 2,474 | 1,749 | 12,480 | 9,599 | 4,667 | 23,643 | 1.89 | 9.56 |
| 1974 | 24 | 2,466 | 1,743 | 12,440 | 10,134 | 4,882 | 22,275 | 1.98 | 9.03 |
| 1975 | 23 | 1,971 | 1,394 | 9,946 | 12,807 | 4,813 | 20,122 | 2.44 | 10.21 |
| Average | 23 | 2,304 | 1,628 | 11,622 | 10,846 | 4,787 | 22,013 | 2.10 | 9.60 |
| 1976 | 27 | 2,671 | 1,888 | 13,474 | 12,049 | 7,074 | 27,964 | 2.65 | 10.47 |
| 1977 | 24 | 2,461 | 1,740 | 12,418 | 15,832 | 5,601 | 20,789 | 2.28 | 8.45 |
| 1978 | 24 | 2,498 | 1,766 | 12,602 | 11,679 | 4,929 | 17,005 | 1.97 | 6.81 |
| Average | 25 | 2,543 | 1,798 | 12,832 | 13,186 | 5,868 | 21,920 | 2.30 | 8.58 |
| 1979 | 22 | 2,282 | 1,613 | 11,512 | 11,198 | 5,257 | 16,289 | 2.30 | 7.14 |
| 1980 | 22 | 1,687 | 1,193 | 8,513 | 11,276 | 5,991 | 16,355 | 3.55 | 9.69 |
| 1981 | 27 | 1,922 | 1,359 | 9,697 | 14,788 | 8,087 | 20,012 | 4.21 | 10.41 |
| Average | 24 | 1,964 | 1,388 | 9,907 | 12,421 | 6,445 | 17,552 | 3.35 | 9.08 |
| 1982 | 24 | 2,683 | 1,897 | 13,538 | 8,871 | 8,503 | 19,821 | 3.17 | 7.39 |
| 1983 | 30 | 2,275 | 1,608 | 11,477 | 9,337 | 10,996 | 24,833 | 4.83 | 10.92 |
| 1984 | 32 | 2,797 | 1,978 | 14,113 | 12,912 | 10,833 | 23,453 | 3.87 | 8.38 |
| Average | 29 | 2,585 | 1,828 | 13,043 | 10,374 | 10,111 | 22,702 | 3.96 | 8.90 |
| 1985 | 28 | 3,050 | 2,156 | 15,390 | 12,273 | 10,386 | 21,712 | 3.40 | 7.12 |
| 1986 | 28 | 2,809 | 1,986 | 14,173 | 7,644 | 10,134 | 20,800 | 3.61 | 7.40 |
| 1987 | 24 | 4,780 | 3,379 | 24,118 | 10,413 | 13,871 | 27,466 | 2.90 | 5.75 |
| Average | 27 | 3,547 | 2,507 | 17,894 | 10,110 | 11,464 | 23,326 | 3.30 | 6.76 |
| 1988 | 22 | 3,515 | 2,485 | 17,733 | 10,386 | 9,521 | 18,104 | 2.71 | 5.15 |
| 1989 | 25 | 3,058 | 2,162 | 15,431 | 8,159 | 9,921 | 17,998 | 3.24 | 5.88 |
| 1990 | 21 | 3,802 | 2,688 | 19,180 | 6,878 | 8,875 | 15,274 | 2.33 | 4.02 |
| Average | 23 | 3,458 | 2,445 | 17,448 | 8,474 | 9,439 | 17,125 | 2.76 | 5.02 |
| 1991 | 19 | 1,517 | 1,073 | 7,655 | 5,213 | 3,606 | 5,955 | 2.38 | 3.92 |
| 1992 | 18 | 1,973 | 1,395 | 9,955 | 7,619 | 5,522 | 8,853 | 2.80 | 4.49 |
| 1993 | 11 | 2,597 | 1,836 | 13,103 | 8,502 | 5,671 | 8,827 | 2.18 | 3.40 |
| Average | 16 | 2,029 | 1,434 | 10,238 | 7,111 | 4,933 | 7,878 | 2.45 | 3.94 |
| 1994 | 12 | 2,465 | 1,742 | 12,435 | 8,407 | 5,829 | 8,847 | 2.36 | 3.59 |
| 1995 | 9 | 2,161 | 1,528 | 10,904 | 8,725 | 6,230 | 9,196 | 2.88 | 4.25 |
| 1996 | 8 | 730 | 516 | 3,684 | 12,414 | 3,497 | 5,013 | 4.79 | 6.87 |
| Average | 10 | 1,785 | 1,262 | 9,008 | 9,849 | 5,185 | 7,685 | 3.35 | 4.90 |
| 1997 | 8 | 884 | 625 | 4,460 | 9,255 | 3,629 | 5,086 | 4.11 | 5.75 |
| 1998 | 7 | 942 | 666 | 4,752 | 12,771 | 4,124 | 5,692 | 4.38 | 6.04 |
| 1999 | 12 | 2,969 | 2,099 | 14,982 | 11,047 | 8,717 | 11,769 | 2.94 | 3.96 |
| Average | 9 | 1,598 | 1,130 | 8,065 | 11,024 | 5,490 | 7,516 | 3.81 | 5.25 |
| 2000 | 8 | 3,283 | 2,321 | 16,566 | 6,413 | 10,148 | 13,255 | 3.09 | 4.04 |

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Nominal | Real ($2011) |
| 2001 | 8 | 1,886 | 1,333 | 9,515 | 4,548 | 5,892 | 7,484 | 3.12 | 3.97 |
| 2002 | 8 | 1,706 | 1,206 | 8,607 | 5,489 | 5,305 | 6,633 | 3.11 | 3.89 |
| Average | 8 | 2,292 | 1,620 | 11,562 | 5,483 | 7,115 | 9,124 | 3.11 | 3.96 |
| 2003 | 10 | 2,396 | 1,694 | 12,091 | 7,141 | 7,376 | 9,017 | 3.08 | 3.76 |
| 2004 | 9 | 2,583 | 1,826 | 13,033 | 8,008 | 8,536 | 10,165 | 3.30 | 3.94 |
| 2005 | 7 | 2,277 | 1,609 | 11,487 | 7,312 | 6,957 | 8,013 | 3.06 | 3.52 |
| Average | 9 | 2,419 | 1,710 | 12,203 | 7,487 | 7,623 | 9,065 | 3.15 | 3.74 |
| 2006 | 6 | 184 | 130 | 930 | 8,565 | 1,150 | 1,283 | 6.23 | 6.96 |
| 2007 | 4 | 113 | 80 | 570 | 6,074 | 983 | 1,066 | 8.69 | 9.43 |
| 2008 | 5 | 26 | 18 | 129 | 2,627 | 236 | 247 | 9.22 | 9.64 |
| Average | 5 | 108 | 76 | 543 | 5,755 | 789 | 865 | 8.05 | 8.67 |
| 2009 | 4 | 57 | 41 | 289 | 3,314 | 350 | 367 | 6.10 | 6.40 |
| 2010 | 6 | 363 | 257 | 1,833 | 5,710 | 2,158 | 2,227 | 5.94 | 6.13 |
| 2011 | 4 | 467 | 330 | 2,355 | 6,626 | 2,774 | 2,774 | 5.94 | 5.94 |
| Average | 5 | 296 | 209 | 1,493 | 5,217 | 1,761 | 1,789 | 6.00 | 6.16 |

#### 7.6.3.2 Alabama

The number of crab processors in Alabama increased from an average of 13 in the mid-1970s, to a peak of 30 in the mid-1990s, and have recently fallen to an average of 18 in the early 2010s (Table 7.11). The annual processed poundage, when evaluated in average three-year intervals, peaked at 10.2M pounds in the early 1990s but declined to an average of 4.4M pounds in the early 2010s. From 1973-1975 Alabama account for 35% of the live weight landings and 25% of the value (Table 7.8 and Figure 7.16). Recently, from 2009-2011, Alabama accounted for 79% of the live weight landings and 77% of the product value in the Gulf.

From 1973-2011, the contribution of Alabama to the Gulf total was higher in terms of product weight than in value (Table 7.8 and Figure 7.16). This reflects the breading nature of much of the product processed in Alabama. Consequently, the price received for breaded product tends to be lower than that observed elsewhere in the region. However, despite a general decline from the mid-1970s until the mid-2000s, the real ($2011) price increased from an average of $2.38 per product weight pound in 2006 to $7.17 per product weight pound in 2011.

The processed quantity reported for Alabama, expressed on a live-weight equivalent basis, greatly exceeded reported landings in the state (Table 7.11). During the early 1990s, for example, the annual processed poundage (live weight equivalent) was almost 52.0M pounds on average while average reported landings were 2.9M pounds. Alabama is a large net importer of live crabs for use in processing activities.

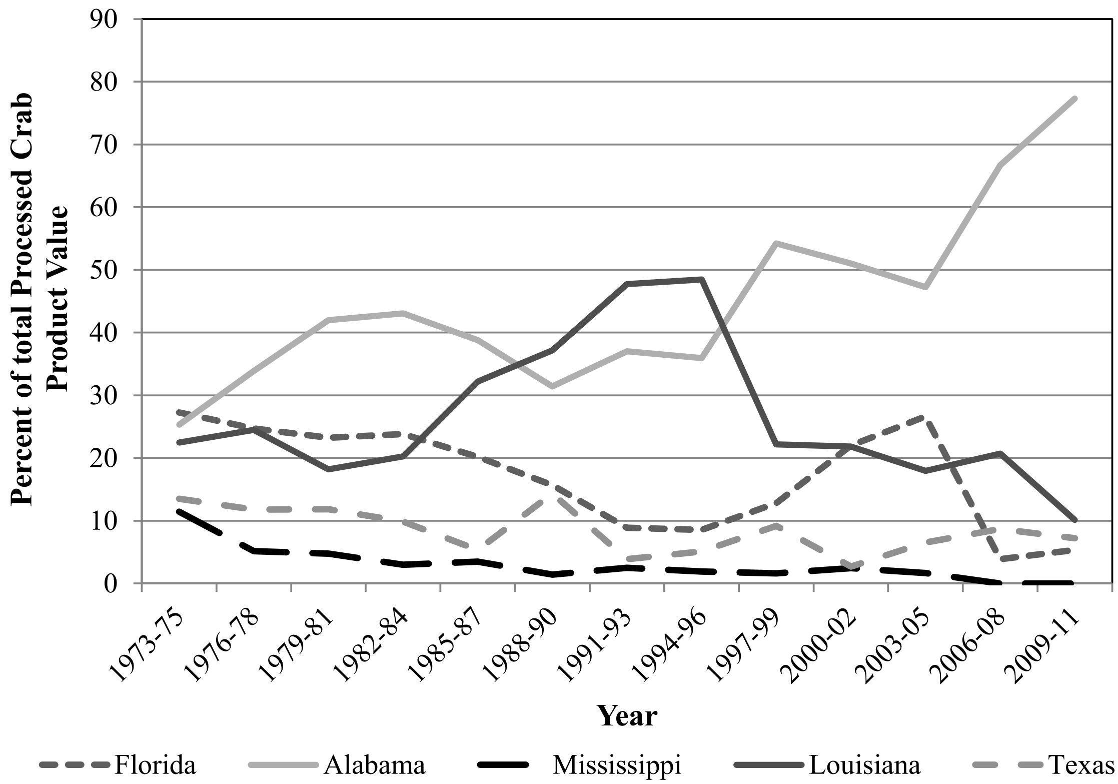



**Figure 7.16** Percentage of total Gulf processed crab product adjusted value by state from 1973-2011. Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

### 7.6.3.3 Mississippi

Mississippi has historically contributed only marginally to the Gulf crab processing activities. Overall, the number of crab processing establishments in the state declined from an average of 11 during the mid-1970s to only four from the mid-1990s to early 2000s (Table 7.12). The annual processed poundage, examined on a product-weight basis, ranged from a high of 851,000 pounds in the mid-1970s to less than 150,000 pounds in the late 1990s, based on three-year averages (Figure 7.16). Less than three crab processors were active in Mississippi following the Hurricane Katrina in 2005 and due to NOAA confidentiality policy, that activity is indicated only as NA in Table 7.12.

When examined on a live-weight basis, Mississippi's annual processing quantity ranged from a high of 4.3M pounds in the mid-1970s to only about 737,000 pounds during the late 1980s, on average (Table 7.12). Live-weight processing quantity was 1.2M pounds in 2003. After 2005 processing capability was diminished and specific numbers could not be disclosed due to NOAA confidentiality policy for less than three processors reporting. While relatively small compared to other Gulf states, these figures generally suggest that Mississippi is a net importer of live crabs to cover processing requirements.

**Table 7.11** Production (pounds) of processed crab in Alabama, 1973-2011, nominal and real $2011 (NOAA personal communication). Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1,000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| 1973 | 13 | 3,307 | 2,338 | 16,685 | 2,099 | 4,201 | 21,284 | 1.27 | 6.44 |
| 1974 | 13 | 2,993 | 2,116 | 15,101 | 1,826 | 3,989 | 18,203 | 1.33 | 6.08 |
| 1975 | 14 | 3,667 | 2,592 | 18,499 | 1,640 | 5,218 | 21,815 | 1.42 | 5.95 |
| Average | 13 | 3,322 | 2,349 | 16,762 | 1,855 | 4,469 | 20,434 | 1.34 | 6.16 |
| 1976 | 13 | 4,309 | 3,046 | 21,741 | 1,299 | 6,529 | 25,810 | 1.52 | 5.99 |
| 1977 | 16 | 5,609 | 3,965 | 28,300 | 2,174 | 8,795 | 32,647 | 1.57 | 5.82 |
| 1978 | 15 | 6,122 | 4,328 | 30,889 | 2,009 | 9,197 | 31,728 | 1.50 | 5.18 |
| Average | 15 | 5,347 | 3,780 | 26,977 | 1,827 | 8,174 | 30,062 | 1.53 | 5.66 |
| 1979 | 17 | 6,793 | 4,802 | 34,273 | 1,341 | 11,944 | 37,005 | 1.76 | 5.45 |
| 1980 | 20 | 6,283 | 4,442 | 31,699 | 1,557 | 12,738 | 34,772 | 2.03 | 5.53 |
| 1981 | 19 | 5,147 | 3,638 | 25,966 | 2,462 | 9,455 | 23,398 | 1.84 | 4.55 |
| Average | 19 | 6,074 | 4,294 | 30,646 | 1,787 | 11,379 | 31,725 | 1.87 | 5.18 |
| 1982 | 24 | 5,906 | 4,175 | 29,796 | 1,266 | 10,654 | 24,835 | 1.80 | 4.21 |
| 1983 | 27 | 7,682 | 5,431 | 38,760 | 1,412 | 16,326 | 36,871 | 2.13 | 4.80 |
| 1984 | 28 | 10,364 | 7,327 | 52,289 | 4,216 | 28,336 | 61,346 | 2.73 | 5.92 |
| Average | 26 | 7,984 | 5,644 | 40,282 | 2,298 | 18,439 | 41,018 | 2.22 | 4.97 |
| 1985 | 28 | 11,082 | 7,834 | 55,913 | 2,261 | 23,206 | 48,512 | 2.09 | 4.38 |
| 1986 | 26 | 9,531 | 6,738 | 48,087 | 2,886 | 23,683 | 48,606 | 2.48 | 5.10 |
| 1987 | 25 | 7,258 | 5,131 | 36,618 | 2,496 | 18,812 | 37,250 | 2.59 | 5.13 |
| Average | 26 | 9,290 | 6,568 | 46,873 | 2,548 | 21,900 | 44,789 | 2.39 | 4.87 |
| 1988 | 27 | 8,074 | 5,707 | 40,734 | 3,869 | 20,511 | 39,001 | 2.54 | 4.83 |
| 1989 | 26 | 5,856 | 4,140 | 29,545 | 4,090 | 16,807 | 30,488 | 2.87 | 5.21 |
| 1990 | 21 | 7,041 | 4,978 | 35,525 | 3,303 | 19,451 | 33,476 | 2.76 | 4.75 |
| Average | 25 | 6,990 | 4,942 | 35,268 | 3,754 | 18,923 | 34,322 | 2.72 | 4.93 |
| 1991 | 28 | 11,415 | 8,070 | 57,595 | 2,731 | 18,513 | 30,574 | 1.62 | 2.68 |
| 1992 | 29 | 10,632 | 7,516 | 53,643 | 3,550 | 22,170 | 35,545 | 2.09 | 3.34 |
| 1993 | 30 | 8,596 | 6,077 | 43,372 | 2,554 | 20,849 | 32,454 | 2.43 | 3.78 |
| Average | 29 | 10,215 | 7,221 | 51,537 | 2,945 | 20,510 | 32,858 | 2.04 | 3.27 |
| 1994 | 29 | 8,791 | 6,215 | 44,355 | 2,688 | 22,875 | 34,719 | 2.60 | 3.95 |
| 1995 | 30 | 7,531 | 5,324 | 37,999 | 2,520 | 21,397 | 31,582 | 2.84 | 4.19 |
| 1996 | 31 | 8,187 | 5,788 | 41,308 | 3,219 | 21,450 | 30,752 | 2.62 | 3.76 |
| Average | 30 | 8,170 | 5,776 | 41,221 | 2,809 | 21,907 | 32,351 | 2.69 | 3.97 |
| 1997 | 29 | 7,721 | 5,458 | 38,956 | 3,476 | 22,910 | 32,108 | 2.97 | 4.16 |
| 1998 | 29 | 8,256 | 5,836 | 41,653 | 3,478 | 23,410 | 32,306 | 2.84 | 3.91 |
| 1999 | 28 | 7,237 | 5,116 | 36,515 | 3,768 | 22,986 | 31,035 | 3.18 | 4.29 |
| Average | 29 | 7,738 | 5,470 | 39,041 | 3,574 | 23,102 | 31,816 | 2.99 | 4.12 |
| 2000 | 26 | 6,803 | 4,809 | 34,324 | 4,780 | 19,165 | 25,034 | 2.82 | 3.68 |
| 2001 | 24 | 5,869 | 4,149 | 29,609 | 2,457 | 16,080 | 20,424 | 2.74 | 3.48 |
| 2002 | 23 | 4,940 | 3,492 | 24,923 | 2,575 | 14,400 | 18,005 | 2.92 | 3.64 |

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1,000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| Average | 24 | 5,871 | 4,150 | 29,619 | 3,271 | 16,548 | 21,154 | 2.82 | 3.60 |
| 2003 | 23 | 7,699 | 5,443 | 38,846 | 2,957 | 17,282 | 21,127 | 2.24 | 2.74 |
| 2004 | 22 | 4,594 | 3,247 | 23,177 | 3,329 | 12,963 | 15,436 | 2.82 | 3.36 |
| 2005 | 21 | 4,422 | 3,126 | 22,310 | 1,024 | 10,135 | 11,673 | 2.29 | 2.64 |
| Average | 22 | 5,572 | 3,939 | 28,111 | 2,437 | 13,460 | 16,079 | 2.45 | 2.91 |
| 2006 | 18 | 5,851 | 4,136 | 29,521 | 2,384 | 12,503 | 13,951 | 2.14 | 2.38 |
| 2007 | 18 | 2,245 | 1,587 | 11,326 | 2,554 | 8,791 | 9,537 | 3.92 | 4.25 |
| 2008 | 20 | 5,001 | 3,536 | 25,234 | 1,799 | 20,217 | 21,122 | 4.04 | 4.22 |
| Average | 19 | 4,366 | 3,086 | 22,027 | 2,246 | 13,837 | 14,870 | 3.37 | 3.62 |
| 2009 | 18 | 5,211 | 3,684 | 26,289 | 1,458 | 26,681 | 27,975 | 5.12 | 5.37 |
| 2010 | 19 | 5,103 | 3,608 | 25,748 | 927 | 26,567 | 27,406 | 5.21 | 5.37 |
| 2011 | 18 | 3,139 | 2,219 | 15,836 | 1,617 | 22,513 | 22,513 | 7.17 | 7.17 |
| Average | 18 | 4,484 | 3,170 | 22,624 | 1,334 | 25,254 | 25,965 | 5.83 | 5.97 |

On the basis of product weight, Mississippi's share of the Gulf's crab processing activities fell from an average of 9% in the mid-1970s to less than 1% in the early 2000s (Table 7.8 and Figure 7.16). Thereafter, the share remained less than 1% contribution to the Gulf for Mississippi crab processing product weight in the mid-2000s and early 2010s.

#### 7.6.3.4 Louisiana

The average number of Louisiana blue crab processors ranged from 23-29 prior to 1990 (Table 7.13). The number of processors more than doubled to an average of 50 in the early 1990s and then declined sharply to only six firms by the early 2010s.

During the mid-1970s, annual production averaged 2.0M pounds and accounted for 22% of the total processed quantity and 22% of total value of crab products in the Gulf (Tables 7.8 and Figure 7.16). Average processed production peaked at almost 4.9M pounds during the early 1990s and accounted for 27% and 48% of the Gulf processing activities by weight and value, respectively. Processed poundage dropped off significantly in Louisiana from the early 2000s to the early 2010s, with production at 801,000 and 350,000 pounds, respectively.

The price of Louisiana's processed crab was relatively high when compared to the Gulf average (Tables 7.13 and 7.9). This higher value is due to the dominance of meat products which receive a substantially higher per pound price than that received for alternative product forms such as breaded products. The maximum price (real $2011) received for the Louisiana processed product occurred in the late 1970s with an average value of $13.98/lb. After falling to only $8.73 per product weight pound in the early 1990s, the price increased to an average of $11.48/lb in the early 2000s. Since about 2010, the average price has fallen to $9.73 per product weight pound.

**Table 7.12** Production (pounds) of processed crab in Mississippi, 1973-2011, nominal and real $2011 (NOAA personal communication). Confidential and unavailable data are presented as N/A. Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| 1973 | 11 | 680 | 481 | 3,433 | 1,815 | 1,898 | 9,618 | 2.79 | 14.14 |
| 1974 | 12 | 784 | 554 | 3,956 | 1,667 | 1,929 | 8,801 | 2.46 | 11.22 |
| 1975 | 11 | 1,088 | 769 | 5,489 | 1,137 | 2,224 | 9,300 | 2.04 | 8.55 |
| Average | 11 | 851 | 601 | 4,292 | 1,539 | 2,017 | 9,239 | 2.43 | 11.30 |
| 1976 | 10 | 520 | 368 | 2,625 | 1,335 | 1,289 | 5,096 | 2.48 | 9.80 |
| 1977 | 8 | 298 | 211 | 1,504 | 1,919 | 1,147 | 4,258 | 3.85 | 14.29 |
| 1978 | 8 | 332 | 235 | 1,675 | 1,940 | 1,254 | 4,325 | 3.78 | 13.03 |
| Average | 9 | 383 | 271 | 1,934 | 1,731 | 1,230 | 4,560 | 3.37 | 12.37 |
| 1979 | 7 | 285 | 202 | 1,440 | 1,313 | 1,150 | 3,562 | 4.03 | 12.48 |
| 1980 | 6 | 340 | 240 | 1,715 | 2,760 | 1,381 | 3,770 | 4.06 | 11.09 |
| 1981 | 6 | 331 | 234 | 1,671 | 1,867 | 1,394 | 3,450 | 4.21 | 10.42 |
| Average | 6 | 319 | 225 | 1,609 | 1,980 | 1,308 | 3,594 | 4.10 | 11.33 |
| 1982 | 6 | 235 | 166 | 1,184 | 1,297 | 1,076 | 2,508 | 4.58 | 10.69 |
| 1983 | 5 | 211 | 149 | 1,066 | 1,140 | 1,043 | 2,354 | 4.93 | 11.14 |
| 1984 | 5 | 430 | 304 | 2,169 | 2,250 | 1,699 | 3,678 | 3.95 | 8.55 |
| Average | 5 | 292 | 206 | 1,473 | 1,562 | 1,273 | 2,847 | 4.49 | 10.13 |
| 1985 | 6 | 347 | 245 | 1,751 | 1,649 | 1,536 | 3,211 | 4.42 | 9.25 |
| 1986 | 6 | 517 | 366 | 2,610 | 1,303 | 2,506 | 5,143 | 4.84 | 9.94 |
| 1987 | 6 | 396 | 280 | 1,997 | 1,374 | 1,846 | 3,655 | 4.66 | 9.23 |
| Average | 6 | 420 | 297 | 2,119 | 1,442 | 1,962 | 4,003 | 4.64 | 9.48 |
| 1988 | 5 | 198 | 140 | 1,001 | 863 | 1,091 | 2,074 | 5.50 | 10.45 |
| 1989 | 5 | 131 | 93 | 663 | 651 | 883 | 1,602 | 6.72 | 12.19 |
| 1990 | 4 | 108 | 77 | 547 | 390 | 559 | 962 | 5.16 | 8.87 |
| Average | 5 | 146 | 103 | 737 | 635 | 844 | 1,546 | 5.79 | 10.51 |
| 1991 | 6 | 382 | 270 | 1,929 | 454 | 1,248 | 2,061 | 3.26 | 5.39 |
| 1992 | 5 | 437 | 309 | 2,207 | 443 | 1,412 | 2,264 | 3.23 | 5.18 |
| 1993 | 6 | 459 | 324 | 2,315 | 253 | 1,512 | 2,354 | 3.30 | 5.13 |
| Average | 6 | 426 | 301 | 2,151 | 383 | 1,391 | 2,227 | 3.26 | 5.23 |
| 1994 | 4 | 334 | 236 | 1,686 | 171 | 758 | 1,150 | 2.27 | 3.44 |
| 1995 | 4 | 314 | 222 | 1,586 | 319 | 1,641 | 2,422 | 5.22 | 7.71 |
| 1996 | 5 | 409 | 289 | 2,064 | 407 | 1,068 | 1,532 | 2.61 | 3.75 |
| Average | 4 | 352 | 249 | 1,778 | 299 | 1,156 | 1,701 | 3.37 | 4.96 |
| 1997 | 4 | 217 | 153 | 1,093 | 683 | 776 | 1,087 | 3.58 | 5.02 |
| 1998 | NA | NA | NA | NA | 592 | NA | NA | NA | NA |
| 1999 | NA | NA | NA | NA | 920 | NA | NA | NA | NA |
| Average | 4 | 217 | 153 | 1,093 | 732 | 776 | 1,087 | 3.58 | 5.02 |
| 2000 | NA | NA | NA | NA | 839 | NA | NA | NA | NA |
| 2001 | NA | NA | NA | NA | 432 | NA | NA | NA | NA |
| 2002 | 4 | 216 | 153 | 1,092 | 716 | 839 | 1,049 | 3.88 | 4.85 |

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| Average | 4 | 216 | 153 | 1,092 | 662 | 839 | 1,049 | 3.88 | 4.85 |
| 2003 | 4 | 243 | 172 | 1,225 | 875 | 838 | 1,025 | 3.45 | 4.22 |
| 2004 | NA | NA | NA | NA | 811 | NA | NA | NA | NA |
| 2005 | NA | NA | NA | NA | 429 | NA | NA | NA | NA |
| Average | 4 | 243 | 172 | 1,225 | 705 | 838 | 1,025 | 3.45 | 4.22 |
| 2006 | NA | NA | NA | NA | 1,127 | NA | NA | NA | NA |
| 2007 | NA | NA | NA | NA | 737 | NA | NA | NA | NA |
| 2008 | NA | NA | NA | NA | 450 | NA | NA | NA | NA |
| Average | NA | NA | NA | NA | 771 | NA | NA | NA | NA |
| 2009 | NA | NA | NA | NA | 545 | NA | NA | NA | NA |
| 2010 | NA | NA | NA | NA | 366 | NA | NA | NA | NA |
| 2011 | NA | NA | NA | NA | 370 | NA | NA | NA | NA |
| Average | NA | NA | NA | NA | 427 | NA | NA | NA | NA |

Louisiana is a net exporter of live crabs to other Gulf states for processing; landings used for processing (estimated live weight) were approximately one-third (28%) of total landings. In the early 1980s, processed poundage converted to a live-weight equivalent basis averaged 8.1M pounds while reported harvest for the same period, by comparison, averaged 22.1M pounds. In the early 1990s, 25.0M pounds were processed while approximately 50.0M pounds were harvested. Recently, in the early 2010s, 1.8M pounds of estimated live weight was processed in Louisiana and 42.0M pounds were harvested.

### 7.6.3.5 Texas

In general, crab processing activities in Texas have been more stable over the last 38 years than in any other Gulf state. Number of processors ranged from four to ten based on three-year averages (Table 7.14). Similarly, with two exceptions in the late 1980s and early 1990s, the weight of processed blue crab has fallen in the comparatively narrow range of 219,000 to 840,000 pounds.

As in Louisiana, crab products in Texas are relatively high-priced because they tend to be largely meat-based products. The average real ($2011) price of product in Texas peaked at nearly $17.00/lb in the mid-1970s, and then declined steadily to about $5.00/lb in the early 2000s. In the mid-2000s, the price averaged $6.38/lb. Based on total volume of product, Texas generally contributed less than 10% to the total Gulf weight based on three-year averages, ranging from 2% in the early 2000s to 10% in the late 1980s (Table 7.8 and Figure 7.16). Because of the high price of Texas blue crab products, their contribution to the total Gulf value has generally exceeded their contribution to total Gulf product by weight.

**Table 7.13** Production (pounds) of processed crab in Louisiana, 1973-2011, nominal and real ($2011) (NOAA personal communication). Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| 1973 | 31 | 2,238 | 1,582 | 11,291 | 23,080 | 3,671 | 18,599 | 1.64 | 8.31 |
| 1974 | 29 | 2,179 | 1,540 | 10,993 | 20,640 | 4,141 | 18,893 | 1.90 | 8.67 |
| 1975 | 26 | 1,809 | 1,279 | 9,129 | 17,144 | 4,051 | 16,939 | 2.24 | 9.36 |
| Average | 29 | 2,075 | 1,467 | 10,471 | 20,288 | 3,954 | 18,144 | 1.93 | 8.78 |
| 1976 | 30 | 1,522 | 1,076 | 7,677 | 15,211 | 5,399 | 21,343 | 3.55 | 14.03 |
| 1977 | 28 | 1,609 | 1,138 | 8,119 | 16,154 | 6,692 | 24,841 | 4.16 | 15.44 |
| 1978 | 30 | 1,520 | 1,075 | 7,669 | 15,074 | 5,500 | 18,976 | 3.62 | 12.48 |
| Average | 29 | 1,550 | 1,096 | 7,822 | 15,480 | 5,864 | 21,720 | 3.78 | 13.98 |
| 1979 | 23 | 1,035 | 732 | 5,224 | 21,334 | 3,378 | 10,466 | 3.26 | 10.11 |
| 1980 | 23 | 1,195 | 845 | 6,029 | 18,183 | 5,245 | 14,319 | 4.39 | 11.98 |
| 1981 | 22 | 1,372 | 970 | 6,921 | 16,237 | 6,673 | 16,512 | 4.86 | 12.04 |
| Average | 23 | 1,201 | 849 | 6,058 | 18,584 | 5,099 | 13,765 | 4.17 | 11.38 |
| 1982 | 26 | 1,180 | 834 | 5,951 | 17,284 | 6,307 | 14,701 | 5.35 | 12.46 |
| 1983 | 27 | 1,651 | 1,167 | 8,329 | 19,616 | 8,882 | 20,060 | 5.38 | 12.15 |
| 1984 | 20 | 1,978 | 1,399 | 9,982 | 29,617 | 10,697 | 23,158 | 5.41 | 11.70 |
| Average | 24 | 1,603 | 1,133 | 8,087 | 22,172 | 8,629 | 19,306 | 5.38 | 12.11 |
| 1985 | 21 | 2,013 | 1,423 | 10,158 | 29,848 | 11,711 | 24,481 | 5.82 | 12.16 |
| 1986 | 27 | 3,460 | 2,446 | 17,458 | 31,611 | 21,251 | 43,615 | 6.14 | 12.60 |
| 1987 | 37 | 3,757 | 2,656 | 18,956 | 52,345 | 21,901 | 43,366 | 5.83 | 11.54 |
| Average | 28 | 3,077 | 2,175 | 15,524 | 37,935 | 18,287 | 37,154 | 5.93 | 12.10 |
| 1988 | 41 | 3,622 | 2,561 | 18,275 | 53,554 | 19,587 | 37,244 | 5.41 | 10.28 |
| 1989 | 42 | 3,926 | 2,776 | 19,809 | 33,390 | 24,745 | 44,888 | 6.30 | 11.43 |
| 1990 | 41 | 3,813 | 2,695 | 19,237 | 38,886 | 23,000 | 39,583 | 6.03 | 10.38 |
| Average | 41 | 3,787 | 2,677 | 19,107 | 41,944 | 22,444 | 40,572 | 5.91 | 10.70 |
| 1991 | 48 | 4,633 | 3,275 | 23,376 | 51,088 | 27,856 | 46,005 | 6.01 | 9.93 |
| 1992 | 52 | 5,018 | 3,548 | 25,318 | 51,744 | 31,350 | 50,262 | 6.25 | 10.02 |
| 1993 | 51 | 4,939 | 3,492 | 24,920 | 45,847 | 19,793 | 30,811 | 4.01 | 6.24 |
| Average | 50 | 4,864 | 3,438 | 24,538 | 49,559 | 26,333 | 42,360 | 5.42 | 8.73 |
| 1994 | 44 | 3,673 | 2,596 | 18,530 | 36,665 | 13,652 | 20,721 | 3.72 | 5.64 |
| 1995 | 41 | 5,061 | 3,578 | 25,534 | 36,914 | 42,949 | 63,392 | 8.49 | 12.53 |
| 1996 | 38 | 4,175 | 2,951 | 21,062 | 39,902 | 32,616 | 46,760 | 7.81 | 11.20 |
| Average | 41 | 4,303 | 3,042 | 21,709 | 37,827 | 29,739 | 43,625 | 6.67 | 9.79 |
| 1997 | 31 | 1,714 | 1,212 | 8,649 | 43,440 | 11,863 | 16,625 | 6.92 | 9.70 |
| 1998 | 29 | 1,330 | 940 | 6,710 | 43,480 | 8,783 | 12,121 | 6.60 | 9.11 |
| 1999 | 25 | 947 | 670 | 4,779 | 46,328 | 7,614 | 10,280 | 8.04 | 10.85 |
| Average | 28 | 1,330 | 941 | 6,713 | 44,416 | 9,420 | 13,009 | 7.19 | 9.89 |
| 2000 | 25 | 944 | 667 | 4,761 | 51,446 | 8,098 | 10,578 | 8.58 | 11.21 |
| 2001 | 22 | 630 | 446 | 3,180 | 41,398 | 5,990 | 7,608 | 9.50 | 12.07 |
| 2002 | 20 | 828 | 585 | 4,178 | 49,751 | 7,210 | 9,015 | 8.71 | 10.89 |

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| Average | 22 | 801 | 566 | 4,040 | 47,531 | 7,099 | 9,067 | 8.93 | 11.39 |
| 2003 | 17 | 624 | 441 | 3,150 | 47,705 | 5,527 | 6,757 | 8.85 | 10.82 |
| 2004 | 10 | 439 | 310 | 2,214 | 44,069 | 4,413 | 5,255 | 10.06 | 11.98 |
| 2005 | 9 | 543 | 384 | 2,737 | 37,880 | 5,482 | 6,313 | 10.10 | 11.64 |
| Average | 12 | 535 | 378 | 2,700 | 43,218 | 5,140 | 6,108 | 9.67 | 11.48 |
| 2006 | 9 | 719 | 508 | 3,628 | 53,252 | 6,330 | 7,062 | 8.80 | 9.82 |
| 2007 | 9 | 366 | 258 | 1,844 | 44,902 | 3,203 | 3,475 | 8.76 | 9.51 |
| 2008 | 8 | 399 | 282 | 2,014 | 41,617 | 3,171 | 3,313 | 7.95 | 8.30 |
| Average | 9 | 495 | 350 | 2,495 | 46,590 | 4,235 | 4,617 | 8.50 | 9.21 |
| 2009 | 6 | 398 | 282 | 2,010 | 52,848 | 3,677 | 3,855 | 9.23 | 9.68 |
| 2010 | 6 | 278 | 197 | 1,404 | 30,621 | 2,662 | 2,746 | 9.56 | 9.87 |
| 2011 | 6 | 372 | 263 | 1,879 | 43,706 | 3,594 | 3,594 | 9.65 | 9.65 |
| Average | 6 | 350 | 247 | 1,764 | 42,392 | 3,311 | 3,398 | 9.48 | 9.73 |

## 7.7 Crab Imports

Foreign crab imports compete with domestic blue crab products. Blue crab products are not distinguished from other ‘swimming crab’ imports, so there is no way to determine the weight or value of specific U.S. imports of blue crab products. Given the 35 countries that imported swimming crab into the U.S. from approximately 2000 to 2011, eight (Indonesia, China, Thailand, Vietnam, Philippines, Mexico, India, and Venezuela – in order), represented 96% of all crab imports into the U.S. In 2011, U.S. imports of crab meat in air-tight containers (ATC) and frozen crabmeat was 38.5M pounds and valued at $335.0M (Table 7.15 and 7.16) (Figure 7.17 and Figure 7.18). Crab imports into the U.S. were heavily dominated by ATC crab meat products from 2000-2011.

From 2000-2011, Indonesia increased imports into the U.S. about two-fold from about 9.0M pounds/year in 2000 to a peak of almost 20.0M pounds in 2007. After 2007, however, Indonesia’s imports into the U.S. declined sharply to 12.0M pounds in 2011. Average crab imports from Indonesia into the U.S., from 2000-2011, were about 13.0M pounds valued at ~$107.0M (real $2011).

China followed a similar trend as Indonesia, with crab imports into the U.S. increasing from 645,000 pounds in 2000 to 14.0M pounds in 2008. After 2008, imports declined to about 10.0M pounds in 2011. Average crab imports from China into the U.S. were about 8.0M pounds/year from 2000-2011 and was valued at ~45.0M/year (real $2011).

Thailand’s imports into the U.S. remained relatively stable at roughly 7.0M pounds/year from 2000-2008. From 2009-2011, however, average imports into the U.S. declined to about 4.0M pounds/year. Average crab imports from Thailand into the U.S. were about 6.2M pounds per year from 2000-2011 and represented ~$45.0M/year in value (real $2011).

**Table 7.14** Production (pounds) of processed crab in Texas, 1973-2011, nominal and real $2011 (NOAA personal communication). Confidential and unavailable data are presented as N/A. Adjusted (real $2011) values and prices were derived using the 1982-1984 CPI (BLS 2012).

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| 1973 | 7 | 958 | 677 | 4,834 | 6,881 | 2,453 | 12,426 | 2.56 | 12.97 |
| 1974 | 8 | 1,009 | 714 | 5,092 | 6,088 | 2,680 | 12,226 | 2.65 | 12.11 |
| 1975 | 8 | 552 | 390 | 2,787 | 5,992 | 1,926 | 8,051 | 3.49 | 14.58 |
| Average | 8 | 840 | 594 | 4,238 | 6,320 | 2,353 | 10,901 | 2.90 | 13.22 |
| 1976 | 11 | 607 | 429 | 3,063 | 6,668 | 2,647 | 10,466 | 4.36 | 17.24 |
| 1977 | 9 | 601 | 425 | 3,034 | 8,249 | 2,736 | 10,156 | 4.55 | 16.89 |
| 1978 | 7 | 622 | 440 | 3,137 | 7,470 | 3,109 | 10,728 | 5.00 | 17.25 |
| Average | 9 | 610 | 431 | 3,078 | 7,462 | 2,831 | 10,450 | 4.64 | 17.13 |
| 1979 | 6 | 598 | 422 | 3,015 | 8,312 | 2,977 | 9,223 | 4.98 | 15.43 |
| 1980 | 6 | 715 | 505 | 3,608 | 8,953 | 3,259 | 8,896 | 4.56 | 12.44 |
| 1981 | 7 | 673 | 476 | 3,397 | 6,952 | 3,511 | 8,688 | 5.21 | 12.90 |
| Average | 6 | 662 | 468 | 3,340 | 8,072 | 3,249 | 8,936 | 4.92 | 13.59 |
| 1982 | 8 | 810 | 573 | 4,087 | 8,010 | 4,645 | 10,827 | 5.73 | 13.36 |
| 1983 | 9 | 738 | 521 | 3,721 | 8,829 | 4,140 | 9,349 | 5.61 | 12.68 |
| 1984 | 12 | 663 | 469 | 3,346 | 7,229 | 3,731 | 8,076 | 5.62 | 12.18 |
| Average | 10 | 737 | 521 | 3,718 | 8,023 | 4,172 | 9,418 | 5.66 | 12.74 |
| 1985 | 11 | 1,778 | 1,257 | 8,970 | 9,722 | 4,140 | 8,655 | 2.33 | 4.87 |
| 1986 | 9 | 1,424 | 1,007 | 7,184 | 9,482 | 2,952 | 6,058 | 2.07 | 4.25 |
| 1987 | 6 | 438 | 309 | 2,208 | 11,688 | 1,889 | 3,740 | 4.32 | 8.55 |
| Average | 9 | 1,213 | 858 | 6,121 | 10,297 | 2,994 | 6,151 | 2.91 | 5.89 |
| 1988 | 8 | 877 | 620 | 4,426 | 10,428 | 4,106 | 7,807 | 4.68 | 8.90 |
| 1989 | 7 | 2,159 | 1,527 | 10,895 | 9,123 | 12,207 | 22,144 | 5.65 | 10.25 |
| 1990 | 7 | 1,762 | 1,246 | 8,892 | 8,599 | 9,885 | 17,012 | 5.61 | 9.65 |
| Average | 7 | 1,600 | 1,131 | 8,071 | 9,383 | 8,733 | 15,654 | 5.31 | 9.60 |
| 1991 | 6 | 534 | 377 | 2,692 | 6,123 | 3,346 | 5,527 | 6.27 | 10.36 |
| 1992 | 6 | 388 | 274 | 1,957 | 6,161 | 2,150 | 3,447 | 5.54 | 8.89 |
| 1993 | 5 | 190 | 134 | 957 | 8,286 | 857 | 1,334 | 4.52 | 7.04 |
| Average | 6 | 370 | 262 | 1,869 | 6,857 | 2,118 | 3,436 | 5.44 | 8.76 |
| 1994 | 7 | 832 | 588 | 4,199 | 5,154 | 3,203 | 4,861 | 3.85 | 5.84 |
| 1995 | 6 | 476 | 336 | 2,399 | 5,787 | 4,026 | 5,942 | 8.46 | 12.49 |
| 1996 | 6 | 321 | 227 | 1,619 | 6,311 | 2,095 | 3,003 | 6.53 | 9.36 |
| Average | 6 | 543 | 384 | 2,739 | 5,751 | 3,108 | 4,602 | 6.28 | 9.23 |
| 1997 | 9 | 1,278 | 904 | 6,448 | 7,084 | 9,543 | 13,374 | 7.47 | 10.46 |
| 1998 | 8 | 189 | 134 | 953 | 6,989 | 1,242 | 1,714 | 6.58 | 9.07 |
| 1999 | 5 | 125 | 88 | 631 | 6,472 | 832 | 1,123 | 6.65 | 8.98 |
| Average | 7 | 531 | 375 | 2,677 | 6,848 | 3,872 | 5,404 | 6.90 | 9.51 |
| 2000 | 5 | 156 | 110 | 787 | 4,653 | 885 | 1,156 | 5.67 | 7.40 |
| 2001 | 4 | 225 | 159 | 1,133 | 5,163 | 620 | 788 | 2.76 | 3.51 |
| 2002 | 4 | 278 | 196 | 1,401 | 7,037 | 1,123 | 1,404 | 4.04 | 5.05 |

| YEAR | No. of Firms | Processed Poundage (X1000) | | | Pounds Landed (X1000) | Product Value (X$1000) | | Product Price ($/Lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Product Weight | Est. Meat Weight | Est. Live Weight | | Nominal | Real ($2011) | Product Weight | Est. Meat Weight |
| Average | 4 | 219 | 155 | 1,107 | 5,618 | 876 | 1,116 | 4.16 | 5.32 |
| 2003 | 4 | 389 | 275 | 1,961 | 4,811 | 2,140 | 2,616 | 5.50 | 6.73 |
| 2004 | 4 | 346 | 245 | 1,747 | 3,961 | 1,756 | 2,092 | 5.07 | 6.04 |
| 2005 | NA | NA | NA | NA | 3,119 | NA | NA | NA | NA |
| Average | 4 | 367 | 260 | 1,854 | 3,964 | 1,948 | 2,354 | 5.29 | 6.38 |
| 2006 | NA | NA | NA | NA | 1,966 | NA | NA | NA | NA |
| 2007 | NA | NA | NA | NA | 3,454 | NA | NA | NA | NA |
| 2008 | NA | NA | NA | NA | 2,635 | NA | NA | NA | NA |
| Average | NA | NA | NA | NA | 2,685 | NA | NA | NA | NA |
| 2009 | NA | NA | NA | NA | 2,844 | NA | NA | NA | NA |
| 2010 | NA | NA | NA | NA | 3,436 | NA | NA | NA | NA |
| 2011 | NA | NA | NA | NA | 2,893 | NA | NA | NA | NA |
| Average | NA | NA | NA | NA | 3,058 | NA | NA | NA | NA |

The relevance of these imported products, with respect to the domestic markets for the domestic crab product, depends upon the ability of the imported products to compete and substitute for the domestic product in the market. From 2000-2011, total pounds of crab imports increased from a low of 21.0M pounds/year in 2000 to a high of 55.0M pounds in 2008, representing a 162% increase (Figure 7.19). Recent total pounds of imports were 38.5M pounds in 2011 while total processed pounds from Gulf processors, for the same time period, was only 4.5M pounds. Total Gulf production ranged from a high of 11.4M pounds/year in 2000 to a low of 3.0M pounds in 2007, representing a 73% decrease (Figure 7.19).

Although there are a number of associated variables that might influence these changes, the overall trend supports the concern raised by harvesters in the Section 8.3.10, that the 'dumping' or 'flooding' of the U.S. market with imports has impacted the domestic production significantly. Additional research is needed to quantify the influence that imports have had on domestic crab prices and consumer demand. In many cases, imported crab products may include other types of crab that may not be comparable to domestic blue crab and are in the market as a substitute.

**Table 7.15** U.S. imports of frozen and in air-tight containers (ATC) swimming crabmeat from China, India, Indonesia, Mexico, Philippines, Thailand, Venezuela, and Vietnam, from 2000-2011 (NOAA personal communication).

| TOTAL IMPORTS BY COUNTRY (x1000 lbs) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year** | **China** | **India** | **Indonesia** | **Mexico** | **Philippines** | **Thailand** | **Venezuela** | **Vietnam** | **Total** |
| 2000 | 645 | NA | 8,744 | 2,932 | 1,348 | 6,367 | 672 | 312 | 21,020 |
| 2001 | 2,642 | 75 | 11,130 | 2,835 | 2,363 | 7,264 | 843 | 497 | 27,649 |
| 2002 | 3,781 | 190 | 11,476 | 2,384 | 2,994 | 6,863 | 1,718 | 705 | 30,111 |
| 2003 | 5,428 | 713 | 9,701 | 2,084 | 3,068 | 5,975 | 2,190 | 1,206 | 30,365 |
| 2004 | 6,780 | 947 | 10,517 | 2,103 | 2,543 | 6,490 | 2,503 | 1,624 | 33,508 |
| 2005 | 8,216 | 1,456 | 13,987 | 1,852 | 2,655 | 8,847 | 2,228 | 5,525 | 44,766 |
| 2006 | 9,871 | 1,973 | 13,895 | 2,778 | 3,145 | 5,570 | 2,036 | 6,944 | 46,212 |
| 2007 | 9,591 | 2,332 | 19,613 | 2,679 | 3,696 | 6,812 | 777 | 5,892 | 51,392 |
| 2008 | 13,990 | 2,586 | 17,526 | 2,558 | 4,147 | 7,352 | 808 | 6,209 | 55,177 |
| 2009 | 8,504 | 2,303 | 13,714 | 2,372 | 3,601 | 4,511 | 1,022 | 3,869 | 39,896 |
| 2010 | 10,669 | 2,041 | 16,035 | 1,359 | 4,325 | 4,534 | 368 | 4,147 | 43,478 |
| 2011 | 10,070 | 1,982 | 12,289 | 2,684 | 3,100 | 3,473 | 1,619 | 3,336 | 38,552 |
| **Total** | **90,186** | **16,600** | **158,627** | **28,621** | **36,986** | **74,057** | **16,782** | **40,265** | **462,125** |

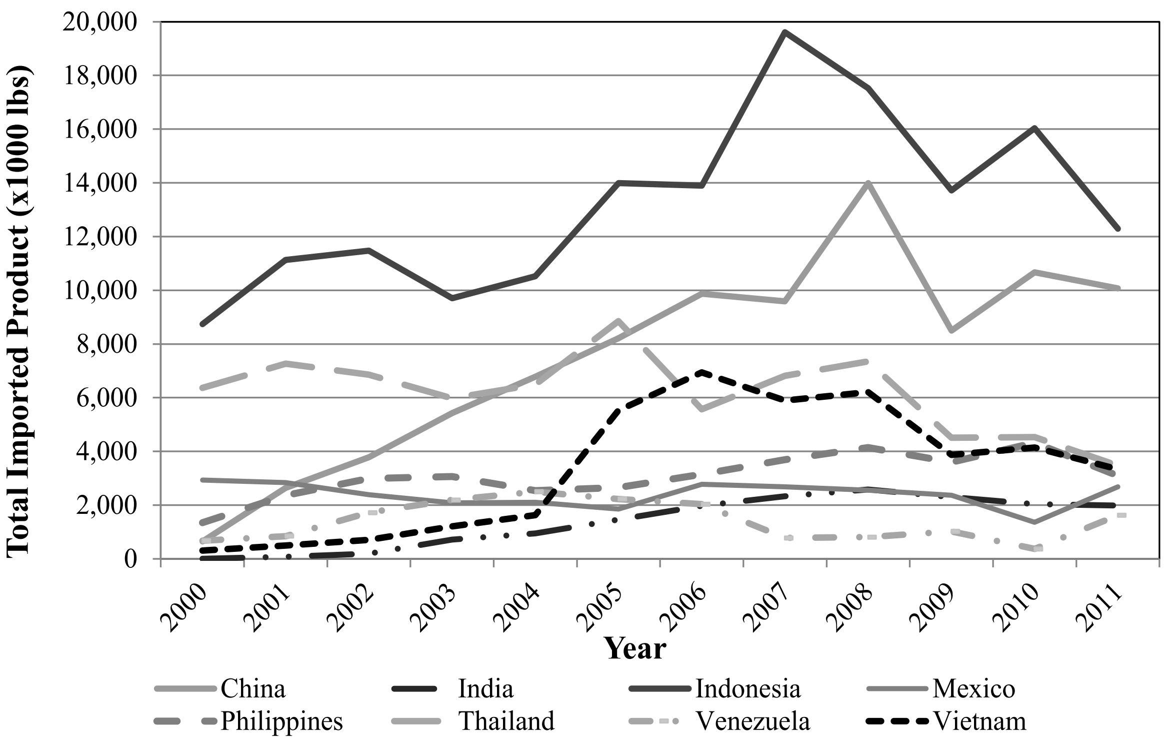



**Figure 7.17** U.S. imports of frozen and in air-tight containers (ATC) swimming crabmeat from China, India, Indonesia, Mexico, Philippines, Thailand, Venezuela, and Vietnam, from 2000-2011 (NOAA personal communication).

**Table 7.16** U.S. imports of frozen and in air-tight containers (ATC) swimming crabmeat from China, India, Indonesia, Mexico, Philippines, Thailand, Venezuela, and Vietnam, from 2000-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

| TOTAL IMPORTS BY COUNTRY (x$1,000) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year** | **China** | **India** | **Indonesia** | **Mexico** | **Philippines** | **Thailand** | **Venezuela** | **Vietnam** | **Total** |
| 2000 | 2,866 | NA | 53,961 | 20,133 | 11,982 | 40,400 | 6,032 | 2,192 | 137,564 |
| 2001 | 12,855 | 650 | 82,604 | 17,706 | 22,580 | 54,117 | 9,307 | 2,937 | 202,755 |
| 2002 | 18,143 | 1,379 | 90,949 | 16,145 | 25,376 | 53,228 | 12,769 | 3,849 | 221,839 |
| 2003 | 28,164 | 6,236 | 70,878 | 14,600 | 27,690 | 39,790 | 15,446 | 7,113 | 209,917 |
| 2004 | 37,049 | 7,367 | 82,247 | 13,882 | 19,911 | 48,736 | 13,811 | 11,277 | 234,280 |
| 2005 | 46,958 | 11,126 | 112,783 | 12,066 | 21,815 | 64,398 | 14,566 | 43,731 | 327,442 |
| 2006 | 54,042 | 17,176 | 110,789 | 20,499 | 25,756 | 35,784 | 13,288 | 54,609 | 331,942 |
| 2007 | 51,511 | 20,058 | 152,660 | 18,985 | 29,663 | 49,389 | 3,883 | 42,486 | 368,636 |
| 2008 | 97,579 | 25,223 | 163,647 | 20,787 | 41,525 | 54,685 | 5,288 | 53,049 | 461,784 |
| 2009 | 52,715 | 19,979 | 103,196 | 17,446 | 29,526 | 32,890 | 4,524 | 26,512 | 286,788 |
| 2010 | 67,511 | 18,752 | 132,959 | 10,481 | 37,730 | 34,621 | 1,953 | 29,015 | 333,022 |
| 2011 | 76,048 | 20,766 | 121,474 | 22,356 | 32,150 | 30,573 | 6,728 | 25,210 | 335,304 |
| **Total** | **545,441** | **148,712** | **1,278,146** | **205,087** | **325,703** | **538,610** | **107,594** | **301,979** | **3,451,272** |

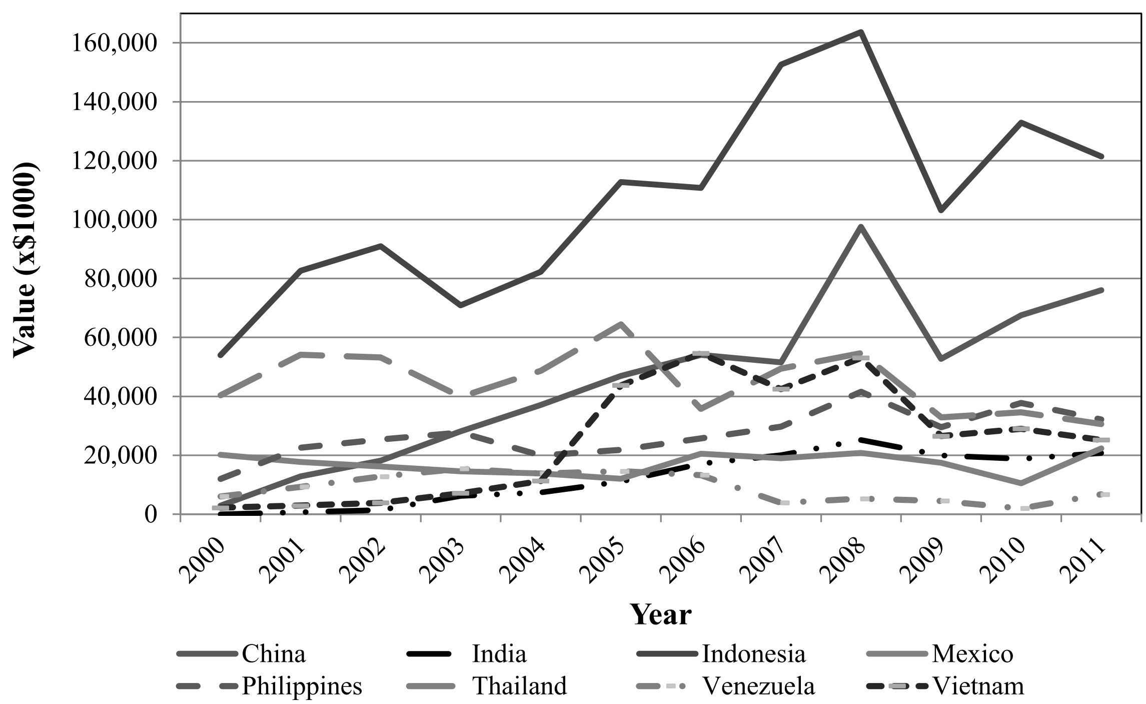



**Figure 7.18** U.S. imports of frozen and in air-tight containers (ATC) swimming crabmeat from China, India, Indonesia, Mexico, Philippines, Thailand, Venezuela, and Vietnam, from 2000-2011 (NOAA personal communication). Adjusted (real $2011) values were derived using the 1982-1984 CPI (BLS 2012).

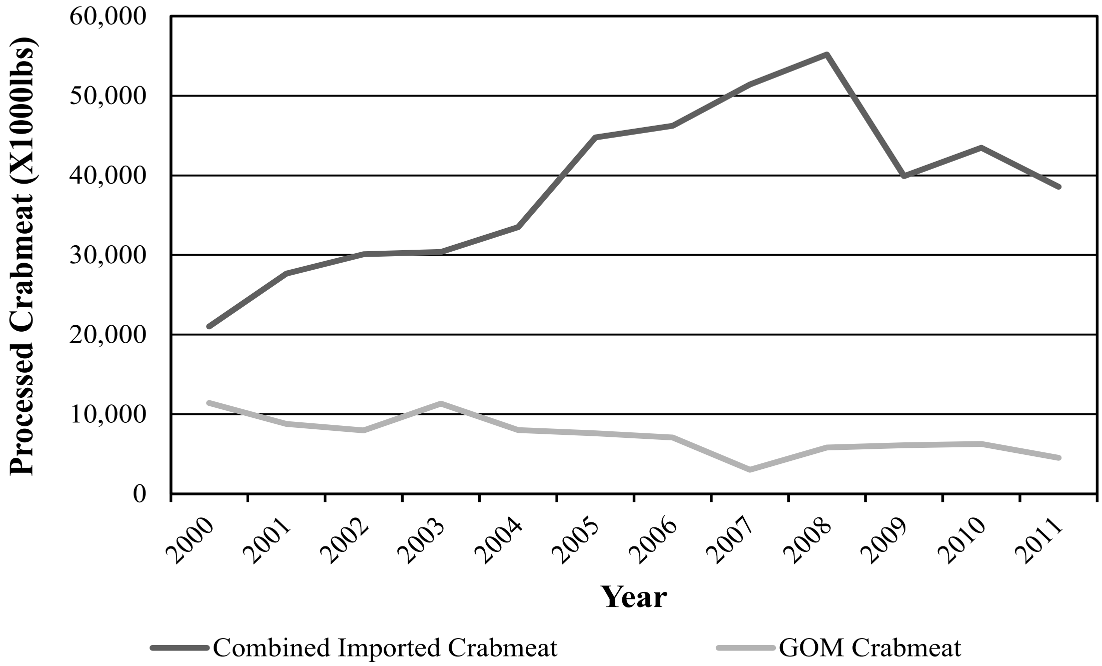



**Figure 7.19** Total pounds of U.S. imports of frozen and in air-tight containers (ATC) of 'swimming crab' meat from China, India, Indonesia, Mexico, Philippines, Thailand, Venezuela, and Vietnam (combined), and U.S. Gulf of Mexico (GOM) processed blue crab meat production from 2000-2011 (NOAA personal communication).

## 8.0 SOCIOCULTURAL CHARACTERIZATION OF THE GULF OF MEXICO BLUE CRAB FISHERY

### 8.1 Background Studies

Few broad-scale studies have been conducted on the sociology of the commercial blue crab fishery in the Gulf of Mexico with most research focused on communities within individual states. Two sociological studies (Pesson 1974, Paredes et al.1977) were conducted in the 1970s to provide information that would enhance the effectiveness of the Marine Advisory services in their interactions with individuals involved with fisheries and seafood industries. The early study by Pesson (1974) surveyed fishermen in the 14 coastal parishes of Louisiana and provided an overview of their general practices, attitudes, and social characteristics. While the study was focused on the shrimp fishery, data were collected on a limited number of blue crab fishermen. Paredes et al. (1977) used standard anthropological techniques of participant observation and key informant interviewing to describe in detail the blue crab fishery in a small community of northeast Florida. Their research provided detailed and candid information on the social structure and daily routines of crab fishermen and their needs and perceptions.

Sullivan (1988) also used a participant-observation approach to study inshore fisheries in the Galveston Bay area of Texas. She noted that the fisheries were carried out "under deteriorating economic conditions amidst a bitter political struggle over access" and that the fisheries were "highly regulated". Formal interviews with Galveston representatives of the NMFS, TPWD, and County Marine Extension Service as well as state legislators and members of the Texas Coastal and Marine Council in Austin were also included in her study. As with the Paredes et al. (1977) study in Florida, the everyday practices of harvesters and producers were detailed and the socio-cultural values and ideals of the fishermen were documented.

A historical and detailed overview of the seafood industry in Alabama was published by Forbus et al. (1989). Survey data were collected through in-depth personal interviews with processors, distributors, dealers, and brokers in Mobile and Baldwin counties, as well as community leaders and representatives of groups and organizations directly involved in the Alabama seafood industry. A separate questionnaire, designed to gauge attitudes and perceptions of harvesters regarding the current situation in the industry, the prospects for the near future, and what role they see the state playing in management of fisheries, was administered to a sample of fishermen in towns of Bayou La Batre and Bon Secour. In 1993, a symposium was held by the GSMFC that identified a number of the social-culture conflicts in the Gulf blue crab fishery (GSMFC 1995) and in 1998, the entire Gulf of Mexico fishery was surveyed in an attempt to provide a detailed social-demographic description of the fishery from Texas to Florida (Guillory et al. 2001).

This section is intended to provide the reader with a comparison of the demographic and social composition of the Gulf commercial blue crab fishery as it existed at the beginning of this century and exists today, as well as an understanding of the impacts that management and public perception have on fishery participants.

## 8.2 Survey Methodology

The socioeconomic survey, conducted by the GSMFC, was largely exploratory in nature and a normative survey methodology was employed. In 1998, every commercially licensed blue crab fishermen in the five Gulf states was provided a chance to participate in a mail survey for inclusion in the 2001 revision of the GSMFC's Blue Crab Fishery Management Plan (Guillory et al. 2001). Fishermen (n = 3,981) were sent paper survey forms (along with a cover letter and a stamped, self-addressed envelope) and were asked to return the completed forms to the GSMFC. Thank-you/follow-up reminders were mailed to participants in subsequent weeks. Approximately 23% (1,023) of the license holders returned the survey including a number of latent license holders who had not fished commercially but simply purchased a license (Table 8.1).

The 2013 survey instrument (Appendix 13.2) was developed in an electronic format using an online subscription survey provider. Paper copies were generated for selective distribution. The original 1998 survey questions were updated but kept similar in wording and structure (where possible) to allow for comparison. Original questions that were determined to be poorly designed or did not provide the desired level of results were modified or replaced. Questions addressing issues unexplored in the 1998 survey were added. New questions in the 2013 survey dealt directly with fishing communities and the individual 'well-being' of crab fishermen. The 2013 survey instrument also included economic questions (Section 7.0) designed to explore the characteristics of the crab harvesting business and addressed the issue of latency (those who simply owned the license for any variety of reasons but were not active) (Section 8.6).

The 12-page survey (Appendix 13.2) was made available to all commercially licensed fishermen in the Gulf in late February 2013 and was active through the end of March 2013. Licensed commercial crab fishermen (n = 4,549) were sent letters informing them of the survey and how to access it electronically. Fishermen were also offered paper copies from their respective state marine agencies if they did not have access to the internet or just preferred paper. A $250 gift card raffle was offered as an incentive to those who participated in the survey. A week after the introduction letters were sent, a reminder postcard was sent to all recipients. All correspondence provided a URL link to the survey website as well as a QR code for those with 'smart' technology. Letters and postcards returned with incorrect or undeliverable addresses were removed from the survey. Of the 4,549 original license holders, 4,347 remained in the sampling pool (Table 8.1). Unlike the 1998 survey, the 2013 survey was divided into two portions. The first portion of the survey (41 questions) addressed those individuals who actively landed crabs in 2012 or in the last five years. The final portion (17 questions) targeted those crab fishermen who held 'latent' licenses or were no longer active (no landings in the previous five years). Inactive license holders were asked questions (which the active fishermen never saw) specifically designed to address the reasons behind the license latency.

Survey results were reviewed and duplicate, incomplete, or unusable forms were eliminated, resulting in a return of 477 individual surveys; 88.6% (423) were active and 11.3% (54) were inactive participants (Table 8.1). About 10% (48) of the respondents provided paper copies of the survey including printing the webpage version and filling it out in ink and returning it by mail. Paper forms returned by mail were entered into the web-based survey form and the results

**Table 8.1** Blue crab survey response data for 1998 and 2013 (a large percentage of respondents in 2013 did not indicate their resident state and are in the "Unknown" category for returns).

| Survey Year | State | Total Number of Fishermen (est.) | Total Mailed Out (Valid Addresses) | Total Surveys Returned | Actual Response Rate Mailed/ Received |
|---|---|---|---|---|---|
| 1998 | Louisiana | 2,550 | 2,480 | 574 | 23% |
| 1998 | Alabama | 176 | 151 | 49 | 32% |
| 1998 | Texas | 553 | 540 | 115 | 21% |
| 1998 | Florida | 715 | 700 | 261 | 37% |
| 1998 | Mississippi | 119 | 110 | 24 | 22% |
| 1998 | Totals | **4,113** | **3,981** | **1,023** | **26%** |
| | | | | | |
| 2013 | Louisiana | 3,630 | 3,486 | 150 | 4.3% |
| 2013 | Alabama | 207 | 176 | 13 | 7.4% |
| 2013 | Texas | 147 | 137 | 4 | 2.9% |
| 2013 | Florida | 355 | 356 | 29 | 8.1% |
| 2013 | Mississippi | 210 | 192 | 16 | 8.3% |
| 2013 | Unknown | | | 265 | 6.1% |
| 2013 | Totals | **4,549** | **4,347** | **477** | **10.3%** |

exported to a format that could be examined using a standard spreadsheet program. Survey entries were proofed by testing for outliers and erroneous or incomplete responses. All analyses were completed using the SPSS software (IBM SPSS Statistics).

Although the response rate for the 2013 survey was much lower than the 1998 sample (Table 8.1), comparative analysis showed that both the 1998 and 2013 surveys were representative of the actual population (Table 8.2). Table 8.2 lists the percent of the Gulf-wide crab fishing population by state and the percent each state represented in the survey returns. With the exception of Florida, the percent response rate by state was similar to the percentage of actual license holders in that state relative to the total Gulf of Mexico. For example, in 1998, 5.6% of licensed crab fishermen in the Gulf were located in Alabama with 4.3% of those fishermen responding.

Louisiana had the majority of licensed fishermen in the Gulf in both surveys although the percentage was much higher in 2013. The notable decline in Florida license holders from 1998 to 2013 is the result of effort management practices that eliminated a number of the 'latent' licenses.

## 8.3 Results from the 1998 and 2013 Surveys

The analytical strategy of the 2013 survey was to provide updated information on how the industry has changed over time. Questions were comprehensive and provided an opportunity to document how commercial crab fishermen view these changes. In addition, new questions were added to assess overall community conditions and well-being of the fishermen. The number

**Table 8.2** Comparison between sampling effort and actual population representativeness by state.

| | 1998 | | 2013 | |
|---|---|---|---|---|
| **State** | **Actual** | **Sample** | **Actual** | **Sample** |
| Alabama | 5.6% | 4.3% | 4.0% | 6.1% |
| Florida | 27.3% | 6.3% | 8.2% | 13.7% |
| Louisiana | 54.7% | 62.0% | 80.2% | 70.8% |
| Mississippi | 2.2% | 2.2% | 4.4% | 7.5% |
| Texas | 10.2% | 13.4% | 3.2% | 1.9% |

of useable responses in the 2013 survey varied greatly as some respondents skipped specific questions, particularly those related to economic activities. Descriptive statistics for the 1998 and 2013 surveys are addressed in Sections 8.3.1 to 8.3.14.

### 8.3.1 Age Characteristics

The mean age of all crab harvesters rose from 44.8 years in 1998 to 47.7 years in 2013 (Table 8.3). In 1998, the modal (most frequently observed) category for age was 41-45 years (16.4%); in 2013 this shifted to 51-55 years (20.8%). In general, there were fewer harvesters under the age of 45 (about 15% less) in 2013 and more respondents in the 46 and older categories (65.6%, 46-71+).

### 8.3.2 Marital Status

Marital status of fishermen changed little between the surveys (Table 8.4). Crab fishermen were more likely to be single in 2013 than in 1998 (15.4% and 10.6% respectively). Three-quarters of the harvesters in 2013 were married, with 7.7% divorced, and 1.9% widowed. In 1998, 77.3% were married, 9.8% divorced, and 2.4% were widowed.

**Table 8.3** Age characteristics of the commercial blue crab fishermen Gulf-wide from the 1998 and 2013 sample results.

| **Age** | **1998 (%)** | **2013 (%)** | **Age** | **1998 (%)** | **2013 (%)** |
|---|---|---|---|---|---|
| 16-20 | 0.7 | 1.9 | 46-50 | 12.7 | 16.0 |
| 21-25 | 2.3 | 1.9 | 51-55 | 12.2 | 20.8 |
| 26-30 | 6.0 | 3.9 | 56-60 | 10.4 | 11.5 |
| 31-35 | 10.9 | 5.5 | 61-65 | 6.8 | 8.7 |
| 36-40 | 13.2 | 9.3 | 66-70 | 4.5 | 4.8 |
| 41-45 | 16.4 | 11.9 | 71+ | 3.9 | 3.8 |
| **Subtotal 16-45** | **49.5** | **34.4** | **Subtotal 46-70+** | **50.5** | **65.6** |
| | | | | | |
| Mean Age | 44.8 | 47.7 | | | |
| Total N | 926 | 366 | | | |

**Table 8.4** Marital status of the 1998 and 2013 sample results.

| Marital Status | 1998 (%) | 2013 (%) |
|---|---|---|
| Single | 10.6 | 15.4 |
| Married | 77.2 | 75.0 |
| Divorced | 9.8 | 7.7 |
| Widowed | 2.4 | 1.9 |
| Total N | 922 | 366 |

### 8.3.3 Race/Ethnicity and Citizenship

A summary of survey responses to questions about race and ethnicity from the 1998 and 2013 surveys is found in Table 8.5. There are often differences between how a person identifies their 'race' and their 'ethnicity' and the two are not always intuitive. Race generally relates to a person's appearance and is determined biologically by genetic traits that are passed on from parents. Ethnicity relates to cultural factors such as nationality, culture, ancestry, language, and beliefs. For the purposes of this survey, eight of the most common races and ethnic groups were provided and a respondent could select single or multiple categories such as Caucasian and African American or Caucasian and Hispanic.

The percentage of Caucasian respondents in 1998 and 2013 was nearly identical in both surveys (75.5% and 75.3% respectively). There were, however, changes in the proportion of other racial/ethnic categories. Vietnamese, Cambodian, and Laotian fishermen represented the largest minority components of the blue crab fishery in the late 1990s (Guillory et al. 2001). Their participation in the fishery continued to increase with overall percentages rising from 7.3% in 1998 to 12.7% in 2013. Within that group, there was an increase in the proportion of Cambodian crab fishermen (1.3% to 3.7%). African American fishermen increased from 1.0% to 2.3% with Native Americans decreasing from 11.8% to 5.0%.

In the 2013 survey, a citizenship question was added to the survey to address non-U.S. citizens participating in the fishery. When asked about citizenship and country of origin, the great

**Table 8.5.** Summary of survey responses to questions about race and ethnicity from the 1998 and 2013 samples.

| Race/Ethnicity | 1998 (%) | 2013 (%) |
|---|---|---|
| Caucasian | 75.5 | 75.3 |
| Vietnamese | 7.3 | 12.7 |
| Cambodian | 1.3 | 3.7 |
| Hispanic | 1.9 | 1.3 |
| African American | 1.0 | 2.3 |
| Native American | 11.8 | 5.0 |
| Total N | 918 | 362 |

majority of respondents (92.9%) were citizens with ~7% of respondents indicating they were not. Respondents who reported not being U.S. citizens were all of Asian descent (Vietnamese and Cambodian). Overall, approximately 43% of the Vietnamese and Cambodian fishermen who responded were not U.S. citizens.

### 8.3.4 Education

Educational characteristics of respondents in the 1998 and 2013 surveys are found in Table 8.6. Educational levels among crab harvesters rose in the 15 years between the surveys. In 1998, 25.6% of harvesters had a high school diploma or GED compared to 53.1% in 2013. The number of fishermen who had a college degree or had attended college was also higher in 2013; 18.3% had attended college and 5.5% had completed a college degree. This was up from 9.2% and 3.0% in 1998, respectively. In 1998, 54% of crab fishermen had not completed a high school degree (17.9% elementary and 36.1% middle school). In 2013, 20.9% had not completed high school (4.8% elementary and 16.1% middle school).

**Table 8.6** Educational attainment of respondents from the 1998 and 2013 surveys (**BOLD** indicates the biggest change between the two survey time periods).

| Education | 1998% | 2013% |
|---|---|---|
| Elementary | 17.9 | 4.8 |
| Middle School | **36.1** | 16.1 |
| High School/GED | 25.6 | **53.1** |
| Some College | 9.2 | 18.3 |
| College | 3.0 | 5.5 |
| Total N | 910 | 365 |

### 8.3.5 Years in the Industry

Longevity (years in the fishery) in the 1998 and 2013 surveys is found in Table 8.7. In both the 1998 and 2013 surveys, about one-quarter of respondents had five or fewer years in the fishery (24.2% and 23.7% respectively) and could be designated as 'rookies' in contrast to 'veterans'. In general, the 1998 survey revealed a more experienced group, even though on average, they were younger in overall age (Table 8.3). The high percentage of fishermen (65.6%) in the older age category reflects the longevity of veterans and older rookies entering the fishery perhaps seeking an alternate or a secondary source of income (Section 8.3.1).

### 8.3.6 Dependence on Fishing

Moving between fisheries is a common occurrence as commercial fishermen tend to hold multiple licenses and shift to other species according to season, product value, or availability. Based on the results of the 2013 survey, 55% of the respondents reported that 100% of their

**Table 8.7** Total years in the fishery from the 1998 and 2013 surveys (n=917 in 1998, 312 in 2013). Also indicated is the mean number of years in the fishery for both survey periods.

| Years in Fishery | 1998 (%) | 2013 (%) | Years in Fishery | 1998 (%) | 2013 (%) |
|---|---|---|---|---|---|
| 1-5 | 24.2 | 23.7 | 26-30 | 8.8 | 11.9 |
| 6-10 | 3.6 | 14.1 | 31-35 | 4.8 | 8.3 |
| 11-15 | 13.6 | 8.3 | 36-40 | 16.4 | 5.1 |
| 16-20 | 12.0 | 10.9 | 41+ | 5.7 | 6.4 |
| 21-25 | 9.1 | 11.2 | | | |
| Subtotal 1-25 years | 62.5 | 68.2 | Subtotal 26-41+ years | 35.7 | 31.7 |
| Mean Years in Fishery | 22.5 | 18.1 | | | |

income came from commercial fishing and only 22% derived 100% of their income from blue crab fishing (hard and soft crabs). For those respondents who indicated participation in fisheries other than blue crabs, shrimp fishermen (21%) derived the least income from commercial crab fishing. Respondents who also commercially harvested finfish (17%) generated considerably more income from crabs on average than did shrimp fishermen. The largest number of respondents who derived the most income from commercial crab fishing also participated in the oyster fishery (36.8%). The variety and seasonality of fishing income sources lends support to the interdependency of the commercial crab fishery with other fisheries in the Gulf of Mexico.

An analysis was conducted examining the differences on a seasonal basis between rookie and veteran fishermen. From January through April, rookie respondents and veterans fished at about the same frequency; however the veterans fished more traps and their fishing trips were longer, thus veterans fished with higher effort. In the other months, especially from June through September, rookies were more likely to continue crab fishing but still fished with less intensity (fewer traps and trip hours) than the veterans that continued to fish at that time. Survey data suggests that more crab fishing veterans move to shrimp fishing once that season opens and return to crab fishing later in the year, presumably as shrimp became scarcer or the prices for crab and shrimp change in value.

### 8.3.7 Family Fishing Network

Family participation in the fishery from the 1998 and 2013 surveys is found in Table 8.8. In general, the 2013 sample shows intense familial and friend networks in the Gulf of Mexico commercial crab fishery with increases in almost all of the network categories. In 1998, 11.5% of the respondents had parents who participated in commercial crabbing; this increased to 22.8% in 2013. Wives were more likely to participate in crab fishing as well, increasing from 4.7% to 15.4% between the two surveys. Though the proportion of sisters crab fishing decreased, the percentage of brothers crab fishing increased from 9.1% to 22.8%. The proportion of children who participated in the fishery also increased from 5.1% in 1998 to 17.7% in 2013. Lastly, the percentage of friends who fished crabs rose from 20% in 1998 to 54.1% in 2013.

In the 2013 survey, the respondents reported 'Father/Mother' (40.1%), 'Friend' (35.6%), and 'Other' (17.5%) as the individuals that brought the respondent into the fishery (Table 8.8). In the 1998 survey, 'Friend' (33.1), 'Father/Mother' (29.8%), and 'Other' (16.6%) were the most influential. The same three groups emerged as most important in the two samples but it is clear that family influences have become more important in recent years.

**Table 8.8** Family participation and introduction to the fishery from the 1998 and 2013 surveys (N = 922 in 1998, 362 in 2013).

| Family who participates in crab fishing | 1998 (%) | 2013 (%) | Introduced to crab fishing | 1998 (%) | 2013 (%) |
|---|---|---|---|---|---|
| Parents | 11.5 | 22.8 | Father/Mother | 29.8 | 40.1 |
| Wife | 4.7 | 15.4 | Wife | 0.4 | 1.0 |
| Sisters | 9.0 | 2.5 | Husband | 1.3 | 1.6 |
| Brothers | 9.1 | 22.8 | Brother | 4.0 | 2.9 |
| Sons/Daughters | 5.1 | 17.7 | Sister | 0.1 | 0 |
| Cousins/In-laws/Uncles | 27.0 | 31.7 | Son/Daughter | 0.7 | 1.0 |
| Friends | 20.0 | 54.1 | Cousin | 4.0 | 5.8 |
| | | | Friend | 33.1 | 35.6 |
| | | | In-Laws | 4.4 | 5.5 |
| | | | Other | 16.6 | 17.5 |

### 8.3.8 Job Satisfaction

A summary of respondents' job satisfaction level from the 1998 and 2013 surveys is found in Table 8.9. In the 1998 sample, crab fishermen were asked to rate their satisfaction with crab fishing as an occupation and 29.8% reported being 'Highly Satisfied' (8.6%) or 'Mostly Satisfied' (21.2%). Satisfaction with crab fishing as an occupation increased greatly in 2013 with 52.4% reporting being 'Highly Satisfied' (15.6%) or 'Mostly Satisfied' (36.8%). Analysis of the 1998 responses indicated that satisfaction with the industry was positively associated with the number of years in the industry (experience or competency). Rookies were far more likely to be neutral or dissatisfied with the fishery based on survey results.

Additional questions on job satisfaction were added in the 2013 survey. Respondents were asked if they would become a crab harvester if they could live their life over. The great majority (81.5%) reported they would become a crab fishermen again, while 18.5% would choose a different occupation. Next, respondents were asked if they had ever seriously considered going into another profession with 63.6% saying 'No' and 36.4% saying 'Yes'. Respondents were then asked if they were free to stay in crab fishing or another job what their choice would be. The great majority (86.1%) said they would stay, while 14.6% would choose to leave. Responses indicated that the individuals enjoyed being commercial crab harvesters and had little interest in pursuing other jobs.

**Table 8.9** Summary of respondents' job satisfaction level from the 1998 and 2013 surveys. Only the first question was asked on both surveys. For all of the remaining questions, there is nothing to compare.

| How satisfied are you with commercial crab harvesting as an occupation? | N | % Highly Satisfied | % Mostly Satisfied | % Neutral | % Not Very Satisfied | % Unsatisfied |
|---|---|---|---|---|---|---|
| 1998 | 905 | 8.6 | 21.2 | 33.4 | 22.6 | 14.2 |
| 2013 | 302 | 15.6 | 36.8 | 28.5 | 14.2 | 5.0 |
| | | | | | | |
| **If you had to do it over again, would you become a harvester?** | | **Yes** | **No** | | | |
| **2013 only** | 302 | 81.5 | 18.5 | | | |
| | | | | | | |
| **Have you ever seriously considered going into another profession?** | | **Yes** | **No** | | | |
| **2013 only** | 302 | 36.4 | 63.6 | | | |
| | | | | | | |
| **If you were free to stay in crabbing or another job what would your choice be?** | | **Stay** | **Leave** | | | |
| **2013 only** | 302 | 86.1 | 14.6 | | | |
| | | | | | | |
| **Do you want your children to crab?** | | **Yes** | **No** | | | |
| **2013 only** | 299 | 29.4 | 70.6 | | | |
| | | | | | | |
| **How would you rate the future of crabbing as an occupation?** | | **Very Good** | **Good** | **Fair** | **Poor** | **Very Poor** |
| **2013 only** | 302 | 3.6 | 15.9 | 38.1 | 32.1 | 10.3 |
| | | | | | | |
| **Rate your satisfaction with these Job components:** | | **Very Satisfied** | **Satisfied** | **Neutral** | **Unsatisfied** | **Very Unsatisfied** |
| Your independence | 302 | 55.0 | 30.8 | 12.3 | 1.7 | 0.3 |
| Respect received as a harvester | 300 | 17.7 | 33.3 | 29.3 | 14.3 | 5.3 |
| Working outdoors | 301 | 62.1 | 28.9 | 8.3 | 0.3 | 0.3 |
| Worthiness of your job | 297 | 30.6 | 37.7 | 26.6 | 3.4 | 1.7 |
| Being a harvester | 299 | 36.1 | 40.1 | 16.7 | 4.3 | 2.7 |
| Your earnings last year | 298 | 4.7 | 15.8 | 24.8 | 31.9 | 22.8 |
| Your future as a harvester | 299 | 8.4 | 27.8 | 35.1 | 15.7 | 13.0 |

Respondents seemed less optimistic about the future (Table 8.9). When asked to rate the future of crab fishing, the modal category was 'Fair' (38.1%) followed by 'Poor' (32.1%). About one-fifth of respondents (19.5%) responded 'Very Good' (3.6%) or 'Good' (15.9%), while 42.4% responded 'Poor' (32.1%) or 'Very Poor' (10.3%).

When asked if they would want their children to go into crab fishing, the great majority of respondents (70.6%) said 'No', while 29.4% said 'Yes'. About 12% of the respondents indicated that they had children working as commercial crab harvesters (Section 8.3.7) and those respondents with children who fished were more satisfied with their occupation, more optimistic about the future, and had been in the fishery longer. While there were large differences in the level of satisfaction overall, the differences based on optimism and inclusion of children in the fishery were relatively small.

Crab fishermen were asked to rate their satisfaction with different aspects of their occupation. They reported being 'Very Satisfied' (modal response) with working outdoors (62.1%) and with job independence (55.0%). They reported being 'Satisfied' with being a harvester (40.1%), job worthiness (37.7%), and respect received as a harvester (33.3%). Respondents were 'Neutral' about the future of the industry (35.1%) and were 'Unsatisfied' with their earnings from the previous year (31.9%).

### 8.3.9 Perceptions of Environmental Conditions Impacting the Industry

Environmental conditions perceived to impact the fishery in the 1998 and 2013 surveys are listed in Table 8.10. Respondents in both surveys indicated that coastal water pollution was a problem for the fishery with increased concern in the 2013 survey. Over 60% of respondents viewed water pollution as a problem in 2013 compared to 47% in 1998. Only one-quarter of the fishermen were concerned over vessel pollution; however, over 50% of the fishermen in both surveys considered increased vessel traffic as problematic.

There was heightened concern over crab disease and industry discharge in the 2013 survey. Fishermen identifying crab disease as a 'Problem' increased from 8.2% in 1998 to 33.4% in the current survey. Concern over industrial discharge rose from 31.6% to 57.5%. More than 60% of the fishermen were not concerned with salinity/water temperature or red tide. A new question was added in 2013 to include the crab fishermen's perception of habitat loss. Nearly two-thirds of the harvesters (63%) indicated habitat loss was a 'Problem'.

### 8.3.10 Perceptions of Economic Conditions Impacting the Fishery

Perceptions of economic conditions impacting the fishery in the 1998 and 2013 surveys are listed in Table 8.11. All issue options for the respondents increased in the 'Problem' category in 2013, though some changes were not large. A large majority of respondents indicated that the number of buyers, shipping costs, and peeler crab availability were not a 'Problem'. Over half of the fishermen did not view local competition as a 'Problem' in both surveys, but there was increased concern in the 2013 survey.

There were heightened concerns over issues that directly affect the livelihood of harvesters; crab meat imports, processing costs, and operational costs. Fifty-one percent of the fishermen were concerned over processing costs in 2013, nearly double the number in the 1998 survey. Imports were a very important issue for crab fishermen (Section 7.7) with over 75% viewing the importation of crabmeat as a threat to their economic well-being. Crab fishermen perceived operational costs

**Table 8.10** Perceived environmental conditions impacting the fishery by respondents from the 1998 and 2013 surveys.

| Environmental Conditions | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **Coastal Water Pollution 1998** | 508 | 25.8 | 27.0 | 47.3 |
| **Coastal Water Pollution 2013** | 209 | 7.7 | 30.1 | 62.2 |
| | | | | |
| **Crab Disease 1998** | 508 | 69.3 | 22.6 | 8.2 |
| **Crab Disease 2013** | 204 | 32.8 | 33.8 | 33.4 |
| | | | | |
| **Vessel Pollution 1998** | 508 | 40.4 | 28.3 | 22.9 |
| **Vessel Pollution 2013** | 205 | 41.0 | 32.7 | 26.4 |
| | | | | |
| **Industry Discharge 1998** | 508 | 29.6 | 38.8 | 31.6 |
| **Industry Discharge 2013** | 205 | 19.5 | 22.9 | 57.5 |
| | | | | |
| **Increased Vessel Traffic 1998** | 508 | 26.8 | 20.7 | 52.5 |
| **Increased Vessel Traffic 2013** | 205 | 28.3 | 21.5 | 50.3 |
| | | | | |
| **Salinity/Water Temp 1998** | 508 | 44.9 | 21.3 | 33.8 |
| **Salinity/Water Temp 2013** | 200 | 31.0 | 29.5 | 39.5 |
| | | | | |
| **Red Tide 1998** | 508 | 47.0 | 23.3 | 29.7 |
| **Red Tide 2013** | 201 | 38.8 | 26.4 | 34.8 |
| | | | | |
| **Habitat Loss (2013 only)** | 197 | 12.2 | 24.9 | 63 |

as increasing greatly between the two surveys. Operational costs were considered a 'Problem' by 70% of the 2013 respondents. For all categories, economic conditions were more of a concern in the 2013 survey.

### 8.3.11 Perceived Sources of Conflict with Other Commercial Crab Harvesters

Perceived sources of conflict with other commercial crab harvesters in the 1998 and 2013 surveys are found in Table 8.12. Respondents in both surveys were split in their concern over user area conflicts. Over 50% of the respondents in both surveys considered user area conflicts as 'Not a Problem'; however, 40%+ viewed it as it a continuing problem. Fishermen in 1998 showed more concern than did those in 2013, although the difference was less than 6%.

Gear conflict issues, cultural differences, and ghost traps were of lesser concern to fishermen. Over 65% of respondents in both surveys viewed issues with gear as 'Not a Problem'.

**Table 8.11** Perceptions of economic conditions impacting the fishery by respondents from the 1998 and 2013 surveys.

| Economic Conditions | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **Number of Buyers 1998** | 508 | 57.9 | 15.3 | 26.7 |
| **Number of Buyers 2013** | 211 | 48.3 | 23.7 | 28 |
| | | | | |
| **Shipping Costs 1998** | 508 | 68.5 | 15.1 | 16.4 |
| **Shipping Costs 2013** | 203 | 39.4 | 27.6 | 33.1 |
| | | | | |
| **Crab Meat Imports 1998** | 508 | 26.5 | 14.7 | 58.7 |
| **Crab Meat Imports 2013** | 205 | 9.8 | 14.6 | 75.6 |
| | | | | |
| **Processing Costs 1998** | 508 | 53.9 | 17.6 | 28.5 |
| **Processing Costs 2013** | 204 | 31.9 | 17.2 | 51 |
| | | | | |
| **Local Competition 1998** | 508 | 41.4 | 16.9 | 41.7 |
| **Local Competition 2013** | 205 | 25.9 | 29.3 | 44.9 |
| | | | | |
| **Operational Costs 1998** | 508 | 18.5 | 22.0 | 59.5 |
| **Operational Costs 2013** | 203 | 10.3 | 19.2 | 70.4 |
| | | | | |
| **Peeler Crab Availability 1998** | 508 | 58.4 | 16.6 | 25.1 |
| **Peeler Crab Availability 2013** | 200 | 38.5 | 25.5 | 36 |

Cultural differences were viewed as 'Not a Problem by 76% of respondents in 1998 and 81% of respondents in 2013. The percentage of respondents who considered the issue of ghost traps as 'Not a Problem' exceeded 60% in both surveys. Issues associated with gear and ghost traps were of more concern in 2013 with cultural differences more important in 1998.

Concerns about poaching and theft were high in both surveys with 81.4% of respondents in 1988 and 74.8% of respondents in 2013 rating it as a 'Problem'. More than half of the respondents viewed excessive fishing effort and the taking of undersized crabs as 'Not a Problem'; however, as with the user area conflicts issue, a number of fishermen in both surveys considered it a 'Problem'. The number of respondents that considered fishing effort a problem was nearly identical in both surveys. Taking of undersized crabs was more of an issue in 1998.

### 8.3.12 Perceived Sources of Conflict with Other Commercial and Recreational Fishermen

Sources of conflict with other commercial fishermen and recreational anglers by respondents to the 1998 and 2013 surveys are found in Table 8.13. Gear conflicts traditionally occur on fishing

**Table 8.12** Perceived sources of conflict with other commercial crab harvesters by respondents from the 1998 and 2013 surveys.

| With Commercial Crab Harvesters | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **User Area Conflicts 1998** | 508 | 38.1 | 16.2 | 45.7 |
| **User Area Conflicts 2013** | 210 | 31.9 | 27.6 | 40.4 |
| | | | | |
| **Gear Conflicts 1998** | 508 | 49.5 | 17.0 | 33.5 |
| **Gear Conflicts 2013** | 205 | 39.5 | 25.9 | 34.7 |
| | | | | |
| **Cultural Differences 1998** | 508 | 64.5 | 11.8 | 23.6 |
| **Cultural Differences 2013** | 207 | 63.8 | 17.4 | 18.9 |
| | | | | |
| **Poaching/Theft 1998** | 508 | 6.5 | 12.2 | 81.4 |
| **Poaching/Theft 2013** | 206 | 9.7 | 15.5 | 74.8 |
| | | | | |
| **Ghost Traps 1998** | 508 | 53.3 | 16.3 | 30.5 |
| **Ghost Traps 2013** | 203 | 37.4 | 25.1 | 37.4 |
| | | | | |
| **Excessive Fishing Effort 1998** | 508 | 38.2 | 21.5 | 40.2 |
| **Excessive Fishing Effort 2013** | 203 | 35.5 | 24.1 | 40.4 |
| | | | | |
| **Taking of Undersized Crabs 1998** | 508 | 40.8 | 15.1 | 44 |

grounds when trap, trawl/dredge fisheries, and recreational water users operate in the same area. Although some fishermen perceived a conflict with the shrimp fishery, a large majority of the respondents in both surveys did not view it as a problem. Conflict with shrimp fishermen decreased overall compared to the 1998 survey results with fewer respondents listing trawl fishermen as problematic. Of note is the increase in concern over the same time period with dredge fishermen. Though not considered a 'Problem' by the majority of the respondents, those fishermen who did perceive a conflict increased in number by ~10% in 2013. Conflicts with recreational boaters and recreational anglers declined from the 1998 survey suggesting that interaction with gear by boaters and anglers may be less of a problem today. The most commonly reported problem for crab fishermen was the loss of catch to poaching. The issue of poaching had the highest concern response in both the 1998 and the 2013 surveys with over 80% of the respondents indicating poaching and theft as a 'Problem'.

### 8.3.13 Perceived Sources of Conflict with Regulations and Enforcement

Sources of conflict with regulations and enforcement are found in Table 8.14. In the 1998 survey fishermen identified three primary sources of conflict with the regulatory agencies and

**Table 8.13** Perceived sources of conflict with other commercial and recreational anglers by respondents to the 1998 and 2013 surveys.

| With Commercial and Recreational | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **Shrimp Fishermen 1998** | 508 | 42.3 | 15.6 | 42.2 |
| **Shrimp Fishermen 2013** | 209 | 46.9 | 20.6 | 32.6 |
| | | | | |
| **Recreational Anglers 1998** | 508 | 22.7 | 16.3 | 61 |
| **Recreational Anglers 2013** | 206 | 34.0 | 24.3 | 41.7 |
| | | | | |
| **Recreational Boaters 1998** | 508 | 22.8 | 16.1 | 61.1 |
| **Recreational Boaters 2013** | 207 | 26.6 | 27.5 | 45.8 |
| | | | | |
| **Dredgers 1998** | 508 | 75.7 | 7.5 | 16.7 |
| **Dredgers 2013** | 208 | 53.4 | 21.2 | 25.5 |
| | | | | |
| **Poaching/Theft 1998** | 508 | 6.4 | 9.88 | 83.8 |
| **Poaching/Theft 2013** | 204 | 7.4 | 14.7 | 77.9 |

fisheries enforcement entities: 1) excessive regulations, 2) state legislators, and 3) inadequate enforcement (GSMFC 2001). While there was considerable variability between states, fishermen overall considered excessive regulations to be a 'Problem'. Fishermen were less concerned with excessive enforcement and more concerned with inadequate enforcement.

The 2013 results indicate an overall decline in concern for the issues provided in the survey with the exception of one, oil and gas activities. For many respondents, there appeared to be increasing concern related to the petroleum industry in the Gulf region. This may stem from the 2010 Deepwater Horizon (DWH) disaster.

### 8.3.14 Perceived Conflicts in the Community (2013 Only)

Conflicts in the community perceived by respondents to the 2013 survey are listed in Table 8.15. A new set of questions was added to the survey in 2013 looking at industry conflicts or concerns within the fishermen's local community. These issues were primarily related to access, cost of living, and quality of life. The majority of respondents did not report high concerns for the issues under consideration. Increasing property taxes and access to health care were both identified as a 'Problem' by just under half of the respondents. The single exception was the topic of pollution in the marine environment. Over 56% of the participants reported marine pollution as a 'Problem'.

**Table 8.14** Perceived sources of conflict with regulations and enforcement by respondents in the 1998 and 2013 surveys.

| With Regulations and Enforcement | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **Excessive Regulation 1998** | 508 | 36.1 | 18.2 | 30 |
| **Excessive Regulation 2013** | 210 | 50.0 | 22.9 | 14.7 |
| | | | | |
| **Inadequate Regulations 1998** | 508 | 53.4 | 15.2 | 17 |
| **Inadequate Regulations 2013** | 206 | 53.9 | 15.0 | 16.5 |
| | | | | |
| **License Application 1998** | 508 | 74.7 | 9.2 | 7.3 |
| **License Application 2013** | 209 | 72.7 | 14.4 | 5.7 |
| | | | | |
| **State Legislators 1998** | 508 | 34.4 | 17.6 | 32.2 |
| **State Legislators 2013** | 206 | 45.1 | 25.2 | 17.5 |
| | | | | |
| **Agency Responsiveness 1998** | 508 | 47.4 | 13.9 | 22.8 |
| **Agency Responsiveness 2013** | 203 | 51.2 | 20.2 | 14.8 |
| | | | | |
| **Excessive Enforcement 1998** | 508 | 66.5 | 12.9 | 12.2 |
| **Excessive Enforcement 2013** | 207 | 63.8 | 19.8 | 7.3 |
| | | | | |
| **Inadequate Enforcement 1998** | 508 | 42.7 | 14.6 | 27.3 |
| **Inadequate Enforcement 2013** | 206 | 43.7 | 23.3 | 18.9 |
| | | | | |
| **Selective Enforcement 1998** | 508 | 49.9 | 12.7 | 21.4 |
| **Selective Enforcement 2013** | 205 | 50.2 | 20.5 | 13.7 |
| | | | | |
| **Oil/Gas Activities 1998** | 508 | 60.1 | 17.9 | 10.2 |
| **Oil/Gas Activities 2013** | 201 | 38.3 | 24.4 | 18.9 |

## 8.4 Location Quotients (LQ) for Blue Crab by State and County

To explore the risk and vulnerability that comes from over-reliance on a single species, such as blue crab, an established economic calculation called the location quotient (LQ) was determined. The LQ is an analytical tool that compares local workforce statistics with national averages and is derived by taking the percentages of the workforce employed in each major industry locally and dividing them by the percentages of the workforce employed in the industry groups nationally (Richardson 1979). If the LQ is near or at one, then local employment is similar to that in the nation. If it is below one, then the local area may not be meeting local demand for that industry.

**Table 8.15.** Perceived conflicts in the community by respondents in 2013.

| With Community (2013 only) | N | Respondents indicating 'Not a Problem' | Respondents indicating 'Potential Problem' | Respondents indicating 'Problem', 'Significant Problem', or 'Major Problem' |
|---|---|---|---|---|
| **Loss of Commercial Dockage** | 210 | 45.7 | 21.0 | 33.3 |
| | | | | |
| **Increased Residential Growth** | 206 | 45.6 | 27.2 | 27.2 |
| | | | | |
| **Increasing Property Taxes** | 205 | 35.1 | 22.0 | 43 |
| | | | | |
| **Access to Health Care** | 204 | 35.8 | 18.1 | 46 |
| | | | | |
| **Pollution of Marine Environment** | 208 | 14.9 | 28.8 | 56.3 |
| | | | | |
| **Traffic Congestion** | 207 | 40.6 | 29.5 | 29.9 |
| | | | | |
| **Growth of Tourism** | 207 | 58.9 | 22.7 | 18.4 |
| | | | | |
| **Access to Quality Education** | 200 | 60.0 | 19.0 | 21 |
| | | | | |
| **Increasing Newcomers** | 204 | 36.3 | 29.9 | 33.9 |

If the figure is over one, it is assumed that the community exports products from that industry to other areas (Richardson, 1979).

Jacob and Jepson (2009) were the first to utilize LQ analysis to look at community risk and vulnerability that comes from economic over-reliance on a single species in a fishery. For the blue crab, county-level data were used to minimize issues with confidentiality. Federal confidentiality rules do not allow use of reporting landings data when there are less than three commercial fishermen, processors, or distributors in a given community (Jacob et al. 2010). The "rule of three" protects confidentiality by prohibiting the reporting of information that might be attributed to a single business or individual. This keeps potential competitors from gaining inside information about the activities of that business or individual (Jacob et al. 2010). In many cases, this makes community-level landings and, as we see here, even county-level data unavailable because of the sensitive and confidential nature of the information.

The blue crab LQ is calculated the same as a workforce LQ and is determined by dividing the county percentage of total landings value for blue crab by the Gulf-wide percentage of total landings value for blue crab. For example, the percentage of total landings value for blue crab (26.8%) in Charlotte County, Florida, when divided by the percentage of total landings value for blue crab in the Gulf of Mexico (6.46%) yields an LQ of 4.15. The mathematical interpretation of this number is straightforward. Charlotte County's landings value for blue crab (as a total of all landings) is 4.15 times greater locally than for the Gulf region. The fisheries management interpretation of this quotient indicates that Charlotte County is four times more reliant upon blue crab than the average county in the Gulf. This means if there is a regulatory or environmental change that impacts blue crabs in the Gulf of Mexico, Charlotte County, Florida is more likely to be adversely affected. Conversely, if the number is under one, such as the landings value for Baldwin County, Alabama, where the LQ is 0.35, then local landings are lower than the regional average. Mathematically, this means the local landings values for blue crabs are approximately 65% lower than the proportion of landings for the Gulf region.

States and counties that have an LQ for blue crab landings value above one are highlighted in Table 8.16. Only Louisiana has an LQ average above one for the five Gulf states. The two coastal counties in Alabama both had LQs below one. Florida however had ten counties with LQs over one, ranging from 1.18-15.47. Many of the counties in Florida that had LQs above one, were either interior counties bordering the St. Johns River (Atlantic Coast) with almost all landings in blue crab or very urban or rural counties with relatively low total landings values.

There were 15 parishes in Louisiana that had LQs above one and ranged from 1.03-13.87. Blue crabs are a very important species in Louisiana and for many of its parishes with some reporting multi-million dollar landings values for blue crabs. Crabs made up at least one-third of all landings values in the parishes of Iberia (49% of landings values, over $2M), St. Charles (89%, $2.8M), St. Mary, (45%, $2.6M), and St. Tammany (73%, $5.3M). Changes in blue crab abundance or regulatory changes could have a disproportionate impact on these parish economies.

There were no counties in Mississippi that had LQs greater than one. In Texas, there were three counties with LQs greater than one. These LQs ranged from a low of 1.83 to a high of 4.88. However, the total of landings values in general was much lower than those of the parishes in Louisiana. Cameron County had the highest percentage of landings value from blue crabs at 31.5% and $786,658 value.

## 8.5 Summary and Discussion

### 8.5.1 Profile of Commercial Gulf of Mexico Blue Crab Fishermen

The early blue crab fishery was organized around a narrow group of traditional Caucasian fishing families. Paredes et al. (1977) noted that the closeness of kinship ties and recognition that one is a member of a particular family was an important element of the social structure in the Florida fishing community he named 'Medicine Springs'. Zarur (1975) also found that the 'kinship' system determined social activities in another Florida fishing village he termed 'Mullet Creek'. In our surveys, Caucasians continue to dominate the fishery and were the largest respondent groups in 1998 and 2013 making up 75.5% and 75.3% of the fishermen, respectively.

In the mid-1970s, a large group of Southeast Asian refugees were moved into coastal fishing communities along the Gulf of Mexico under the U.S. Indochinese refugee resettlement

**Table 8.16** Total seafood production, blue crab production only values, percent contribution of blue crab production value, and location quotients (LQ) for blue crab by state and county (* indicates data suppressed for compliance with NOAA confidentiality rules).

| State | County | All Seafood Total Value | Blue Crab Only Value | Blue Crab Only % Value | LQ Value |
|---|---|---|---|---|---|
| **Gulf Wide** | | $771,591,011 | $49,837,721 | 6.46% | 1.00 |
| **Alabama** | | $50,999,569 | $1,151,673 | 2.26% | 0.35 |
| | Baldwin | $6,803,068 | $55,907 | 0.82% | 0.13 |
| | Mobile | $44,196,501 | $1,095,766 | 2.48% | 0.38 |
| **Florida** | | $163,251,642 | $8,809,171 | 5.40% | 0.84 |
| | Bay | $9,550,634 | $125,156 | 1.31% | 0.20 |
| | Bradford | * | * | * | * |
| | Charlotte | $2,407,338 | $645,176 | **26.80%** | **4.15** |
| | Citrus | $5,276,814 | $848,549 | **16.08%** | **2.49** |
| | Clay | $501,827 | $501,592 | **99.95%** | **15.47** |
| | Collier | $6,516,073 | $156,495 | 2.40% | 0.37 |
| | Dixie | $2,211,393 | $824,143 | **37.27%** | **5.77** |
| | Escambia | $2,442,557 | $148,608 | 6.08% | 0.94 |
| | Franklin | $11,837,732 | $337,729 | 2.85% | 0.44 |
| | Gulf | $3,583,852 | $49,669 | 1.39% | 0.21 |
| | Hernando | $4,281,691 | $244,639 | 5.71% | 0.88 |
| | Hillsborough | $4,575,141 | $282,017 | 6.16% | 0.95 |
| | Jefferson | * | * | * | * |
| | Lee | $14,152,779 | $879,569 | 6.21% | 0.96 |
| | Levy | $3,099,814 | $1,053,061 | **33.97%** | **5.26** |
| | Manatee | $5,131,522 | $76,413 | 1.49% | 0.23 |
| | Marion | $31,466 | $25,125 | **79.85%** | **12.36** |
| | Monroe | $57,615,748 | $20,905 | 0.04% | 0.01 |
| | Okaloosa | $5,119,392 | $26,768 | 0.52% | 0.08 |
| | Pasco | $1,980,482 | $78,437 | 3.96% | 0.61 |
| | Pinellas | $17,564,139 | $411,316 | 2.34% | 0.36 |
| | Putnam | $679,997 | $669,928 | **98.52%** | **15.25** |
| | Santa Rosa | * | * | * | * |
| | Sarasota | $411,302 | $31,354 | **7.62%** | **1.18** |
| | Seminole | * | * | * | * |
| | Suwannee | * | * | * | * |
| | Taylor | $916,457 | $170,661 | **18.62%** | **2.88** |
| | Unknown County | $446,718 | $9,039 | 2.02% | 0.31 |
| | Wakulla | $2,916,776 | $1,192,821 | **40.90%** | **6.33** |

| State | County | All Seafood Total Value | Blue Crab Only Value | Blue Crab Only % Value | LQ Value |
|---|---|---|---|---|---|
| | Walton | * | * | * | * |
| **Louisiana** | | $316,031,405 | $36,810,406 | **11.65%** | **1.80** |
| | Acadia | $119,841 | $36,303 | **30.29%** | **4.69** |
| | Ascension | $106,840 | $39,881 | **37.33%** | **5.78** |
| | Avoyelles | * | * | * | * |
| | Beauregard | * | * | * | * |
| | Calcasieu | $5,547,876 | $584,265 | **10.53%** | **1.63** |
| | Cameron | $15,460,141 | $1,713,537 | **11.08%** | **1.72** |
| | East Baton Rouge | * | * | * | * |
| | East Feliciana | * | * | * | * |
| | Iberia | $4,222,302 | $2,087,636 | **49.44%** | **7.65** |
| | Iberville | * | * | * | * |
| | Jefferson | $27,525,064 | $1,830,818 | 6.65% | 1.03 |
| | Jefferson Davis | * | * | * | * |
| | Lafayette | $22,585,488 | $4,315,546 | **19.11%** | **2.96** |
| | Livingston | $106,657 | $66,622 | **62.46%** | **9.67** |
| | Null | $1,861,781 | $105,838 | 5.68% | 0.88 |
| | Orleans | $2,708,301 | $1,882,755 | **69.52%** | **10.76** |
| | Plaquemines | $105,219,146 | $2,136,173 | 2.03% | 0.31 |
| | Pointe Coupee | * | * | * | * |
| | St. Charles | $3,203,996 | $2,869,932 | **89.57%** | **13.87** |
| | St. James | $299,792 | $42,354 | **14.13%** | **2.19** |
| | St. John Baptist | $117,434 | $54,824 | **46.68%** | **7.23** |
| | St. Landry | * | * | * | * |
| | St. Martin | $4,042,724 | $76,259 | 1.89% | 0.29 |
| | St. Mary | $5,885,791 | $2,625,348 | **44.60%** | **6.90** |
| | St. Tammany | $7,225,248 | $5,298,163 | **73.33%** | **11.35** |
| | St. Bernard | $13,331,563 | $4,015,888 | **30.12%** | **4.66** |
| | Tangipahoa | $974,155 | $810,856 | **83.24%** | **12.88** |
| | Terrebonne | $56,243,378 | $3,735,254 | **6.64%** | **1.03** |
| | Vermilion | $39,243,887 | $2,482,154 | 6.32% | 0.98 |
| | Washington | * | * | * | * |
| | Winn | * | * | * | * |
| **Mississippi** | | $30,710,186 | $259,718 | 0.85% | 0.13 |
| | Hancock | * | * | * | * |
| | Harrison | $19,970,237 | $249,678 | 1.25% | 0.19 |
| | Jackson | $10,739,949 | $10,040 | 0.09% | 0.01 |

| State | County | All Seafood Total Value | Blue Crab Only Value | Blue Crab Only % Value | LQ Value |
|---|---|---|---|---|---|
| **Texas** | | $210,598,208 | $2,806,753 | 1.33% | 0.21 |
| | Aransas | $5,111,034 | $605,103 | **11.84%** | **1.83** |
| | Brazoria | * | * | * | * |
| | Calhoun | $2,497,063 | $786,658 | **31.50%** | **4.88** |
| | Cameron | $56,281,400 | $105,146 | 0.19% | 0.03 |
| | Chambers | $2,933,218 | $613,859 | **20.93%** | **3.24** |
| | Galveston | $53,213,035 | $280,975 | 0.53% | 0.08 |
| | Harris | $1,349,747 | $61,624 | 4.57% | 0.71 |
| | Jefferson | $44,812,669 | $335,924 | 0.75% | 0.12 |
| | Liberty | * | * | * | * |
| | Matagorda | $42,964,099 | $2,238 | 0.01% | 0.00 |
| | Nueces | $1,435,943 | $15,226 | 1.06% | 0.16 |
| | Orange | * | * | * | * |
| | San Patricio | * | * | * | * |
| | Willacy | * | * | * | * |

program (MAS/TAMU 1979). Many of the immigrants were fishermen in their native countries and they chose to continue fishing as a livelihood. Vietnamese, Cambodian, and Laotian fishermen represented the largest minority components of the blue crab fishery in the late 1990s (Guillory et al. 2001). Most of these individuals moved into established commercial fisheries in the Gulf. As a result, conflict over fishing patterns, economic organization, and regulatory oversight occurred, sometimes with violent consequences (MAS/TAMU 1979, GSMFC 1995). With the diversity of crab harvesters, also came issues related to language and communication, equal access to support and relief efforts (especially during disasters), and cultural sensitivity. The movement of this ethnic group into commercial crab fishing was one of the most significant changes to occur in the fishery since the development of the wire trap in the 1950s. By the end of the 1980s, the new entrants had transitioned into their respective communities and many of the conflicts between trap fishermen dissolved. In Alabama, the Asian refugees stepped into a declining labor market in the crab fishery and were credited with the rise of Bayou LaBatre and Coden as major processing centers for the industry (Forbus et al. 1989). In the Forbus et al. (1989) survey, eleven of twelve processors interviewed noted that the Asian immigrants were responsible for greatly improving production with processing capabilities in some shops increasing by as much as 200%. Conflicts with other fisheries (i.e. shrimp and crab), however, have continued. The years following the 1998 survey saw other significant changes in the fishery that included the movement of Hispanic immigrants into fishing, a faltering national economy, the expansion of the import market for foreign crab products, and numerous natural and man-made disasters.

The mean age of harvesters in the fishery was 47.7 years in 2013, an age slightly above the mean age in 1998. Pesson (1974) in his survey of Louisiana fishermen noted that 52% of all fishermen were between 40-59 years of age (35% under age 40) and that age composition of harvesters in the different fisheries was similar to the overall average.

There was a significant increasing trend in the educational level of crab fishermen with respondents in 2013 survey more than twice as likely to have completed high school (25.6% in 1998, 53.1% in 2013). Fishermen did not appear to delay entry into the fishery in order to remain in school as most rookie fishermen in 2013 were 43 years in age, an age similar to the average age of rookies in 1998. The average age of all the respondents entering the fishery was 45, suggesting that crabbing provides a supplemental income source later in life and this has been the trend over the last 15 years. New entrants to the fishery in 2013 received ~55% of their income, on average, from fishing with ~70% coming from commercial crab fishing. Fishermen with more experience earned ~70-80% of their total annual income from fishing with ~70% of that income from crab fishing.

Movement between fisheries was common and was dependent on fishing logistics, seasonal resource availability, and market value of the product. Oysters were traditionally harvested in the winter, a time when tides, weather, and resource availability were less favorable for blue crab fishing. Although the price per pound for crabs were highest in January-April, landings and effort were typically the lowest (Table 7.5). The commercial shrimp season typically begins in June and continues through most of the peak blue crab fishing season thus limiting the number of full time shrimp fishermen that participate in crab fishing. Commercial finfish harvesters may use any number of gears at any time of year and may switch fisheries as prices and availability go up (Section 7.1.3). Fishermen reported that an average of 31% of their income was derived from commercial shrimping, 10% from finfish, and an additional 25% as unclassified or 'other'. For those individuals who indicated participation in other fisheries, shrimp fishermen (21%) derived the least income from commercial crabbing. Fishermen who also commercially harvested finfish (17%) generated considerably more income from crabs on average than did shrimp fishermen. The largest number of fishermen who derived the most income from commercial crab fishing participated in the oyster fishery (36.8%). The interdependency of the crab fishery with other commercial fishing activities as described in the earlier studies of Paredes et al. (1977) and Guillory et al. (2001) has continued through the present.

New entrants to the fishery were far less satisfied than veterans of the industry. Overall, the job satisfaction of commercial blue crab harvesters was a complex issue. They enjoyed working outdoors and being independent; however, they did not see it as a good career for their children and they were not optimistic about the future of crab fishing. Most harvesters did not consider pursuing other careers and were satisfied with everything except income; most were largely dissatisfied with their previous year's earnings.

Three-quarters of the fishermen were married and crab fishing was an important livelihood strategy for families and extended families, more so today than in 1998. As a result, the impact of regulations and disasters in the fishery target smaller community units focused on families and friends. A deleterious impact to the fishery would make it difficult for crab fishermen to secure help as their closest social networks would also be experiencing the same stress (Section 8.4). This is compounded in rural and small communities because the crab industry may be one of the most important economic drivers in those places (Table 8.16). Paredes et al. (1977) and Zarur (1975) in their studies of Florida fishing communities in the mid-1970s also noted that employment in fishing was centered on family groups (either a father and his sons or brothers) and that kinship and social structure were important factors in their economic well-being. They found that maintaining a network of kinsman was crucial for survival and was so important that individuals did not make social investments in voluntary associations that might alienate their family group. Kinsmen were an insurance policy and, "in times of need, a person could cash in on his relatives". Fishermen were concerned with changing population demographics in coastal areas and with lack of infrastructure relative to their fishing needs. Increasing property taxes and access to health care were also issues were also considered problems.

### 8.5.2 Issues and Stress in the Fishery

#### 8.5.2.1 Major Issues of Concern to Respondents

Major problems for this discussion are defined as issues identified by over 50% of the responding fisherman in the 2013 survey. Where 2013 data deviate greatly from the 1998 survey, the initial survey information will be compared. Major problems in the fishery were primarily associated with issues that directly impacted the livelihood of fishermen (poaching and theft, operational and processing costs, imports) and with environmental issues (various forms of pollution, increased vessel traffic, industry discharge, habitat loss).

##### 8.5.2.1.1 Poaching and Theft

There were heightened concerns over poaching and theft, both with other crab fishermen and with harvesters in trawl/dredge fisheries and recreational boaters/anglers. Seventy-five percent of crab fishermen indicated that poaching and trap theft were issues with other crab fishermen with 78% viewing harvesters in other fisheries and recreational boaters/anglers a major issue. Concerns over gear and product loss were also noted in the 1975 study of Paredes et al. (1977) and in the study of Pesson (1978). In the Paredes et al. (1977) study, fishermen complained of loss of product by other crab fishermen, sports fishermen, and animals (turtles, sharks, porpoises) and shrimp fishermen were noted as a major source of gear loss. Seventy percent of crab fishermen in the Pesson (1978) survey reported that poaching was one of the most important problems they faced.

Loss of raw product and gear can be costly. The average cost to maintain or replace gear and to maintain their primary vessel (repairs, upgrades) was ~$5-7K annually with the average estimated total value of all their gear, including boat and motor, being between $15-35K (Section 7.2). As a result, the majority of fishermen self-insure their fishing property (vessels and gear), assuming that they will simply repair or replace their equipment as necessary. With a loss of up to 50% of their fishing gear annually, the cost of replacing unserviceable or lost traps is high (Section 7.2).

##### 8.5.2.1.2 Operational Costs

Operational and processing costs continue to rise in the fishery as income decreases (Section 7.2). Paredes et al. (1977) reported operational start-up costs for the trotline fishery of $50, provided the fishermen already had a small boat and motor. They noted that costs escalated with the advent of the trap fishery with start-up costs ranging from $1,300 to $4,400. Operational costs (bait, fuel, oil, labor) in the early trap fishery were estimated to range from $16 to $56.50 (Paredes et al. 1977).

The average price per gallon for regular, unleaded fuel, which most of the outboard motors today operate on, was about $1.50 in 1998 when the previous survey was completed and around $3.50/gallon in 2012 (adjusted for inflation to 2012 dollars). This represents over a 200% increase over 15 years (Energy Information Administration website). Most crab fishermen (86% of respondents) in the Gulf region fish with vessels less than 27 feet in length which makes it easier to trailer vessels to and from the launch areas. Maintenance of trailers and tow vehicles may increase the expense of the average fishing trip.

Crab harvesters in the Gulf of Mexico reported spending almost as much on bait per trip as they did on fuel (Section 7.2). The traditional bait for most crab fishermen in the Gulf has been menhaden. This bait supply has diminished over the last decade as Atlantic menhaden populations have been afforded more protection and the bait industry in the Gulf almost eliminated. Today, most of the bait menhaden in the Gulf originates from three major areas on the east coast: Virginia, New Jersey, and South Carolina. As a result of the reduction in availability, the cost of bait has increased substantially in recent years. VanderKooy and Smith (2014) reported that a single 100lb box of individually quick frozen (IQF) menhaden sold for around $12 in 1985 and $24 in 2007. This was comparable to the solid block of frozen Atlantic menhaden bait imported from the east coast at a cost of $0.35/lb which included about $0.10/lb for shipping. While frozen menhaden catch more crabs than fresh, they do not last as long so crab traps must be re-baited frequently in order to remain effective. At the height of the crab season (April-September), the rapid deterioration of bait increases the demand for a limited product and increases the cost to fishermen.

#### 8.5.2.1.3 Imports

Three-quarters of the respondents to the 2013 survey were concerned over the increasing importation of crab meat products. As noted in Section 7.6, there is high competition between domestic crab and crab imported from other countries such as Indonesia, China, Thailand, Vietnam, Philippines, Mexico, India, and Venezuela. Most of the product entering the U.S. market from foreign sources is not blue crab but a substitute product. The product is generally believed by most to be inferior to domestic product and is often labeled as 'swimming crab'. A cheaper labor force allows foreign companies to produce products at a lower cost, package it, and distribute to U.S. and European seafood market chains where it directly competes with domestic product. Imports have flooded the U.S. market with a cheaper substitute product while operational costs have increased in the U.S. fishery (fuel, traps, bait, etc.). For crab fishermen, this means lowered prices for domestic product, increased operational costs, and reduced disposable income.

#### 8.5.2.1.4 Environmental Issues

As a result of multiple natural and man-made disasters, fishermen in 2013 showed more concern over the potential for short- and long-term environmental impacts associated with various forms of pollution in estuarine and marine waters. The DWH disaster in 2010 resulted in the closure of almost 90,000 square miles of the Gulf of Mexico to fishing. This greatly impacted the fishery as large portions of the traditional crab fishing areas were closed during the peak of the season (Section 3.2.9.1.2). Fear of eating seafood from the region decreased product sales and distribution and created economic hardships in many fisheries. The uncertainty associated with this event and the continued release of information on potential consequences heightened fears over coastal water quality. The impacts to natural resources as a result of the DWH oil spill, including blue crabs, continue to be investigated through the Natural Resource Damage Assessment.

A large portion of the respondents voiced concern over habitat loss in the 2013 survey. Local, state, and federal educational and outreach activities and non-profit environmental programs continue to increase awareness of habitat loss issues and the importance of habitat to fisheries production. Fishermen participation in many of these programs has provided 'first-hand' experience of the problems leading to a greater appreciation of the role of the environment in maintaining their livelihood. Increasing commercial and recreational vessel traffic was seen as a problem with the potential to degrade habitat quality and as a source of increasing gear loss.

### 8.5.2.2 Issues of Lesser Concern to Respondents

Issues of lesser concern to respondents included water quality (temperature/salinity, red tide), competition, peeler crab availability/harvest of undersized crabs, area and gear conflicts, loss of gear, and excessive fishing effort. Unattended fishing gear, such as crab traps, often leads to conflict. The placement and saturation of some waters with actively fished crab traps and their associated floats and line often pose navigation hazards to waterfowl hunters, recreational anglers, pleasure boat operators, and trawl/dredge fishermen. In addition, crab fishermen who leave the fishery seasonally or permanently may leave their fishable traps in the water causing continued interactions with other user groups. Improper disposal of unfishable traps poses significant economic and public relations problems for the fishery. Abandoned or lost traps are referred to as derelict (Section 6.4.2) or ghost traps and they contribute to unintended mortality of blue crabs and bycatch as well as create visual pollution and navigation hazards. Specific management initiatives were instituted to decrease the number of traps in the fishery following the 1998 study.

In the last decade, measurable efforts have been made by the states, general public, and the blue crab industry to remove derelict traps from the water (Section 6.4.3). The removal programs have resulted in a great reduction in the number of traps remaining in the water each year. Since the start of these efforts in 2002, over 75,000 derelict traps have been removed from coastal waters in the Gulf of Mexico (Table 6.10). The result has been positive with a noticeable decrease in conflict. Effort limitation programs in some states have decreased the number of active traps fishing, further reducing the risk of trap loss.

Excessive effort was identified as a problem by over 40% of the respondents in both surveys. The problem is heightened in Florida with two accessible coastlines and fishermen using large numbers of traps. Gandy (2012) noted that many crab fishermen in Florida are highly mobile, fish large numbers of traps, and 'follow' the crabs not only from county to county, but also across the State (Gandy personal communication). Additional analysis of the 2013 Gulf-wide survey (data not shown) found that respondents from Florida more frequently reported excessive effort as a major problem than did the other states and this difference was statistically significant. The increasing practice of 'hot spot fishing' (crab fishermen from outside an area move in and saturate the area with traps when it is highly productive) can fish out an area leaving local harvesters with a depleted population. Once the crab catch drops, they retrieve their gear and move on to other areas along either the Gulf or Atlantic coast. The 'local' fishermen, who do not fish outside of the area, are left with crab numbers that may not be economically fishable (Gandy personal communication).

Less than one-quarter of respondents voiced concern over regulations, regulatory agencies, enforcement, and legislative interactions in the more recent survey.

#### 8.5.2.3 Other Issues in the Fishery

A series of devastating tropical storms and hurricanes occurred between the two survey periods that directly affected the fishery. Hurricane Katrina struck the Gulf Coast in August of 2005, heavily impacting fishing ports in parts of Mississippi, Louisiana, and Alabama. Two weeks later, Hurricane Rita made landfall along the central Louisiana coast. The economic loss to marine infrastructure Gulf-wide was estimated at $330M (IAI 2007). Boats, docks, processing establishments, icehouses, and restaurants were damaged or destroyed. In addition to infrastructure damage, labor was in short supply as well as the facilities in which to process the product if it could be harvested. The amount of debris in the near-shore fishing grounds was extensive and docks, marinas, and boat launches were inaccessible for months. Crab fishermen who removed their gear from the water prior to the storms making landfall to prevent loss, found many of their storage areas completely submerged with storm surge, resulting in an estimated loss of around 44,000 traps in Mississippi alone (Floyd personal communication). Following the storms, many fishermen, including crab harvesters, went to work for the Federal Emergency Management Agency (FEMA) removing storm debris and shoring up damaged residences across the affected area. These activities resulted in a temporary decline in commercial license sales.

### 8.6 Latent 'Inactive' License Holders

The number of licensed fishermen, Gulf-wide, continues to be substantially higher than the number of those believed to be the core of the actual fishing community. Effort in the commercial crab fishery in the Gulf has been difficult to quantify primarily because of a lack of reasonable participation estimates. In recent years, the states have begun to push for better effort data and with the implementation of trip tickets, they have achieved better resolution in the fishery. For example, in the state of Florida, prior to implementation of Florida's Blue Crab Effort Management Program (BCEMP) in 2008, the number of endorsements sold for blue crabs was 1,190. At the same time, the number of fishermen reporting crab landings on Florida trip tickets was 307; a discrepancy of 84%. In 2011, following the implementation of the BCEMP, those not reporting landings dropped to ~60% (Section 6.6.1, Table 6.11), but the gap between active and latent fishermen was still high. The 2013 socioeconomic survey addressed latency with the aim of identifying reasons for purchase of a commercial endorsement annually with no participation in the fishery.

An alternate set of questions was developed for those license holders who had not participated in the fishery over the last five years (Section 8.2). Inactive license holders were asked 17 separate questions specifically designed to address the reasons behind the license latency. At the beginning of the survey, a 'qualification' question about recent effort separated active from non-active fishermen. Neither group was aware that the alternate survey existed so the questions could be analyzed independently.

The number of licensed commercial crab harvesters in 2012 was 4,549 Gulf-wide. After name and address discrepancies were removed from the list, 4,347 potential respondents remained. The response rate for the whole survey was 10.3% (477 respondents). The response rate for the 'inactive' portion of the survey was considerably less at 0.02% (78 respondents) although latent license holders comprised 17% of the actual respondents. Once invalid forms were eliminated, 54 'inactive' fishermen were evaluated. While the low response rate made it impossible to expand the information past the respondent pool, the information provided is informative and offers insight into license latency.

### 8.6.1 General Description of Latent Respondents

Of those fishermen indicating they had latent licenses, 42 respondents reported the length of time they had owned a commercial license. Seven (35%) owned licenses for 10 years or less with the remaining fishermen holding their licenses between 11 and 35 years. Half of the respondents indicated they never used the license while 37% had stopped fishing only in the last five years. One individual owned the license but hadn't fished in nearly 30 years. When asked how many years they had actively fished before they stopped, 18 of the respondents fished 1-5 years with 10 reporting active participation between 6-25 years; nearly 22% had never fished.

The inactive respondents provided basic demographic information similar to the active fishermen. Of those who had not fished for crabs but continued to purchase a commercial license, nearly all were over 40 with the majority between 41 and 60 (37%). Most (81.5%) were married and identified themselves as 'Caucasian'. The remaining ~20% were split between Vietnamese and Native American (9.5% each) and all respondents were U.S. citizens. About 72% reported having at least a high school degree or the equivalent and some college education but not a college degree. Over half the survey participants (65%) skipped the 'family network' question, but of those that did, most had an immediate family member or friend active in the fishery even though they were not.

When asked about other commercial fishing activities, 62% of the respondents were active in other fisheries (shrimp 65.5%, oysters 10%, finfish 17%, and 'other' 34.5%). Thirty-eight percent of the respondents with latent licenses indicated no connection to other commercial fishing activities. For those participating in commercial fishing, the majority (52%) earned <10% of their income from fishing and 6 individuals (14%) reported 100%. Respondents (21 individuals) reported other income from multiple categories including (in order highest to least) construction, government, oil and gas, retail, and one each in education, municipalities, and public safety; 4 reported being retired.

When respondents were asked the reasons for their latency, about one-third indicated they were 'active in other fisheries' and another third confirmed that 'most commercial fishermen hold multiple licenses'. Thirteen percent indicated they had 'flexibility to switch species' and 16% said that crabs were a 'backup if their current fishery declined. Two respondents reported that they 'purchased a license as an investment for future resale' while 11 (36.7%) held an inactive license because they 'plan to crab when they retire'. The majority of the respondents (76%) indicated that there were no economic reasons for not harvesting crabs at this time. Of those who did report economic reasons (24%), the majority reported high fuel costs and dockside price as reasons to not utilize their license at the current time.

A total of 39 respondents replied to questions about their perception of overall health of blue crab populations and nearly 75% did not believe there were population issues that would prevent them from utilizing their license. Of the 25% that did feel there were problems with harvesting blue crabs, 8 respondents (80%) felt 'blue crab numbers seem low' and four (40%) believed there were 'too many environmental effects on blue crab populations' (answers were not cumulative). When asked to expand on their answers, one individual reported that blue crab populations have been low in his area the last few years and another indicated that the water had been too fresh for blue crabs.

Thirty-six license holders replied to questions about crab management. When asked if there were issues with current blue crab management preventing them from using their crab license, an overwhelming majority (92%) did not feel there were management issues in the fishery. The three who did have management concerns cited too many licenses, too many traps, and unfair pricing at the dock (supply and demand not driving the value – underpayment from buyers).

As in the 'active' fishing portion of the survey, questions were asked to specifically address satisfaction with the fishery and crab fishing in general. Of the 36 who responded to the question, the majority (53%) were 'neutral' to crab fishing as an occupation; eight individuals (22%) indicated dissatisfaction with the fishery as an occupation. When asked if they would return to commercial crab harvesting, 63% (22 respondents) indicated that they would, 37% (13) would not; this question did not separate individuals who had never fished or purchased the license as an investment however. When asked if they wanted their children to pursue commercial crab harvesting, nearly 75% indicated that they did not. A little more than 50% only considered crab harvesting as 'fair' for an occupation, 41% believed it was 'poor' and 'very poor'.

In summary, the respondents were split between commercial fishermen participating in other fisheries and simply owning a crab license as a fallback (62%) and those who purchased a license intending to commercially fish for crabs in the future or anticipating an investment value for a license that could be sold in the future. Most of the inactive crab license holders were middle-aged Caucasians and had purchased their license in the last ten years; a few had owned a license much longer (up to 25 years). A large proportion had never fished on their license and a number indicated they planned to fish in retirement.

## 9.0 MANAGEMENT GOALS, OBJECTIVES AND RECOMENDATIONS

This management plan is a comprehensive review of relevant aspects of the biology, ecology, and fisheries associated with blue crabs in the Gulf of Mexico. The plan provides a framework for resource management and maintenance of a sustainable fishery. The GSMFC used a Southeast Data Assessment and Review (SEDAR) process named herein as the Gulf Data Assessment and Review (GDAR) that resulted in a successful peer reviewed region-wide stock assessment and served as a platform for an initial exploration into the structural dynamics of the blue crab population in the Gulf of Mexico. The formalized GDAR process revealed complexities and resource interrelationships throughout the region that iterative benchmark assessments on a regular schedule will build upon and result in the eventual development of regional management reference points in future management plans. The term regional management is used herein to denote the inter-jurisdictional nature of the fishery and highlight the ongoing coordination and cooperation between state agencies in the Gulf of Mexico and is not intended to denote a need to further consolidate under a regional managing entity. The states have direct management authority over resources in state waters, but work in cooperation with each other on management plans through the GSMFC.

### 9.1 Definition of the Fishery

The fishery includes all harvesting activities for hard and soft blue crabs, (*Callinectes sapidus* Rathbun, 1896) conducted in the Gulf of Mexico. The blue crab, *C. sapidus*, comprises 100% of the hard and soft crab landings in the Gulf of Mexico fishery.

### 9.2 Management Unit(s)

The GDAR process investigated the appropriateness of developing regional assessment of the blue crab fishery within the Gulf of Mexico (GOM). The resulting 2013 stock assessment (GDAR01 – VanderKooy 2013) was a successful first attempt to investigate regional assessment by dividing the fishery into two management units based upon information presented in Section 3.2.1.2; a Florida or 'Eastern GOM stock' unit (peninsular Florida to Apalachee Bay with a geographic center in Tampa Bay), and a 'Western GOM stock' unit (south Texas to Apalachicola Bay with a geographic center in Louisiana). The management units used in the GDAR01 provided for a successful peer reviewed benchmark assessment and a proof of concept for regional assessment. The assessment was unsuccessful in providing the structure for the development of regional management strategies. Clear and defensible management units must be developed before the GSMFC's FMP achieves its ultimate goal of developing regional management strategies for the blue crab fishery in the Gulf of Mexico.

### 9.3 Status of the Stock(s)

***Gulf Data Assessment and Review 2013***

The blue crab, *Callinectes sapidus,* has the broadest latitudinal distribution of all the *Callinectes* species, ranging from Nova Scotia and Maine to northern Argentina and is found throughout the US Gulf of Mexico. Based on tagging and genetic investigations, the potential for two management units was investigated by the GDAR01 for the Gulf of Mexico: a Florida or 'Eastern GOM stock' occurring along the Florida peninsula to Apalachee (centered in Tampa Bay), and a 'Western GOM stock' occurring from south Texas to Apalachicola Bay (centered in Louisiana). A similar population separation was suggested for red snapper by Johnson et al. (2009 and 2013) who found that red snapper larval transport across the northern Gulf of Mexico from west to east was complicated by topographic impediments to the along-shelf flow that included the Apalachicola Peninsula. They noted that there "seems to be a natural population break near Florida's Apalachee Bay", just east of Apalachicola Bay in the panhandle region. This two-unit population structure was quantitatively analyzed to examine the status of the Western and Eastern GOM stocks through 2011.

Total reported commercial blue crab landings in the Gulf have increased from less than one million pounds in the late 1800s when landing statistics were first collected, to approximately 18M lbs prior to World War II. Landings increased markedly in the late 1950s with introduction of the wire trap that replaced traditional trotlines by the mid-1960s. The increased availability of raw product associated with adoption of the wire trap stimulated processing capacity and market development, and landings continued to rise through the 1980s. Record landings of 78M and 79M lbs occurred in 1987 and 1988, respectively. Although landings continue to fluctuate, a general downward trend in Gulf-wide landings began in 2000 and continued through 2010. Natural and anthropogenic events as well as changes in management measures have contributed to fluctuations in landings.

Fishery-independent estimates of abundance for both juvenile and adult stocks have shown either decreasing or steady trends throughout the last two decades while commercial landings have declined. The Western GOM stock has undergone a strong decline in juvenile abundances since the mid-1980s and a decline in adult abundances from the mid-1980s until the mid-1990s, after which catch has remained relatively stable. Eastern GOM stock adult abundances have shown a similar trend (declining through the mid-1990s and stable since), while the juvenile abundance has been relatively stable since the late 1980s. In both stocks, the abundances have experienced substantial variability from year-to-year, and in the case of the Eastern GOM stock, these abundances typically peaked in years following high rainfall.

In the regional assessment (GDAR01 - VanderKooy 2013), two separate modeling approaches were used to address the Gulf of Mexico stocks. The primary model was a modified catch-survey analysis similar in structure to those used in previous blue crab stock assessments (Florida, Texas, Louisiana, Chesapeake, and Delaware), while the supporting model was a surplus production model. The estimated MSY from the base model configuration was 164.0M individuals for the 'Western GOM stock' and 23.0M individuals for the 'Eastern GOM stock', where fisheries on both stocks have landed less than the MSY for the majority of the time series. The 'Western GOM stock' experienced overfishing in 1999 and 2002, while the 'Eastern GOM stock' experienced overfishing in 1996 and 1998. The base model found that both stocks are currently not overfished nor are they undergoing overfishing. The population abundance in the Eastern and Western GOM stocks are currently approximating the optimal abundance for achieving MSY, however the assessment model indicated that in the last few years, the Western GOM stock has been slightly lower than that optimal abundance.

The GDAR01 was a successful peer reviewed region wide stock assessment and served as a platform for an initial exploration into the structural dynamics of the blue crab population in the Gulf of Mexico. This assessment was unable to provide sufficiently defensible relationships for the development of fisheries management goals. The regional complexities within the fisheries and resource interrelationships require further investigation and assessment throughout the region in regular benchmark assessments intended to build upon each other and result in the eventual development of regional management reference points in future management plans.

### 9.4 Management Goals

Management of the blue crab fishery in the Gulf of Mexico lacks coordinated monitoring and management across the fishery due to its segregation into the jurisdictions of five states. The GDAR01 assessment revealed that the population of blue crabs in the Gulf of Mexico crosses state lines and jurisdictions and is a potential candidate for regional assessment and management. Prior to the next benchmark assessment there is a critical need to develop a clear and defensible stock structure to determine if the Gulf of Mexico should be managed as a single or mixed stock. The first management goal is to develop justifiable fisheries management units based on population distributions.

The GDAR01 assessment expressed specific concern over the Gulf-wide trend in decreasing biomass in recent decades. The trend is suggestive of a population level response to changing hydrologic cycles which have the potential to incrementally force the fishery into overfishing. One goal is to develop assessments that include climatic drivers that affect abundance within management regions. A second goal is for routine assessments that include regional climate trends that are associated with stock abundance and would allow for adjustments of management reference points in a timely manner. Timely assessment and management would result in sustained economic viability in the fishery as regional climatic regimes fluctuate through wet and dry cycles.

### 9.5 Management Objectives

1. Update the Gulf-wide stock assessment for blue crabs in the Gulf of Mexico on a three-year cycle.
2. In 2015 begin to:
   a) Evaluate the impact of ecosystem variables on population dynamics to better understand the influence of environmental factors on regional population abundances.
   b) Improve the coordination of basin-wide monitoring and research to ascertain the linkages between fluctuating climatic regimes and the population dynamics of the stock.
   c) Evaluate the quality, consistency, and coverage of existing fisheries-independent data for use in regional stock assessments.
   d) Investigate and describe the socio-economic changes in the fishery.
   e) Determine how the economics of the fishery functions to self-regulate effort when abundance fluctuates.
   f) Develop justifiable fisheries management units based on the stock status of blue crab fisheries resources in the management regions using comprehensive assessment techniques to estimate population parameters and biological reference points that

include the driving forces of climate with those regions.

3. By 2020, perform a benchmark assessment of blue crabs in the Gulf of Mexico using the ‘current understanding’ of applicable management units.
4. By 2023, the GSMFC should have begun working with the states to refine regional management of the fishery.

### 9.6 Recommendations

Current levels of abundance, as documented in the GDAR01 assessment, are sufficient for maintaining MSY in eastern and western stocks. There is concern, however, that the populations have been in the process of undergoing changes in biomass since the last assessment, possibly due to global and annual climate regime shifts that affect hydrology in the Gulf of Mexico. Management strategies for maintaining long term sustainability of the fishery may be altered if populations continue to decline. More frequent assessments should be undertaken in the form of updates to the GDAR01 assessment every three years to provide continuity between benchmark assessments in order to continue to investigate the fishery in light of contemporary issues and the appropriateness of regional management of the fishery. To achieve these aforementioned goals and objectives the following items are recommended prior to the next benchmark assessment.

#### 9.6.1 Management of the Fishery

The current level of management in this fishery is adequate to maintain status quo based on the data currently available to the assessment (GDAR01). Through the entire assessment and management plan revision, the Task Force has determined that no additional management measures are necessary. The population dynamics that underlie the fishery are tied more to ongoing climate regimes than effort. Therefore, ongoing monitoring programs need to be continued and enhanced to increase the resolution of future stock assessments and FMPs.

1. Recommend no changes to current management scenarios are necessary based on the assessment results but monitoring should be continued or enhanced in each state.
2. Recommend monitoring abundance closely because the (current $N/N_{MSY}$) benchmark for the western stock indicated an overfished status in the terminal year.

#### 9.6.2 Fishery-Dependent Data

Gulf-wide there is a specific need to improve fishery-dependent data collection across Gulf of Mexico states through the standardization of data collection methods and the coordination amongst agencies and researchers to develop Gulf-wide data sets collected over the same temporal scales.

1. Commercial
   a) Recommend the states improve the trip level effort data from trip tickets across the Gulf of Mexico to better describe commercial effort.
   b) Recommend that the states conduct bio-statistical sampling of commercial catch (i.e.

size and sex) to provide for sex-based stock assessment.

2. Recreational
   a) Recommend the states collect landings (by state)
   b) Recommend the states determine catch composition (number, size, sex, capture methods)
   c) Recommend the states determine participation rates and effort.
3. By-catch/Incidental catch in other fisheries
   a) Recommend the states determine effort in the commercial shrimp fishery and collect associated crab by-catch data on catch composition (number, size, sex) and evaluate crab moralities from all other fisheries.

### 9.6.3 Fishery-Independent Data

Prior to the next benchmark assessment there is a need to evaluate and develop a clear and defensible stock structure to determine if the Gulf of Mexico should be managed as a single or mixed stock. Institute fishery monitoring programs in each state to characterize crabs entering the fishery (size, sex, number of ovigerous females, abundance), monitor CPUE, and assess health of the population. There is a specific need for a coordinated Gulf-wide fishery-independent index to monitor spawning stock biomass within state boundaries or within regional subdivisions of the stock. Continued investigation of the SEAMAP data set for these purposes should be pursued to determine the effectiveness of these data for informing a future assessment. The extent to which an individual state's stock dynamics are affected by larval transport, migration, and fisheries in other Gulf states or countries is unknown at this time and should be a high priority for future blue crab research. A coordinated research program utilizing academic, federal, and state scientists needs to be developed to address the stock structure of blue crabs in the Gulf of Mexico through modeling based on Gulf-wide hydrodynamic, genetic and mark-recapture studies. In addition to determining the stock structure of blue crab subpopulations in U.S. waters, the role of subpopulations along the Mexican coast needs to be investigated. To these ends the following fishery-independent data items are presented:

1. Spawning stock
   a) Recommend the states monitor adult female crab abundance in the near shore Gulf waters.
2. Spawning sources, larval linkages, juvenile sources and population sinks
   a) Recommend the states determine primary spawning regions important for preserving the stock including:
      i. Spatial and temporal distribution of spawning.
      ii. Larval transport modeling.
      iii. Genetic parentage to link spawners to recruits.
3. Stock recruit relations
   a) Recommend the states investigate/confirm/modify stock-recruitment relationships and recruitment indices based on regions and climate.
   b) Recommend the states reformulate the stock recruit relationship, if necessary, based on the following:
      i. investigations of stock structure throughout the Gulf of Mexico,

    ii. determination of the role of environmental drivers upon the stock recruit relationship,
    iii. assessment of the most reliable surveys to estimate spawning stock and recruitment throughout the Gulf.
4. Migration studies
    a) Recommend the states conduct a Gulf-wide tagging study coordinated among the states to determine adult migratory patterns.
5. Diets and predation (for ecosystem based assessment modeling)
    a) Recommend the states determine blue crab diet by region and habitat.
    b) Recommend the states determine predators on blue crabs (e.g. FWRI Finfish Gut Lab).
6. Recommend the states examine the contribution of offshore low density populations (SEAMAP data) to spawning stock.
7. Recommend the states improve, increase, and standardize fishery-independent monitoring of all life-history stages and institute more frequent population assessments to better detect changes in abundance.
8. Recommend the states monitor parasites and diseases known to affect blue crab development and survival.

### 9.6.4 Environment and Population Abundance

Essential marine/estuarine habitats of the Gulf of Mexico have undergone dramatic changes. Mississippi Sound lost nearly 25% of their coastal wetlands between 1956 and 2007. Habitat conservation, protection, access, and restoration are essential to the maintenance and stability of the fishery. It is important to support those programs that identify, preserve, and restore essential blue crab habitat and assess and discourage projects which negatively alter or pollute blue crab habitat, or impede access by crabs to essential habitats. Investigations into the habitat, environment and hydrodynamic drivers of demographic changes in blue crab populations are needed throughout the Gulf of Mexico. In addition, the GSMFC's TCC Habitat Subcommittee has not been able to meet regularly and be as active as they would like since the dissolution of the joint relationship with the Gulf of Mexico Fisheries Management Council in 2012. The Subcommittee traditionally reviewed and provided monitoring of habitat related projects, etc. and report to the Commission on issues of concern within the region.

1. Recommend the states develop a better understanding of the role of global and annual climate regime shifts in determining suitable habitat and the effects on population abundances in the Gulf of Mexico.
    a) Develop a quantitative understanding of the relationship between habitat, environment and blue crab abundance.
    b) Establish the relationship between stream flow and changes in population abundance.
    c) Determine effect of managed water releases on populations.
2. Recommend the states reassess the status of the GSMFC's Habitat Subcommittee, if warranted, seek additional support and funding for the Subcommittee to address issues related to habitat and habitat loss in the Gulf of Mexico affecting marine fisheries.

### 9.6.5 Stock Status and Assessment

One of the items noted by the reviewers of GDAR01 was the degree to which an individual state's stock dynamics are affected by larval transport, migration, and fisheries in other Gulf states or countries is at this time and should be a high priority for future blue crab research. The reviewers agreed with the recommendations in the GDAR01 report that the 'western' and 'eastern' divide used to partition stocks did not adequately account for differences between climatic sub regions along the Gulf of Mexico coastline. Refinement of a spatially explicit two stage model will help further define the stocks along alternate climatic eco-zones (Twilley et al. 2001; Section 3.2.9.1.4) that provides a more suitable breakdown of the Gulf of Mexico blue crab populations and enables a more thorough analysis of any environment effects.

1. Recommend the states refine the spatially explicit two stage model used in GDAR01.
2. Recommend that prior to the next assessment the states define alternative management units for regional assessments based on sub-climate regions and their relation to blue crab productivity.
3. Recommend the states explore implementation of a sex-specific stock assessment.

**9.6.6 Socioeconomic**

The first studies to characterize the social structure of the commercial blue crab fishery along the Gulf of Mexico focused on 'fishing' villages in the 1970s within individual states. Included in the last revision of the Blue Crab FMP (Guillory et al. 2001), was a 1998 Gulf-wide survey of fishery participants that captured an updated snapshot of the fishing community. The development of a contemporary understanding of both social and economic factors that impact fishing communities and the changes in fishing practices that result is essential to comprehensive and adaptable fisheries management.

The Magnuson Fishery Conservation and Management Act and subsequent reauthorizations (Mag-Stevens) have laid out ten national standards for fishery conservation and management which guide how many of the U.S. fisheries, federal and state, are managed (See Section 5.1.3.1). National Standard 8 provides guidance on the prevention of overfishing and rebuilding of overfished stocks, taking into account the importance of fishery resources to fishing communities in order to:

a) provide for the sustained participation of such communities, and
b) to the extent practicable, minimize adverse economic impacts on such communities.

Thus, the need for baseline socioeconomic data is critical to effectively manage fisheries such as blue crabs where effort and harvest are the only tangible variables that the state management agencies can control when recruitment and populations are environmentally driven.

The age composition of Gulf of Mexico crab fishermen is skewed towards older and approaching retirement age. Any regulations that seek to limit entry or reduce effort should factor in the coming wave of retirements. In addition, there are significant differences between those who crab 'full time' (50% or more of income from blue crab) than those who crab 'part time' (less than 50% of income from blue crab). Full timers are older and have been in the fishery longer.

Part timers depend on fishing a variety of species from different fisheries depending on abundance and value. If limited entry or effort reduction programs are needed, future regulations should be particularly sensitive to these blue crab dependent fishing communities. There are communities across the Gulf where over 90% of fishery income is derived from blue crab harvesting. Particularly restrictive policies may disproportionately impact these communities. Therefore, some effort should be made to develop an information system to profile crabbers, their economic activities, attitudes, and economic well-being. Collecting data on a once per decade basis is not sufficient to monitor how regulations and conditions are impacting those who are dependent on the resource.

In addition to improved socioeconomic data collection, efforts are also needed to differentiate the Gulf of Mexico blue crab from the other portunid crab products (import and non-Gulf domestic) in the commodity market in light of the increase in U.S. annual per capita consumption of fish and shellfish over the last century. Creating a recognizable 'Gulf' brand for crabs may improve the financial performance of blue crab businesses in the Gulf and create a premium market similar to Gulf shrimp. The need for such initiatives are supported in Section 7 and 8. These sections present the concerns raised by harvesters about the flooding and dumping of foreign crabmeat into the U.S. and the supporting evidence related to the decrease in the number of domestic processors and the historical quantities of imported of crabmeat, respectively.

1. Recommend the states analyze economic contribution of the recreational component to provide information that can be used for improved management. The economic contribution of the recreational component of the Gulf of Mexico blue crab fishery is lacking.
2. Recommend that the states analyze the economic performance and contribution of the commercial component to provide information for improved management. Data and analysis related to the economic performance and contribution of the commercial blue crab fishery in the Gulf are lacking.
3. Recommend the states develop more complete social characterizations of the individuals involved in the blue crab fishery and how they will be affected by potential regulatory measures. The process could provide another avenue for crab fishermen input into the regulatory process as they are the most impacted by management efforts.
4. Recommend that the states develop an economic development initiative for the Gulf of Mexico commercial blue crab fishery in an effort to create a niche market by differentiating Gulf blue crab products from other commoditized crab products. Any economic development initiative should include a multifaceted approached by including the following:
   a) product quality,
   b) marketing,
   c) electronic traceability,
   d) origin, and
   e) sustainability.

## 10.0 REGIONAL RESEARCH PRIORITIES AND DATA REQUIREMENTS

There is a demonstrated need for a regional approach to both management and research based on blue crab life history characteristics and interstate transport of raw and finished product. Attainment of the goal and objectives as defined in this plan will require longrange planning, coordination, and funding for interstate research programs and standardized, Gulfwide fishery independent and fishery dependent data collection programs. These categories do not reflect any order of priority.

### 10.1 Biological/Ecological

1. Determine the relationship between planktonic availability of megalopae and settlement;

2. Determine the relationship between megalopal settlement and subsequent juvenile abundance;

3. Assess the effects of environmental variables on growth, size, and maturity;

4. Identify essential juvenile blue crab habitats;

5. Investigate adult migration patterns;

6. Quantify factors contributing to natural mortality (predation, environmental factors, parasites, and diseases);

7. Identify sources of environmental degradation and the impact of habitat alteration on all phases of blue crab life history;

8. Determine the effect of rhizocephalan infection (*Loxothylacus texanus*) on growth, reproduction, mortality, and size at maturity;

9. Determine size at 50% and 100% sexual maturity; determine fecundity and viability of embryos in second and third egg clutches;

10. Determine impacts of coastal restoration projects (marsh management, freshwater diversion, etc.) on blue crabs.

### 10.2 Fisheries Related

1. Develop fishery-dependent collection programs to obtain more reliable data including the quantity of catch, size and sex composition of the catch, gear type and units, days fished, areas fished, and disposition of catch;

2. Determine the effects of trap capture and onboard culling on mortality and growth;

3. Quantify nondirected fishing mortality and develop protocols for bycatch separation using salt boxes;

4. Obtain catch and effort data in the recreational fishery;

5. Establish standardized Gulf-wide sampling programs to obtain fishery-independent data on size and weight, sex, maturity, parasitic infection, and molt cycle stage;

6. Review and expand monitoring where necessary to more accurately evaluate fluctuations in juvenile abundance indices;

7. Add a blue crab component to the Marine Recreational Information Program/Access Point Angler Surveys (MRIP/APAIS).

## 10.3 Industrial/Technological

1. Develop suitable alternatives to traditional crab baits;

2. Obtain data correlating meat yield with size, sex, and season;

3. Encourage research to develop alternative uses for crab processing waste.

## 10.4 Economic/Social

1. Determine the economic impact of existing and proposed management regulations on the processing and harvesting sectors;

2. Determine economic impact of the commercial crab fisheries on small fishing communities;

3. Determine the economic multipliers of the commercial hard crab, soft crab, and recreational fisheries;

4. Obtain data on sociological and cultural effects of changes in the blue crab fishery;

5. Obtain commercial crab harvester cost-earning economic data to determine economic performance and contribution;

6. Obtain commercial crab dockside dealer and processor cost-earning economic data to determine economic performance and contribution;

7. Obtain recreational crabber economic data to determine expenditures and economic contribution.

## 11.0 REVIEW AND MONITORING OF THE PLAN

As needed, status of the stock, condition of the fishery and habitat, effectiveness of management regulations, and research efforts will be reviewed. Results of the review will be presented to the TCC and the S-FFMC for approval and recommendation to the GSMFC and the appropriate management authorities in the Gulf states.

The GSMFC, the NMFS, states, and universities should document their efforts at plan implementation and review these with the S-FFMC. The S-FFMC will also monitor each state's progress with regard to implementing recommendations in Section 9.0 on an annual basis.

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## 13.0 APPENDICES

### 13.1 Glossary of Terms

Modified from: Roberts et al. 1994,Wallace et al. 1994.

## A

**Abundance** - See relative abundance and absolute abundance.

**Allele** – One member of a pair (or any of the series) of genes occupying a specific spot on a chromosome (called locus) that controls the same trait.

**Allocation** - Distribution of the opportunity to individuals among user groups or individuals. The share a user group gets is sometimes based on historic harvest amounts.

**Allozyme** – Variant of an enzyme coded by a different allele.

**Annual Mortality (A)** - The percentage of individuals dying in one year due to both fishing and natural causes.

**Aquaculture** - The raising of fish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used. Feed is often used.

**Availability** - Describes whether a certain sized individual can be caught by a type of gear in an area.

## B

**Bag Limit** - The number and/or size of a species that a person can legally take in a day or trip. This may or may not be the same as a possession limit.

**Benthic** - Refers to organisms that live on or in the water bottom.

**Biomass** - The total weight or volume of a species in a given area.

**Bycatch** - The harvest of fish or shellfish other than the species for which the fishing gear was set. Example: blue crabs caught in shrimp trawls. Bycatch is also often called incidental catch. Some bycatch is kept for sale.

## C

**Catch** - The total number or poundage of individuals captured from an area over some period of time. This includes individuals that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the individuals are landed. Note: Catch, harvest, and landings are different terms with different definitions.

**Catch Per Unit of Effort (CPUE)** - The number of individuals or poundage caught by an amount of effort. Typically, effort is a combination of gear type, gear size, and length of time gear is used. Catch per unit of effort is often used as a measurement of relative abundance for a particular organism.

**Cohort (Modal Group)** - A group of individuals spawned during a given period.

**Commercial Fishery** - A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses directly or indirectly involved in harvesting, processing or sales.

**Common Property Resource** - A term that indicates a resource owned by the public. The government regulates the use of a common property resource to ensure its future benefits.

**Compensatory Growth** - An increase in growth rate shown by fish when their populations fall below certain levels. This may be caused by less competition for food and living space.

**Compensatory Survival** - A decrease in the rate of natural mortality (natural deaths) that some fish show when their populations fall below a certain level. This may be caused by less competition for food and living space.

**Condition** - A mathematical measurement of the degree of plumpness or general health of a fish or group of fish.

**Confidence Interval** - The probability, based on statistics, that a number will be between an upper and lower limit.

## D

**Directed Fishery** - Fishing that is directed at a certain species or group of species. This applies to both sport fishing and commercial fishing.

**Disappearance (Z')** - Measures the rate of decline in numbers of fish caught as fish become less numerous or less available. Disappearance is most often calculated from catch curves.

**Discarded Catch** – The portion of the catch returned to the sea because of regulatory, economic, or personal considerations.

## E

**Economic Efficiency** - In commercial fishing, the point at which the added cost of producing a unit of crabs is equal to what buyers pay. Harvesting at the point of economic efficiency produces the maximum economic yield.

**Economic Overfishing** - A level of harvesting that is higher than that of economic efficiency; harvesting more than is necessary to have maximum profits for the fishery.

**Economic Rent** - The total amount of profit that could be earned from a fishery owned by an individual. Individual ownership maximizes profit, but an open entry policy usually results in so many fishermen that profit higher than opportunity cost is zero. See maximum economic yield.

**Effort** - The amount of time and fishing power used to harvest a species. Fishing power includes gear size, boat size, and horsepower.

**Environmental Impact Statement (EIS)** - An analysis of the expected impacts of a fisheries management plan (or some other proposed action) on the environment.

**Escapement** - The percentage of fish in a particular fishery that escape from an inshore habitat and move offshore, where they eventually spawn.

**Ethnicity** – The cultural factors such as nationality, ancestry, language and beliefs with which someone identifies themself.

**Euryhaline** - Organisms that live in a wide range of salinities.

**Ex-vessel** - Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain for the catch is an ex-vessel price.

**Exclusive Economic Zone (EEZ)** - All waters from the seaward boundary of coastal states out to 200 nautical miles. This was formerly called the Fishery Conservation Zone.

## F

**F** - See fishing mortality

**Fmax** - The level of fishing mortality (rate of removal by fishing) that produces the greatest yield from the fishery.

**Fecundity** - A measurement of the egg-producing ability of an organism. Fecundity may change with the age and size of the crab.

**Fishery** - All activities involved in catching a species or group of species.

**Fishery Conservation Zone (FCZ)** - The area from the seaward limit of state waters out to 200 miles.

The term is used less often now than the current term, exclusive economic zone.

**Fishery-Dependent Data** - Data collected on an organism or fishery from sport fishermen, commercial fishermen, and seafood dealers.

**Fishery-Independent Data** - Data collected on an organism by scientists who catch the organisms themselves, rather than depending on fishermen and seafood dealers.

**Fishery Management Plan (FMP)** - A plan to achieve specified management goals for a fishery. It includes data, analyses, and management measures for a fishery.

**Fishing Effort** - See effort.

**Fishing Mortality (F)** - A measurement of the rate of removal of organisms from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of organisms dying in one year. Instantaneous is the percentage of organisms dying at any one time. The acceptable rates of fishing mortality may vary from species to species.

## G

**Growth** - Usually an individual's increase in length or weight with time. Also may refer to the increase in numbers of individuals in a population with time.

**Growth Model** - A mathematical formula that describes the increase in length or weight of an individual with time.

**Growth Overfishing** - When fishing pressure on smaller individuals is too heavy to allow the fishery to produce its maximum poundage. Growth overfishing, by itself, does not affect the ability of a population to replace itself.

## H

**Harvest** - The total number or poundage of individuals caught and kept from an area over a period of time. Does not include organisms caught and released. Catch includes the number or poundage caught whether kept or released.

## I

**Incidental Catch** - See bycatch.

**Instantaneous Mortality** - See fishing mortality, natural mortality, and total mortality.

**Intrinsic Rate of Increase (z)** - The change in the amount of harvestable stock. It is estimated by recruitment increases plus growth minus natural mortality.

**Isopleth** - A method of showing data on a graph which is commonly used in determining yield-per-recruit.

## J

**Juvenile** - A young individual that has not reached sexual maturity.

## L

**Landings** - The number or poundage of crabs unloaded by commercial fishermen or brought to shore by recreational fishermen for personal use within a geographic area. Landings are reported at the points at which crabs are sold or brought to shore.

**Latency** – A state of inactivity.

**Latent License** – A commercial harvesting license or permit which is not actively fished or fishery landings are not attributed to for a period of at least one year.

**Limited Entry** - A program that changes a common property resource like crabs into private property for individual fishermen. License limitation and the individual transferable quota (ITQ) are two forms of limited entry.

**Length Frequency** - A breakdown of the different lengths of a kind of fish in a population or sample.

**Length-Weight Relationship** - Mathematical formula for the weight of a fish in terms of its length. When only one is known, the scientist can use this formula to determine the other.

**Limited Entry** - A program that changes a common property resource like fish into private property for individual fishermen. License limitation and the ITQ are two forms of limited entry.

## M

**M** - See natural mortality.

**MSY** - See maximum sustainable yield.

**Mariculture** - The raising of marine species under some controls. Ponds, pens, tanks, or other containers may be used, and feed is often used.

**Mark-Recapture** - The tagging and releasing of crabs to be recaptured later in their life cycles. These studies are used to examine movement, migration, mortality, and growth, and to estimate population size.

**Maximum Sustainable Yield (MSY)** - The largest average catch that can be taken continuously (sustained) from a stock under average environmental conditions. This is often used as a management goal.

**Mean** - Another word for the average of a set of numbers. Simply add up the individual numbers and then divide by the number of items.

**Microsatellite** – A section of DNA consisting of very short nucleotide sequences repeated many times, the number of repeats varying between members of the species: used as a marker in determining genetic diversity, identifying important genetic traits, and in forensics, population studies, and paternity studies.

**Model** - In fisheries science, a description of something that cannot be directly observed. Often a set of equations and data used to make estimates.

**Morphometrics** - The physical features of a species, for example, coloration.

**Multiplier** - A number used to multiply a dollar amount to get an estimate of economic impact. It is a way of identifying impacts beyond the original expenditure. It can also be used with respect to income and employment.

## N

**National Standards** - The Fishery Conservation and Management Act requires that a fishery management plan and its regulations meet seven standards.

**Natural Mortality (M)** - A measurement of the rate of removal of individuals from a population from natural causes. Natural mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of individuals dying in one year. Instantaneous mortality is the percentage of individuals dying at any one time. The rates of natural mortality may vary from species to species.

## O

**Open Access Fishery** - A fishery in which any person can participate at any time.

**Opportunity Cost** - An amount a fisherman could earn for his time and investment in another business or occupation.

**Optimum Yield (OY)** - The harvest level for a species that achieves the greatest overall benefits, including economic, social, and biological considerations. Optimum yield is different from maximum sustainable yield in that MSY considers only the biology of the species. The term includes both commercial and sport yields.

**Overfishing** - Harvesting at a rate equal to or greater than that which meet the management goal.

## P

**Pelagic -** Refers to organisms that live in the water column in the open sea.

**Population** - Individuals of the same species inhabiting a specified area.

**Population Dynamics** - The study of populations and how fishing mortality, growth, recruitment, and natural mortality affect them.

**Possession Limit** - The number and/or size of a species that a person can legally have at any one time. Refers to commercial and recreational fishermen. A possession limit generally does not apply to the wholesale market level and beyond.

**Predator -** A species that feeds on another species. The species being eaten is the prey.

**Predator-Prey Relationship** - The interaction between a species (predator) that eats another species (prey).

**Prey -** A species being fed upon by another species. The species eating the other is the predator.

**Primary Productivity** - A measurement of plant production that is the start of the food chain. Much of the primary productivity in marine or aquatic systems is made up of phytoplankton (tiny one-celled algae that float freely in the water).

# Q

**Quota** - The maximum number or weight of individuals that can be legally landed in a time period. It can apply to the total fishery or an individual fisherman's share.

# R

**Race** – The biological or genetic traits of a person or group of people that are passed down from the parents.

**Recreational Fishery -** Harvesting for personal use, fun, and challenge. Recreational fishing does not include sale of catch. The term refers to and includes the fishery resources, fishermen, and businesses providing needed goods and services.

**Recruit -** An individual that has moved into a certain class, such as the spawning class, modal group, or fishing-size class.

**Recruitment** - A measure of the number of individuals that enter a class during some time period, such as the spawning class or fishing-size class.

**Recruitment Overfishing** - When excessive mortality of the spawning stock does not allow a population to replace itself.

**Regression Analysis** - A statistical method to estimate any trend that might exist among important factors. An example in fisheries management is the link between catch and other factors like fishing effort and natural mortality.

**Relative Abundance** - An index of population abundance used to compare populations from year to year. This does not measure the actual numbers of individuals, but shows changes in the population over time.

**Rent -** See economic rent.

**Rookie** - A person who has just started a job or activity and has little experience.

# S

**s -** See survival rate.

**Satisfaction** – An individual's attitude regarding their contentedness with his or her job.

**Selectivity -** The ability of a type of gear to catch a certain size or kind of individual, compared with its ability to catch other sizes or kinds.

**Size Distribution -** A breakdown of the number of individuals of various sizes in a sample or catch. The sizes can be in width, length, or weight.

**Social Impacts** - The changes in people, families, and communities resulting from a fishery management decision.

**Socioeconomics** - A word used to identify the importance of factors other than biology in fishery management decisions. For example, if management results in more fishing income, it is important to know how the income is distributed between small and large boats or part-time and full-time fishermen.

**Spawner-Recruit Relationship** - The concept that the number of young individuals (recruits) entering a population is related to the number of parents (spawners).

**Species** - A group of similar organisms that can freely interbreed.

**Standing Stock** - See biomass.

**Stock** - A grouping of individuals usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit.

**Stock-Recruit Relationship** - See spawner-recruit relationship.

**Surplus Production Model** - A model that estimates the catch in a given year and the change in stock size. The stock size could increase or decrease depending on new recruits and natural mortality. A surplus production model estimates the natural increase in weight or the sustainable yield.

**Survival Rate (s)** - The number of individuals alive after a specified time, divided by the number alive at the beginning of the period.

# T

**Territorial Sea** - The area from average low-water mark on the shore out to three miles for the states of Louisiana, Alabama, and Mississippi, and out to nine miles for Texas and the west coast of Florida. The shore is not always the baseline from which the three miles are measured. In such cases, the outer limit can extend further than three miles from the shore.

**Total Mortality (Z)** - A measurement of the rate of removal of individuals from a population by both fishing and natural causes. Total mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of individuals dying in one year. Instantaneous mortality is that percentage of individuals dying at any one time. The rate of total mortality may vary from species to species.

**Trip Interview Program (TIP)** - A cooperative state-federal commercial fishery dependent sampling activity conducted in the Southeast region of NMFS, concentrating on size and age information for stock assessments of federal, interstate, and state managed species. TIP also provides information on the species composition, quantity, and price for market categories, and catch-per-unit effort for individual trips that are sampled.

# U

**Underutilized Species** - A species of fish that has potential for large additional harvest.

**Unit Stock** - A population of fish grouped together for assessment purposes which may or may not include all the fish in a stock.

# V

**Veteran** - A person who has had long experience in a particular field.

**Vicariance** - A process by which the geographical range of an individual taxon, or a whole biota, is split into discontinuous parts by the formation of a physical barrier to gene flow or dispersal.

**Virgin Stock** - A stock of fish with no commercial or recreational harvest. A virgin stock changes only in relation to environmental factors and its own growth, recruitment, and natural mortality.

**Virtual Population Analysis (VPA)** - A type of analysis that uses the number of individuals caught at various ages or lengths and an estimate of natural mortality to estimate fishing mortality in a cohort. It also provides an estimate of the number of individuals in a cohort at various ages.

## W

**Width Frequency** - A breakdown of the different carapace widths of individuals in a population or sample. Size in crabs is usually given as carapace width, the distance from point to point between the long lateral spines.

**Width-Weight Relationship** - Mathematical formula for the weight of an individual in terms of its width. When only one is known, the scientist can use this formula to determine the other.

## Y

**Year-Class** - Individuals spawned and hatched in a given year.

**Yield** - The production from a fishery in terms of numbers or weight.

## Z

**z** - See intrinsic rate of increase.

**Z** - See total mortality.

**Z'** - See disappearance.

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**Appendix 13.2**

# Commercial Blue Crab Survey

Thank you for participating in our update of the Commercial Blue Crab fishery Social Survey we originally conducted Gulf-wide in 1999. We are working in conjunction with the five Gulf States' marine resource agencies in an effort to characterize the changes that have occurred in the fishery over the past decade.

The purpose of this research is to assess the health of the commercial blue crab industry and evaluate the role that fishing has had on the broader Gulf community. The information collected will be used to determine how the crab fishery has been impacted from internal and external changes to the environment, local and global economies, and natural and manmade disasters. The data will also allow us to determine how the fishing workforce has changed in the last decade. Results from this survey will be included in the revision to our regional management plan for the blue crab fishery of the Gulf of Mexico.

For this survey to be accurate and representative, your participation in this process is critical. It is important that each license holder complete the survey as truthfully as possible. You may be assured of complete confidentiality -- your name will not be recorded and no information will be asked that can identify individuals.


*Your decision to be included in this research is voluntary and, if you participate, there is no compensation; however, your submission will qualify you for a* ***$250 gift card*** *drawing which will take place April 2, 2013.*

To qualify, just return this survey to your respective state agency office when you are finished or mail directly to:

Steve VanderKooy
Interjurisdictional Fisheries Program Coordinator
Gulf States Marine Fisheries Commission
2404 Government St.
Ocean Springs, MS 39564

Thanks again for your participation.

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## COMMERCIAL BLUE CRAB SURVEY

*With pencil or pen, please darken all boxes that apply:* 1-5 *(For computer scoring)*

For this survey to be accurate and representative, your participation in this process is critical. It is important that each blue crab harvesting license holder complete the survey as accurately as possible. You may be assured of complete confidentiality – your name will not be recorded and no information will be asked that can identify individuals. Thank you for your assistance in helping us address the commercial harvesting needs in the U.S. Gulf of Mexico blue crab harvesting industry.

- Once you've completed the survey, please tear off the back page and either mail it to us or register on our website for a chance to win a $250 cash card for participating. The drawing will be Tuesday, April 2, 2013 and the winner will be notified by e-mail.

**Section A:** *The following questions ask you about your characteristics.*

1. What is your age? 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41-45 | 46-50 | 51-55 | 56-60 | 61-65 | 66-70 | 71+

2. Are you? Single 1 Married 2 Divorced 3 Widowed 4

3. What is your race or ethnic background?

   Caucasian 1 Asian-American VIET LAO CAM THAI
   Hispanic-American 3 African-American 4 Native American 5 Other 6

4. Are you a US citizen? Yes 1 No 2
   If no, what is your country of origin? ______________________

5. Indicate highest level of education completed:

   Elementary 1 Middle School 2 High School/GED 3
   Some College 4 College Degree 5 Graduate School Degree 6

**Qualifying Question:** *Since we are attempting to characterize the current commercial blue crab harvesting industry, we need to determine whether the license holder is actively harvesting or simply holding a commercial license.*

Even if you didn't harvest crabs in 2012, were you an active Gulf commercial blue crab harvester in the last five years?

Yes 1 No 2 ➡ **If you answered no, please continue to page 9.**

⬇

**If you answered yes, please continue below.**

13-11

6. How many years have you been in the commercial blue crab harvesting industry?

1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41+

7. Which other members of your immediate family/friends are in the harvesting industry? Please mark the total number of each that applies:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wife | 1 | | | | | Husband | 1 | | | | |
| Parents | 1 | 2 | | | | Sons/Daughters | 1 | 2 | 3 | 4 | 5 |
| Brothers | 1 | 2 | 3 | 4 | | Sisters | 1 | 2 | 3 | 4 | |
| Cousins/uncles/in-laws | 1 | 2 | 3 | 4 | 5 | Friends | 1 | 2 | 3 | 4 | 5 |

8. Who first introduced you to the commercial blue crab harvesting industry?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Father/Mother | 1 | Wife | 2 | Husband | 3 | Brother | 4 | Sister | 5 |
| Son/Daughter | 6 | Cousin | 7 | Friend | 8 | In-laws | 9 | Other | 10 |

**Section B:** *The following questions ask you about your overall satisfaction with commercial harvesting and crabbing specifically.*

1. How satisfied are you with the commercial crab harvesting as an occupation?
   Highly Satisfied 1 Mostly Satisfied 2 Neutral 3 Not Very Satisfied 4 Unsatisfied 5

2. If you had it to do over again, would you become a harvester? Yes 1 No 2

3. Have you ever seriously considered going into another profession? If yes, what would it be?
   No 1 Yes

4. At present, if you were free to stay in a commercial harvesting industry or go into another job, what would your choice be?
   Stay 1 Not Stay

5. Do you want your children to go into commercial blue crab harvesting? Yes 1 No 2

6. If you had to rate the future of commercial blue crab harvesting as an occupation, how would you describe it?
   very good | good | fair | poor | very poor

7. Indicate your satisfaction rate with your commercial blue crab harvesting for these various components.

| | Very Satisfied | Satisfied | Neutral | Unsatisfied | Very Unsatisfied |
|---|---|---|---|---|---|
| Your independence | 1 | 2 | 3 | 4 | 5 |
| Respect received as a harvester | 1 | 2 | 3 | 4 | 5 |
| Working outdoors | 1 | 2 | 3 | 4 | 5 |
| Worthiness of your job | 1 | 2 | 3 | 4 | 5 |
| Being a harvester | 1 | 2 | 3 | 4 | 5 |
| Your earnings last year | 1 | 2 | 3 | 4 | 5 |
| Your future as a harvester | 1 | 2 | 3 | 4 | 5 |

**Section C:** *The following questions ask you about your Gulf blue crab harvesting business.*

1. Please estimate what percentage of your annual ***harvesting income*** comes from the following (Total 100%):

Hard crab [ % ] Soft crab [ % ] Shrimp [ % ] Oysters [ % ] Finfish [ % ] Other [ % ]

2. Please estimate what percentage of your annual ***total income*** comes from ***commercial harvesting of any species***:

[10%] [20%] [30%] [40%] [50%] [60%] [70%] [80%] [90%] [100%]

3. Please estimate your operating costs in the following categories for an average ***trip*** last year on your primary crabbing vessel:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Fuel | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Oil | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Ice | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Bait | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Hired Crew and Captain | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Groceries | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |
| Other Supplies (gloves, baskets/crates, etc) | 0 | <$25 | $26-50 | $51-75 | $76-100 | $101-125 | $126-150 | $151-200 | $201+ |

4. What is your best estimate of the total amount that you spent on gear (traps, etc), boat maintenance, repair, replacement, new purchases, or upgrades to your primary crabbing vessel last year?

[$0-1,000] [$1,001-2,500] [$2,501-5,000] [$5,001-7,500]
[$7,501-10,000] [$10,001-12,500] [$12,501-15,000] [$15,001+]

5. What was your average vessel insurance premium ***per month*** for your primary crabbing vessel last year?

[No Insurance] [$0-50] [$51-100] [$101-200]
[$201-300] [$301-400] [$401-500] [$501+]

6. Did you have any loan(s) on your primary crab vessel any time last year? Yes [1] No [2]

If Yes:
Total amount you still owed at ***end of*** last year: [ , ]
Average loan payment ***per month*** last year: [ , ]
Estimated annual interest rate on loan last year: [ % ]

7. Last year, did you hire any crew to work on your primary crabbing vessel? Yes [1] No [2]

If yes, what was the average number of crew onboard the vessel on a typical crab trip?

[1] [2] [3] [4] [≥5]

8. How much would you estimate is the combined current value of your primary crabbing vessel, motor, and gear (traps, etc)?

[$1,000-5,000] [$5,001-10,000] [$10,001-15,500] [$15,501-20,000]
[$20,001-20,500] [$20,501-30,000] [$30,001-35,500] [$35,501+]

9. Please estimate your ***total overhead*** expenses last year for your primary crabbing vessel last year? ***INCLUDE*** *docking fees, permits, share of rent, cell phone bills, professional services,etc.* ***DO NOT INCLUDE*** *insurance, loans, etc.*

| | | | |
|---|---|---|---|
| <1,000 | 1,001-5,000 | 5,001-10,000 | 10,001-15,000 |
| 15,001-20,000 | 20,001-25,000 | 25,001-30,000 | 30,001+ |

10. Please estimate your ***total* money received** (gross revenue) last year for ***crabs*** caught by your primary commercial crabbing vessel.

| | | | |
|---|---|---|---|
| <1,000 | 1,001-5,000 | 5,001-10,000 | 10,001-15,000 |
| 15,001-20,000 | 20,001-25,000 | 25,001-30,000 | 30,001+ |

11. Please estimate your ***total* other money received** (gross revenue) last year from commercial harvesting of other seafood species (shrimp, oysters, fish, etc), government payments, grant money, BRD money, and disaster assistance for your primary commercial vessel.

| | | | |
|---|---|---|---|
| <1,000 | 1,001-5,000 | 5,001-10,000 | 10,001-15,000 |
| 15,001-20,000 | 20,001-25,000 | 25,001-30,000 | 30,001+ |

12. Last year, what percentage of your commercial blue crab harvesting catch did you sell to:

| | | | | | | |
|---|---|---|---|---|---|---|
| Dealers | % | Processing Plants | % | Wholesaler | % | |
| Direct to Restaurants | % | Private Individuals | % | Others | % | (Total 100%) |

## Section D: *The following questions ask you about your blue crab fishing effort.*

1. How many boats do you use?

| | | | | |
|---|---|---|---|---|
| 10-18 ft. | 1 | 2 | 3 | |
| 19-26 ft. | 1 | 2 | 3 | |
| 27-32 ft. | 1 | | | |
| 33-38 ft. | 1 | | | |
| 39+ ft. | 1 | | | |

2. Are you both owner and the captain? Yes 1 No 2

3. Please indicate the percentage of each of the following gear you are running (Total 100%):

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Traps | % | Peeler gear | % | Trotline/bait | % | Trotline/bush | % | Trawl | % |

4. Think back about what you were doing four years ago and what you are doing now. Have there been any changes in your fishing activities?

| | Major Decrease | Some Decrease | No Change | Some Increase | Major Increase |
|---|---|---|---|---|---|
| Your annual crab landings | 1 | 2 | 3 | 4 | 5 |
| Your income from crabbing | 1 | 2 | 3 | 4 | 5 |
| Regions or areas in which you fish | 1 | 2 | 3 | 4 | 5 |
| Total time spent crab fishing annually | 1 | 2 | 3 | 4 | 5 |
| Ability to sell your catch | 1 | 2 | 3 | 4 | 5 |
| Your competition | 1 | 2 | 3 | 4 | 5 |
| Additional species or fisheries you participate in | 1 | 2 | 3 | 4 | 5 |

5. During which months do you fish for crab?

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 1 | February | 2 | March | 3 | April | 4 | May | 5 | June | 6 |
| July | 7 | August | 8 | September | 9 | October | 10 | November | 11 | December | 12 |

6. Please estimate how many ***trips*** you made during a typical week for each month last year for your primary crabbing vessel last year?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Jan | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Feb | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| March | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| April | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| May | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| June | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| July | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Aug | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Sept | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Oct | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Nov | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Dec | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

7. Please approximate how many ***hours*** each trip took for your primary crabbing vessel last year?

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Jan | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Feb | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| March | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| April | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| May | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| June | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| July | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Aug | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Sept | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Oct | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Nov | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |
| Dec | <1 | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | >7hrs |

8. Please approximate how many ***traps*** you would check on each ***trip*** for your primary crabbing vessel last year?

| | | | | | | |
|---|---|---|---|---|---|---|
| Jan | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Feb | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| March | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| April | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| May | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| June | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| July | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Aug | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Sept | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Oct | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Nov | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |
| Dec | <25 | 26-50 | 51-100 | 101-150 | 150-200 | 201+ |

9. What percentage of your active traps did you have to replace last year due to damage or loss?

0-10% [1] 11-20% [2] 21-30% [3] 31-40% [4] 41-50% [5]

51-60% [6] 61-70% [7] 71-80% [8] 81-90% [9] 91-100% [10]

10. Do you participate in other commercial fishing activities?

No [1] Yes [2] If yes, indicate your alternative: Shrimp [1] Oysters [2] Finfish [3] Other [4]

If you participate in non-fishing activities, check all that apply: Construction [5] Retail [6] Oil & Gas [7] Hospitality [8] Other [ ]

**Section E: *Issues of Concern:*** *From your experience, indicate how much of a problem the following factors are:*

*Not a Problem* [N] *Potential Problem* [PP] *Problem* [P] *Significant Problem* [SP] *Major Problem* [MP]

1. *Environmental conditions:* **(leave blank if not applicable)**

| | | | | | |
|---|---|---|---|---|---|
| Coastal water pollution | N | PP | P | SP | MP |
| Crab disease | N | PP | P | SP | MP |
| Vessel pollution | N | PP | P | SP | MP |
| Industry discharge | N | PP | P | SP | MP |
| Increased vessel traffic | N | PP | P | SP | MP |
| Salinity/water temp | N | PP | P | SP | MP |
| Red tide | N | PP | P | SP | MP |
| Habitat Loss | N | PP | P | SP | MP |
| Other ____________ | N | PP | P | SP | MP |

2. *Commercial/economic conditions:*

| | | | | | |
|---|---|---|---|---|---|
| Number of buyers | N | PP | P | SP | MP |
| Shipping costs | N | PP | P | SP | MP |
| Crab meat imports | N | PP | P | SP | MP |
| Processing costs | N | PP | P | SP | MP |
| Local competition | N | PP | P | SP | MP |
| Operational costs | N | PP | P | SP | MP |
| Peeler crab availability | N | PP | P | SP | MP |
| Other ____________ | N | PP | P | SP | MP |

3. *Potential sources of conflict; other commercial crabbers*:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Use area conflicts | N | PP | P | SP | MP | Ghost traps | N | PP | P | SP | MP |
| Gear conflicts | N | PP | P | SP | MP | Excessive fishing effort | N | PP | P | SP | MP |
| Cultural differences | N | PP | P | SP | MP | Taking of undersized crabs | N | PP | P | SP | MP |
| Poaching/theft | N | PP | P | SP | MP | Other ________________ | N | PP | P | SP | MP |

4. *Potential sources of conflict; other fishermen and recreational users*:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shrimp fishermen | N | PP | P | SP | MP | Dredgers | N | PP | P | SP | MP |
| Recreational anglers | N | PP | P | SP | MP | Poaching/theft | N | PP | P | SP | MP |
| Recreational boaters | N | PP | P | SP | MP | Other ______________ | N | PP | P | SP | MP |

5. *Potential sources of conflict; regulations and enforcement:*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Excessive regulations | N | PP | P | SP | MP | Excessive enforcement | N | PP | P | SP | MP |
| Inadequate regulations | N | PP | P | SP | MP | Inadequate enforcement | N | PP | P | SP | MP |
| License application | N | PP | P | SP | MP | Selective enforcement | N | PP | P | SP | MP |
| State Legislators | N | PP | P | SP | MP | Oil/gas activities | N | PP | P | SP | MP |
| Agency responsiveness | N | PP | P | SP | MP | Other _______________ | N | PP | P | SP | MP |

6. *Potential sources of conflict; community and local population changes:*

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Loss of commercial dockage | N | PP | P | SP | MP | Traffic congestion | N | PP | P | SP | MP |
| Increased residential growth | N | PP | P | SP | MP | Growth of tourism | N | PP | P | SP | MP |
| Increasing property taxes | N | PP | P | SP | MP | Access to quality education | N | PP | P | SP | MP |
| Access to health care | N | PP | P | SP | MP | Increasing newcomers | N | PP | P | SP | MP |
| Pollution of marine environment | N | PP | P | SP | MP | Other _______________ | N | PP | P | SP | MP |

7. What percentage of the residents in your community do you believe are directly involved in commercial fishing or the seafood industry?

[ %]

8. In what city and state do you live? [ ]

9. From which port, harbor, or landing area do you normally fish?

[ ]

10. If you were in charge of blue crab management in your state, what changes would you recommend?

Thank you for completing our survey!

You now qualify for the $250 cash card drawing. Please tear off the back page from this form and either mail in the registration form or go to our website at the link provided. This will qualify you for the drawing which will take place Tuesday, April 2, 2013. The winner will be contacted via email.

Again, thank you for taking the time to help us.

Steve VanderKooy
Interjurisdictional Fisheries Program Coordinator
Gulf States Marine Fisheries Commission
2404 Government St.
Ocean Springs, MS 39564
www.gsmfc.org

# If you filled out Sections B-E, <u>do not</u> fill in these questions.

**Inactive License Holders –** *These questions are designed to better understand why you may not be fishing at this time or if you are simply holding a license for future use.*

**Section F:** *The following questions ask you about your **current** profession and any commercial fishing activities that contribute to your income and livelihood.*

1. How many years have you held a commercial blue crab harvesting license?

   1-5 | 6-10 | 11-15 | 16-20 | 21-25 | 26-30 | 31-35 | 36-40 | 41+

2. How long ago did you stop using your blue crab harvesting license to harvest blue crab?

   1-5 | 6-10 | 11-15 | 16-20 | 21-25
   26-30 | 31-35 | 36-40 | 41+ | Never

3. Do any other members of your immediate family/friends harvest blue crabs at this time? Please mark total number of each that apply:

| | | | |
|---|---|---|---|
| Wife | 1 | Husband | 1 |
| Parents | 1 2 | Sons/Daughters | 1 2 3 4 5 |
| Brothers | 1 2 3 4 | Sisters | 1 2 3 4 |
| Cousins/uncles/in-laws | 1 2 3 4 5 | Friends | 1 2 3 4 5 |

4. Do you participate in commercial fishing activities other than blue crab harvesting?

   No 1 Yes 2 If yes, indicate all that apply: Shrimp 1 Oysters 2 Finfish 3 Other 4

5. If you answered yes to the above question, please estimate what percentage of your annual ***fishing income*** comes from the following (Total 100%):

   Shrimp ____ % Oysters ____ % Finfish ____ % Other ____ %

6. Please estimate what percentage of your annual ***total income*** comes from ***commercial fishing***:

   0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100%

7. Please indicate if any of your income comes from a ***non-fishing job/profession***.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Construction | 1 | Retail | 2 | Oil & Gas | 3 | Hospitality | 4 |
| Medical | 5 | Governmental | 6 | Municipality | 7 | Public Safety | 8 |
| Education | 9 | Finance | 10 | Retired | 11 | Other | ______ |

**Section G:** *The following questions are to understand the underlying reasons you're not using your commercial blue crab license.*

1. Why aren't you using your blue crab harvesting license? (Please check all that apply)

- 1 Active in other commercial fisheries
- 2 flexibility to switch from other commercial fisheries
- 3 backup if current fishery declines
- 4 waiting for crab prices to increase
- 5 most commercial fishermen hold multiple licenses
- 6 purchased as investment and future resale
- 7 plan to crab when retired
- 8 Other

2. Are there economic reasons you aren't using your blue crab harvesting license?

Yes 1 No 2

If yes, please indicate any that apply:

- 1 Fuel Cost too high
- 2 Dockside price of crab
- 3 Market access or demand for crab too low
- 4 The fishery is over-capitalized
- 5 Access to business loans difficult
- 6 Access to insurance difficult
- 7 There are no economic reasons keeping me from using my license
- 8 Other

3. Do you believe there are issues with the blue crab population that cause you to not actively harvest them?

Yes 1 No 2

If yes, please indicate any that apply:

- 1 Blue crab populations seem low
- 2 Too many undersized crabs
- 3 Too much bycatch in the blue crab fishery
- 4 Too many derelict traps
- 5 Loss of crab habitat
- 6 Need more crabs in the environment as food for other species
- 7 Environmental conditions are harming blue crab populations
- 8 Other

4. Do you believe that there are management issues related to the blue crab fishery preventing you from fishing? Yes [1] No [2]

If yes, please describe:

**Section H:** *The following questions target individuals who no longer participate in commercial harvesting of blue crabs but still hold a commercial license.*

1. How many years did you use your blue crab harvesting license to harvest crabs?

| | | | | |
|---|---|---|---|---|
| 1-5 | 6-10 | 11-15 | 16-20 | 21-25 |
| 26-30 | 31-35 | 36-40 | 41+ | Never |

2. How satisfied were you with commercial crab harvesting as an occupation?

Highly Satisfied [1] Mostly Satisfied [2] Neutral [3] Not Very Satisfied [4] Unsatisfied [5]

3. Do you want to return to commercial crab harvesting? Yes [1] No [2]

4. Would you want your children to go into commercial blue crab harvesting? Yes [1] No [2]

5. If you had to rate the future of commercial blue crab harvesting as an occupation, how would you describe it?

very good [1] good [2] fair [3] poor [4] very poor [5]

6. Are there questions we should have asked and didn't?
   If yes, please elaborate. Yes [1] No [2]

Thank you for completing our survey!

You now qualify for the $250 cash card drawing. Please tear off the back page from this form and either mail in the registration form or go to our website at the link provided. This will qualify you for the drawing which will take place Tuesday, April 2, 2013. The winner will be contacted via email.

Again, thank you for taking the time to help us.

Steve VanderKooy
Interjurisdictional Fisheries Program Coordinator
Gulf States Marine Fisheries Commission
2404 Government St.
Ocean Springs, MS 39564
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# Gulf States Marine Fisheries Commission Blue Crab Survey Gift Card Raffle

Name ______________________________

Address ______________________________

______________________________

City ______________________________

State ______________________________

Zipcode ______________________________

E-mail ______________________________

**Drawing will be held on April 2, 2013. Winner will be notified by email.**

**Terms and Conditions:**

- Gift Card can be used at most stores that accept credit card or debit card payments or any Walmart/Sam's Club.
- Merchants are not required to accept all Visa Gift Cards; check before completing purchase.
- Funds on the Gift Card cannot be exchanged for cash.
- Gift Card Expiration date is based on the issuing financial institution.
- Reload on this Gift Card is not allowed.
- Gift Card is active when delivered to recipient.
- If Gift Card is stolen or lost after delivery, Gulf States Marine Fisheries Commission waives responsibility and Gift Card will not be replaced. It is equivalent to cash.
- Gift Card is active as long as selecting "credit" payment option at time of purchase.
- Gift Card must be registered by recipient to receive a PIN for use as debit card but is not an ATM card for cash withdrawal.
- Only one entry per license holder.

Form may be mailed but must be received by March 29, 2013:

**Gulf States Marine Fisheries Commission**
**Attn: Social Survey**
**2404 Government St.**
**Ocean Springs, MS 39564**
or submit by fax to: **1-228-875-6604**

**Gulf States Marine Fisheries Commission**
**2404 Government Street**
**Ocean Springs, Mississippi, 39564**

**Appendix 13.3**

# GDAR
## Gulf Data, Assessment, and Review

# GDAR 01
# Stock Assessment Report

## Gulf of Mexico Blue Crab

Prepared by
S. VanderKooy (editor)

June 2013

## GSMFC Number 215

Gulf Data, Assessment, and Review
Gulf States Marine Fisheries Commission
2404 Government Street
Ocean Springs, MS  39564

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## (Alphabetically)

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**Executive Summary**

The blue crab, *Callinectes sapidus,* has the broadest latitudinal distribution of all the *Callinectes* species, ranging from Nova Scotia and Maine to northern Argentina and is found throughout the US Gulf of Mexico (GOM). Based on tagging and genetic investigations, two potential management populations may exist in the Gulf of Mexico: a Florida or "Eastern GOM stock" occurring along the Florida coast to Apalachee (centered in Tampa Bay), and a "Western GOM stock" occurring from central Texas to Apalachicola Bay and centered in Louisiana. Using this population structure, we provide quantitative analyses on the status of the Western and Eastern stocks through 2011.

Total reported commercial blue crab landings in the Gulf have increased from less than one million pounds in the late 1800s when landing statistics were first collected, to approximately 18 million lbs prior to World War II. Landings increased markedly in the late 1950s with introduction of the wire trap that replaced traditional trotlines by the mid-1960s. The increased availability of raw product associated with adoption of the wire trap stimulated processing capacity and market development, and landings continued to rise through the 1980s. Record landings of 78 and 79 million pounds occurred in 1987 and 1988, respectively. Although landings continue to fluctuate, a general downward trend in Gulf-wide landings began in 2000 and has continued through 2010. Natural and anthropogenic events as well as changes in management measures may have directly influenced landings. These include a number of catastrophic hurricanes and the sinking of BP's Deepwater Horizon oil platform off Louisiana in 2010 that closed most of the north-central GOM to harvest during the most productive portion of the fishing season.

Fishery-independent estimates of abundance for both juvenile and adult stocks have shown either decreasing or steady trends throughout the last two decades while commercial landings have declined. The Western stock has undergone a strong decline in juvenile abundances since the mid-1980s, and a decline in adult abundances from the mid-1980s until the mid-1990s, after which it has remained relatively stable. Eastern stock adult abundances have shown a similar trend (declining through the mid-1990s and stable since), while the juvenile abundance has been relatively stable since the late 1980s. In both stocks, the abundances have experienced substantial variability from year-to-year, and in the case of the Eastern stock, these abundances typically peak in years following high rainfall.

In this assessment, we employed two separate modeling approaches to address the GOM stocks. The primary model was a modified catch-survey analysis similar in structure to those used in previous blue crab stock assessments (Chesapeake, Louisiana, Florida, Delaware), while the supporting model was a surplus production model. The estimated MSY from the base model configuration was 164 million individuals for the Western GOM stock and 23 million individuals for the Eastern GOM stock, where fisheries on both stocks have landed less than the MSY for the majority of the time series. The Western GOM stock experienced overfishing in 1999 and 2002, while the Eastern GOM stock experienced overfishing in 1996 and 1998. The base model found that both stocks are currently neither overfished nor undergoing overfishing, although the Western stock is in a depressed state and approaching an overfished limit.

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## Appendix 13.4

# PARASITES, DISEASES, SYMBIONTS, AND FOULING ORGANISMS OF BLUE CRABS

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| **VIRUSES** | | | | | |
| RLV (Reo-like virus); infects RNA; CsRV, thought be synonymous with RLV. | Rhabdo-like virus A (RhVA always found with RLV; causes cytoplasmic inclusions, increased cytoplasmic volume in hemocytes, hemopoietic tissue, and glial nerves<br>RhVA not associated with RLV. Instead, virus-induced cellular changes have some similarity to rhabdoviruses | RLV and RhVA act synergistically, causing necrosis of hemopoietic tissue, hemocytes, and CNS; death due to nerve and hemocytic dysfunction; fatal<br>CsRV/RLV infect hemocytes | Sluggishness, paralysis; withdrawn blood clots incompletely | Chincoteague and Chesapeake Bays; infects crabs from high and low salinities; actual prevalence unknown<br>CsRV observed in crabs from Gulf coast of FL to Delaware Bay<br>Highly prevalent in softrshell systems. | Vago 1966, Johnson 1977a, 1977c, 1983, 1984 and 1985, Johnson and Bodammer 1975, Overstreet 1978, Bowers et al. 2010, Tang et al. 2011. |
| RhVA (Rhabdo-like virus A); synergistic; infects RNA | Always seen with other viruses; infects cytoplasm of nerve ganglia, hemocytes, hemopoietic tissue | Stress related; may have synergistic effect with other virus diseases | No reported gross signs | Atlantic and Gulf Coasts; may be ubiquitous | Jahromi 1977, Yudin and Clark 1978 and 1979, Johnson 1978b, 1983, 1984 and 1985, Messick 1998 |
| RhVB (Rhabdo-like virus B); infects RNA; formerly labeled EGV-1 | Associated extra-cellularly with basal lamina of mandibular gland | AInfected@ glands normal and crabs showed no sign of abnormal behavior; very similar to EHV, probably same | No reported gross signs | Found only in 1 of 60 (3%) confined crabs from Galveston, TX | Yudin and Clark 1978, Johnson 1985 |
| EHV (enveloped helical); infects RNA; paramyxo-like virus | Infects cytoplasm of hemocytes and hemopoietic tissue | Effect unreported; always associated with other viruses which synergistically may cause pathology | No reported gross signs | Chesapeake and Chincoteague Bays; east coast of Florida; prevalence low | Johnson and Farley 1980, Johnson 1984 and 1985 |
| CBV (Chesapeake Bay virus); infects RNA; a picorna-like virus | Causes focal infections; cytoplasmic inclusions in epithelium of gill, gut, bladder, CNS cells, and epidermis | Extensive destruction of gill and bladder epithelium and neuro-secretory cells; blindness, and death | Abnormal behavior, erratic swimming, blindness | Chesapeake Bay; infects captive juveniles and probably wild populations | Johnson 1978a, 1978b, 1983, 1984 and 1985, Overstreet 1978, Shields and Overstreet 2007 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| BFV (Bi-facies virus ); infects DNA; formerly herpes-like virus (HLV) | Nuclei of hemocytes hypertrophied; infected cells have refractive cytoplasmic inclusions | Nuclear hypertrophy followed by cell lysis; death due to hemocytic dysfunction; fatal | Crabs become inactive; withdrawn blood is milky and clots improperly | Chincoteague and Assawoman Bays only; captive and wild populations; reported infections up to 13% | Johnson 1976b, 1978b, 1983, 1984, Overstreet 1978 |
| Baculo-A; DNA virus (non-occluded) | Nuclei of epithelial cells of hepatopancreas hypertrophied; focal infections | Benign, since hepatopancreatic cells constantly replaced | Crabs appear healthy | Widespread along Atlantic coast; infections from 4 to 20% in adults and juveniles | Johnson 1976a, 1983, 1984 and 1985, Johnson and Lightner 1988 |
| Baculo-B; DNA virus, similar to baculovirus of *Carcinus maenas* | Nuclear hypertrophy of hemopoietic tissue and hemocytes | Lysing and dysfunction of hemocytes otherwise effect unknown; fatal | Occurs in either normal-appearing crabs or in those with other viral infections | Tred Avon River; Chesapeake Bay | Bazin et al. 1974, Johnson 1983, 1984 and 1985, Messick 1998 |
| **BACTERIA** | | | | | |
| *Acinetobacter* sp. | Non-motile, gram-negative rods; aerobic; isolated from hemolymph and exoskeletal lesions | Unknown | Shell lesions (*A. calcoaceticus*) | Chesapeake and Chincoteague Bays, Pamlico Sound, NC | Colwell et al. 1975, Sizemore et al. 1975, Noga et al. 2000 |
| *Acinetobacter baumanii, A. calcoaceticus, A. johnsonii, A. lwoffi,* | Non-motile, gram-negative rods; aerobic; all isolated from hemolymph, all except *A. lwoffii* also isolated from exoskeleton | Unknown | No reported gross signs, shell lesions (*A. calcoaceticus*) | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Aeromonas* sp.; now considered to be Group F vibrios | Motile, gram-negative rods to coccobacilli; facultative anaerobes; isolated from helmolymph and gills | Unknown | No reported gross signs | Atlantic coast | Sizemore et al. 1975, Babinchak et al. 1982, Noga et al. 2000 |
| *Aeromonas cavaie, A. hydrophila, A. sobria, A. punctata* | Motile gram-negative rods to coccobacilli; facultative anaerobes*; A. cavaie* and *A. hydrophila* isolated from hemolymph, *A. hydrophila A. sobria, and A. punctata* isolated from exoskeleton | *A. hydrophila A. sobria*, and *A. punctata* are chitinoclastic | No reported gross signs | Pensacola Bay and tributaries, Pamlico Sound, NC | Overstreet and Rebarchik 1995, Noga et al. 2000 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Alcaligenes latus, A. xylosoxydans* | Motile, gram-negative rods or cocci; obligate aerobes; *A. latus* isolated from hemolymph, *A. xylosoxydans* isolated from exoskeleton | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Bacillus* sp. | Motile, gram-positive rods; aerobes or facultative anaerobes; isolated from hemolymph and exoskeleton | Unknown | No reported gross signs | Chesapeake and Chincoteague Bays, Pensacola Bay and tributaries | Colwell et al. 1975, Sizemore et al. 1975, Overstreet and Rebarchik 1995 |
| *Benekea* type I (now *Vibrio*; Kreig and Holt 1984) | Motile, gram-negative rods; facultative anaerobe; isolated from exoskeletal lesions; thought to be causative organism; invasion requires mechanical abrasion of exoskeleton | Dissolution of chitonous and calcified portions of exoskeleton; heavily infected crabs weak, lethargic, die rapidly out of water | Necrotic exoskeletal lesions; Abox burn@ or Ashell disease@ | Atlantic and Gulf coasts | Cook and Lofton 1973 |
| *Citrobacter freundii* | Motile, gram-negative rod; facultative anaerobe; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Clavibacter michagenese* | Non-motile gram-positive rod; obligate aerobe; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Clostridium perfringes* | Motile, gram-positive rod; anaerobe; transmitted through blue crabs from waters containing the bacterium; exposure may cause gas gangrene in humans | Unknown | No reported gross signs | Atlantic Coast | Elliot 1984 |
| *Clostridium botulinum* | Motile, gram-positive rod; anaerobe; transmitted through blue crabs from waters containing the bacterium; exposure may cause botulism in humans | Unknown | No reported gross signs | Atlantic Coast | Williams-Walls 1968 |
| *Enterobacter aerogenes* | Motile, gram-negative rod; facultative anaerobe; isolated from gills and hemolymph | Unknown | No reported gross signs | South Carolina, Gulf Coast | Babinchak et al. 1982, Overstreet and Rebarchik 1995 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Enterobacter agglomeranns, E. cloacae, E. intermedium* | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Escherichia coli* | Motile, gram-negative rod; facultative anaerobe; isolated from hemolymph and gills; exposure may cause gastric problems in humans, fatal in some instances | Unknown | No reported gross signs | Atlantic Coast | Sizemore et al. 1975, Babinchak et al. 1982 |
| *Escherichia vulneris* | Motile, gram-negative rod; facultative anaerobe; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Flavobacterium* sp. | Non-motile, gram-negative rod; aerobe; isolated from hemolymph | Unknown | No reported gross signs | Atlantic Coast | Johnson 1983, Sizemore et al. 1975 |
| *Haemophilus parainfluenzae, H. parasuis, H. somnus* | Non-motile, gram-negative spheres, ovals, or rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Kingella kingae* | Non-motile, gram-negative rod; aerobe or facultative anaerobe; isolated from hemolymph and exoskeleton | Chitinoclastic | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Klebsiella oxytoca, K. phenmonaie, K. terrigena* | All isolated from hemolymph, *K phenmonaie* also isolated from exoskeleton | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Leucothrix mucor* | Gram-negative, filamentous; aerobe; reported on egg mass; associated with *Lagenidium callinectes* | Unknown | Eggs of crabs infected with *L. callinectes* are smaller and darker than non-infected eggs | North Carolina | Bland and Amerson 1974 |
| *Moraxella* sp. | Non-motile, gram-negative rods or cocci; aerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995, Wang 2011 |
| *Pasteurella* sp. | Non-motile gram-negative, coccoid to straight rods; aerobes and facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995, Wang 2011 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Pleisomonas shigelloides* | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Proteus mirabilis, P. penneri* | Isolated from exoskeleton | Chitinoclastic | Shell lesions | Pamlico Sound, NC | Noga et al. 2000 |
| *Providencia ruttgeri* | Motile, gram-negative rod; facultative anaerobe; isolated from exoskeleton | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Pseudomonas* sp. | Motile, gram-negative rods; aerobes; isolated from exoskeletal lesions and hemolymph; thought to be opportunistic invader | Some are chitinoclastic | Necrotic exoskeletal lesions; Abox burn@ or Ashell disease@ | Gulf Coast | Cook and Lofton 1973, Overstreet and Rebarchik 1995 |
| *Pseudomonas acidovorans, P. alkaligenes, P. putrefaciens, P. testosteroni* | Isolated from exoskeleton lesions | Chitinoclastic | Shell lesions | Pamlico Sound, NC | Noga et al. 2000 |
| *Psychrobacter immobilis* | Non-motile, gram-negative coccobacilli; aerobe; isolated from exoskeleton | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Salmonella* sp. | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Serratia marscescens, S. rubidea* | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph and exoskeleton lesions | *S. marscescens* is chitinoclastic | Shell lesions | Pensacola Bay and tributaries, Pamlico Sound, NC | Overstreet and Rebarchik 1995, Noga et al. 2000 |
| *Shigella sp.* | Non-motile, gram-negative rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995, Marshall et al. 1996 |
| *Shewanella putrifaciens* | Motile, gram-negative rod; facultative anaerobe; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Staphyloccoccus aureus* | Non-motile, gram-positive cocci; facultative anaerobe | Unknown | No reported gross signs | | Elliot 1984 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Vibrio alginolyticus* | Motile, gram-negative rods; facultative anaerobe; isolated from hemolymph and exoskeleton | Chitinooclastic | Shell lesions | Pensacola Bay and tributaries | Elliot 1984, Overstreet and Rebarchik 1995 |
| *Vibrio anguillarum* | Motile, gram-negative rod; facultative anaerobe; isolated from hemolymph and exoskeleton | Chitinoclastic | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Vibrio fischeri* (formerly *Achromobacter fischeri*) | Motile gram-negative rod; facultative anaerobe; isolated from hemolymph | Unknown | No reported gross signs | Atlantic Coast, Pamlico Sound, NC | Sizemore et al. 1975, Noga et al. 2000 |
| *Vibrio campbellii* | Gram-negative rod; anaerobe | Physical obstruction of hemolymph flow through the gill vasculature – respiration impairment; Hemocytopenia | No reported gross signs | Atlantic | Johnson et al. 2011, Holman et al. 2004, Burnett et al. 2006, Shock et al. 2010, Macey et al. 2008 |
| *Vibrio cholerae*; causes intestinal disease in man, diarrheal illness; severe dehydration may result from infection; disease highly specific to man | Motile, gram-negative rod; facultative anaerobe; transmitted through blue crabs taken from waters containing the bacterium, isolated from exoskeleton and hemolymph, and gut | Chitonoclastic | No reported gross signs | Gulf Coast | Moody 1982, Overstreet and Rebarchik 1995, Rivera 1999, Huq et al. 1986, Yalcinkaya et al. 2003 |
| *Vibrio fluvialis, V. mimicus* | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph and exoskeleton | Chitinoclastic | Shell lesions | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995, Yalcinkaya et al. 2003 |
| *Vibrio harveyii, V. splendidus* | Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph | Chitinoclastic | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995, Yalcinkaya et al. 2003 |
| *Vibrio mediteraneii* | Motile, gram-negative rod; facultative anaerobe; isolated from exoskeleton | Chitinoclastic | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Vibrio parahaemolyticus* and related facultative bacteria | Motile gram-negative rod; facultative anaerobe; found in marine waters; isolated from hemolymph and exoskeleton; causes hemocytic aggregations in gills, heart, and other tissues | Formation of hemocytic aggregations and nodules; causes internal clotting of hemolymph; chitinoclastic | Lethargy and weakness due to systemic infections; withdrawn blood clots incompletely; injured or stressed crabs prone to disease; Shell lesions mortalities reported 50% or higher in shedding tanks; causes intestinal disease in man (diarrhea, vomiting, mild fever) | Atlantic and Gulf coasts | Krantz et al. 1969, Sizemore et al. 1975, Tubiash et al. 1975, Johnson 1976c, Overstreet 1978, Blake et al. 1980a, b, Messick and Kennedy 1990, Overstreet and Rebarchik 1995, Davis and Sizemore 1982 |
| *Vibrio vulnificus*; may cause septacemia in man from wound infections or ingestion | Motile, gram-negative rod; facultative anaerobe; found in marine waters; isolated from hemolymph and exoskeleton | Chitinoclastic | Shell lesions | Gulf Coast | Davis and Sizemore 1982, Overstreet and Rebarchik 1995 |
| *Xanthomonas albilineans, X. campestris* | Motile, gram-negative rods; aerobes; isolated from exoskeleton | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| *Yersinia* sp. | Motility dependent on temperature, gram-negative rods; facultative anaerobes; isolated from hemolymph | Unknown | No reported gross signs | Pensacola Bay and tributaries | Overstreet and Rebarchik 1995 |
| **PROTISTA** | | | | | |
| Algae | Exoskeleton | Fouling organism | | | Overstreet 1982 |
| **CHROMISTA** | | | | | |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Lagenidium callinectes* | Phycomycete zoospores settle on eggs, germinate, and extend germ tubes which develop into branched septate mycelia | Eggs fail to hatch or abnormal larvae are produced; may also kill newly hatched larvae within 48 hr. | Diseased portions of egg mass appear either brownish or grey, depending on maturity of infected egg mass | Atlantic and Gulf coasts | Couch 1942, Sandoz et al. 1944, Newcombe and Rogers 1947, Rogers-Talbert 1948, Bland and Amerson 1973 and 1974 |
| *Thraustochytrium* sp. | Associated with *L. callinectes*, saprophytic secondary invader of eggs | Unknown | | North Carolina | Bland and Amerson 1974 |
| *Hematodinium sp.* (protozoan, parasitic dinoflagellate, Sarcomastigophora) | Uninucleate and binucleate plasmodial parasites in hemolymph, also in hepatopancreas and muscle; chromosomes condensed or diffused with no nuclear membrane | Debilitating and lethal due to ability to proliferate and replace host tissues; laboratory-infected crabs die | Lethargy and weakness; withdrawn blood milky or opaque in heavy infections, slow to clot, and contains few hemocytes | Maryland to Gulf Coast; found in waters with salinities greater than 11 ‰ | Newman and Johnson 1975, Newman 1977, Couch and Martin 1982, Couch 1983, Shields 1994, Messick and Shields 2000, Shields and Squyars 2000, Shields 2001, Grubel et al. 2002, Shields et al. 2003, Frischer et al. 2006, Small et al 2007a and 2007b, Nagel et al. 2009, Walker et al. 2009, Jensen et al. 2010, Li et al. 2011a and 2011b, Pagenkopp Lohan et al. 2011, Pagenkopp Lohan et al. 2012a and 2012b, Numerous others |
| *Urosporidium crescens* | Haplosporidan hyper-parasite of *M. basodactylophallus* metacercaria | No known pathological effects | Causes condition known as 'buckshot' or 'pepper crabs' | Atlantic and Gulf coasts | Perry 1975, Overstreet 1978, Messick 1998 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Haplosporidium sp.* | Haplosporidan; histozoic intercellular parasites; hemolymph and various tissues | Heavy infestations; vascular spaces filled with uninucleate and plasmodial stages; lethal | Lethargy; opaque white hemolymph | Atlantic Coast | Newman et al. 1976, Couch and Martin 1982 |
| *Lagenophrys callinectes* (protozoan, peritrich, loricate ciliate) | Ectocommensals living in loricae found on flat surfaces of gill lamellae | Secretes a protective lorica on gill lamellae; may interfere with respiratory and excretory function of gills; heavy infestations may cause death in floats and traps | No gross signs; diagnosis through microscope for presence of lorica | Chincoteague and Chesapeake Bays; Gulf Coast; peak prevalence during summer months | Couch 1966, 1967 and 1983, Overstreet 1978, Couch and Martin 1982, Messick 1998 |
| *Acineta* sp. (protozoan, suctorian ciliate) | Associated with *Lagenophrys callinectes* | May interfere with respiratory and excretory function of gills; heavy infestations may cause death in floats and traps | No gross signs; diagnosis through microscope for presence of lorica | Gulf Coast | Overstreet 1978, Overstreet and Rebarchik 1995 |
| *Epistylis* sp. (protozoan, peritrich, stalked ciliate) | Ectocommensals attached to margins and stems of gill lamellae | May interfere with respiratory and excretory function of gills | No gross signs; diagnosis through microscope for presence of ciliate | Atlantic and Gulf coasts | Couch 1966, Overstreet 1978, Overstreet and Rebarchik 1995, Messick 1998, Ma and Overstreet 2006 |
| *Mesanophrys chesapeakensis* (protozoan, ciliate) | Hemolymph and tissue | Histophagous | Lethargy | Chesapeake Bay | Messick and Small 1996, Messick 1998 |
| *Orchitophyra stellarum* (protozoan, ciliate) | Hemolymph and tissue | Histophagous | Lethargy | Chesapeake Bay, cool water/seasonal | Small et al. 2011 |
| **PROTOZOA** | | | | | |
| *Paramoeba perniciosa* (protozoan, amoeba, Sarcomastigophora) | Organisms with well-defined nucleus plus a secondary body; large halos may surround individual amoeba | Amoeba fills tissues, replaces hemocytes, and alters hemolymph; probably causes winter mortalities | Grey-colored abdomen and appendages; called Agrey crab@ disease | From Sandy Hook Bay to Georgia; usually seen in higher salinity waters | Sprague and Beckett 1966, Sawyer 1969, Sprague et al. 1969, Newman and Ward 1973, Pauley et al. 1975, Johnson 1977b, Overstreet 1978, Couch and Martin 1982, Couch 1983 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| **FUNGI** | | | | | |
| *Ameson michaelis* (protozoan, microsporida) | Microsporidan within blood cells, transmitted to muscle tissue by blood cells | Muscle lysis; parasite destroys musculature by lysis | Lethargy; muscle has chalky opaque appearance; abdomen may have white or grey color | Delaware and Chesapeake Bays, southward to Gulf Coast | Sprague 1950, 1965, 1970 and 1977, Overstreet and Weidner 1974, Overstreet and Whatley 1975, Overstreet 1977 and 1978, Couch 1983 |
| *Ameson sapidi* | Microsporidan; muscle tissue | Destroys host muscle tissue | Lethargy; muscle has chalky opaque appearance | Atlantic Coast | Sprague 1977, Couch and Martin 1982 |
| *Pleistophora cargoi* | Microsporidan; muscle tissue | Unknown | | Atlantic Coast | Sprague 1966 and 1977, Couch and Martin 1982 |
| *Thelohania sp.* | Microsporidan; muscle tissue | Replaces muscle tissue | Lethargy; muscle has chalky opaque appearance | Atlantic and Gulf coasts | Sprague 1977, Weidner et al. 1990 |
| **ANIMALIA** | | | | | |
| PORIFERA (sponges) | Exoskeleton | Fouling organism | | North Carolina | Pearse 1947 |
| CNIDARIA | | | | | |
| *Obelia bidentata* (hydroid) | Exoskeleton | Fouling organism | | Gulf Coast | Overstreet 1983 |
| *Bougainvillia* sp. (hydroid) | Exoskeleton | Fouling organism | | Gulf Coast | Overstreet 1983 |
| *Astrangia danae* (anthozoan) | Exoskeleton | Fouling organism | | North Carolina | Pearse 1947 |
| *Leptogorgia vingulata* (anthozoan) | Exoskeleton | Fouling organism | | North Carolina | Pearse 1947 |
| *Epizoanthus americanus* | Exoskeleton | Fouling organism | | North Carolina | Pearse 1947 |
| TREMATODA | | | | | |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Microphallus basodactylophallus* (digenean, fluke, may be hyper-parasitized by *Urosporidium crescens*, haplosporidan) | Metacercarial cysts present in thoracic muscles, hepatopancreas, and ventral ganglion | Pigmented spores of haplosporidan hyperparasite debilitate and enlarge worm cyst; actual effect on crabs by worm slight; market value of crabs reduced when cycts are heavily infected by *U. crescens* | Uninfected metacercaria not visible to naked eye; hyperparasitized metacercaria are black and cause the condition called Apepper spot@ or Abuckshot@ | Chesapeake Bay to Texas | DeTurk 1940, Couch 1974, Overstreet 1978, 1982 and 1983, Heard and Overstreet 1983 |
| *Levinseniella capitanea* (digenean, fluke) | Metacercarial cysts found in gonads and hepatopancreas | None, unless heavy abnormal infection | Visible to naked eye | Gulf Coast | Overstreet and Perry 1972, Overstreet 1978, 1982 and 1983 |
| *Megalophallus diodontis* (digenean, fluke) | Metacercarial cycts found primarily at base of gill filaments | None, unless heavy abnormal infection | | Gulf Coast and Caribbean Sea | Overstreet 1982, Prevot and Deblock 1970 |
| NEMATODA | | | | | |
| *Hysterothylacium* sp. | Encapsulates in body cavity and tissues | None noted | None noted | Gulf Coast | Deardoff and Overstreet 1981 |
| ANNELIDA | | | | | |
| HIRUDINEA | | | | | |
| *Calliobdella vivida* | Exoskeleton and gills | Unknown | | Gulf Coast; low-salinity habitats | Overstreet 1982 |
| *Myzobdella lugubris* | Exoskeleton | Unknown; associated in some reports with mortalities | | Atlantic and Gulf coasts; low-salinity habitats; male crab usual host | Moore 1946, Hutton and Sogandares-Bernal 1959, Sawyer et al. 1975, Perry 1975, Daniels and Sawyer 1975, Overstreet 1978, 1982 and 1983 |
| BRANCHIOBDELLIDA | | | | | |
| *Cambarincola vitrea* | Exoskeleton and gills | Unknown; no apparent harm | | Gulf Coast; low salinity /freshwater habitats | Perry 1975, Overstreet 1978 and 1982 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Cambarincola mesochoreus, C. pamelae* | Exoskeleton and gills | Unknown; no apparent harm | | Gulf Coast; low salinity /freshwater habitats | Gelder and Messick 2006 |
| NEMERTEA | | | | | |
| *Carcinonemertes carcinophila* | Infests gills and egg mass | Feeds on host=s eggs; causes reduction in reproductive potential; cements gill lamellae together; used as indicator of spawning in host | Destruction of egg mass; worms seen grossly on gills between lamellae | Atlantic and Gulf coasts; infects crabs from high salinity habitats | Humes 1942, Hopkins 1947, Pyle and Cronin 1950, Davis 1965, Overstreet 1978, 1982 and 1983, Overstreet and Rebarchik 1995, Messick 1998 |
| MOLLUSCA | | | | | |
| *Crassostrea virginica* | Exoskeleton | Fouling organism | Spat settle on exoskeleton; may attach beneath apron | Gulf Coast | Overstreet 1982 |
| *Mytilus edulis* | Exoskeleton | Fouling organism | | Atlantic and Gulf coasts | Cargo 1959, Overstreet 1982 |
| ARTHROPODA | | | | | |
| AMPHIPODA | Exoskeleton | Fouling organism | | Atlantic and Gulf coasts | Overstreet 1982 |
| ISOPODA | Exoskeleton | Fouling organism | | Atlantic and Gulf coasts | Van Engel 1987 |
| CIRRIPEDIA | | | | | |
| *Balanus eburneus* (acorn barnacle) | Exoskeleton | Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement | | Atlantic and Gulf coasts | Overstreet 1978 and 1982 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Balanus venustus niveus* (acorn barnacle) | Exoskeleton | Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement | | Atlantic and Gulf coasts | Overstreet 1978 and 1982 |
| *Chelonibia patula* (acorn barnacle) | Exoskeleton | Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement | | Atlantic and Gulf coasts | Overstreet 1978 and 1982, Key et al. 1997, Shields and Overstreet 2007 |
| *Loxothylacus texanus* (parasitic barnacle, rhizocephalan) | Internal parasite sends rootlike system throughout host=s muscle; develops an external sac which serves as brood sac for nauplii larvae | Inhibits crab growth, terminates reproduction, removes individuals from fishery; may reduce up to 50% of commercial stocks in some areas | Parasite=s externa protrudes under crab=s apron; male crabs acquire secondary adult female sexual qualities | Gulf Coast; more prevalent in higher salinity waters | Reinhard 1950a, 1950b and 1956, Adkins 1972b, Ragan and Matherne 1974, Overstreet 1978, 1982 and 1983 |
| *Octolasmis muelleri* (pedunculate barnacle) | Gill chamber | Heavy infestations decrease respiration efficiency | Easily visible on gills and in gill chamber | Gulf Coast | Perry 1975, Overstreet 1978, 1982 and 1983, Overstreet and Rebarchik 1995, Shields and Overstreet 2007 |
| BRYOZOA | | | | | |
| *Acanthodesia tennuis* | Exoskeleton | Fouling organism | | | Osburn 1944 |
| *Alcyonidium mytili* | Exoskeleton | Fouling organism | | | Pearse 1947 |
| *Alcyonidium albescens* | Exoskeleton | Fouling organism | | | Key et al. 1999 |
| *Alcyonidium verrelli* | Exoskeleton | Fouling organism | | | Osburn 1944 |
| *Conopeum tenuissium* | Exoskeleton | Fouling organism | | | Overstreet 1982 |
| *Membranipora arborescens* | Exoskeleton | Fouling organism | | | Key et al. 1999 |
| *Membranipora crustulenta* | Exoskeleton | Fouling organism | | | Osburn 1944 |
| *Membranipora tenius* | Exoskeleton | Fouling organism | | | Overstreet 1982 |

| ORGANISMS | HISTOPATHOLOGY AND TISSUES INFECTED | EFFECT ON HOST | GROSS SIGNS OF DISEASE | GEOGRAPHIC LOCATION AND PREVALENCE | REFERENCE |
|---|---|---|---|---|---|
| *Triticella elongata* | Etenostomate ectoproct; branchial chamber | Fouling organism | | | Osburn 1944, Overstreet 1982, Key et al. 1999 |
| UROCHORDATA | | | | | |
| *Molgula manhattensis* (tunicate) | Exoskeleton | Fouling organism | | Atlantic and Gulf coasts | Pearse 1947, Shields and Overstreet 2007 |

## About the Artist

*Valerie Winn*

Valerie Winn, of the Mississippi Gulf coast, is an artist and writer. A former high school teacher of art and journalism, she has written and edited for several Mississippi newspapers. She is also a former writer/editor for Mississippi-Alabama Sea Grant Consortium and *NMEA News,* the newsletter of the National Marine Educators Association. In 2012 her coming-of-age novel, *Forsaking Mimosa*, was published by Dogwood Press. She creates images primarily in acrylics, watercolor, and pen and ink and holds a bachelor's degree in art education from Mississippi State University and a Master's in the same field from the University of South Alabama.

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