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

A REGIONAL MANAGEMENT PLAN

by

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The Gulf States Marine Fisheries Commission (GSMFC) would like to thank the Blue Crab Technical Task Force (TTF) for their many hours of work and dedication in developing this blue crab fishery management plan (FMP). The GSMFC also thanks the Stock Assessment Team, Law Enforcement Committee, and Technical Coordinating Committee's (TCC) Habitat Subcommittee for their review, critique, and guidance in the development of the stock assessment and habitat sections.

The Blue Crab TTF would like to express its appreciation to former TTF members Perry Joyner, Paul Prejean, and Stevens Heath for their contributions early in the revision process. Thanks also go to Dr. Richard Leard and James Duffy who served as IJF Coordinators for the GSMFC during the first year of the revision process.

Other individuals who made contributions to this document include: Christine Trigg, Kirsten Larsen, Virginia Shervette, James "Tut" Warren, Dr. Cynthia Moncreiff, Dr. Robin Overstreet, and Dr. Don Johnson. Finally, the Blue Crab TTF and GSMFC extend their most heartfelt thanks to Mrs. Cynthia B. Yocom for her special talents, effort, and dedication to ensure the quality of this document.

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.

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Abbreviations and Symbols

m	meters
mm	millimeters
km	kilometer
ha	hectare
ft	feet
‰	parts per thousand
ppm	parts per million
°C	degrees Celsius
DO	dissolved oxygen
SL	standard length
TL	total length
g	grams
kg	kilograms
lbs	pounds
mt	metric tons
TW	total weight
CPI	Consumer Price Index
yr	year(s)
h	hour(s)
min	minute(s)
sec	second(s)
SE	standard error
SD	standard deviation
EFH	Essential Fish Habitat
YOY	young-of-the-year
BRD	bycatch reduction device
TED	turtle exclusion device
TPWD	Texas Parks and Wildlife Department
MDMR	Mississippi Department of Marine Resources
ADCNR	Alabama Department of Conservation Natural Resources
FDEP	Florida Department of Environmental Protection
LDWF	Louisiana Department of Wildlife and Fisheries
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USDOC	United States Department of Commerce
NMFS	National Marine Fisheries Service
MRFSS	Marine Recreational Fisheries Statistical Survey
GSMFC	Gulf States Marine Fisheries Commission
GMFMC	Gulf of Mexico Fisheries Management Council
S-FFMC	State-Federal Fisheries Management Committee
EPA	Environmental Protection Agency
GMEI	Gulf of Mexico Estuarine Inventory
TTC	Technical Coordinating Committee
TTF	Technical Task Force
IJF	Interjurisdictional Fisheries Management Program
FMP	Fishery Management Plan
EEZ	Exclusive Economic Zone
TTS	Texas Territorial Sea

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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. There is a low level of genetic variation between Gulf populations, and genetic exchange is not impeded by physical or physiological barriers; consequently, the existence of more than one stock of Gulf blue crabs has not been demonstrated.

The blue crab life history is typical of other estuarine-dependent species in the Gulf of Mexico. Mating may take place year round in brackish areas of the estuary while spawning occurs in high salinity nearshore waters. Larval forms are principally oceanic until the megalopae are transported back into the estuary. Juvenile crabs are widely distributed in estuaries. Adults show a differential distribution by sex and salinity with 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 for the 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 are applicable primarily to 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. During the 1990s, annual Gulf hard crab commercial landings averaged 61.6 million lbs, and the contribution of Gulf landings to total United States production ranged between 21.6% and 35.4%. The average percent contributions of state landings to Gulf production were: Louisiana, 60.9%; Florida, 17.7%; Texas, 14.3%; Alabama, 4.9%; and Mississippi, 1.9%. 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. In addition, there is a high-value fishery for soft-shell crabs which averaged 188,000 lbs during the 1990s.

Fishing effort as measured by the number of fishermen has increased dramatically; the number of fishermen increased from 1,516 in 1980 to 4,028 in 1991, an increase of 166%. Increased effort has led to economic overcapitalization; catch per fishermen has declined, and the number of traps has increased or stabilized in most Gulf states.

Blue crab dockside prices appear to be unresponsive to changes in landings. Blue crab products move through various outlets and undergo significant transformation before reaching the consumer. Some meat is pasteurized although most is sold as a fresh, ice-pack product. Firms may also process other specialty products including claws, deviled crab, crab cakes, crab patties, stuffed crab, and soft-shell crab. The number of processors peaked at 108 in 1992 and then declined to 73 in 1997. Alabama has become the center of processing in the Gulf. Crab imports have increased in recent years.

The blue crab industry has recently undergone major changes in its ethnic and economic organization. The entry of Southeast Asians into the fishery resulted in social, cultural, and economic conflicts. The current demographic and social composition of the Gulf fishery was characterized. Major sources of conflict were identified: other crab fishermen—theft of crabs or traps and capture of undersized crabs; shrimp and recreational fishermen—conflicts over loss of traps due to their activities; and regulations and enforcement—excessive regulations, legislative management of the fishery, and inadequate enforcement.

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. Protection of essential habitat must be an integral part of the management strategy, and policies should address sources of juvenile blue crab mortality.

Gulfwide, the blue crab population appears to be biologically stable. There was little uniform indication of stock stress for any indicator of stock health. The inconsistencies in stock indicators illustrate the need for collection of appropriate fishery dependent and fishery independent data across the Gulf. Collection of these data would facilitate a more comprehensive assessment of blue crab stocks in the future.

Specific recommendations were made to address other identified problems, including gear saturation/overcapitalization, wasteful harvesting practices (i.e., capture and harvest of sublegal blue crabs, bycatch in the shrimp fishery, ghost trap mortality); user group conflicts; trap and crab theft; and peeler crab availability. In addition, critical fishery dependent and independent data needs were identified.

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. 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), which included fisheries data through 1987. While many of these changes are reflective of socioeconomic conditions and management regimes within the fishery in individual Gulf states, continued loss and alteration of habitat, enforcement of existing regulations, user group conflicts, and increasing fishing effort are among the problems that affect the fishery Gulfwide (Guillory et al. 1998). Since the publication of the 1990 blue crab plan, new research has expanded our knowledge of both the species and the fishery.

At the fall 1996 meeting of the GSMFC, the TCC Crab Subcommittee recommended that the regional blue crab FMP be revised. The TCC and S-FFMC agreed to the revision.

2.1 IJF Program and Management Process

The Interjurisdictional Fisheries Act of 1986 (Title III, Public Law 99-659) was established 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 the 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 council.

The GSMFC subsequently initiated the development of a FMP planning and approval process. This process has been modified as various plans have been developed, and its current form is outlined as follows:

DMS						
↕						
TTF	→	**TCC**	→	**S-FFMC**	→	**GSMFC**
↕				↕		
SAT				**Outside Review***		

DMS=Data Management Subcommittee
GSMFC=Gulf States Marine Fisheries Commission
SAT=Stock Assessment Team
S-FFMC=State-Federal Fisheries Management Committee
TCC=Technical Coordinating Committee
TTF=Technical Task Force

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

Once the TTF completes the plan it may be approved or modified by the 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 this approval, 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 recommended to the individual states for consideration of adoption and implementation.

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Section 4.0 - Steele
Section 5.0 - Wagner
Section 6.0 - Guillory
Section 7.0 - Keithly
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Section 9.0 - Perry, Guillory, Pellegrin
Section 10.0 - Guillory, Perry
Section 11.0 - All
Section 12.0 - All

Section 13.0 - Perry, Guillory
Section 14.0 - Appendices
Section 14.1 - Glossary - All
Section 14.2 - Stock Assessment - Pellegrin

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. There are currently 15 species recognized in the genus, three in the Pacific and 12 in the Atlantic and adjacent seas.

Callinectes sapidus Rathbun is distributed throughout the Gulf of Mexico. The type locality 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 (1974) listed seven additional *Callinectes* species in the Gulf of Mexico; *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. *Callinectes marginatus, 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* is distributed Gulfwide.

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 Williams et al. (1989) 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
            - Family Portunidae

3.2.1.2 Morphology

Rathbun (1930), Williams (1974), 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 with shades of grayish, bluish or brownish green occurring. The propodi of chelae of males are blue on the inner and outer surfaces and tipped with red. The fingers of chelae of mature females are orange tipped with purple.

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 ('typica' form) found along the east coast and the acute spined individuals ('acutidens' form) 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 'typica' 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."

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. The most comprehensive study is that of McMillen-Jackson et al. (1994). Using electrophoretic allozyme analysis, they examined genetic structure of blue crab populations over a broad geographic area (New York to Texas). They found that 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 to date indicate a lack of distinct genetic populations of blue crabs in the Gulf of Mexico. Larval mixing (Perry et al. 1999, Johnson and Perry 1999), long-distance migration of adults (Evink 1976, Oesterling and Evink 1977, Oesterling and Adams 1982), and/or the masking of genetic structuring by genetic patchiness (McMillen-Jackson et al. 1994) may contribute to the observed homogeneity.

3.2.2. Age, Growth, and Maturation

3.2.2.1 Growth

Because growth in blue crabs is discontinuous or step-wise, estimation of growth is problematic. Growth takes place during ecdysis or molting, although 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 determinants of size. Early crab stages molt every few days, but as crabs increase in size, molt frequency decreases. Newcombe et al. (1949a) estimated the postlarval in stars for male and female blue crabs to be 20 and 18, respectively. Growth is determinate (Hartnoll 1985), and the number of molts (including larval molts) is assumed to be fixed at about 25 (Newcombe et al. 1949a,b; Van Engel 1958). Thus, the maximum size attained reflects incremental growth per molt rather than the number of molts (Leffler 1972).

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 in 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. 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.

Studies examining the influence of environmental parameters on molt frequency and incremental growth are conflicting. Newcombe (1945), Porter (1955), Cargo (1958), Van Engel (1958), and Tagatz 1968a) 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 the 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‰ to 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‰, and Haefner and Shuster (1964) concluded that "within the parameters of the experiment, the salinity variation of the environment is not related to percentage increase in length at the terminal molt." Tagatz (1968b) 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 (unpublished data) examined size increases in pubertal molt females in salinities of 5.0‰, 12.0‰, and 25.0‰. Percent increases in carapace width were not significantly different among the test groups (Figure 3.1). Average increases were 38.5%, 40.4%, and 40.5% at salinities of 5.0‰, 12.0‰, and 25.0‰, respectively. Tagatz (1968b) reported incremental growth increases in pubertal molt females of 34.4% and 30.2% in salt (>5‰) and fresh (<1‰) waters, respectively.

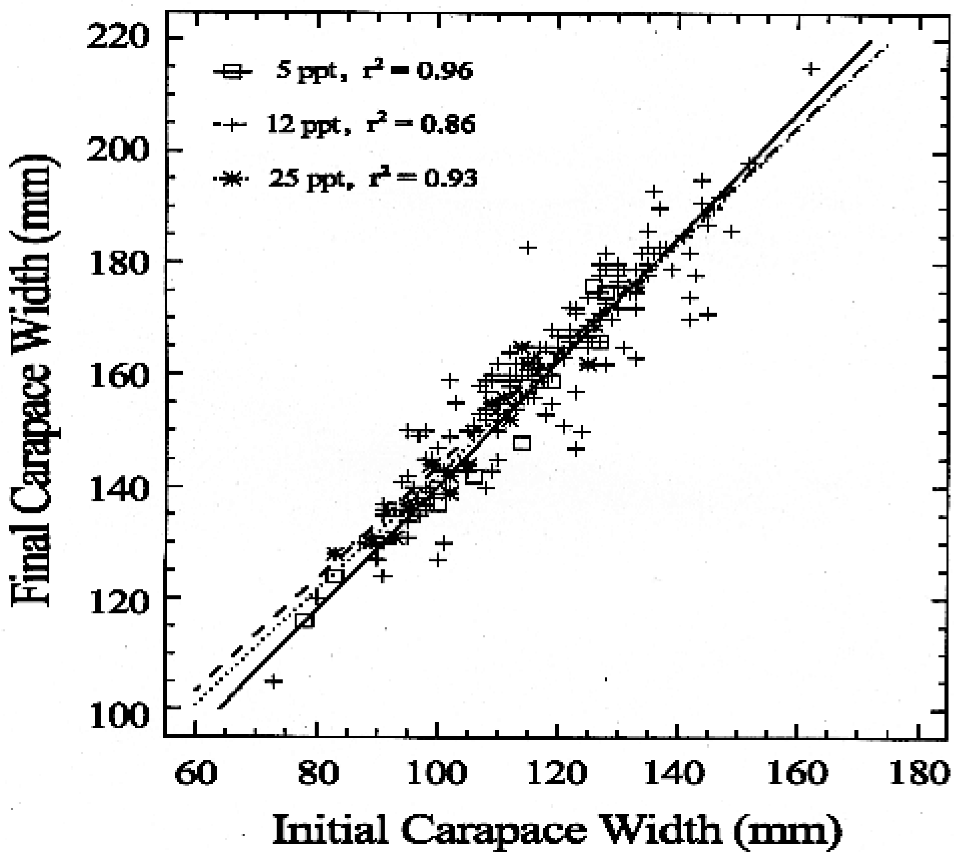

Figure 3.1. Percent increase in carapace width in pubertal molt females in salinities of 5, 12, and 25 ppt (or ‰) (Perry unpublished data).

Growth of blue crabs appears to be strongly affected by temperature as 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). In laboratory studies, Leffler (1972) demonstrated that the molting rate (molts per unit of time) increased rapidly with increasing temperature from 13.0°C to 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 (1968b) 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's crabs were held 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 (1968b) 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% to 50.0% with a mean of 25.3%. Both Tagatz (1968b) and Millikin and Williams (1984) noted that growth rate of juvenile crabs did not vary between males and females.

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. 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.

Seasonal size differences have been reported in wild caught *C. sapidus* megalopae and first crab stages. Stuck and Perry (1982) found 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 fall-caught megalopae may be related to seasonal differences in food availability.

3.2.2.2 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 determination of growth rates for use in estimating total mortality. Rugolo et al. (1997) approximated size at age from fishery independent data (Virginia Institute of Marine Science trawl surveys, Chesapeake Bay area) as follows: age class 0 (0-59 mm CW), age class 1 (60-119 mm CW), age class 1+ (>60 mm CW), age class 2+ (≥120 mm CW). Tagatz (1968b) 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 at a carapace width 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 (1968b). Assuming that crabs in the northern Gulf reach maturity within a year (Perry 1975, Tatum 1980), these crabs provide an estimate of size at age one. 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 one (163 mm CW) for mature females when compared to the estimated size of 142 mm CW proposed by Tagatz (1968b) may be attributed to sex-related morphological changes associated with lateral spine length in pubertal molt females (Gray and Newcombe 1938a, 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 1968b).

3.2.2.3 Maturation

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 appears to influence maturation size. Temperature exerts control on maximum size by affecting incremental growth and molt interval. Tagatz (1968b) 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),

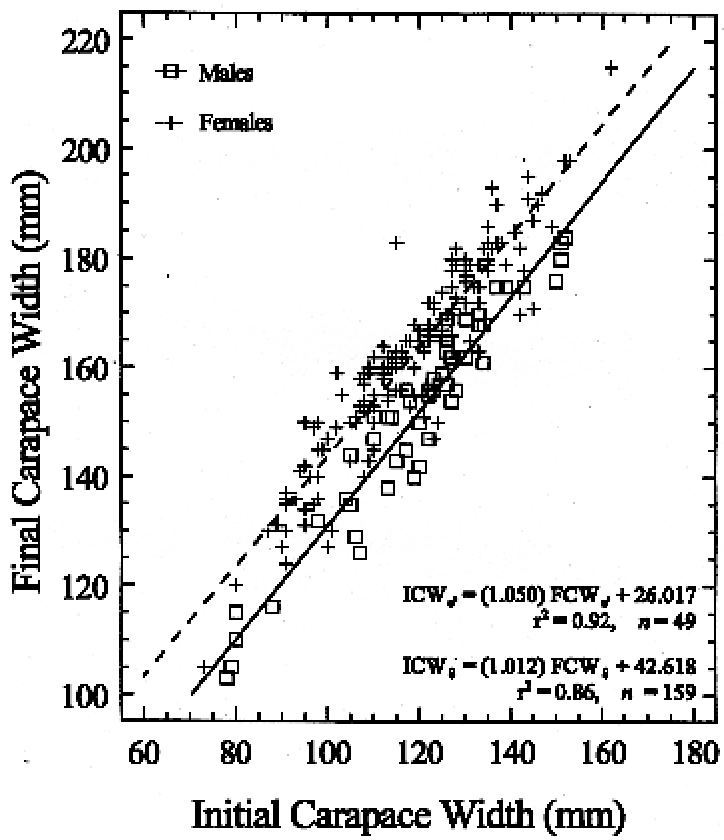

Figure 3.2. Post-molt gain in carapace width for similar-sized male and pubertal molt female blue crabs in Mississippi (Perry unpublished data).

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 3.2).

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 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 also 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 (Dr. Theresa Bert personal communication).

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.

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. After insemination, the male continues to carry the female until her shell has hardened. Sperm remain viable for at least one year 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. 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. After the second ovulation, the ovary is collapsed and grey or tan in color.

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. 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.

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.

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. 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." As many as two million eggs may be present in a single sponge. 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 eggs hatch in about two weeks.

Most females spawn at least twice. Females generally return to inland waters to develop their second sponge (Tagatz 1968a, 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 1968a). 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 potential 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.

3.2.3.4. 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 1.75×10^6 and 2.00×10^6 (Churchill 1921, Van Engel 1958). The more recent estimates are higher: 2.75×10^6 (Hines 1982), 3.2×10^6 (Prager et al. 1990), and $2.1\text{-}3.2 \times 10^6$ (Hsueh et al. 1993). 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. Hines (1982) observed that female body weight was correlated with reproductive output in brachyuran crabs and accounted for 95% of the variance in brood weight, 79% of the variance in the number of eggs per brood, 63% of the variance in annual brood weight, and 74% of the variance in annual fecundity. Brood weight was generally constrained to approximately 10% of body weight. He found no correlation between number of broods and body size. In his study, he noted that *Callinectes sapidus* had extremely small eggs (251 µm mean ovum diameter), large numbers of eggs per brood, and a high adjusted yearly fecundity. Prager et al. (1990) found that fecundity varied within and between years and was significantly related to carapace width.

3.2.3.5 Stock-Recruitment Relationship

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).

No stock recruitment relationship has been quantified for the Gulf of Mexico blue crab fishery. Blue crab populations in the Gulf are not recruitment limited but are influenced by post-settlement biotic processes that affect juvenile survival (Livingston et al. 1976, Heck and Coen 1995, van Montfrans et al. 1995, Perry et al. 1998). Steele and Perry (1990) noted the 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."

3.2.4 Larvae

3.2.4.1 Development

There has been some discussion in the literature concerning the existence of a prezoeal stage in *C. sapidus*. Robertson (1938), Churchill (1942), Truitt (1942), and Davis (1965) reported prezoeae emerging from the eggs. Time estimates for length of stay in the prezoeal stage ranged 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. Additionally, Bookhout and Costlow (1974, 1977) did not mention a prezoeal stage for *Portunus spinicarpus* or *C. similis*.

Costlow and Bookhout (1959) reported seven zoeal stages and one megalopal stage for the blue crab. An eighth zoeal stage was sometimes observed though survival to the megalopal stage was rare. Development through the seven zoeal stages required from 31 to 49 days with the megalopal stage persisting from six to 20 days. In salinities below 20.1‰, the larvae rarely survived the first molt.

3.2.4.2 Distribution and Abundance

3.2.4.2.1 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 (Andyrszak 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.

3.2.4.2.2 Megalopae

Callinectes spp. megalopae have been reported to occur throughout the year. 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 through 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. 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 (K. 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 referable to *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 (1968a) 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.

3.2.4.2.3 Megalopal 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 coastwide 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, 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.

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 to 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 thigmokenetic response may be a mechanism favoring maintenance of position on ebb tides.

3.2.5. Juveniles

3.2.5.1 Megalopal Recruitment 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 to 19.9 mm) 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 3.3). 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. Because they declined at an equal rate relative to the initial abundance of early juveniles, the authors suggested that the decrease in numbers of individuals with increasing size may represent an index of mortality. 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. 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.

3.2.5.2 Seasonal and Areal Distribution

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 3.1). 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 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 catch per unit of effort in 16 ft 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

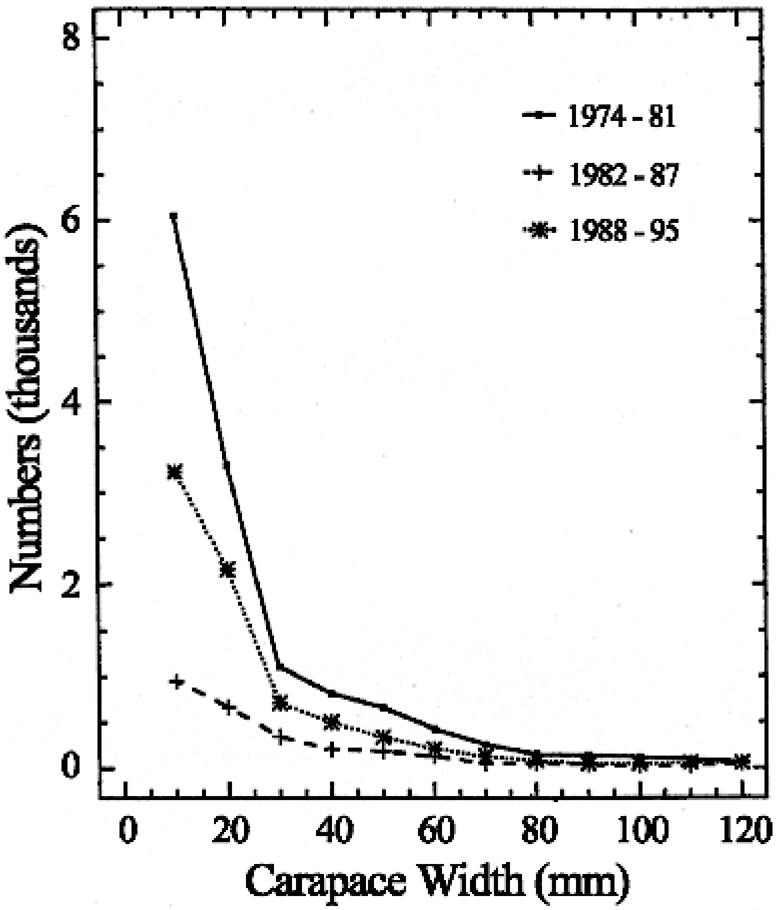

Figure 3.3. Number of blue crabs by 10 mm CW size intervals for selected years (from Perry et al. 1998b).

(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.

Table 3.1. Distribution of *C. sapidus* by salinity intervals showing number of samples (above) and catch per sample (below).

	Salinity (‰)							
Modified from:	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 6.0	15 4.7	14 2.6	19 2.3	33 3.1	18 3.3	18 4.4	179 3.9
Perret et al. (1971)	197 12.0	185 6.0	263 6.0	278 6.0	182 6.0	82 5.0	12 5.0	1,199 7.0
Christmas and Langley (1973)	134 1.2	87 2.7	110 3.8	99 3.2	145 4.1	169 2.2	74 0.9	818 2.6
Perry and Stuck (1982)	561 7.6	423 7.8	482 7.1	520 8.3	517 5.9	489 3.0	257 2.7	3,249 6.3

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), and Perry and Stuck (1982) 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 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.

3.2.6 Factors Affecting Survival

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 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). 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.

3.2.6.1 Larvae

Availability of appropriate size zooplankton as prey may be important for larval blue crab survival. Phytoplankton is consumed by larvae (Costlow and Sastry 1966), but plant material alone is believed to be deficient in protein content. Survival rates of larvae fed various phytoplankton species or unicellular algae were depressed when compared to larvae fed zooplankton (Costlow and Bookhout 1959). Blue crab larvae fed rotifers show higher survival and molting rates (Sulkin and Epifanio 1975, Sulkin 1978) than did those fed *Artemia* (Costlow and Bookhout 1959).

In laboratory studies, successful hatching never occurred at 15‰ (Costlow and Bookhout 1959) although Davis (1965) hatched larvae at 18‰. Sandoz and Rogers (1944) determined that optimum salinities for hatching lay between 23‰ and 30‰. Optimum temperatures for hatching of eggs were reported to be 19° to 29°C (Sandoz and Rogers 1944) and 20° to 35°C (Costlow 1967).

Early stage crab zoeae are good osmoregulators but lose this ability as they progress through later zoeal stages (Kalber 1970). Sandoz and Rogers (1944) reported optimum salinities for metamorphosis during the first three zoeal stages ranged from 21‰ to 28‰. Kalber (1970) suggested that osmoregulatory adaptations are related to the sequence of salinity stress normally experienced during development and that megalopae become good osmoregulators by the fifth day.

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 (five to 11 days) at 30°C in salinities from 10‰ to 40‰. Duration of the megalopal stage was prolonged from 30 to 67 days at salinities ≥20‰ at a temperature of 15°C. 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.

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. Millikin and Williams (1984) provided a review of these studies.

3.2.6.2. Juveniles and Adults

Mortalities associated with chemical and biological pollutants, sediment, 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.

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 have been lower in the James River than in the York or Rappahannock rivers for the past 15 years (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 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 (<18°C) and high body burdens of DDT (Koenig et al. 1976).

Jaworski (1972) noted a decline in blue crab landings during the 1960s from the upper Barataria Bay basin, Louisiana, and suggested that this decline may be associated with pollution and drainage alteration. Adkins (1972a) concluded that domestic, agricultural, and industrial pollution as well as dredge and fill operations have adversely affected blue crab populations in Louisiana.

Low levels of dissolved oxygen not only cause mortality of crabs but also impede migration. 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 phenomenon. May (1973) reported that 81,000 kg of blue crabs died during an anoxic event along Great Point Clear, Alabama. Low levels of dissolved oxygen in the deeper waters of Chesapeake Bay and associated tributaries during the summer months have also been implicated in trap death (Carpenter and Cargo 1957). Price et al. (1985) noted that blue crab fishermen in Chesapeake Bay have had to set their traps progressively closer to shore because of hypoxic conditions in deeper water. Periodic "kills" of blue crabs following excessive freshwater runoff and subsequent depletion of oxygen due to rapid decomposition of organic matter were reported by Van Engel (1982).

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 (TL_m) values. Crabs were acclimated to 20°C. At 0°C there was no survival at any salinity. At 8.6‰ the tolerance zone extended from 3.2° to 22°C, and at 36‰, it extended from 18.5° to 35.2°C. The greatest tolerance zone extended over 27°C 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 6°, 14°, 22°, or 30°C. 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) and to red tides (Wardle et al. 1975, Gunter and Lyles 1979). Adkins (1972a) and Perry (1975) reported large numbers of dead crabs periodically littered the beaches of Louisiana and Mississippi, respectively and observed that the vast majority of these crabs were spent females.

Mortality of small juvenile blue crabs (20-60 mm TL) from Texas fishery-independent bag seine sampling steadily increased from 1978 to 1996 (Mark Fisher personal communication). Possible sources of increasing mortality include increased predation, shrimp trawl bycatch, and unfavorable environmental conditions such as habitat loss.

3.2.6.3 Parasites and Disease

A listing of parasites, diseases, symbionts, and other associated organisms reported from blue crabs is found in Table 3.2. Couch and Martin (1982) provided a synopsis of the protozoan symbionts and related diseases of blue crabs. Of the protozoans that utilize the blue crab as host, the amoeba *Paramoeba perniciosa* and the dinoflagellate *Hematodinium* were identified as lethal pathogens. The history of the incidence of *P. perniciosa* along the eastern coast of the United States was reviewed by Couch and Martin (1982). This highly pathogenic amoeba is responsible for outbreaks of gray crab disease. Mass mortalities of blue crabs occurred 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. Couch and Martin (1982) described *P. perniciosa* as an opportunistic parasite/pathogen of blue crabs and other Crustacea. To date, this organism has not been isolated from blue crabs in the Gulf of Mexico.

Hematodinium sp., a dinoflagellate found predominantly in the hemolymph, has been identified from *Callinectes sapidus* from the northern Gulf of Mexico (Couch and Martin 1982). The disease exhibits no external signs although infected crabs are weak and lethargic. In heavily infected crabs, the dinoflagellates may be found in the musculature, gonads, and hepatopancreas.

Table 3.2. Symbionts and fouling organisms of blue crabs (adapted from Van Engel 1987, Millikin and Williams 1984, and Messick and Sindermann 1992).

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
VIRUSES					
RLV (Reo-like virus); infects RNA	Rhabdo-like virus A (RhVA always found with RLV; causes cytoplasmic inclusions, increased cytoplasmic volume in hemocytes, hemopoietic tissue, and glial nerves	RLV and RhVA act synergistically, causing necrosis of hemopoietic tissue, hemocytes, and CNS; death due to nerve and hemocytic dysfunction; fatal	Sluggishness, paralysis; withdrawn blood clots incompletely	Chincoteague and Chesapeake Bays; infects crabs from high and low salinities; actual prevalence unknown	Vago 1966, Johnson 1977a, c, 1983, 1984, 1985, Johnson and Bodammer 1975, Overstreet 1978
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, 1979, Johnson 1978b, 1983, 1984, 1985, Messick 1998
RhVB (Rhabdo-like virus B); infects RNA; formerly labeled EG V-1	Associated extra-cellularly with basal lamina of mandibular gland	"Infected" 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, 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, b, 1983, 1984, 1985, Overstreet 1978
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, 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, 1985; Messick 1998
MONERA Bacteria					
Acinetobacter sp.	Non-motile, gram-negative rods; aerobic; isolated from hemolymph	Unknown	No reported gross signs	Chesapeake and Chincoteague Bays	Colwell et al. 1975, Sizemore et al. 1975
Acinetobacter baumanii, A. calcoaceticus, A. johnsonii, A. lwoffii	Non-motile, gram-negative rods; aerobic; all isolated from hemolymph, all except *A. lwoffii* also isolated from exoskeleton	Unknown	No reported gross signs	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
Aeromonas cavaie, A. hydrophila, A. sobria	Motile gram-negative rods to coccobacilli; facultative anaerobes; *A. cavaie* and *A. hydrophila* isolated from hemolymph, *A. hydrophila* and *A. sobria* isolated from exoskeleton	*A. hydrophila* and *A. sobria* are chitinoclastic	No reported gross signs	Pensacola Bay and tributaries	Overstreet and Rebarchik 1995
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

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
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; "box burn" or "shell 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	William-Walls 1968
Enterobacter aerogenes	Motile, gram-negative rod; facultative anaerobe; isolated from gills and hemolymph	Unknown	No reported gross signs	South Carolina, Gulf of Mexico	Babinchak et al. 1982, Overstreet and Rebarchik 1995
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 fungus, *L. 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
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

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
Proteus mirabilis, P. penneri	Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph	Unknown	No reported gross signs	Pensacola Bay and tributaries	Overstreet and Rebarchik 1995
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; "box burn" or "shell disease"	Gulf of Mexico	Cook and Lofton 1973, Overstreet and Rebarchik 1995
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	*S. marscescens* is chitinoclastic	No reported gross signs	Pensacola Bay and tributaries	Overstreet and Rebarchik 1995
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
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
Vibrio alginolyticus	Motile, gram-negative rods; facultative anaerobe; isolated from hemolymph and exoskeleton	Unknown	No reported gross signs	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	Sizemore et al. 1975
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	Chitonoclastic	No reported gross signs	Gulf of Mexico	Moody 1982, Overstreet and Rebarchik 1995
Vibrio fluvialis, V. mimicus	Motile, gram-negative rods; facultative anaerobes; isolated from hemolymph and exoskeleton	Chitinoclastic	No reported gross signs	Pensacola Bay and tributaries	Overstreet and Rebarchik 1995
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
Vibrio mediteraneii	Motile, gram-negative rod; facultative anaerobe; isolated from exoskeleton	Chitinoclastic	No reported gross signs	Pensacola Bay and tributaries	Overstreet and Rebarchik 1995
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; 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
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	Unknown	No reported gross signs	Gulf of Mexico	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

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
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
FUNGI					
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, 1974
Thraustochytrium sp.	Associated with *L. callinectes*, saprophytic secondary invader of eggs	Unknown		North Carolina	Bland and Amerson 1974
PROTISTA					
Algae	Exoskeleton	Fouling organism			Overstreet 1982
Hematodinium perezi (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 of Mexico; found in waters with salinities greater than 11 ppt	Newman and Johnson 1975, Newman 1977, Couch and Martin 1982, Couch 1983
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 "grey 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
Mesanophrys chesapeakensis (protozoan, ciliate)	Hemolymph and tissue	Histophagous	Lethargy	Chesapeake Bay	Messick and Small 1996, Messick 1998
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 of Mexico; peak prevalence during summer months	Couch 1966, 1967, 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 of Mexico	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
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 of Mexico	Sprague 1950, 1965, 1970, 1977, Overstreet and Weidner 1974, Overstreet and Whatley 1975, Overstreet 1977, 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, 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
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

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
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
ANIMALIA					
Porifera (sponges)	Exoskeleton	Fouling organism		North Carolina	Pearse 1947
Cnidaria					
Obelia bidentata (hydroid)	Exoskeleton	Fouling organism		Gulf of Mexico	Overstreet 1983
Bougainvillia sp. (hydroid)	Exoskeleton	Fouling organism		Gulf of Mexico	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					
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 "pepper spot" or "buckshot"	Chesapeake Bay to Texas	DeTurk 1940, Couch 1974, Overstreet 1978, 1982, 1983; Heard and Overstreet 1983
Digeneans, flukes (microphallid metacercariae, several species, taxonomy of some in question, under study)	Primarily muscle tissue, vessels and hepatopancreas	None unless heavy abnormal infection	None, require microscopic diagnosis	Atlantic and Gulf coasts	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 of Mexico	Overstreet and Perry 1972, Overstreet 1978, 1982, 1983
Megalophallus diodontis (digenean, fluke)	Metacercarial cycts found primarily at base of gill filaments	None, unless heavy abnormal infection		Gulf of Mexico and Caribbean Sea	Overstreet 1982, Prevot and Deblock 1970
Nemertea					
Carcinonemertes carcinophila (nemertean)	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, Overstreet 1978, 1982, 1983, Overstreet and Rebarchik 1995, Messick 1998
Nematoda *Hysterothylacium* sp.	Encapsulates in body cavity and tissues	None noted	None noted	Gulf of Mexico	Deardoff and Overstreet 1981
Mollusca					
Crassostrea virginica	Exoskeleton	Fouling organism	Spat settle on exoskeleton; may attach beneath apron	Gulf of Mexico	Overstreet 1982
Mytilus edulis	Exoskeleton	Fouling organism		Atlantic and Gulf coasts	Cargo 1959, Overstreet 1982
Bryozoa					
Acanthodesia tennuis	Exoskeleton	Fouling organism			Osburn 1944
Alcyonidium mytili	Exoskeleton	Fouling organism			Pearse 1947
Alcyonidium verrelli	Exoskeleton	Fouling organism			Osburn 1944
Conopeum tenuissium	Exoskeleton	Fouling organism			Overstreet 1982
Membranipora crustulenta	Exoskeleton	Fouling organism			Osburn 1944
Membranipora tenius	Exoskeleton	Fouling organism			Overstreet 1982
Triticella elongata	Etenostomate ectoproct; branchial chamber	Fouling organism			Osburn 1944, Overstreet 1982

Pathogen	Histopathology and Tissues Infected	Effect on Host	Gross Signs of Disease	Geographic Location and Prevalence	Reference
Annelida					
Hirudinea					
Calliobdella vivida (leech)	Exoskeleton and gills	Unknown		Gulf of Mexico; low-salinity habitats	Overstreet 1982
Myzobdella lugubris (leech)	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, Overstreet 1978, 1982, 1983
Brachiobdellid					
Cambarincola vitreus	Exoskeleton and gills	Unknown; no apparent harm		Gulf of Mexico; low salinity /freshwater habitats	Perry 1975, Overstreet 1978, 1982
Arthropoda				Atlantic and Gulf coasts	
Amphipoda	Exoskeleton	Fouling organism			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			
Balanus improvisus (acorn barnacle)	Exoskeleton	Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement			
Balanus venustus niveus (acorn barnacle)	Exoskeleton	Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement		Gulf of Mexico	Overstreet 1978, 1982
Chelonibia patula (acorn barnacle)	Exoskeleton	Fouling organism; heavy infestations may reduce mobility of crab and increase energy expenditures associated with movement		Gulf of Mexico	Overstreet 1978
Loxothylacus texanus (cirriped, 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 of Mexico; more prevalent in higher salinity waters	Reinhard 1950a,b; 1956; Adkins 1972b; Ragan and Matherne 1974; Overstreet 1978, 1982, 1983
Octolasmis muelleri (pedunculate barnacle)	Gill chamber	Heavy infestations decrease respiration efficiency	Easily visible on gills and in gill chamber	Gulf of Mexico	Perry 1975, Overstreet 1978, 1982, 1983, Overstreet and Rebarchik 1995
Urochordata					
Molgula manhattensis (tunicate)	Exoskeleton	Fouling organism			Pearse 1947

Other protozoans infecting the blue crab are the haplosporidan parasite *Urosporidium crescens* and the microsporidan pathogen *Ameson michaelis*. *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.

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*. *Ameson michaelis*, commonly found in blue crabs from Gulf and Atlantic waters (Sprague 1977), infects the musculature and is thought to cause lysis of the muscle tissue. Overstreet (1978) noted the occurrence of this species in crabs from lakes Pontchartrain and Borgne, Louisiana, and Mississippi Sound and diagramed the life cycle. Heavily infected crabs can be distinguished from healthy individuals by the chalky opaque appearance of the muscle tissue.

Heavy infestations of ectocommensal ciliate protozoans 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.

A variety of cirripede symbionts are either ecto-commensal or parasitic on blue crabs. Fouling species include the barnacles *Balanus venustus niveus* 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. 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.

The barnacle, *Loxothylacus texanus,* is a true parasite of blue crabs in the Gulf of Mexico. Reinhard (1950a,b, 1951); Overstreet (1978); and O'Brien and van Wyk (1985) described aspects of the process of parasitization. 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 emerges as a small "bud" on the external surface. 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. Life history characteristics of different sacculinid species vary and caution must be applied in relating data from one species to another (R. Overstreet personal communication).

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. 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. Studies using trawls (Perry unpublished data, Guillory unpublished data) would be expected to have larger numbers of smaller individuals than those studies using traps (Hochberg et al. 1992). Largest individuals were recorded by Hochberg et al. (1992) and occurred in south Florida (mean size between 110 and 120 mm CW) and Apalachee Bay (mean size between 80 and 90 mm CW). They reported that 51% of the infected crabs in their samples were $\geq$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 to 98.0 mm CW with a mean carapace width of 48.1 mm (Perry unpublished data).

The influence of rhizocephalan infection on blue crab stocks is of particular concern in Louisiana. In Bayou Jean LaCroix, Ragan and Matherne (1974) examined juvenile crabs from 33 to 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. Adkins (1972b), Ragan and Matherne (1974) and Wardle and Tirpak (1991) found peak occurrence of the barnacle in higher salinities. 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 through 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. Overstreet (1978) suggested that the "dwarf" or "button" crabs that appear seasonally in the commercial catch in Mississippi may be a result of sacculinid infection. 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 through July. In Florida, Steele and Hochberg (1987) reported a 4% incidence rate of *L. texanus* infection of blue crabs in Tampa Bay.

Carcinonemertes carcinophila, a parasitic nemertean, is common on the gills and egg masses of mature female crabs (More 1969, Perry 1975). 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.

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. 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*.

Because the types of habitats in which these trematodes complete their life cycle are often quite specific, they have potential use as "biological tags" (R. 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.

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). The taxonomic status of several species of microphallids is in question (R. Heard personal communication).

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 (R. Overstreet personal communication).

Leeches (*Myzobdella lugubris*) are common on crabs from low salinity waters. 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. A branchiobdellid annelid, *Cambarincola vitreus*, also infests blue crabs from low salinity and freshwater habitats. These small worms (2 to 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).

Microbial infections of blue crabs include the nonfatal bacteria responsible for "shell disease" and pathogenic species of *Vibrio*. 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.

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* and *V. vulnificus* were commonly isolated from the same crab; however, *V. parahaemolyticus* and *V. cholerae* were never found together. *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.

3.2.7. Food Habits

3.2.7.1 Larvae

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 to 80 µm 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) and 2) rotifers *(Brachionus plicatilis)* or polychaete larvae (*Hydroides dianthus*) in combination with *Artemia* nauplii (Sulkin 1975, Sulkin and Epifanio 1975). 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 in stars, 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).

3.2.7.2. Juveniles and Adults

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 1968a, 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.

Ontogenic shifts in blue crab feeding habits were discussed by Darnell (1958); Laughlin (1979, 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 (1968a) 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 (1968a), Tarver (1970), and Alexander (1986). Plant material may also contribute significantly to the diet of blue crabs (Truitt 1939, Darnell 1958, Tagatz 1968a, 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 (1968a): 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 (0.1%). 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.

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, 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).

3.2.8 Predator/Prey Relationships

3.2.8.1 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 (15-35 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. 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 1991a, 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.

3.2.8.2. Foraging Behavior

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.

3.2.8.3. Predation on Blue Crabs

3.2.8.3.1 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).

Table 3.3. Organisms documented in the diet of blue crabs.

Species	Source
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
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

Table 3.4. Documented predators of *C. sapidus*.

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, GCRL)
- *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]
- *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, GCRL)
- *Lutjanus campechanus* - red snapper (Felder 1971)
- *Lutjanus griseus* - gray snapper (Starck 1971)
- *Lobotes surinamensis* - tripletail (Gunter 1945; Franks, unpublished data, GCRL)

Table 3.4. Continued

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)

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)

Blue crabs also serve as important prey items for other vertebrate species (Table 3.4). Among reptilian predators, the American alligator (*Alligator mississippiensis*) may feed heavily on *C. sapidus* (Valentine et al. 1972). Van Engel (1987) reported that sub-adult loggerhead sea turtles (*Caretta caretta*) consumed a variety of prey including *C. sapidus*, but the Kemps Ridley (*Lepidochelys kempii*) fed exclusively on blue crabs in the lower Chesapeake Bay. Avian predators include the clapper rail (*Rallus longirostris*), great blue heron (*Ardea herodias*), American merganser (*Mergus merganser americanus*), and hooded merganser, *Lophodytes cucullatus* (Bateman 1965, Day et al. 1973, Stieglitz 1966). The primary mammalian predator is the raccoon (*Procyon lotor*) (Norse 1975), although river otters (*Lutra canadensis*) have been reported to eat blue crabs (Wilson 1955, 1959; Chabreck et al. 1982).

3.2.8.3.2 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 1968a, 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.

3.2.9 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). Width-weight relationships for male and female blue crabs from Mississippi are shown in Figures 3.4 and 3.5, respectively (Perry unpublished data). 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 premolet (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). Premolt females were heavier than intermolt females; this difference was not observed for males.

Pullen and Trent (1970) reported CW to total weight relations for crabs >25 mm CW from Galveston Bay, Texas: male (log weight = -3.74 + 2.775 log CW) and female (log weight = -3.54 + 2.639 log CW). 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 (1938b) 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.

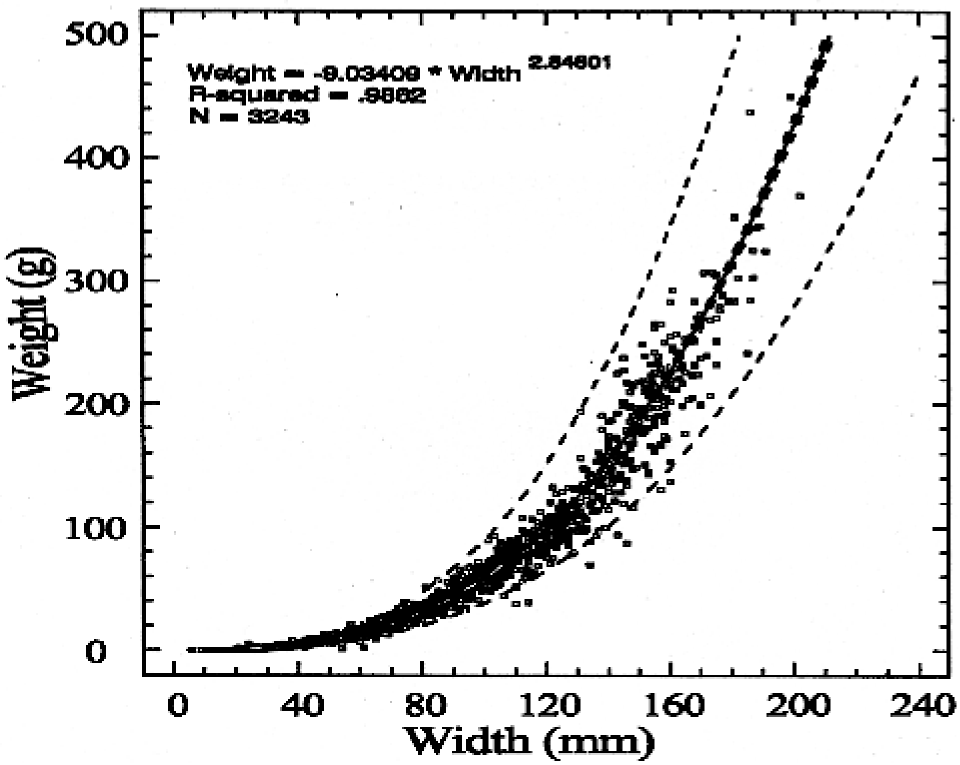

Figure 3.4. Width-weight relationship for male blue crabs in Mississippi (Perry unpublished data).

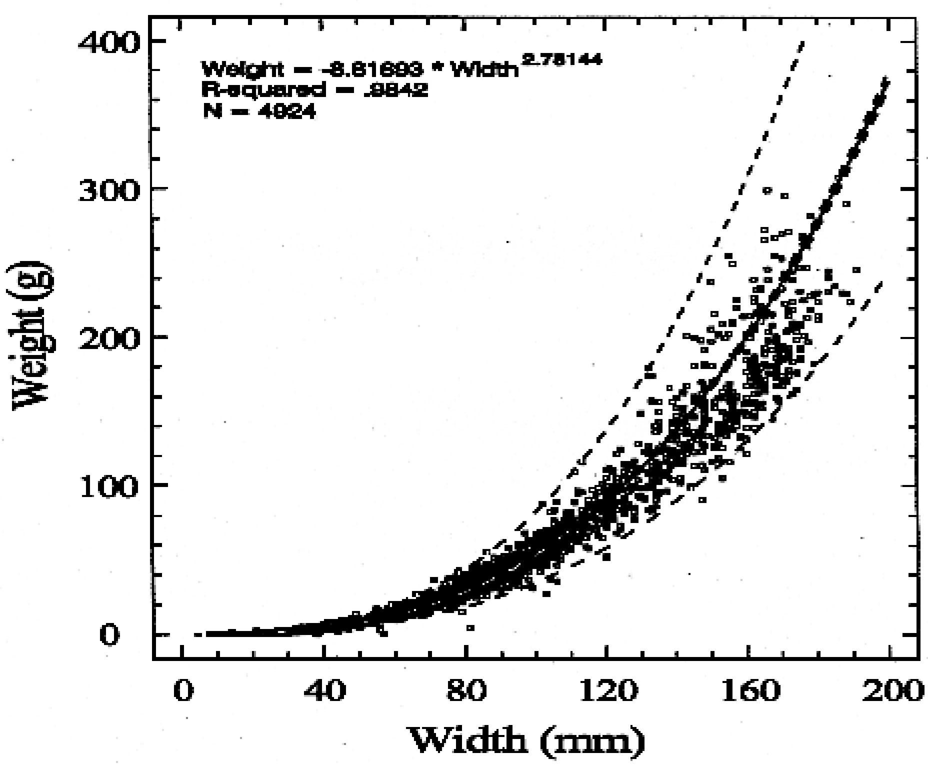

Figure 3.5. Width-weight relationship for female blue crabs in Mississippi, sponge crabs removed (Perry unpublished data).

3.2.10 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 (199lb) 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.

3.2.11 Behavior

3.2.11.1 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 posses 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 (D.F. Johnson 1985). However, once in the estuary, 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.

3.2.11.2 Juveniles and Adults

3.2.11.2.1 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.

3.2.11.2.2 Other Behaviors

In addition to previously discussed behavioral traits, a complex behavioral repertoire has been documented, including 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).

3.2.12 Movements and Migrations

3.2.12.1 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 (1968a), More (1969), Judy and Dudley (1970), Perry (1975), and Eldridge and Waltz (1977).

3.2.12.2. 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 previous studies (Fiedler 1930, Van Engel 1958, Fischler and Walburg 1962, Tagatz 1968a, 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 two to 38 mi, with recapture times ranging from four to 261 days. 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 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 (2.2 mi) 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 (4.9 mi) for males and 19.1 km (11.9 mi) for females. Time to recapture averaged 112 days and ranged from 76 to 144 days.

Blue crab migratory patterns along the west coast of Florida differ from patterns observed in the northern Gulf. Oesterling (1976); Evink (1976); Oesterling and Evink (1977); Oesterling and Adams (1982); and Steele (1987, 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 through 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 (30.2 mi), 43% moved >16.1 km (10.1 mi), 4% traveled >322 km (201 mi), and three individuals traveled 494.1 km (306.9 mi) 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 (1991) 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 (500 mi) in approximately 100 days. Twenty-nine of the tag returns were recovered >765 km (478 mi) from Tampa Bay. Steele (1991) 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.

4.0 DESCRIPTION OF THE HABITAT OF THE STOCK(S) COMPRISING THE MANAGEMENT UNIT

4.1 Description of Essential Habitat

The GSMFC has endorsed the definition of essential fish habitat (EFH) as found in the NMFS guidelines for all federally-managed species under the revised Magnuson-Stevens Act of 1996. The NMFS guidelines define EFH as:

> "those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat: 'Waters' include aquatic areas and their associated physical, chemical, and biological properties that are widely 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 the purposes of describing those habitats that are critical to *Callinectes sapidus* in 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 required federal agency consultation regarding proposed adverse impacts to those habitats.

4.1.1 Gulf of Mexico

Galstoff (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 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 has a surface area of approximately 1,600,000 km^2 (GMFMC 1998), 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). 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). Five of the ten largest commercial fishing ports in the United States are located in the Gulf and account for an estimated 559.7 million kg of fish and shellfish harvested annually from Gulf waters [United States Department of Commerce (USDOC) 1992]. Commercial fishing in the Gulf accounts for 18% of the nation's total commercial landings and supports the most valuable shrimp fishery in the United States (USDOC 1992). Additionally, the Gulf's wetlands, coastal estuaries, and barrier islands support large populations of wildlife (e.g., waterfowl, shorebirds); play a significant role in flood control and water purification; and lessen wind damage and storm surges from hurricanes.

4.1.2 Sediments

Two major sediment provinces exist in the Gulf of Mexico: 1) carbonate sediments found predominantly east of Desoto Canyon and along the Florida west coast and 2) terrigenous sediments 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).

4.1.3 Circulation Patterns and Tides

Hydrographic studies depicting general circulation patterns of the Gulf of Mexico include those of Parr (1935), Drummond and Austin (1958), Ichiye (1962), Nowlin (1971), and Jones et al. (1973). 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 Current, crosses the Caribbean Sea, continues into the Gulf through the Yucatan Channel, and eventually becomes the eastern Gulf Loop Current. Upon entering the Gulf through the Yucatan Channel, the volume transported by the Loop Current is 25-30 million ft^3/sec (Cochrane 1965).

Moving clockwise, the Loop Current dominates surface circulation in the eastern Gulf and generates eddies that move into the western Gulf. During late summer and fall, the progressive expansion and intrusion of the Loop may reach as far north as the continental shelf off the Mississippi River Delta. Nearshore currents are influenced by shelf circulation dynamics, tides, and local wind patterns. The orientation of the shoreline and bottom topography also affect the speed and direction of shelf currents.

Gulf tides are small and noticeably less developed than along the Atlantic or Pacific coasts. Normal tidal ranges in the Gulf are 0.3-0.6 m. 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 h) existing from St. Andrew's Bay, Florida, to western Louisiana. The tide is semi-diurnal in the Apalachicola Bay area of Florida and mixed in western Louisiana and in Texas.

4.1.4 Salinity and Temperature

Gulf salinities beyond the continental shelf average 36.0‰. However, salinity values in shelf regions may vary widely due to opposing effects of river input and enhanced evaporation. Surface salinities in nearshore coastal waters (shallow shelf) range between 29.0‰-32.0‰ during months of high freshwater input [Minerals Management Service (MMS) 1997]. In general, lowest salinities occur in the spring, and highest salinities occur in the summer and fall. Surface temperatures for the Gulf of Mexico were measured by the National Oceanic and Atmospheric Administration (NOAA) (1985) for the warmest and coldest months (January and July). January surface temperatures ranged from 14° to 24°C and surface temperatures in July ranged from 28° to 30°C. The coldest surface water temperatures in January were found along the Texas/Louisiana border on the upper shelf, and the warmest water was located off the southwestern coast of Florida. In July, the coolest water temperatures were located off the south Texas coast while the warmest waters were located off the Mississippi/Alabama coast and southern Florida. Surface temperature data for the Gulf for January ranged from 25°C (Loop Current) to 15°C in the shallow coastal estuaries of the northern Gulf (MMS 1997). Donaldson et al. (1997) reported that surface water temperatures in the Gulf during July ranged from 28°-31°C.

4.1.5 Dissolved Oxygen

Dissolved oxygen levels in the Gulf of Mexico average 6.5 ppm (Barnard and Froelich 1981). Anoxic bottom conditions have not been reported for most of the eastern Gulf with the exceptions of local hypoxic events in Mobile Bay and several bay systems in Florida (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 (Justić 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. The close association that crabs have with estuaries during the hot summer months tends to decrease the effects that offshore hypoxic areas have on the population. Minor inshore hypoxic events have been documented frequently in the Gulf of Mexico (Rabalais et al. 1991) and its estuaries; however, the impact of these events typically does not lead to blue crab mortality.

4.1.6 Submerged Vegetation

Submerged vegetation comprises an estimated 1,475,000 ha of seagrasses and associated macroalgae in the estuarine and shallow coastal waters of the Gulf (MMS 1983). Turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), star grass (*Halophila engelmanni*), and widgeon grass (*Ruppia maritima*) are the dominant seagrass species (GMFMC 1998). Distribution of seagrasses in the Gulf is predominantly along the Florida and Texas coasts (MMS 1983) with 910,000 ha of seagrass (98.5%) being located on the west Florida continental shelf, in contiguous estuaries, and in embayments. Macroalgae species including *Caulerpa*, *Udotea*, *Sargassum*, and *Penicillus* are found throughout the Gulf but are most common on the west Florida shelf and in Florida Bay.

4.1.7 Emergent Vegetation

Emergent vegetation is not evenly distributed along the Gulf coast. The marshes in the Gulf of Mexico consist of several species of grasses, succulents, mangroves, and other assorted marsh compliments. In Texas, emergents include shore grass (*Monanthochloe littoralis*), saltwort (*Batis maritima*), smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), black needlerush (*Juncus roemerianus*), coastal dropseed (*Sporobolus virginicus*), saltmarsh bulrush (*Scirpus robustus*), annual glasswort (*Salicornia bigelovii*), seacoast bluestem (*Schizachyrium scoparium*), sea blite (*Suaeda linearis*), sea oat *(Uniola paniculata*), and gulfdune paspalum (*Paspalum monostachyum*) (Diener 1975, GMFMC 1998). The southern most reaches of Texas also have a few isolated stands of black mangrove (*Avicennia germinans*). Over 247,670 ha of fresh, brackish, and salt marshes occur along the Texas coastline.

Louisiana marshes comprise more than 1.5 million ha or over 60% of all the marsh habitat in the Gulf of Mexico (GMFMC 1998). They include a diverse number of species including smooth cordgrass, glasswort, black needlerush, black mangrove, saltgrass, saltwort, saltmeadow cordgrass, three corner grass (*Scirpus olneyi*), saltmarsh bulrush, deer pea (*Vigna luteola*), arrowhead (*Sagittaria* sp.), wild millet (*Echinochloa walteri*), bullwhip (*Scirpus californicus*), sawgrass (*Cladium jamaicense*), maiden cane *(Panicum hemitomon*), pennywort (*Hydrocotyl*e sp.), pickerelweed (*Pontederia cordata*), alligator-weed (*Alternanthera philoxeroides*), and water hyacinth (*Eichhornia crassipes*) (Perret et al. 1971).

Mississippi and Alabama have a combined 40,246 ha of mainland marsh habitat (26,237 and 14,009 ha, respectively). Mississippi marshes are dominated by black needlerush, smooth cordgrass, saltmeadow cordgrass, and three corner grass (Eleuterius 1973, Wieland 1994). Other common species of saltmarsh vegetation include saltgrass, torpedo grass (*Panicum repens*), sawgrass, saltmarsh bulrush, sea myrtle (*Baccharis halimifolia*), sea ox-eye (*Borrichia frutescens*), marsh elder (*Iva frutescens*), wax myrtle (*Myrica cerifera*), poison bean (*Sesbania drummondii*), pennywort, and marsh pink (*Sabatia stellaris*) (C. Moncreiff personal communication). Alabama marshes contain the same compliment of species as Mississippi with the addition of big cordgrass (*Spartina cynosuroides*), common reed (*Phragmites communis*), and hardstem bulrush (*Scirpus californicus*). The Mississippi Sound barrier islands contain about 860 ha of saltmarsh habitat (GMFMC 1998).

Florida's west coast and Panhandle include 213,895 ha of tidal marsh (GMFMC 1998). Emergent vegetation is dominated by black needlerush but also includes saltmarsh cordgrass, saltmeadow cordgrass, saltgrass, perennial glasswort (*Salicornia perennis*), sea ox-eye, saltwort, and sea lavender (*Limonium carolinianum*). An additional 159,112 ha of Florida's west coast is covered in red mangrove (*Rhizophora mangle*), black mangrove, and buttonwood (*Conocarpus erectus*). A fourth species, white mangrove (*Laguncularia racemosa*), occurs on the west coast but is much less abundant.

4.2 Estuaries

Gulf estuaries provide essential habitat for a variety of commercially and recreationally important species, serving primarily as nursery grounds for juveniles but also as habitat for adults during certain seasons. The Gulf of Mexico is bordered by 207 estuaries (Buff and Turner 1987) that extend from Florida Bay to the lower Laguna Madre. The Cooperative Gulf of Mexico Estuarine Inventory (McNulty et al. 1972) reported 5.62 million ha of estuarine habitat in the five Gulf states including 3.2 million ha of open water and 2.43 million ha of emergent tidal vegetation. Emergent tidal vegetation includes 174,000 ha of mangrove and 1.0 million ha of salt marsh (GMFMC 1998); submerged vegetation covers 324,000 ha of estuarine bottom throughout the Gulf (GMFMC 1998). The majority of the Gulf's salt marshes are located in Louisiana (63%) while the largest expanse of mangroves (93%) is located along the southern Florida coast (GMFMC 1998). Vegetative, sedimentary, and physical descriptions for major Gulf estuarine systems are presented in Tables 4.1-4.5. The percent contribution to individual state commercial blue crab landings by estuarine system is also shown. Major estuarine systems for each state are shown in Figures 4.1-4.5.

4.2.1 Eastern Gulf

The eastern Gulf of Mexico extends from Florida Bay northward to Perdido Bay on the Florida/Alabama boundary and includes 40 estuarine systems covering 1.2 million ha of 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 213,895 ha with greatest area occurring in the Suwanee Sound and Waccasassa Bay. The coast from 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 tip of the Florida peninsula. Approximately 9,150 ha of estuarine area, principally in the Tampa Bay, have been filled for commercial or residential development.

Table 4.1. Vegetative, physical, and sedimentary characteristics of Florida estuarine systems and percent contribution to reported commercial landings (NA = Data not available).

Hydrologic Unit	Tidal Marsh/ Mangrove Swamp[1] (hectares)	Submerged Vegetation[1] (hectares)	Sediment Type[1]	Surface Area[1] (hectares)	Drainage Area[1] (km^2)	River Discharge[1] (ℓ/sec)	Percent Contribution[2] to West Coast Landings
Escambia Bay	3,510	769	Sand, sand/shell	51,005	14,315	268,402	2.8
Choctawhatchee Bay	1,139	1,251	Sand, sand/shell, mud	34,924	11,525	204,810	0.9
St. Andrews Bay	4,479	2,684	Sand, silt, clay	27,972	NA	NA	2.5
St. Joseph Bay	345	2,560		17,755			0.4
Apalachicola Bay	8,621	3,795	Sand covered with silt and clay	68,788	47,818	768,123	6.0
Apalachee Bay	22,529	9,518	Sand	24,817	7,552	90,822	29.1
Suwanee Sound and Waccasassa Bay	25,560 / 354	13,030	Sand	35,618	26,304	322,760	21.0
Tampa Bay	699 / 7,088	8,450	Sand, sand/clay, clay/silt	110,338	3,398	43,530	7.4
Sarasota Bay	95 / 1,463	3,079	Sand, sand/shell	14,061	160	2,285	0.2
Charlotte Harbor	3,678 / 9,500	9,463	Sand/shell, mud/shell	49,290	5,174	55,739	9.7
Caloosahatchee River	687 / 1,203	293	Sand/shell	15,180	699	29,934	19.9
Florida Bay	4,916 / 14,932	103,849	Coral, sand/shell, sand/mud	225,631	NA	NA	<0.1

[1]McNulty et al. 1972, [2]Florida Marine Fisheries Information System 1997

Table 4.2. Vegetative, physical, and sedimentary characteristics of Alabama estuarine systems and percent contribution to reported commercial landings (NA = Data not available).

Hydrologic Unit	Tidal Marsh (hectares)	Submerged Vegetation (hectares)	Sediment Type[3]	Surface Area[3] (hectares)	Drainage Area[3] (km^2)	River Discharge[3] (ℓ/sec)	Percent Contribution[4] to State Landings
Mobile Bay	1,333[1]	2,024[3]	Sand, clay, mud	107,030	113,995	1,947,329	20.0
Mississippi Sound	5,369[2]	NA*	Sand, clay, mud	37,516	259	NA	57.0
Perdido Bay	434[3]	NA	Sand, clay, mud	6,989	2,637	26,539	0.2

[1]Stout 1979, [2]Stout and de la Cruz 1981, [3]Crance 1971, [4]Swingle 1976

Table 4.3. Vegetative, physical, and sedimentary characteristics of Mississippi estuarine systems and percent contribution to reported commercial landings (NA = Data not available).

Hydrologic Unit	Tidal Marsh[1] (hectares)	Submerged Vegetation[2] (hectares)	Sediment Type[3]	Surface Area[4] (hectares)	Drainage Area[4] (km^2)	River Discharge[4] (ℓ/sec)	Percent Contribution[2] to State Landings
Pascagoula River	11,281		Sandy and muddy, Sandy deposits	53,110	24,346	430,464	NA*
Biloxi Bay	4,683		Sandy and muddy, Sandy deposits	60,896	1,735	38,232	NA
St. Louis Bay	6,173		Sandy and muddy, Sandy deposits	66,568	291	41,347	NA
Pearl River	3,520		Sandy and muddy, Sandy deposits	22,335	3,521	365,328	NA
Mississippi Sound South of Intracoastal Waterway	860 Barrier Islands	1,970/809[6]	Sand Mud				NA

[1]Eleutarius 1973, MDMR and Mississippi State University Cooperative Extension Service 1968 unpublished data, [2]Eleuterius and Miller 1976, [3]Otvos 1973, [4]Christmas and Langley 1973, [5]H. Hague personal communication, [6]Moncreiff et al. 1998

Table 4.4. Vegetative, physical, and sedimentary characteristics of Louisiana estuarine systems and percent contribution to reported commercial landings.

Basin	Tidal Marsh[1]	Submerged Vegetation[2]	Sediment[3]	Surface Area[2]	Drainage Area[4]	Percent Landing[5]
Pontchartrain	107,300	8,094	Clayey silt, silty clay, sand	183,052	36,848	14.0
Breton/Chandeleur Sound	69,100		Clayey silt, silty clay, sand	312,968	584,909	10.0
Mississippi Delta	33,900		Silty clay, clayey silt	46,268	9,986	NA
Barataria	171,100		Clayey silt, sand	28,571	9,780	22.0
Terrebonne	197,500		Sandy silt, clayey silt	104,774	54,244	22.0
Atchafalaya	19,600		Clayey silt, sand clay	54,505		NA
Teche/Vermilion	94,700		Clayey silt, silty clay	118,909		14.0
Mermentau	178,200		Clayey silt, silty clay			NA
Calcasieu/Sabine	120,400					14.0

[1]Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998, [2]Perret et al. 1971, [3]Barrett et al. 1971, [4]Sloss 1971, [5]NMFS unpublished data

Table 4.5. Vegetative, physical, and sedimentary characteristics of Texas estuarine systems and percent contribution to reported commercial landings (NA = Data not available).

Hydrologic Unit	Tidal Marsh[1] (hectares)	Submerged Vegetation (hectares)	Sediment Type	Surface Area[2] (hectares)	Drainage Area	River Discharge	Percent Contribution[3] to State Landings
Sabine Lake	171,955	NA	Mud, silt, shell	17,799	53,421	326 m^3/sec[1]	9.3
Galveston Bay	93,624	113[4]	Mud, shell, clay, sand	141,676	51,958	10,100,000 acre-ft/yr	24.3
East Matagorda Bay	NA	NA	Mud, sand	15,308	NA	NA	3.8
West Matagorda Bay	48,552	1,550[4]	Mud, shell, clay, sand	98,984	10,713	87 m^3/sec[7]	10.5
San Antonio Bay	10,115	4,289[4]	Silty clay, mud, sand, shell	55,158	26,563	2,344,140 acre-ft/yr	26.0
Aransas Bay	18,207	3,237[5]	Mud, sand	45,296	6,800	634,000 acre-ft/yr[8]	18.8
Corpus Christi Bay	NA	9,955[5]	Mud, sand	43,316	44,963	378,000 acre-ft/yr[8]	3.1
Upper Laguna Madre	NA	27,195[6]	Sand, silt, shell	41,040	7,752	NA	0.8
Lower Laguna Madre	NA	47,997[6]	Sand, silt, clay	72,688	3,193	3,100	2.7

[1]Diener 1975, [2]Matlock and Osborn 1982, [3]Robinson et al. 1998, [4]Texas Parks and Wildlife Department 1998, [5]Pulich et al. 1997, [6]Quamman and Onuf 1993, [7]Shipley and Kiesling 1994, [8]Asquith et al. 1997

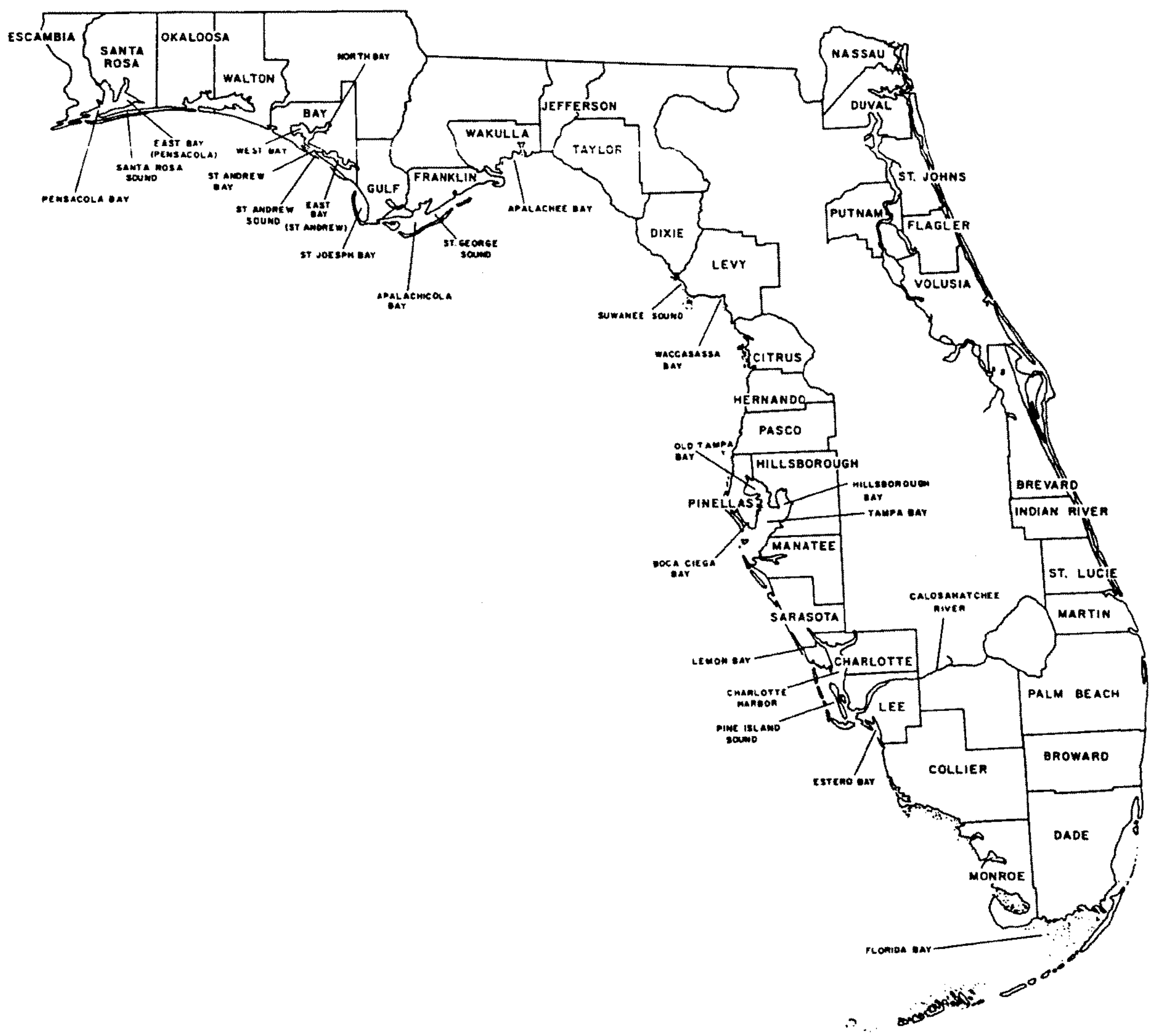

Figure 4.1. Major estuarine systems in Florida.

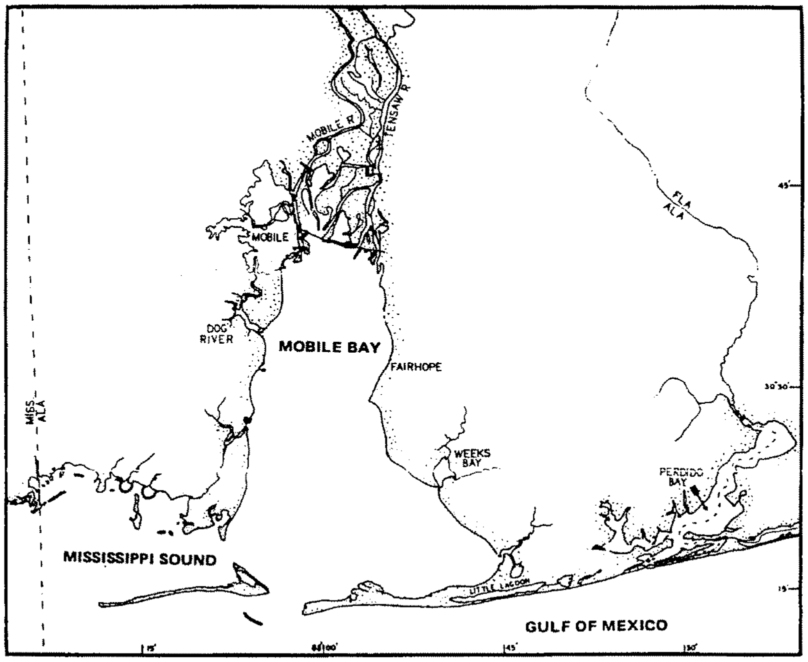

Figure 4.2. Major estuarine systems in Alabama.

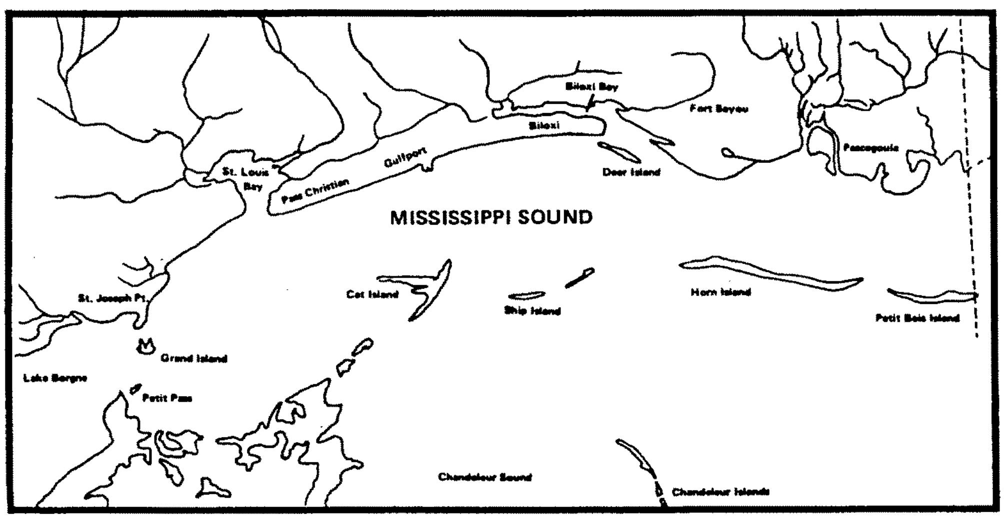

Figure 4.3. Major estuarine systems in Mississippi.

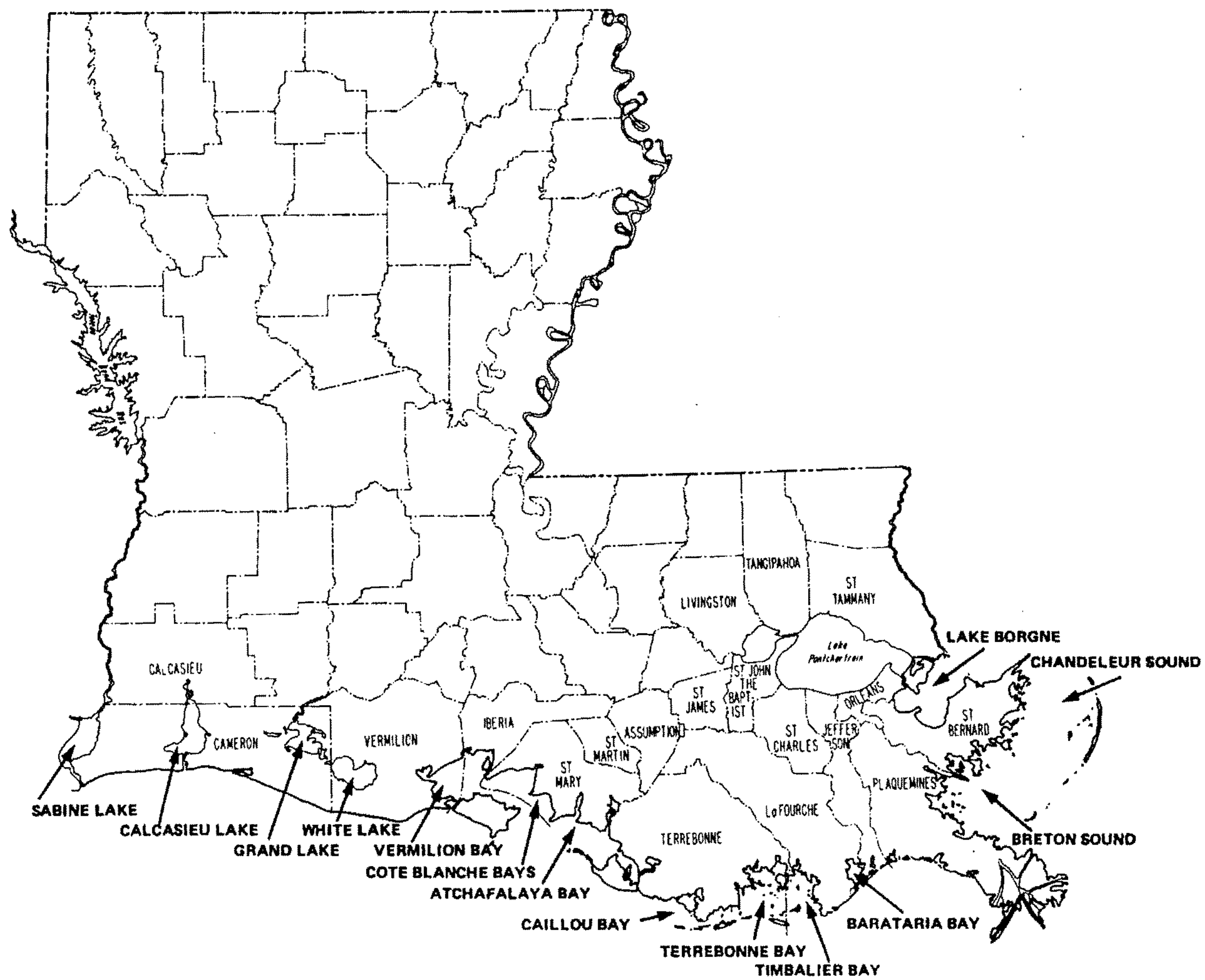

Figure 4.4. Major estuarine systems in Louisiana.

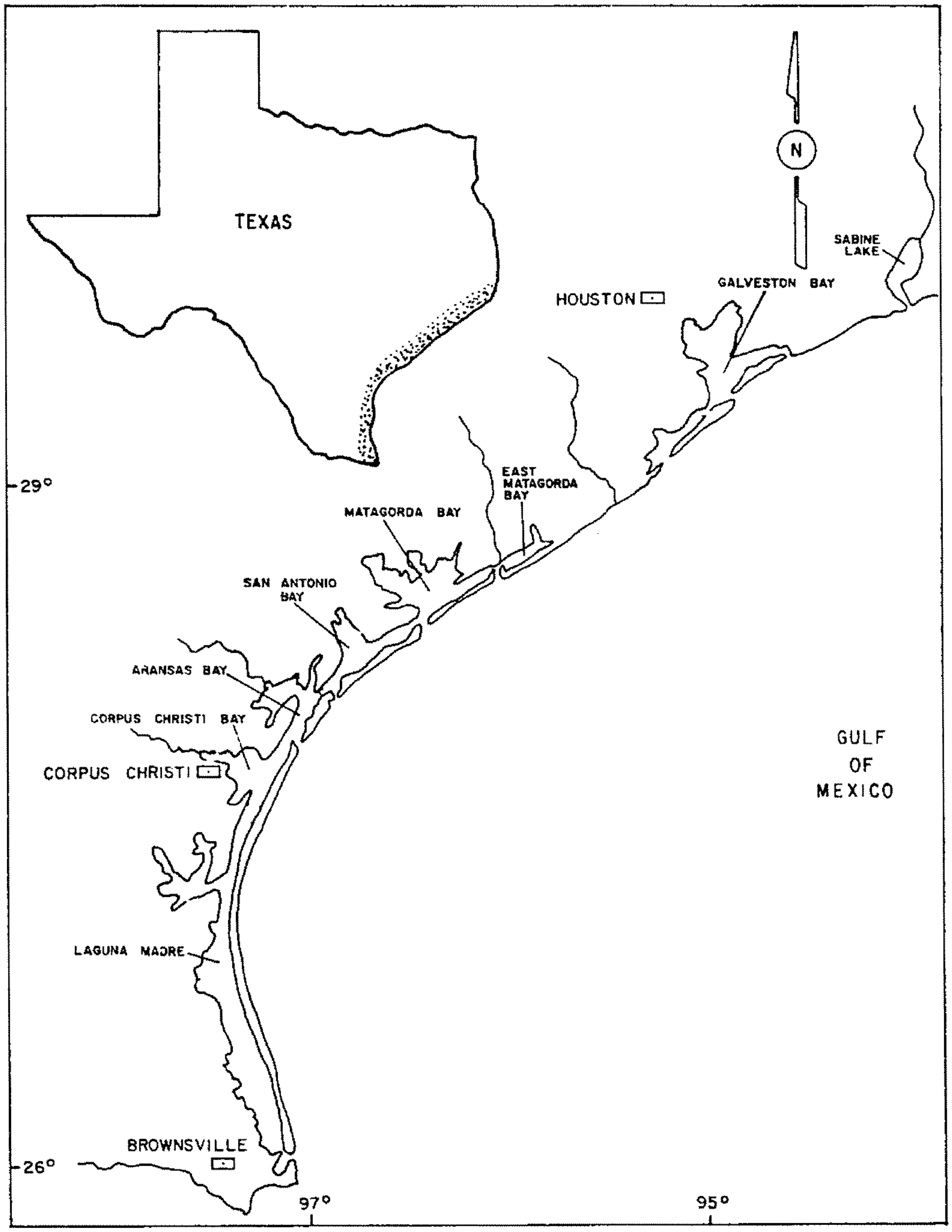

Figure 4.5. Major estuarine systems in Texas.

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. 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).

4.2.2 Northcentral Gulf

The northcentral Gulf includes Alabama, Mississippi, and Louisiana. Total estuarine area for Louisiana includes 29 major water bodies covering 2.9 million ha of which 1.3 million ha is surface water and 1.5 million ha is marsh (Perret et al. 1971). The eastern and central Louisiana coasts are dominated by sand barrier islands and associated bays and marshes. The most extensive marshes in the United States are associated with the Mississippi/Atchafalaya River deltas. The loss of wetlands along the Louisiana Coastal Zone is estimated to be 6,600 ha/yr [United States Environmental Protection Agency (USEPA) 1994a]. The shoreline of the western one-third of Louisiana is made up of sand beaches with extensive inland marshes. A complex geography of sounds and bays protected by barrier islands and tidal marshes acts to delay mixing resulting in extensive areas of brackish conditions. The Alabama and Mississippi coasts are bounded offshore by a series of barrier islands which are characterized by high energy, sand beaches grading to saltmarsh in the interior. The mainland shoreline is made up of saltmarsh, beach, seawall, and brackish-freshwater marsh in the coastal rivers. Approximately 26,000 ha of mainland marsh existed in southern Mississippi in 1968 (Eleuterius 1973). Salt marsh on the barrier islands covers 860 ha.

Approximately 2,928 ha of submerged vegetation, including attached algae, have been identified in Mississippi Sound and in the ponds and lagoons on Horn and Petit Bois islands (C. Moncreiff personal communication). Approximately 4,000 ha of mainland marsh along the Mississippi Coastal Zone have been filled for industrial and residential use since the 1930s (Eleuterius 1973). Seagrass coverage in Mississippi Sound has declined 40%-50% since 1969 (Moncreiff et al. 1998). The Alabama Coastal Zone contains five estuarine systems covering 160,809 ha of surface water and 14,008 ha of tidal marsh (GMFMC 1998). An estimated 4,047 ha of submerged vegetation exists in the Alabama Coastal Zone.

In general, estuaries and nearshore Gulf waters of Louisiana and eastern Mississippi 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 River deposits 684 million metric tons of sediment annually near its mouth (Holt et al. 1982). Average daily discharge for the Mississippi and Atchafalaya rivers is 464,400 cfs and 223,800 cfs, respectively (USEPA 1994b). 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.

4.2.3 Western Gulf

The shoreline of the western Gulf consists of salt marshes and barrier islands. The estuaries are characterized by low but extremely variable salinities and reduced tidal action. Eight major estuarine systems are located in the western Gulf and include the entire Texas coast. These systems contain 620,634 ha of open water and 462,267 ha of tidal flat and marshlands (GMFMC 1998). Submerged seagrass coverage is approximately 92,000 ha. Riverine influence is highest in Sabine Lake and Galveston Bay. Estuarine wetlands along the western Gulf decreased 10% between the mid 1950s and early 1960s with an estimated loss of 23,840 ha (Moulton et al. 1997).

4.3 Habitat Alteration

The high degree of natural variation and proximity to human activities make estuarine areas the weakest link in the life cycle of estuarine-dependent crabs. Human population growth in southeastern coastal regions, accompanied by industrial growth, is responsible for the alteration or destruction of approximately one percent of estuarine habitats required for commercial and recreational species (Klima 1988). Louisiana marshes are disappearing at a rate of about 64,750 ha/year (USEPA 1994a). Some researchers also forecast that sea level will rise due to global warming, which could compound the loss of critical estuarine areas in the Gulf of Mexico (Klima 1988). Except in terms of lost acreage, the effects of this development on overall estuarine productivity in the Gulf are largely undocumented. Human activities in inshore and offshore habitats of blue crabs that may affect recruitment and survival of stocks include: 1) projects, ports, marinas, and maintenance dredging for navigation; 2) discharges from wastewater plants and industries; 3) dredge and fill for land use development; 4) agricultural runoff; 5) ditching, draining, or impounding wetlands; 6) oil spills; 7) thermal discharges; 8) mining, particularly for phosphates and petroleum; 9) entrainment and impingement from cooling operations associated with industrial activities; 10) dams; 11) alteration of freshwater inflows to estuaries; 12) saltwater intrusion; and, 13) nonpoint source discharges of contaminants (Lindall et al. 1979).

Shallow water dredging for sand, gravel, and oyster shell not only alters the bottom directly but may also change local current patterns leading to erosion or siltation of productive habitats. Destruction of wetlands by development of waterfront properties results directly in loss of productive habitat acreage and in the reduction of detrital production. Channeling or obstruction of water courses emptying into estuaries can result in loss of wetland acreage and/or changes in the salinity profile of the estuary. Lowered flow rates of drainage systems can reduce the amount of nutrients that are washed into estuaries and permanently alter the composition of shoreline communities. For example, the accumulation of leaves in a red mangrove forest could result in ecological succession to a willow and buttonwood community. Red mangrove forests are a major source of detritus in the blue crab food web of south Florida estuaries.

In Louisiana, there were 7,360 km of canals dredged south of the Intracoastal Waterway by 1970 (Barrett 1970). Canal construction results in wetland degradations far beyond the direct loss of habitat seen at dredge sites. Additional marsh loss is produced through secondary hydrologic effects: increased erosive energy, salinity intrusion, and disruption of natural flow effects. Some affected areas experience excessive sediment drying, while others undergo extended flood periods (Turner and Cahoon 1988); both effects produce loss of vegetative cover and increased conversion to open water. Freshwater storage effects, where freshwater inputs are held for gradual release through the seaward marshes, are also disrupted (Gagliano 1973). Direct wetland loss from canal dredging accounted for 120 km^2 of the total loss (about 16%) between 1955 and 1978; the combined contribution of direct and indirect effects from canal building is estimated at 30% to 59% of the total marsh loss in Louisiana in this period (Turner and Cahoon 1988).

Power plants produce such large quantities of heated effluent that thermal pollution is now a consideration in habitat alteration. Roessler and Zieman (1970) found that the area in which all plants and animals were killed or greatly reduced in number was adjacent to a nuclear plant outflow in Biscayne Bay, Florida, corresponded closely to the area delineated to the +4°C isotherm.

Early degradation of Gulf coast estuarine habitat can be traced to the early 1900s, when exploration for and exploitation of oil and gas, with its concomitant development of refineries and chemical companies, began in the northern Gulf (Texas and Louisiana) along major rivers and bays. In the 1930s and 1940s, alteration of marshes and coastal waters for oil exploration included seismic blasting, dredging of canals, construction of pipelines, storage tanks and field buildings, and other types of development. These activities caused a number of problems for blue crab habitat including saltwater intrusion into brackish water areas and direct reductions in the amount of marsh habitat.

In addition, levees built in the early 1900s to protect urban and agricultural areas from flooding along the Mississippi River have deprived marshlands the replenishment of needed water and sediments. Agricultural development and urban expansion in Florida have caused similar negative effects on the Everglades that may have negatively affected Florida Bay. Urban centers such as Orlando, Tampa, and Miami have tapped water from the Everglades system to the point that freshwater run-off into Florida Bay has decreased significantly. Fluctuations in salinity as a result of these alterations may have caused the die-off of many seagrass beds in Florida Bay.

Marsh loss, wetland impoundments, and salinity intrusion are critical topics with regard to management of estuarine dependent species such as the blue crab. Land loss is the synergistic culmination of both natural and man-induced factors (Craig et al. 1979). Subsidence, eustatic sea-level rise, and erosion due to wave and wind action are naturally occurring factors. Man-induced factors include levee construction along the lower Mississippi River (which eliminated the major source of sediment introduction to marshes), canal construction, dredge and fill activities, pipeline construction, and land reclamation. Salinity levels may have increased in portions of coastal Louisiana in association with marsh loss and canal construction. Approximately 30% of the total wetland area in the Louisiana coastal zone was intentionally impounded before 1985 (Day et al. 1990).

Habitat and hydrological changes occurring in other Gulf coastal states could have detrimental impacts on blue crabs. Orth and van Montfrans (1990) found a significant relationship between blue crab production and total vegetated habitat for the combined Gulf states. Other investigators have shown positive correlations between yield of estuarine species other than blue crab and extent of vegetated habitat (Turner 1977, Nixon 1980, Deegan et al. 1986). The impact of marsh loss on blue crab production may not be initially evident. Biological productivity increases temporarily in deteriorating marshes (Gagliano and Van Beek 1975), possibly due to an increase in "edge" (marsh-water) habitat and in detrital input to the estuarine food web. However, biological productivity will eventually decrease as the conversion of marsh habitat to open water continues and suitable marsh habitat of appropriate salinity regimes declines below the critical point. Low salinity marsh is an important nursery habitat for juvenile blue crabs and increased salinity may adversely impact the species (Rounsefell 1964). Marsh management by means of levees and weirs, or other water control structures, is usually detrimental to fisheries in the short term because of interference with migratory cycles of estuarine dependent species (Herke 1979, Herke et al. 1987, Herke and Rogers 1989). During the course of their life cycle, blue crabs utilize all salinity regimes of an estuary and disruption of estuarine salinity gradients in association with physical habitat alteration could have adverse impacts on blue crab populations.

Changes in the amount and timing of freshwater inflow may have a major effect on that segment of the blue crab life cycle taking place in the estuary. Wetlands are maintained by rivers that transport sediment and nutrients. Reduction in freshwater inflow denies the nutrients to wetlands that are necessary for healthy growth. Activities affecting freshwater inflow include leveeing of rivers (eliminating overflow into surrounding marshes), damming of rivers, channelization, and pumping water for redistribution.

The feasibility of introducing freshwater from the Mississippi River into wetland areas experiencing saltwater intrusion has been studied since the 1950s. Various agencies have been working with the USACOE and Congress to design, build, and operate freshwater diversions in Louisiana (Etzold 1980). Three diversion sites have been selected: 1) the Caernarvon site into Breton Sound (currently operating); 2) the Bonnet Carré site into Lake Pontchartrain (proposed); and 3) the Davis Pond site into upper Barataria Bay (under construction). The ultimate purpose of these three diversions is to reduce marsh loss and enhance wildlife and fishery production in the Mississippi Delta.

The discharge of toxic substances and pesticides into the Gulf of Mexico is increasing due to increased industrial activity in the region and the continued use of agriculturally-related pesticides throughout the Mississippi River drainage system (USEPA 1994a). Point sources for the introduction of these contaminants include discharge from industrial facilities, municipal wastewater treatment plants, and accidental spills. Nonpoint sources include urban storm water runoff, air pollutants, and agricultural activities. Approximately six million kg of toxic substances are discharged annually into the Gulf of Mexico estuarine drainage areas and approximately two million kg of pesticides were applied to agricultural fields bordering Gulf coastal counties in 1990 (USEPA 1994a). The effects of these substances on aquatic organisms include: 1) interruption of biochemical and cellular activities; 2) alterations in populations dynamics; and 3) sublethal effects on ecosystem functions (Capuzzo and Moore 1986).

4.3.1 Loss of Wetlands

According to Dahl and Johnson (1991) estuarine vegetated wetlands decreased by 28,734 ha from the mid 1970s through the mid 1980s with the majority of these losses occurring in Gulf coast states. Most of this loss was due to the shifting of emergent wetlands to open saltwater bays. The most dramatic coastal wetland losses in the United States are in the northern Gulf of Mexico. This area contains 41% of the national inventory of coastal wetlands and has suffered 80% of the nation's total wetlands loss (Turner 1990, Dahl 1990). These wetlands support 28% of the national fisheries harvest, the largest fur harvest in the United States, the largest concentration of overwintering waterfowl in the United States, and provide the majority of the recreational fishing landings (Turner 1990).

4.4 Essential Habitat

Extensive habitat partitioning by the blue crab suggests that spatial distribution in this species is the product of a complex array of endogenous processes interacting with exogenous stimuli. Decapod crustaceans are known to use specific habitats for spawning, molting and mating, maintaining seasonal thermal optima, increasing food availability, and decreasing the likelihood of predation. Many or all of these factors appear to influence the extensive use by blue crabs of almost every type of estuarine and nearshore marine habitat.

Orth and van Montfrans (1990) established a quantitative relationship between blue crab production and habitat. Turner and Boesch (1988) examined the relationship between wetland area and fisheries yields and found evidence of decreased fishery production following wetland losses and increased fishery production following wetland gains. These data suggest loss of habitat may be a significant factor in determining blue crab production.

Areas of particular concern include all habitats required during the blue crab's life cycle but especially estuarine nursery grounds. The estuarine tidal creeks, salt marshes, and grass beds are perhaps the most sensitive habitats occupied by blue crabs. Quantity and quality of nursery habitat are major factors limiting crab production. Barrier islands are vital to the maintenance of estuarine conditions needed by juvenile crabs, and the waters surrounding the islands serve as spawning areas.
Although these areas are generally less vulnerable to habitat alteration than the salt marsh and the estuarine nursery areas, dredging activity and dredge spoil disposal can result in habitat and water quality degradation.

Approximately 41,440 km^2 of coastal wetlands remain in the Gulf. This is 60% of the coastal wetland area within United States' waters. An estimated 2.5 million ha is composed of tidal marsh, mangroves, and submerged aquatic vegetation (seagrasses), while 3.4 million ha are classified as unvegetated estuarine open water. There is little doubt that blue crab production in the Gulf depends on the quantity and quality of the estuarine marshes, mangrove areas, submerged vegetation, and nearshore soft sediment unvegetated habitat. Although the quantity of marsh acreage has not declined in some areas, the quality of the marsh as habitat for juvenile blue crabs has diminished. These areas not only provide postlarval, juvenile, and subadult crabs with food and protection from predation but also help to maintain an essential gradient between fresh and salt water.

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. Wetlands bordering Tampa Bay have declined 44% since the 1950s. 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. Marsh habitat in Mobile Bay declined approximately 4,000 ha between 1955 and 1979 due to commercial and residential development, erosion, and subsidence (Duke and Kruczynski 1992).

4.4.1.3 Mississippi

Estimations of marsh loss vary. Meyer-Arendt (1989) reported a marsh loss of 7.3% from the early 1950s through 1978 (27,977 ha to 25,937 ha). Eleuterius (1973) estimated 405 ha of marsh was filled prior to 1930 with approximately 3,306 ha filled from 1930 to 1968. Marsh loss subsequent to the implementation of the state Wetlands Protection Law of 1973 has been minimized. Estimates from a 1994 survey [MDMR/Mississippi State University Cooperative Extension Service (MSUCES) unpublished data] of tidal marsh in Mississippi were relatively unchanged from the 1968 estimates of Eleuterius (1973). Although marsh acreage has remained relatively unchanged, the quality of marsh habitat may have deteriorated. 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. 1999) 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 estuarine-dependent 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 to 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/yr in the 1940s and 1950s to over 100 km^2/yr in the 1970s and have now fallen to approximately 65 km^2/yr (Britsch and Dunbar 1993). Regional differences in wetland loss patterns have occurred; the annual land loss rates by region were 65.7 km^2/yr in the coastal plain, 51.8 km^2/yr in the Mississippi River deltaic plain, and 13.9 km^2/yr in the chenier plain.

4.4.1.5 Texas

Texas estuarine wetlands decreased approximately 24,000 ha 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 37 million m^3 of spoil annually, and reservoir construction has changed the timing of freshwater inflow to critical estuarine habitat. Saltwater intrusion has diminished the quality of juvenile blue crab habitat in some areas (E. Holder personal communication). Agricultural, municipal, and industrial runoff is increasing due to population and industrial growth along the Texas coast.

4.5 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. Fertile 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 metamorphose into the first crab stage. The estuarine phase is perhaps the most critical because all postsettlement growth and the major components of the reproductive cycle occur there. Male blue crabs usually remain within the estuary during their entire postsettlement life. Juvenile and adult blue crabs exhibit wide seasonal and areal distribution within estuaries. 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, 0°-40°C; optimum catch between 10° and 35°C.
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.

4.5.1 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, D. Johnson 1985). Larvae are exported from estuaries on an ebbing tide (Provenzano et al. 1983, D. 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 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), and Rabalais et al. (1995a). 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). Peak settlement on collectors occurs from July through September. Habitat selection by megalopae may be chemically-mediated or a tactile response mechanism as opposed to passive deposition (Orth and van Montfrans 1990). 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 occurs 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).

4.5.2 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) and Thomas et al. (1990) have shown that vegetated habitats (seagrass and salt marsh) are important nursery areas for estuarine-dependent species such as the blue crab. Orth and van Montfrans (1990) noted that vegetated habitats were characterized by higher overall abundances of blue crabs and lower predation rates than were non-vegetated habitats. 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).

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). 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), and Perry and Stuck (1982). 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).

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.

4.5.3 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. 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). 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). 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.

5.0 FISHERY MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES AFFECTING THE STOCK

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 more 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

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.

5.1.1.1 Regional Fishery Management Councils

With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA), 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 miles from the (inner) baseline of the territorial sea. Management of fisheries in the EEZ is based on 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 USDOC.

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

The GMFMC has not developed a management plan for blue crabs. Furthermore, no significant fishery for blue crabs is known to exist in the EEZ of the United States Gulf of Mexico.

5.1.1.2 National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), United States 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 Magnuson Act and Lacey Act 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 habitat.

The USDOC, in conjunction with coastal states, administers the National Estuarine Research 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.

5.1.1.3 Office of Ocean and Coastal Resource Management (OCRM), NOAA, DOC

The OCRM asserts management authority over marine fisheries through the National Marine Sanctuaries Program. Under this program, marine sanctuaries are established with specific management plans that may include restrictions on harvest and use of various marine and estuarine species.

The OCRM may influence fishery management for blue crab indirectly through administration of the Coastal Zone Management (CZM) Program and by setting standards and approving funding for state CZM programs.

5.1.1.4 National Park Service (NPS), Department of the Interior (DOI)

The NPS under the DOI may regulate fishing activities within park boundaries. Such regulations could affect blue crab harvest if implemented within a given park area. The NPS has developed regulations which affect fishing activities in Everglades National Park in Florida and prevent commercial fishing within one mile of the barrier islands in the Gulf Islands National Seashore off Mississippi.

5.1.1.5 United States Fish and Wildlife Service (USFWS), DOI

The USFWS has little direct management authority over blue crab. The USFWS may affect the management of blue crab through the Fish and Wildlife Coordination Act, under which the USFWS and NMFS review and comment on proposals to alter habitat.

In certain refuge areas, the USFWS may directly regulate fishery harvest. This harvest is usually restricted to recreational limits developed by the respective state. In certain refuge areas, the USFWS may directly regulate fishery harvest through the National Wildlife Refuge Administration Act (Section 5.1.3.18). Special use permits may be required if commercial harvest is to be allowed in refuges.

5.1.1.6 United States Environmental Protection Agency (USEPA)

The USEPA through its administration of the Clean Water Act and the National Pollutant Discharge Elimination System (NPDES) may provide protection to blue crab habitat. Applications for permits to discharge pollutants into estuarine waters may be disapproved or conditioned to protect resources on which blue crabs and other species rely.

5.1.1.7 United States Army Corps of Engineers (USACOE), Department of the Army (DOA)

Under the Clean Water Act and Section 10 of the Rivers and Harbors Act, the USACOE issues or denies permits to individuals and other organizations for proposals to dredge, fill, and construct in wetland areas and navigable waters. The USACOE is also responsible for planning, construction, and maintenance of navigation channels and other projects in aquatic areas.

5.1.1.8 United States Coast Guard

The United States Coast Guard is responsible for enforcing fishery management regulations adopted by the DOC pursuant to management plans developed by the GMFMC. The Coast Guard also enforces laws regarding marine pollution and marine safety, and they assist commercial and recreational fishing vessels in times of need.

5.1.1.9 United States Food and Drug Administration (FDA)

The FDA may directly regulate the harvest and processing of fish through its administration of the Food, Drug, and Cosmetic Act and other regulations that prohibit the sale and transfer of contaminated, putrid, or otherwise potentially dangerous foods.

5.1.1.9.1 Hazard Analysis Critical Control Points (HACCP:21 C.F.R Parts 123 and 1,240)

The FDA issued its final rule on HACCP for seafood in December 1995. HACCP is a seven-step system designed to ensure safe food from raw material to finished product.

1) Analyze hazard.
2) Identify critical control points.
3) Establish preventative measures.
4) Establish procedures to monitor control points.
5) Establish corrective actions to be taken.
6) Establish effective record keeping to document the HACCP system.
7) Establish procedures to verify system is working correctly.

HACCP will impact processing activities in the Gulf of Mexico blue crab industry.

5.1.2 Treaties and Other International Agreements

5.1.2.1 North American Free Trade Agreement (NAFTA) (1994)

The World Trade Agreement, including the General Agreement on Tariffs and Trade (1994) led to the NAFTA, implemented January 1, 1994, declaring a free-trade area between Canada, the United States, and Mexico. This agreement will eliminate tariffs on agricultural products, including blue crabs and blue crab products, allowing for increased import and export of these products between the three countries.

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 (MFCMA) of 1976 (P.L. 94-265)

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.

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

The IJF Act of 1986 established a program to promote and encourage state activities in support of management plans and to promote and encourage management of IJF 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 Magnuson-Stevens Conservation and Management Act of 1996 (Mag-Stevens)

The 1996 reauthorization of the MFCMA added three additional national standards to the original seven for fishery conservation and management and included a revision of standard number five.

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

The SFRA provides funds to states, the USFWS, and the GSMFC to conduct research, planning, and other programs geared at enhancing and restoring marine sportfish populations.

5.1.3.5 Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA)

The MPRSA provides protection of fish habitat through the establishment and maintenance of marine sanctuaries. The MPRSA and the SPA acts regulate ocean transportation and dumping of dredged materials, sewage sludge, and other materials. Criteria for issuing such permits include consideration of effects of dumping on the marine environment, ecological systems, and fisheries resources.

5.1.3.6 Federal Food, Drug, and Cosmetic Act of 1938 (FDCA)

The FDCA prohibits the sale, transfer, and importation of "adulterated" or "misbranded" products. Adulterated products may be defective, unsafe, filthy, or produced under unsanitary conditions. Misbranded products may have false, misleading, or inadequate information on their labels. In many instances the FDCA also requires FDA approval for distribution of certain products.

5.1.3.7 Clean Water Act (CWA) of 1981

The CWA requires that an USEPA-approved NPDES permit be obtained before any pollutant is discharged from a point source into waters of the United States including waters of the contiguous zone and the adjoining ocean.

Under Section 404 of the CWA, the USACOE is responsible for administration of a permit and enforcement program regulating alterations of wetlands as defined by the act (e.g., dredging, filling, bulk-heading). The NMFS is the federal trustee for living and nonliving natural resources in coastal and marine areas under U.S. jurisdiction pursuant to the CWA.

5.1.3.8 Federal Water Pollution Control Act (FWPCA) of 1972 and MARPOL Annexes I and II

Discharge of oil and oily mixtures is governed by the FWPCA and 40 Code of Federal Regulations (CFR), Part 110, in the navigable waters of the United States. Discharge of oil and oily substances by foreign ships or by United States ships operating or capable of operating beyond the United States territorial sea is governed by MARPOL Annex I.

MARPOL Annex II governs the discharge at sea of noxious liquid substances primarily derived from tank cleaning and deballasting. Most categorized substances are prohibited from being discharged within 12 nautical miles of land and at depths of less than 25 meters.

5.1.3.9 Coastal Zone Management Act (CZMA) of 1972, as amended

Under the CZMA, states receive federal assistance grants to maintain federally-approved planning programs for enhancing, protecting, and utilizing coastal resources. These are state programs, but the act requires that federal activities must be consistent with the respective states' CZM programs. Depending upon the state program, the act provides the opportunity for considerable protection and enhancement of fishery resources by regulation of activities and by planning for future development in the least environmentally-damaging manner.

5.1.3.10 Endangered Species Act of 1973, as amended (P.L. 93-205)

The Endangered Species Act provides for the listing of plant and animal species that are threatened or endangered. Once listed as threatened or endangered, a species may not be taken, possessed, harassed, or otherwise molested. It also provides for a review process to ensure that projects authorized, funded, or carried out by federal agencies do not jeopardize the existence of these species or result in destruction or modification of habitats that are determined by the Secretary of the DOI to be critical.

5.1.3.11 National Environmental Policy Act (NEPA) of 1970

The NEPA requires that all federal agencies recognize and give appropriate consideration to environmental amenities and values in the course of their decision making. In an effort to create and maintain conditions under which man and nature can exist in productive harmony, the NEPA requires that federal agencies prepare an environmental impact statement (EIS) prior to undertaking major federal actions that significantly affect the quality of the human environment. Within these statements, alternatives to the proposed action that may better safeguard environmental values are to be carefully assessed.

5.1.3.12 Fish and Wildlife Coordination Act of 1958

Under the Fish and Wildlife Coordination Act, the USFWS and NMFS review and comment on fish and wildlife aspects of proposals for work and activities sanctioned, permitted, assisted, or conducted by federal agencies that take place in or affect navigable waters, wetlands, or other critical fish and wildlife habitat. The review focuses on potential damage to fish, wildlife, and their habitat; therefore, it provides protection to fishery resources from activities that may alter critical habitat in nearshore waters. The act is important because federal agencies must give due consideration to the recommendations of the USFWS and NMFS.

5.1.3.13 Fish Restoration and Management Projects Act of 1950 (P.L. 81-681)

Under this act, the DOI is authorized to provide funds to state fish and game agencies for fish restoration and management projects. Funds for protection of threatened fish communities that are located within state waters could be made available under the act.

5.1.3.14 Lacey Act of 1981, as amended

The Lacey Act prohibits import, export, and interstate transport of illegally-taken fish and wildlife. As such, the act provides for federal prosecution for violations of state fish and wildlife laws. The potential for federal convictions under this act with its more stringent penalties has probably reduced interstate transport of illegally possessed fish and fish products.

5.1.3.15 Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or "Superfund")

The CERCLA names the NMFS as the federal trustee for living and nonliving natural resources in coastal and marine areas under United States jurisdiction. It could provide funds to "clean-up" fishery habitat in the event of an oil spill or other polluting event.

5.1.3.16 MARPOL Annex V and United States Marine Plastic Research and Control Act (MPRCA) of 1987

MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/1978. Regulations under this act prohibit ocean discharge of plastics from ships, restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 25 nautical miles from any land, restrict discharge of victual and other recomposable waste up to 12 nautical miles from land, and require ports and terminals to provide garbage reception facilities. The MPRCA of 1987 and 33 CFR, Part 151, Subpart A, implement MARPOL V in the United States.

5.1.3.17 Fish and Wildlife Act of 1956

This act provides assistance to states in the form of law enforcement training and cooperative law enforcement agreements. It also allows for disposal of abandoned or forfeited property with some equipment being returned to states. The act prohibits airborne hunting and fishing activities.

5.1.3.18 National Wildlife Refuge Administration Act of 1966 (16USC668dd)

This Act serves as the "organic act" for the National Wildlife Refuge System. The National Wildlife Refuge System Administration Act, as amended, consolidated the various categories of lands administered by the Secretary of the Interior through the Service into a single National Wildlife Refuge System. The Act creates a refuge system for the purpose of protection and conservation of fish and wildlife, including species that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas and ensure opportunities for compatible wildlife-dependent uses.

5.1.4 Federal Programs Specific to Habitat Protection and Restoration

Federal environmental agencies such as the NMFS, the USFWS, and the USEPA evaluate projects proposing wetland alterations for potential impacts on resources under their purview. Recommendations resulting from these analyses are submitted to the USACOE where they are included in a public interest review that determines whether or not a permit will be issued for a proposed alteration.

Conservation of habitat depends largely on whether the recommendations of agencies such as the NMFS, USFWS, USEPA, and the various state fish and wildlife agencies are incorporated into permitting decisions. Although granted input under Section 404 statutes, the NMFS, USFWS, and state regulatory and management agencies are not granted veto power in the permitting process. These agencies are, however, granted commenting authority on applications for federal agency permits pursuant to the Federal Fish and Wildlife Coordination Act.

Several other agencies are also involved in habitat matters at the federal level. The Soil Conservation Service assists owners of coastal wetlands in developing management plans to stabilize and freshen coastal marshes. The NOAA Office of Ocean and Coastal Resource Management may aid in establishing standards for approval to designate estuarine sanctuaries. The NPS may also establish coastal near shore national parks and monuments such as the Everglades National Park. The USEPA has authority to regulate the discharge of spoil and disposal materials in wetlands covered under their programs. Construction in offshore areas is regulated primarily by MMS and discharges are regulated by USEPA. The USACOE can also regulate construction but does not accept comments relative to fish and wildlife resources. Recommendations pertaining to navigation and national defense issues are accepted.

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) 488-9924

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. 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 nine-member board appointed by the Governor and confirmed by the Senate, was created by constitutional amendment effective July 1999. The commission will ultimately be reduced to a seven-member board.

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.

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.

Table 5.1. State management institutions - Gulf of Mexico.

	Administrative body and its responsibilities	Administrative policy-making body and decision rule	Legislative involvement in management regulations
FLORIDA	FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION ·administers management programs ·enforcement ·conducts research	·creates rules in conjunction with management plans ·ten member commission	·responsible for setting fees, licensing, and penalties.
ALABAMA	DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES ·administers management programs ·enforcement ·conducts research	·Commissioner of department has authority to establish management regulation ·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	MISSISSIPPI DEPARTMENT OF MARINE RESOURCES ·administers management programs ·conducts research ·enforcement	COMMISSION ON MARINE RESOURCES ·seven-member board establishes ordinances on recommendation of executive director (MDMR)	·authority for detailed management regulations delegated to commission statutes concern licenses, taxes and some specific fisheries laws
LOUISIANA	DEPARTMENT OF WILDLIFE AND FISHERIES ·administers management programs ·enforcement ·conducts research ·makes recommendations to legislature	WILDLIFE AND FISHERIES COMMISSION ·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 ·authority for detailed management regulations delegated to commission
TEXAS	PARKS AND WILDLIFE DEPARTMENT ·administers management programs ·enforcement ·conducts research ·makes recommendations to Texas Parks & Wildlife Commission (TPWC)	PARKS AND WILDLIFE COMMISSION ·nine-member body establishes regulations based on majority vote of quorum (five members constitute a quorum) ·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.

Regulation	Florida	Alabama	Mississippi	Louisiana	Texas
Size Limits					
Commercial	-5" CW minimum	-5" CW minimum	-5" CW minimum	-5" CW minimum	-5" CW minimum
Recreational	-none	-none	-5" CW minimum	-none	-5" CW minimum
Gear Limits					
Traps					
-escape rings	-three, 2 3/8" ID	-none	-none	-two, 2 5/16" ID	-four, 2 3/8" ID
-degradable panel	-yes, 5 options	-none	-none	-none	-yes, 2 options
-maximum volume	-8 cubic feet	-27 cubic feet	-none	-none	-18 cubic feet
-maximum number	-none (commercial) -five (recreational)	-none -five (recreational)	-none (commercial) -six (recreational)	-none (commercial) -ten (recreational)	-200 (commercial) -six (recreational)
-identification	-buoy (commercial and recreational, see Section 5.2.1.7.3)	-buoy (commercial) (see Section 5.2.2.7.3)	-buoy/vessel (see Section 5.2.3.7.3)	-steel tag on trap (see Section 5.2.4.7.3)	-buoy (commercial and recreational, see Section 5.2.5.7.3)
Trawls	-see possession limits	-none	-must comply with legal shrimp trawl regulations (see Sec. 5.2.3.7.3)	-must comply with legal shrimp trawl regulations (see Sec. 5.2.4.7.3)	-must comply with legal shrimp trawl regulations (see Sec. 5.2.5.7.3)
Possession Limits					
Commercial	-none (traps) -200 pounds/trip of shrimp trawl bycatch	-none	-none	-none	-none
Recreational	-10 gallons	yes*	-none	-12 dozen, certain areas (see Section 5.2.4.7.5)	-none
Closed Areas	none	yes*	yes*	yes*	yes*
Closed Seasons	none	none	none	none	none
Data Reporting Required	yes*	yes*	yes*	yes*	yes*
Licenses Required					
Commercial	yes*	yes*	yes*	yes*	yes*
Recreational	yes*	none	none	yes*	yes*

*see state regulations

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 370.01(20) 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, Marine Fisheries Information System.

5.2.1.5 Penalties for Violations

Penalties for violations of Florida laws and regulations are established in Section 370.021 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	$300.00
· state	450.00
Nonresident wholesale seafood dealer	
· county	500.00
· state	1,000.00
Alien wholesale seafood dealer	
· county	1,000.00
· state	1,500.00
Resident retail seafood dealer	25.00
Nonresident retail seafood dealer	200.00
Alien retail seafood dealer	250.00
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 (ten day)	11.50
· resident (annual)	13.50
· nonresident (three day)	6.50

· nonresident (seven day)	16.50
· nonresident (annual)	31.50
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)	3,001.50

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

A minimum size of five (5) inches carapace width (CW), measured from tip of one lateral spine to tip of the opposite lateral spine, is established for the commercial blue crab fishery; except that 5% of the total number of crabs in each container in such person's possession may be undersized. The minimum size limit does not apply to the harvest of peeler crabs or crabs to be used as live bait.

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 1½" and have throats or entrances located only on a vertical surface. Beginning on January 1, 1995, traps shall have a maximum dimension of 24" x 24" x 24" or a volume of eight 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 six inches or some other shape so long as it is no shorter than ten inches in the longest dimension and the width at some point exceeds five inches. No more than five 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 two 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 ten inches in height, painted thereon in contrasting color. Otherwise the display shall exhibit the harvester's approved buoy design, unobstructed, on a circle 20" in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than ten 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 eight inches in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than four 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 two 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 1½" or larger shall have at least three unobstructed escape rings installed, each with a minimum inside diameter of 2⅜". 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 six 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 one 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 one 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" or a volume of eight 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 ⅜" 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 six inches in height by three 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 six inches in height by three inches in width. This opening must be obstructed with an untreated pine slat or slats no thicker than ⅜".

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 six inches in height by three 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 six inches by three 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 ten gallons of whole blue crabs. Blue crabs may be harvested as incidental bycatch of shrimp trawls lawfully harvesting shrimp, with a maximum of 200 lbs of blue crabs per vessel per trip. Blue crabs less than five inches CW, harvested as a directed catch with a dip or landing net or as bycatch of live bait shrimp trawls, may not exceed ten 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 willfully to 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 $240 million 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 Coastal Zone Management Act 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 DEP 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 370, 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.

5.2.2 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
(334) 861-2882

Management authority for fishery resources in Alabama is held by the Commissioner of the Department of Conservation and Natural Resources. 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; however, all regulations are to be directed at the best interest of the seafood industry.

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: 1) the advertisement of the intent of the regulation, 2) a public hearing for the regulation, 3) a 35-day waiting period following the public hearing to address comments from the hearing, and 4) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that provides advice on policies of the ADCNR. The board consists of the governor, the ADCNR commissioner, the Agricultural Commissioner, the director of the Cooperative Extension Service, and thirteen 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)	$51.00
Recreational Trap (five traps maximum)	No license needed
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 for commercial purposes blue crabs that are smaller than five 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 without said license.

It is unlawful to set or place any trap used for the taking of crabs in any man-made canal, named waterway, or in any marked navigational channel or within 100 yards of any public boat launching ramp or 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 six 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 and a registered color code design. Buoys must be attached to the traps by use of a weighted line. Plastic bottles are prohibited for use as a commercial trap buoy. 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. Crabs 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.

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 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 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.

5.2.3 Mississippi

5.2.3.1 Mississippi Department of Marine Resources

Mississippi Department of Marine Resources (MDMR)
1141 Bayview Avenue, Suite 101
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 seven members appointed by the Governor. One member is also a member of the Mississippi Commission on Wildlife, Fisheries, and Parks (MCWFP) and serves as a liaison between the two agencies. The MDMR has full power to "manage, control, supervise, and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency" (Mississippi Code Annotated 49-15-11).

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

Ordinance Number 9.001 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 97-17-58. 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 thirty 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	None
Resident commercial crabbing license	$75.00
Nonresident commercial crabbing license	200.00
Seafood processor	200.00
Wholesale dealers	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 an ordinance for the purpose of taking *Callinectes sapidus* (blue crab) or allied species. Ordinance Number 4.006 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

It is unlawful for any person, firm, or corporation in command of or control of any boat with a commercial shrimping license, fish net license, or oyster license to fail to immediately return to the water any crabs caught in trawls regardless of the location unless the boat operating the trawl net or dredge has a valid commercial crab license. 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.

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 six inches in width, six inches in length, six 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. In addition, Ordinance 4.006 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 thirty minutes after legal sunset to thirty 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.

5.2.3.7.5 Bag/Possession Limits

There are no bag or possession limits in effect for the blue crab fishery in Mississippi.

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 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 Ordinance Number 10.001.

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 seven-member 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 dealer buying crabs from any commercial crab fisherman and commercial fishermen selling crabs to anyone other than a wholesale/retail seafood dealer are 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. A soft shell crab shedder who does not have a wholesale/retail dealer license 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 Louisiana Department of Wildlife and Fisheries.

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 fishermen'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 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 are 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
Commercial Crab Trap Attached to Trotline (up to 25 traps)*	
· resident	1.00/trap
· nonresident	4.00/trap
Soft-Shell Crab Shedder	
· resident	100.00

· nonresident	400.00
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
Wholesale/retail seafood dealer (business)	
· resident	250.00
· nonresident	1,105.00
Wholesale/retail seafood dealer (vehicle)	
· resident	250.00
· nonresident	1,105.00
Seafood Retail Dealer (Business)	105.00
Seafood Retail Dealer (Vehicle)	105.00
Recreational	
Crab Trap (no more than ten traps)	
· resident	25.00
· nonresident	100.00
Crab Trap Attached to Trotline (up to ten traps)	
· resident	1.00/trap
· nonresident	4.00/trap

*Beginning October 1, 2000 and continuing through December 31, 2001, there will be an additional one-time only crab trap gear fee of $45.00.

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 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 softshell 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 ten percent 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 two percent 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, 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 (six inches minimum diameter), a non-floating buoy line (¼ inch minimum diameter), be marked, and have escape rings.

Each crab trap shall be marked with a ½" stainless steel self-locking tag containing the commercial fisherman's license number attached to the center of the trap ceiling.

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 $2^{5}/_{16}$" 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 by persons holding a soft shell crab shedder's license are exempt from this provision.

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 has the required identification tag, is constructed to department specifications, and capable of capturing and retaining harvestable crabs.

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 ¼" mesh or less and measuring 30 ft or less in length, cast nets, dip nets, minnow traps, or any other devices approved by the Commission may be utilized. Seines 100 ft or less may be used for taking bait only in saltwater areas.

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.

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 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.

5.2.5 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) 389-4863

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 make-up 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:

1) General commercial fisherman's license
2) Commercial fishing boat license; and
3) 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:

1) Retaining undersized or left claws of a stone crab,
2) Possessing egg-bearing crabs or female crabs with its abdominal apron detached,
3) Removing crabs or crab traps 30 minutes before or after legal crabbing hours,
4) Fishing crab traps in restricted areas,
5) Fishing crab traps in excess of legal trap numbers,
6) Fishing for crabs without the appropriate license, or
7) 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 11 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 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 to $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	$500.00
· nonresident	2,000.00
Commercial crab fisherman's license transfer	
· resident	500.00
· nonresident	2,000.00
Duplicate license plates	
· resident	5.00
· nonresident	5.00
Commercial finfish fisherman's license	
· resident	300.00
· nonresident	1,200.00
Wholesale fish dealer (business)	525.00
Wholesale fish dealer (truck)*	325.00
Retail fish dealer (business)	46.00
Retail fish dealer (truck)*	86.00
Recreational	
General fishing license	
· resident	$19.00
· non-resident	30.00
· special resident**	6.00
Temporary (three-day) resident sportfishing	10.00
Temporary (14-day) resident sportfishing	12.00
Temporary (five-day) non-resident sportfishing	20.00
Saltwater sportfishing stamp***	10.00

* Refers to the use of a truck as a place of business.
** Required of residents exempt from fish licenses to obtain red drum trophy tag.
***Required in addition to fishing license when fishing in saltwater.

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 five percent 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 ft 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 2⅜" 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 three inches by six 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 six inches in height, six inches in length, and six 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 ft of a marked navigable channel in Aransas County and in the water area of Aransas Bay within ½ 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 Nine-Mile 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 ft 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 two-year 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 Resource Protection Division of the Texas Parks and Wildlife Department, 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.

5.3 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 United States 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 Interjurisdictional Fisheries Act of 1986 (P.L. 99-659, Title III)

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

5.3.2.1 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 IJF Act. Additional funds were authorized to support the development of interstate FMPs by the Gulf, Atlantic, and Pacific States Marine Fisheries Commissions.

6.0 DESCRIPTION OF THE FISHERY

Significant changes have occurred in the blue crab fishery in the Gulf of Mexico since publication of the regional FMP (Steele and Perry 1990) and earlier descriptions of the Gulf fishery (Moss 1982; Otwell and Cato 1982; Perry et al. 1982, 1984; Perry and McIlwain 1986). Guillory et al. (1998) recently summarized the Gulf of Mexico blue crab fishery. Effort has increased significantly while harvest levels have stabilized or decreased, and new management regulations have been implemented. Problems identified by Steele and Perry (1990) including economic overcapitalization, habitat loss and/or degradation, and competition from imported crab products still persist in the fishery.

The blue crab is an abundant, environmentally tolerant estuarine organism with year-round 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 non-traditional, 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 hand-held dip nets with lanterns or torches to harvest crabs. Dip nets were long-handled 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, half-barrels, or burlap sacks. Crab fishermen also used drop nets consisting of a net-covered 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 City-Berwick area. This period also coincided with the first crab processing operations in other Gulf states. Although there were several small-scale processing plants in Florida by 1897 that handled a variety of seafood products, the first full-scale crab meat processing plant was started in the Apalachicola area in 1930 (Steele and Bert 1998). Hard-crab 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 oil-producing states, economic overfishing in interdependent fisheries, and movement of Indochinese 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. 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 (ten 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. Otter trawls used in the shrimp fishery generally harvest blue crabs as incidental catch, although a directed trawl fishery did exist in Florida in some years (Steele and Bert 1998). Crab traps, 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 vinyl-coated 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 0.5" x 1.0" 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" to more than 36" in length and width, most traps average 24" wide and deep and 14.5" 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 1.5" hexagonal, black vinyl-coated mesh, although 1.5" square mesh and different colors (green, orange, red) have become increasingly popular. Some blue crab fishermen weight their traps by attaching 0.5"-0.75" diameter reinforcing iron bars (re-bar) 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 one-third 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 sides two feet square, and made of 18-gauge galvanized poultry wire with 1"-1½" 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 self-culling 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, 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 127-136 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 in crab traps are currently required in Florida, Louisiana, and Texas (Section 5.2).

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 pink-line and red-line premolt crabs (Guillory 1990). Most premolt crabs are obtained from hard crab trap fishermen. Reductions in premolt crab catches in traps with escapement rings limits 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 44.4 mm (1.75") square was superior to other tested squares and to the commercially available 1.5" square and hexagonal mesh wire.

Diamondback terrapin (*Malaclemys terrapin*) excluder devices placed in the entrance funnels of crab traps have been evaluated in several studies (Wood 1992, 1994; Guillory and Prejean 1998; Stehlik et al. 1998). Use of turtle excluder devices in crab traps reduced the catch of diamondback terrapins and maintained or actually increased the catch of legal blue crabs.

The impact of ghost fishing in blue crab traps was evaluated by Guillory (1993), Arcement and Guillory (1993), and Casey and Daugherty (1989). Guillory (1993) concluded that substantial numbers (25/trap/yr) of crabs died in each trap and that unbaited traps continued to attract crabs (35/trap/yr). 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 two-ply #18 or three-ply #30) decomposed fairly quickly; the number of days to decomposition ranged from 51-59 days for a jute panel and from 30-36 days for a jute tie-down 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 S. McKenna (personal communication). His study found that decomposition times for jute and sisal twines ranged from 28 to 63 days ($\bar{X}$ = 48) and 35 to 77 days ($\bar{X}$ = 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 tie-down 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 and 5.2.5.7.3).

6.1.4 Effort

The numbers of 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 trotline-drop 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. NA indicates data not available. "Full" represents full time fishermen, "Part" represents part time fishermen.

	Trap		Trotline		Drop Net		Other		Overall			
Year	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
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

Table 6.1. Continued.

	Trap		Trotline		Drop Net		Other		Overall			
Year	No.	%	No.	%	No.	%	No.	%	Full	Part	Total	% Part
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 Gulfwide 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.

Table 6.2. Number and overall percent contribution of commercial hard crab fishermen by state, 1950-1993. 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

Table 6.2. Continued.

Year	FL		AL		MS		LA		TX	
	No.	%	No.	%	No.	%	No.	%	No.	%
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	--

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 Gulfwide increased through the 1990s.

The percentage of part-time fishermen peaked from 1979-1985 with an average of 29.6% (Table 6.3); 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 6.2). In the early 1950s, Mississippi ranked second with 17% and 18% of the total, but then declined to 2%-5% through the 1980s and to 1% or less since 1990. Louisiana lead the Gulf in numbers of fishermen, with percentages generally ranging from 55% to 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 are shown in Table 6.3. 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 Gulfwide effort data (Tables 6.1 through 6.3) is currently undergoing a transition from the NMFS port agent collections to individual state effort estimates. As of the late 1990s, Florida and Texas effort estimates are substantially higher than previously reported by the NMFS.

6.1.5 Landings

Unreported hard crab landings in the Gulf of Mexico (Adkins 1972a, Moss 1982, Roberts and Thompson 1982, Keithly et al. 1988, Steele and Perry 1990) is a serious problem. 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 landings can be identified.

Total reported landings in the Gulf increased from less than one million lbs in the late 1800s to approximately 18 million lbs prior to World War II (Table 6.4). Landings increased markedly in the late 1950s with introduction of the wire trap (Table 6.5 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 78 and 79 million lbs 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 50 to 70 million lbs and except for 1989, 1990, 1994, and 1995 remained above the 15-year (1983-1997) average of 60.7 million lbs.

Blue crab fisheries are characterized by seasonal, annual, and geographic fluctuations in landings. Gulf landings increased 48.0% from 1986 to 1987 but declined 29.8% from 1988 to 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).

Table 6.3. Number of vessels, fishermen, total number of traps, average number of traps, and landings (X1000 lbs), in the commercial trap fishery, Gulf of Mexico, 1950-1993. NA indicates not available. "Full" represents full time fishermen, "Part" represents part time fishermen.

Years	Vessels	Number of Fishermen			Total Traps	Average Traps Per		Trap Landings
		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

Table 6.3. Continued.

Year	Vessels	Number of Fishermen			Total Traps	Average Traps Per		Trap Landings
		Full	Part	Total		Fisher	Vessel	
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

Table 6.4. Historical Gulf of Mexico hard-shell blue crab landing statistics, 1880-1950 (X1000 lbs; X1000 dollars).

Year	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1880	--	--	--	--	--	--	288	7	36	1	324	8
1887	(2)	(2)	(2)	(2)	38	1	837	13	111	4	(2)	(2)
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	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1892	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1895	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1897	6	(1)	24	1	132	3	1,459	13	138	4	1,759	21
1898	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1899	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1901	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1902	1	(1)	75	2	235	5	312	16	43	2	666	25
1904	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1905	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1908	2	(1)	246	6	380	10	244	8	199	5	1,071	29
1915	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1918	--	--	96	3	216	6	282	10	193	11	787	30
1919	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1920	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1921	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)

Table 6.4. Continued.

Year	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1922	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1923	--	--	84	3	435	11	312	8	109	9	940	31
1924	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1925	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1926	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
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	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1934	49	1	257	4	603	7	11,676	164	258	13	12,843	189
1935	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
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
1940	1,170	16	1,381	28	1,488	26	14,062	172	252	6	18,353	248
1941	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1942	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)

Table 6.4. Continued.

Year	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1943	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1944	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1945	1,092	54	2,207	110	5,639	282	31,280	1,418	339	39	40,557	1,903
1946	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1947	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1948	(2)	(2)	2,373	119	5,503	275	21,110	608	526	34	(2)	(2)
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

(1) Less than 500 lbs or $500
(2) Data not available
* Partial surveys were done prior to 1912 and in 1934, 1936 through 1940, 1945, 1948 and 1949 and 1951.

Table 6.5. Hard crab landings (X1000 lbs) by state, 1950-1997.

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

Table. 6.5. Continued.

Year	FL	AL	MS	LA	TX	Total
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
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

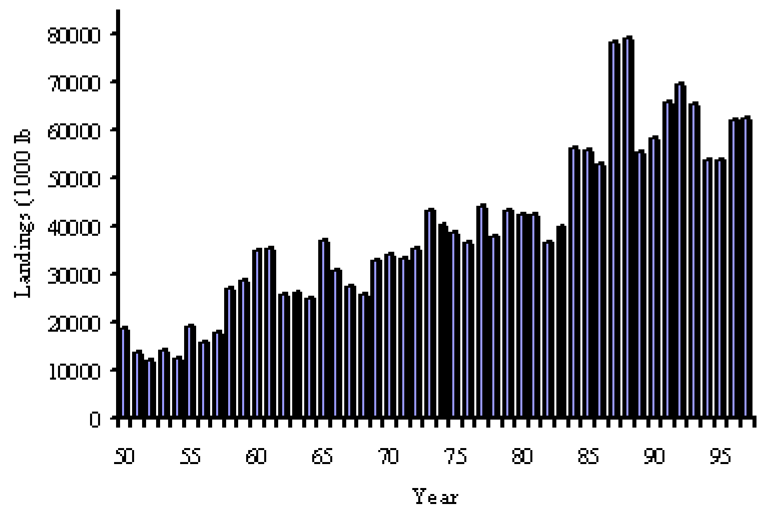

Figure 6.1. Annual Gulf hard crab landings, 1950-1997.

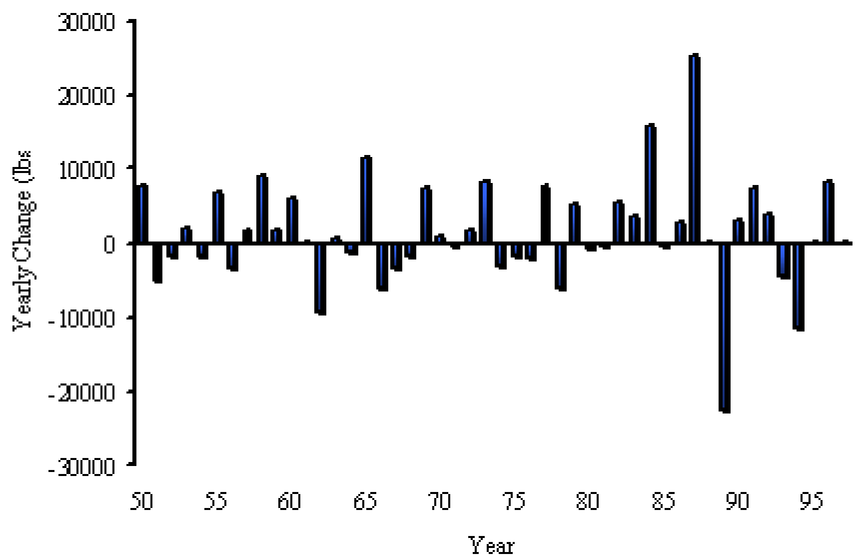

Figure 6.2. Yearly changes in annual Gulf hard crab landings, 1950-1997.

During the 1950s and 1960s the fishery gradually evolved from a trotline to trotline-drop net to a trap dominated fishery (Table 6.6 and Figure 6.3). 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 to 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 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 Gulfwide contribution of trap landings steadily increased from 2% in 1950 to 99% in 1979. 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 1985-1994 period trawl landings were <1% of the total.

Percentage of Gulf landings to total United States landings ranged from 12.0%-38.9% in 1952 and 1987, respectively (Table 6.7 and Figure 6.4). From 1962 through 1967, the Gulf states generally contributed less than 20% of total United States landings. 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 production increased to 38.9% of total United States landings in 1987. Gulf production averaged 26.8% of United States landings during the 1990s.

Landings by state are listed in Table 6.5. The percent contribution of each Gulf state to total Gulf landings is shown in Table 6.7 and Figure 6.5. Louisiana ranked first 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 1986-1991 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 addition to inter-state 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 in those counties north of Hillsborough, Pinellas, and Indian River counties and along the Gulf coast eastward and southward of Cape San Blas. In Alabama, the bulk of production comes from Mississippi Sound (57%) with 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 to 1997, 48% of Texas commercial hard crab landings came from the Galveston Bay and San Antonio Bay systems (Robinson et al. 1998).

Table 6.6. Percent contribution by gear of Gulf of Mexico hard crab landings, 1950-1994.

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

Table 6.6. Continued.

Year	Trap	Trotline	Trawl	Drop Net
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
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

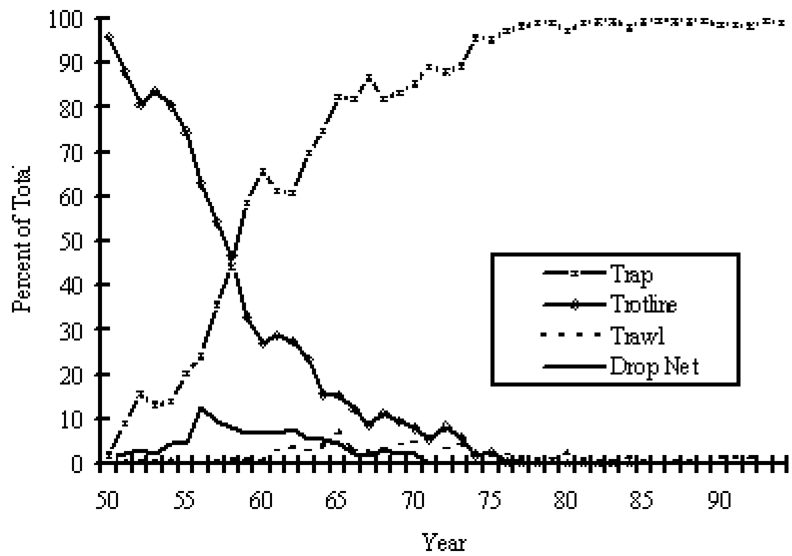

Figure 6.3. Percent of Gulf of Mexico hard crab landings by gear type, 1950-1997.

Table 6.7. Percent contribution by state to Gulf of Mexico hard crab landings and Gulf to United States landings, 1950-1997.

Year	FL	AL	MS	LA	TX	Gulf
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

Table 6.7. Continued.

Year	FL	AL	MS	LA	TX	Gulf
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
1988	13.1	4.9	1.1	67.7	13.2	35.8

Table 6.7. Continued.

Year	FL	AL	MS	LA	TX	Gulf
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

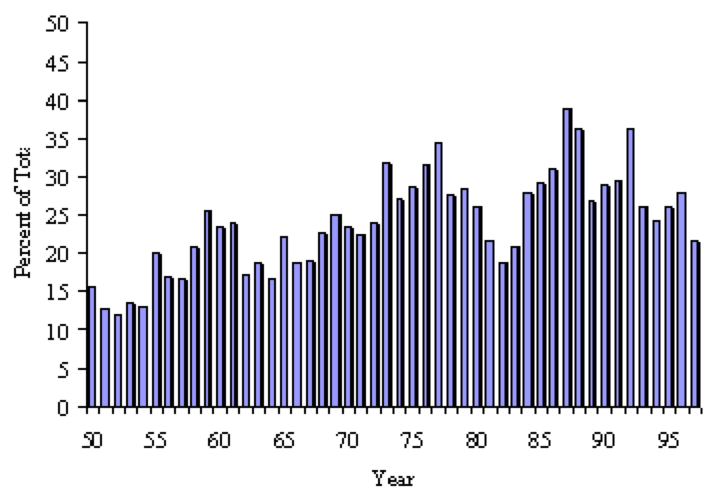

Figure 6.4. Percent contribution of Gulf hard crab landings to the total United States landings, 1950-1997.

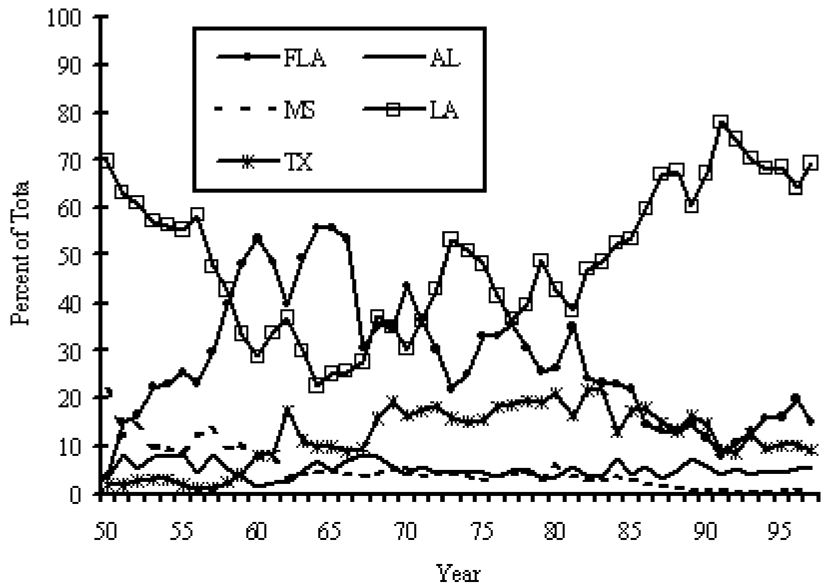

Figure 6.5. Percent contribution of hard crab landings by state, 1950-1997.

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 15°C. 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.

To review historical trends in catch rates, effort and harvest data from the trap fishery for the 1969 to 1993 period were utilized to calculate annual CPUE by fishermen and by trap. There were significant downward trends over time for CPUE by trap fishermen (r^2=0.46, p=0.0002) and by trap (r^2=0.77, p=0.0001) (Figures 6.6 and 6.7). The downward trend in CPUE by fishermen was probably lessened somewhat by utilization of increased number of traps, and by better documentation of landings by states in recent years.

6.1.6 Mariculture

Culture from egg to adult crab has not been practiced commercially. 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, and cannibalism are impediments to successful mariculture (Oesterling and Provenzano 1985). Probably the major factor in the failure of most early attempts to mass culture blue crabs in artificial environments was cannibalism. Relatively low market value for hard crabs also discouraged their mariculture (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 mariculture 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).

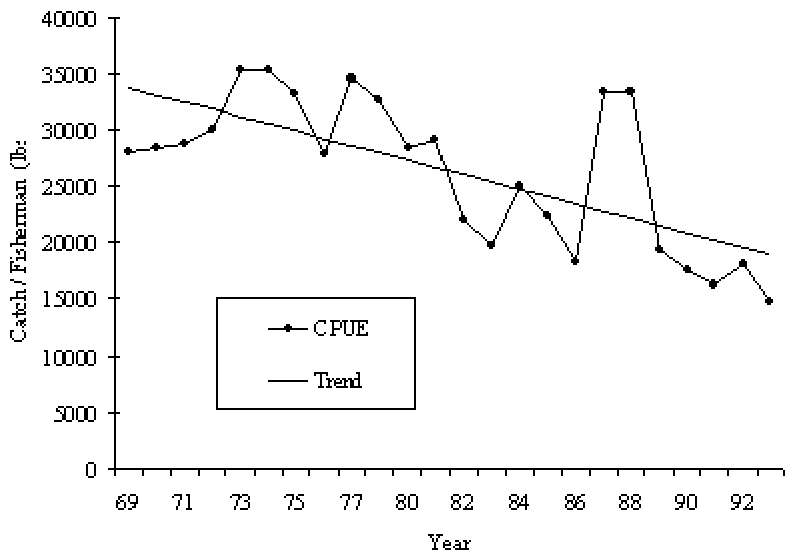

Figure 6.6. Mean annual catch per fisherman (CPUE) in the Gulf trap fishery and calculated regression line of CPUE and time (r^2=0.46, p=0.0001).

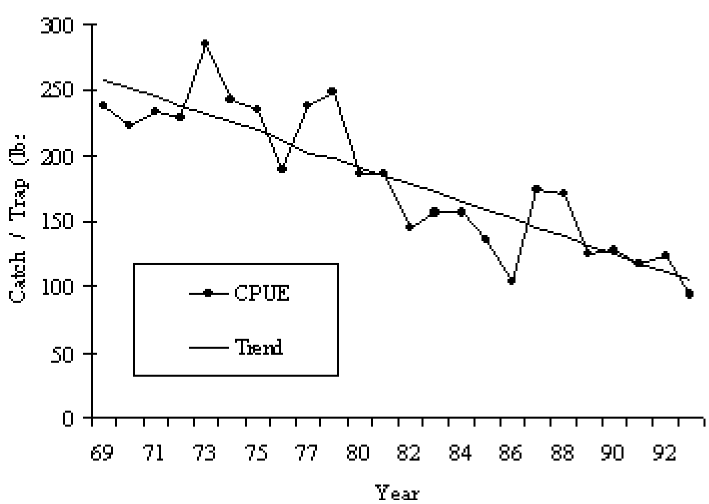

Figure 6.7. Mean annual catch trap (CPUE) in the Gulf trap fishery and calculated regression line of CPUE and time ($r^{2=}$0.77, p=0.0001).

6.2 Gulf Commercial Soft Crab Fishery

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 lbs valued at $7,000 were harvested in Louisiana, and 15,000 lbs worth $1,000 were recorded from Mississippi. Recorded production in Texas, Florida, and Alabama began much later with landings rarely exceeding 10,000 lbs. 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 to 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 slow-moving water three to six ft deep and suspended just above the water's surface, with ten to 100 bundles of brush, preferably wax myrtle, tied to the line with snoods or ganglions (Horst 1982).

Hand-held 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 flow-through 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 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 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. 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 14-19 times greater than reported landings. Because of recognized limitations in soft crab production data, trends will be emphasized.

Annual Gulf soft crab production from 1950-1997 is reported in Table 6.8; historic landings (1880-1949) are located in Table 6.4. Soft crab production peaked from 1955 to 1961, when annual production was at least 525,000 lbs (Figure 6.8). Despite year-to-year fluctuations, Gulf production displayed a long-term decline until 1986 when 88,000 lbs were recorded. Production increased to a peak of 290,000 lbs in 1990, but declined thereafter. During the 1990s, production ranged from 111,000-290,000 lbs and averaged 188,000 lbs.

Table 6.8. Soft crab landings (X1000 lbs) by state, 1950-1997. Landings not recorded or 0 indicated by "--".

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

Table. 6.8. Continued.

Year	FL	AL	MS	LA	TX	Total
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
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

(1) = less than 1000 lbs.

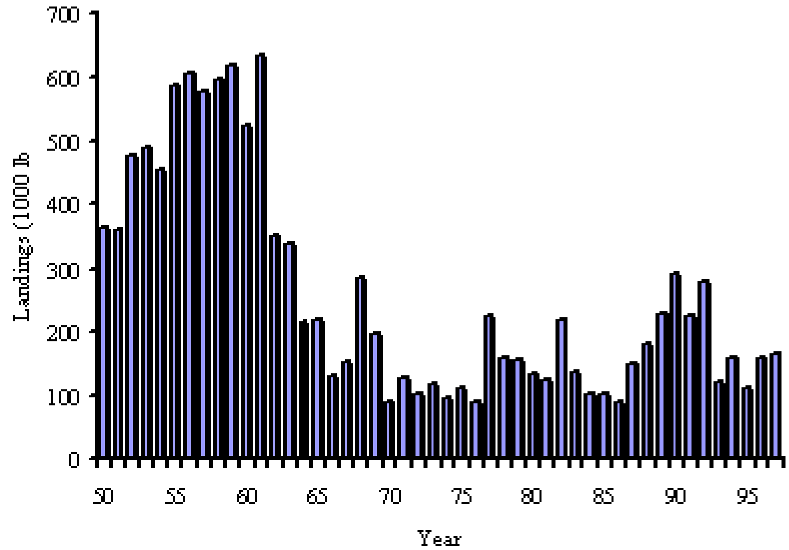

Figure 6.8. Annual Gulf soft crab production, 1950-1997.

Annual soft crab production by state (Table 6.8) shows that, until recently, Gulf soft crab production was largely from Louisiana. Louisiana averaged 97.8% of Gulf production from 1950 to 1977. In the late 1970s and 1980s, Florida soft crab production increased, and from 1978 to 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 figures (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 flow-through 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 closed-recirculating 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 shrimped commercially.

6.3 Recreational Fishery

6.3.1 Hard Crabs

Recreational crabbing is a relatively inexpensive, low key, family-oriented activity (Guillory 1998a). It occurs year-round, 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 Gulfwide 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 Gulfwide, 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. The annual recreational catch was estimated in pounds and expressed as a percentage of the commercial catch: 33,125 lbs (5.9%) in Galveston Bay, Texas (Benefield 1968); 50,000 lbs (less than 4%) in Mississippi (Herring and Christmas 1974); 20% of the commercial landings in Alabama (Tatum 1982); and 398,500 lbs (4.1%) in Terrebonne Parish, Louisiana (Guillory 1998a). Over 51,000 lbs were harvested from Rockefeller Refuge, Louisiana, in 1981 (Davidson and Chabreck 1983).

Guillory (1998b) provided several statewide estimates of recreational harvest in Louisiana. An estimated annual harvest of 1,848,000 lbs 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 1998a). Annual statewide effort and harvest estimates for trap fishermen were 29,200 trap sets and 1,752,000 crabs or 463,100 lbs.

In a creel and mail survey in Terrebonne Parish, Louisiana, Guillory (1998b) found that approximately one-third of saltwater fishing license holders participated in recreational crabbing. Recreational crab fishermen averaged 5.8-7.9 nontrap trips per year and a harvest of 34.7-83.8 crabs/trip while recreational trap fishermen 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 crabbing trips per year. The Texas recreational fishery comprised 0.3%-1.7% of all fishing activities in 1990 (Cody et al. 1992) and showed no discernable pattern in catch rates from 1983 to 1994 (Hammerschmidt et al. 1998).

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, handlines, trotlines, and drop nets. Guillory (1998b) reported that recreational shrimp trawlers averaged 7.9 trips/yr and incidentally harvested an average of 0.2 soft crabs/trip.

6.4 Incidental Catch/Bycatch and Impingement

Blue crabs are captured in large numbers in gear used in the shrimp fishery. An average of 82 million blue crabs were captured annually from 1990 to 1994 in the Texas inshore shrimp fishery (Hammerschmidt et al. 1998). Based upon an estimated 1989 bycatch of 227.8 million lbs 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 20.5 million lbs; 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 that number harvested by commercial crab fishermen.

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 26% 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.

Bycatch of other species also occurs in blue crab traps. Seigel and Gibbons (1995) concluded that drowning in crab traps is a major threat to diamondback terrapin (*Malaclemys terrapin*) populations in some areas, and otters (*Lutra canadensis*) have drowned in crab traps (E. Holder personal communication). Numerous species of finfish are also caught in crab traps. Guillory (1993) and Whitaker (1979) documented 11 and 13 species in monitored ghost traps in Louisiana and South Carolina, respectively. Manatees (*Trichechus manatus*) in Florida (P. Steele personal communication) have been injured after becoming entangled in crab trap buoy lines.

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 recently 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 is the conflict between shrimp and crab fishermen. Crab fishermen have seen increased numbers of traps lost, damaged, or misplaced due to shrimping activities. Conversely, crab traps caught in shrimping gear can cause damage and loss of catch. Reports of friction and conflicts between these two commercial user groups have escalated in recent years.

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 The Fishery by State

The blue crab fishery within each Gulf state was recently evaluated in reports published in the *Proceedings of the North American Blue Crab Symposium*, Journal of Shellfish Research (Steele and Bert 1998, Heath 1998, Perry et al. 1998, Guillory and Perret 1998, Hammerschmidt et al.1998) and elsewhere (Guillory et al. 1996, Guillory 1997a). Individual state accounts were largely extracted from these state reports.

Older historic literature on the blue crab fishery by state include: Florida (Landrum and Prochaska 1980, Prochaska and Taylor 1982, Steele 1982); Alabama (Tatum 1980, 1982); Mississippi (Perry 1975); Louisiana (Adkins 1972a, Jaworski 1971, 1972, 1982, Keithly et al. 1988); and Texas (Leary 1967, More 1969, Miller and Nichols 1986, Cody et al. 1992).

6.6.1 Florida West Coast

After World War II, blue crab landings increased until peaking at 20 million lbs in 1965 after the introduction and wide-spread acceptance of the crab trap. Landings subsequently declined; during 1987-1997, annual landings averaged 8.6 million lbs and ranged from 5-10 million lbs (Figure 6.9). Pronounced annual fluctuations in commercial hard crab landings with four to seven year cycles have been evident since 1969. Landings of 5.2 million lbs in 1991 were the lowest since 1957.

The number of commercial fishermen increased from 244 in 1969 to a peak of 1,057 in 1994 and declined to 911 fishermen in 1995. The estimated number of traps in the fishery increased from 28,626 in 1969 to 141,200 traps in 1995. Annual catch per fishermen has decreased from 46,000 lbs/fishermen in 1969 to 9,493 lbs/fishermen in 1995.

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.

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 lbs in 1978. Production peaked in 1984 at 53,000 lbs. During the 1990s, production ranged from 21,000 to 66,000 lbs and averaged 45,000 lbs.

Most soft crab shedding facilities in Florida are small "Mom and Pop" operations that deal in small volume. Despite increased demand for soft crabs, production has remained low due to the inconsistent supply of peeler crabs and the unfamiliarity of local crab fishermen with shedding techniques.

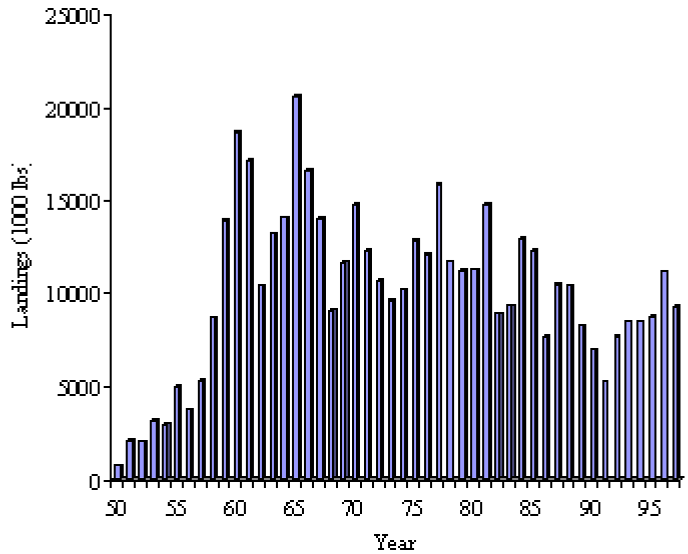

Figure 6.9. Annual Florida (west coast) hard crab landings, 1950-1997.

6.6.2 Alabama

Hard crab landings remained below one million lbs until 1940. The early increases in production were probably associated with the development of improved transport systems. Landings ranged from 0.6 to 2.4 million lbs during the 1940s through the 1970s. Landings peaked in 1984 at 4.2 million lbs (Figure 6.10). After 1984, landings fluctuated between 2.5 and 4.1 million lbs. 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.

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 has declined since 1980.

The soft crab fishery is minimal and is based upon commercial hard crab fishermen shedding their own crabs. Annual soft crab production was less than 500 lbs prior to the 1990s.

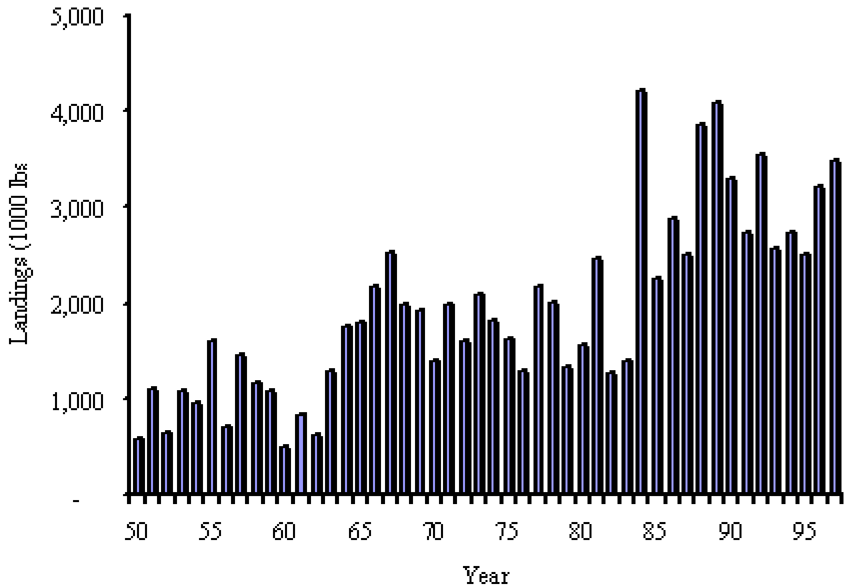

Figure 6.10. Annual Alabama hard crab landings, 1950-1997.

6.6.3 Mississippi

With the exception of the post World War II period when over 5 million lbs were landed, landings were stable and generally fluctuated between one to two million lbs until 1987 (Figure 6.11). From 1970 to 1989 landings averaged 1,546,000 lbs. Reported landings declined in 1988 and continued to decrease; harvest during the 1990s averaged 397,400 lbs. 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 the NMFS estimates, the number of trap fishermen was very stable during the 1970s and 1980s; the average number was 61 and ranged from 43 to 73. During the 1990s, there was an average of 42 trap fishermen.

The soft crab fishery is a small 'cottage-type' industry and is based upon commercial hard crab fishermen shedding their own crabs. Annual soft crab production averaged less than 2,000 lbs prior to the 1990s.

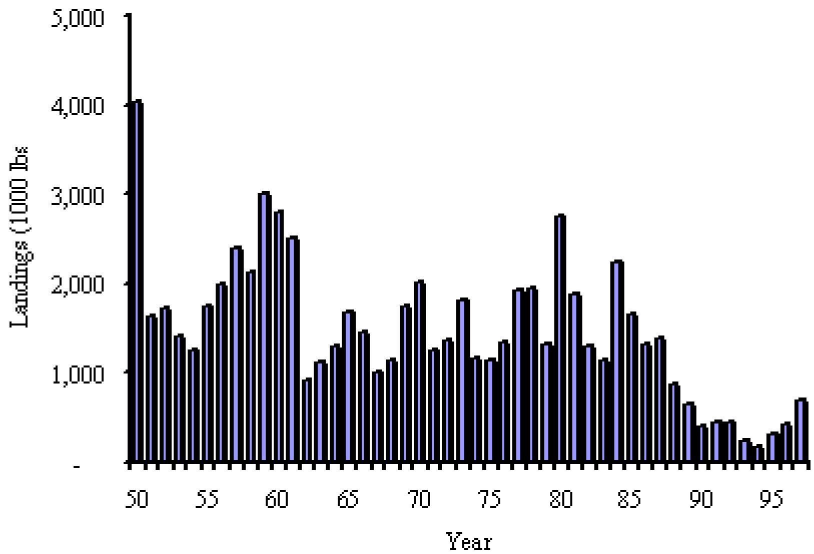

Figure 6.11. Annual Mississippi hard crab landings, 1950-1997.

6.6.4 Louisiana

Landings increased gradually but erratically from the late 1960s through the early 1980s and then increased dramatically in the mid 1980s with five successive landings records set from 1984 through 1988 (Figure 6.12). Landings averaged 43.2 million lbs during the 1990s. While there were several relatively poor years (1989, 1990, 1994, and 1995) after fishing effort peaked and stabilized in the late 1980s, annual landings during this period were above the 15-year mean of 39.7 million lbs. Significant downward trends over time in catch per unit of effort (CPUE) by fishermen and by trap were found.

Fishing effort has increased both in number of fishermen and units of gear. The number of LDWF crab trap licenses ranged between 751 and 832 from 1979 to 1981; increased to a peak of 3,019 in 1989; decreased slightly and stabilized (2,503-2,807) from 1990-1994; and increased sharply to 3,482 in 1995 and 2,948 in 1996. The latter increase associated with speculative license purchases prior to a three-year license moratori um. The estimated number of traps per fisherman increased from 25 in 1957 to 228 in 1987 and then declined to between 129 and 163 in the 1990s. The total number of traps ranged from 75,760 to 139,044 from 1970 to 1983 but then increased dramatically during the mid and late 1980s to a peak of 441,710 in 1993.

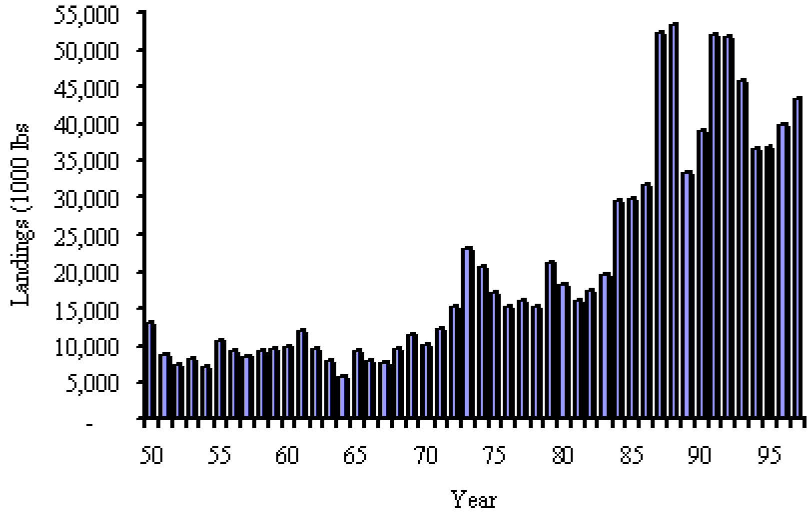

Figure 6.12. Annual Louisiana hard crab landings, 1950-1997.

Soft crab production varied between 350,000 and 605,000 lbs during the 1950s; peaked at 620,000 lbs in 1961; and then declined to a low of 75,000 lbs in 1984. Production increased after 1984 with more than 200,000 lbs reported from 1990-1992. After 1992, annual production was 100,000 lbs or less. Several estimates of the number of Louisiana soft crab shedders exists. Manthe (1985) estimated that there were 425 in 1985, and Caffey et al. (1993) estimated that there were from 228-300 in 1991. A total of 185 shedder's licenses were sold by the LDWF in 1996.

6.6.5 Texas

Hard crab landings gradually increased from the late 1960s before peaking at over 10 million lbs in 1987 and 1988. Since then landings have declined, reaching a low of 5.2 million lbs in 1994 (Figure 6.13). Landings ranged from 5.2 to 8.6 million lbs and averaged 6.5 million lbs during the 1990s.

According to the NMFS estimates, the number of commercial crab fishermen peaked in 1987, with an estimated 317 crab fishermen fishing 41,490 traps. Numbers of fishermen fluctuated around 300 through 1990 and then decreased to an estimated 160 fishermen using 22,627 traps in 1992, the last year in which the NMFS data are available for Texas. The TPWD crab trap tag sales indicated steadily increasing fishing effort throughout the 1990s. Estimated numbers of commercial trap fishermen were markedly higher than the NMFS estimates through 1992, increasing from 368 to 553 fishermen from 1992 to 1997. Effort estimates should improve in 1998 with adoption of a new commercial crab fisherman's license.

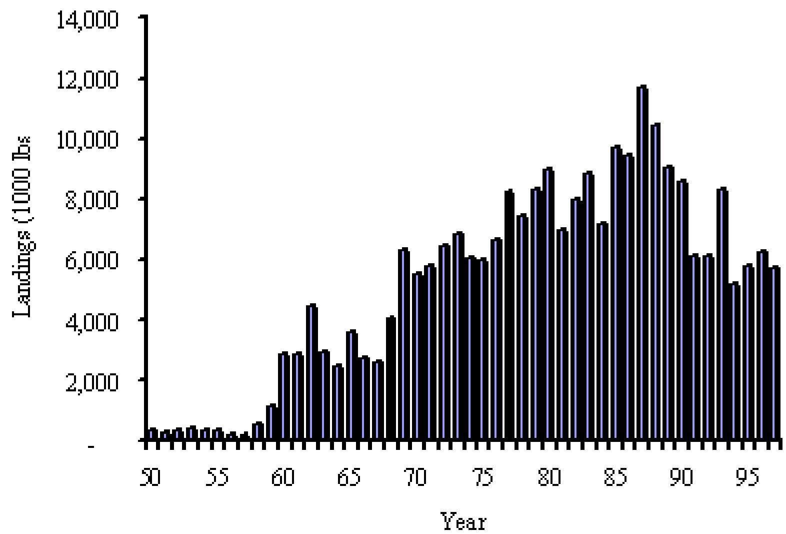

Figure 6.13. Annual Texas hard crab landings, 1950-1997.

Catch per trap declined throughout the 1970s until 1976, increased sharply to a peak of 752 lbs/trap in 1979 and then declined to less than 300 lbs/trap throughout the 1990s. Since 1992 numbers of traps per fisherman are unavailable, but declining landings coupled with increasing effort mean that catch per trap continues to decline. Recent soft crab production is unknown because soft/peeler landings are not separated from hard crab landings.

7.0 ECONOMIC CHARACTERISTICS OF THE COMMERCIAL AND RECREATIONAL FISHERIES

There are a number of underlying economic characteristics of the commercial and recreational blue crab fisheries in the Gulf of Mexico. Commercial dockside value represents the total amount paid by the first handler to the harvester during the initial off-loading of the crabs. Markups that might occur in subsequent market levels are not included. Annual and monthly dockside values will be discussed for each state and the region in general. Insight on prices and dockside value provide the economic importance and performance of the commercial harvesting sector. Landings and value data throughout this section were provided by the NMFS (Fisheries Statistics and Economics Division unpublished data).

The sources and product form of blue crabs by wholesale distributors and processors in the Gulf provide insight into the importance of the stocks to blue crab purveyors in the region, as compared to blue crabs obtained from other domestic sources and foreign suppliers.

7.1 Domestic Harvesting Sector

7.1.1 Annual Gulf of Mexico Landings and Value

Reported 1960-1997 Gulf of Mexico blue crab landings, expressed in terms of pounds, value, and price per pound are provided in Table 7.1. Average landings peaked in the Gulf of Mexico in the late 1980s at over 64 million lbs. Since 1990, production decreased slightly based on five-year averages. Recent landings averaged just over 59 million lbs. While average landings have declined slightly, they increased approximately 115% from reported average landings of 29.6 million lbs in the early 1960s.

Similar to landings, the product value of the Gulf blue crab increased substantially over the last 38 years, with recent dockside values of $39 million annually. This increase can be attributed to two factors, the quantity and price of the product. The increase over the last three years was further attributed to the sharp decline in production in the Chesapeake production during this period (Section 7.1.3).

The increase in price and value for blue crab products since 1960 reflected an overall increase in the price for goods and services across the entire United States economy. When inflation was removed from the equation, the average price (deflated) indicated a more modest increase in blue crab price, increasing from roughly $0.17 to $0.43/lb landed between 1960 and 1997. Deflated, or adjusted, blue crab prices were based on the 1982-1984 Consumer Price Index and represented a real price increase of about 150% over the last 38 years with a peak in the early 1990s.

The deflated dockside value of blue crab landings increased from an average of $5.1 million in the early 1960s to $25.2 million currently. This fourfold increase in dockside value (based on a five-year average) was paralleled by a doubling of the average number of pounds landed in the Gulf.

7.1.2 Annual Gulf of Mexico Landings and Value by State

A brief discussion of 1960-1997 blue crab landings of each Gulf state is presented below and in Tables 7.2-7.6. In addition, summary statistics for those tables are presented in Table 7.7.

Table 7.1. Selected statistics pertaining to blue crab landings in the Gulf of Mexico, 1960-1997.

Year	Pounds (1,000s)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	34,875	1,764	5,958	0.05	0.17
1961	35,257	1,617	5,409	0.05	0.15
1962	25,894	1,329	4,400	0.05	0.17
1963	26,520	1,429	4,671	0.05	0.18
1964	25,292	1,589	5,127	0.06	0.20
Average	29,567	1,546	5,113	0.05	0.17
1965	37,008	2,390	7,587	0.06	0.21
1966	30,951	1,964	6,061	0.06	0.20
1967	27,528	1,826	5,468	0.07	0.20
1968	25,759	2,077	5,970	0.08	0.23
1969	33,184	3,146	8,572	0.09	0.26
Average	30,886	2,281	6,731	0.07	0.22
1970	34,001	2,847	7,337	0.08	0.22
1971	33,531	3,113	7,686	0.09	0.23
1972	35,195	3,752	8,976	0.11	0.26
1973	43,473	5,314	11,967	0.12	0.28
1974	40,354	5,324	10,800	0.13	0.27
Average	37,311	4,070	9,353	0.11	0.25
1975	38,718	5,503	10,228	0.14	0.26
1976	36,561	6,754	11,870	0.18	0.32
1977	44,328	9,852	16,257	0.22	0.37
1978	38,172	8,309	12,744	0.22	0.33
1979	43,495	9,864	13,587	0.23	0.31
Average	40,255	8,056	12,937	0.20	0.32
1980	42,729	10,328	12,534	0.24	0.29
1981	42,306	11,093	12,204	0.26	0.29
1982	36,728	10,254	10,626	0.28	0.29
1983	40,334	12,986	13,038	0.32	0.32
1984	56,224	15,655	15,067	0.28	0.27
Average	43,664	12,063	12,694	0.28	0.29
1985	55,753	16,177	15,034	0.29	0.27
1986	52,926	16,866	15,389	0.32	0.29
1987	78,339	29,714	26,157	0.38	0.33
1988	79,117	31,295	26,454	0.40	0.33

Year	Pounds (1,000s)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1989	55,394	23,952	19,316	0.43	0.35
Average	64,306	23,601	20,470	0.37	0.32
1990	58,056	22,077	16,891	0.38	0.29
1991	65,609	23,605	17,331	0.36	0.26
1992	69,516	35,009	24,953	0.50	0.36
1993	65,378	34,277	23,721	0.52	0.36
1994	53,024	31,921	21,539	0.60	0.41
Average	62,317	29,378	20,887	0.47	0.34
1995	53,836	41,268	27,079	0.76	0.50
1996	60,978	37,300	23,773	0.61	0.39
1997	62,583	39,845	24,826	0.64	0.40
Average	59,132	39,471	25,226	0.67	0.43

Note: Deflated values and prices were derived using 1982-1984 Consumer Price Index.

Table 7.2. Selected statistics pertaining to blue crab landings in Florida, 1960-1997. Deflated values and prices were derived using the 1982-1984 Consumer Price Index (Bureau of Labor Statistics 1999).

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	18,648	895	3,024	0.05	0.16
1961	17,130	737	2,463	0.04	0.14
1962	10,356	487	1,612	0.05	0.16
1963	13,148	644	2,105	0.05	0.16
1964	14,069	843	2,718	0.06	0.19
Average	14,670	721	2,385	0.05	0.16
1965	20,598	1,184	3,760	0.06	0.18
1966	16,547	912	2,814	0.06	0.17
1967	13,976	817	2,445	0.06	0.17
1968	9,008	674	1,936	0.07	0.21
1969	11,584	1,074	2,927	0.09	0.25
Average	14,342	932	2,776	0.07	0.20
1970	14,786	1,073	2,765	0.07	0.19
1971	12,279	952	2,351	0.08	0.19
1972	10,673	959	2,294	0.09	0.21
1973	9,599	1,147	2,583	0.12	0.27
1974	10,134	1,280	2,597	0.13	0.26

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
Average	11,494	1,082	2,518	0.09	0.22
1975	12,807	1,585	2,946	0.12	0.23
1976	12,049	1,966	3,454	0.16	0.29
1977	15,832	3,119	5,147	0.20	0.33
1978	11,679	2,235	3,429	0.19	0.29
1979	11,198	2,235	3,078	0.20	0.27
Average	12,713	2,228	3,611	0.18	0.28
1980	11,276	2,387	2,896	0.21	0.26
1981	14,788	3,327	3,660	0.23	0.25
1982	8,871	2,209	2,289	0.25	0.26
1983	9,337	2,524	2,534	0.27	0.27
1984	12,912	3,197	3,077	0.25	0.24
Average	11,437	2,729	2,891	0.24	0.25
1985	12,273	3,113	2,893	0.25	0.24
1986	7,644	2,414	2,203	0.32	0.29
1987	10,413	4,068	3,581	0.39	0.34
1988	10,386	3,751	3,171	0.36	0.31
1989	8,159	3,183	2,567	0.39	0.31
Average	9,775	3,306	2,883	0.34	0.30
1990	6,878	3,139	2,402	0.46	0.35
1991	5,213	2,763	2,029	0.53	0.39
1992	7,619	3,886	2,770	0.51	0.36
1993	8,437	4,960	3,432	0.59	0.41
1994	8,407	5,262	3,551	0.63	0.42
Average	7,311	4,002	2,837	0.55	0.39
1995	8,636	6,419	4,212	0.74	0.49
1996	11,140	7,041	4,487	0.63	0.40
1997	9,246	6,520	4,062	0.71	0.44
Average	9,674	6,660	4,254	0.69	0.44
Grand Average	11,519	2,499	2,954	0.22	0.26

Table 7.3. Selected statistics pertaining to blue crab landings in Alabama, 1960-1997. Deflated values and prices were derived using the 1982-1984 Consumer Price Index (Bureau of Labor Statistics 1999).

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	499	26	88	0.05	0.18
1961	838	46	154	0.05	0.18
1962	634	35	117	0.06	0.18
1963	1,297	75	244	0.06	0.19
1964	1,762	110	356	0.06	0.20
Average	1,006	58	192	0.06	0.19
1965	1,812	153	487	0.08	0.27
1966	2,183	182	562	0.08	0.26
1967	2,353	188	564	0.08	0.24
1968	1,980	159	456	0.08	0.23
1969	1,915	223	608	0.12	0.32
Average	2,049	181	535	0.09	0.26
1970	1,407	144	371	0.10	0.26
1971	1,997	212	523	0.11	0.26
1972	1,613	195	467	0.12	0.29
1973	2,099	294	663	0.14	0.32
1974	1,826	283	575	0.16	0.31
Average	1,788	226	520	0.13	0.29
1975	1,640	283	526	0.17	0.32
1976	1,299	281	494	0.22	0.38
1977	2,174	548	904	0.25	0.42
1978	2,009	458	703	0.23	0.35
1979	1,341	391	538	0.29	0.40
Average	1,692	392	633	0.23	0.37
1980	1,557	465	564	0.30	0.36
1981	2,462	850	935	0.35	0.38
1982	1,266	479	496	0.38	0.39
1983	1,412	514	516	0.36	0.37
1984	4,216	1,374	1,322	0.33	0.31
Average	2,183	736	767	0.34	0.36
1985	2,261	830	771	0.37	0.34
1986	2,886	950	866	0.33	0.30
1987	2,496	1,005	885	0.40	0.35
1988	3,869	1,551	1,311	0.40	0.34
1989	4,090	1,735	1,399	0.42	0.34
Average	3,121	1,214	1,047	0.39	0.34
1990	3,303	1,265	968	0.38	0.29

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1991	2,731	942	692	0.34	0.25
1992	3,550	1,465	1,044	0.41	0.29
1993	2,554	1,186	820	0.46	0.32
1994	2,688	1,474	994	0.55	0.37
Average	2,965	1,266	904	0.43	0.31
1995	2,520	1,712	1,123	0.68	0.45
1996	3,219	1,822	1,161	0.57	0.36
1997	3,476	2,053	1,279	0.59	0.37
Average	3,072	1,862	1,188	0.61	0.39
Grand Average	2,190	683	699	0.31	0.32

Table 7.4. Selected statistics pertaining to blue crab landings in Mississippi, 1960-1997. Deflated values and prices were derived using the 1982-1984 Consumer Price Index (Bureau of Labor Statistics 1999).

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	2,812	169	570	0.06	0.20
1961	2,505	143	478	0.06	0.19
1962	907	55	183	0.06	0.20
1963	1,112	64	208	0.06	0.19
1964	1,286	82	263	0.06	0.20
Average	1,724	102	340	0.06	0.20
1965	1,692	131	415	0.08	0.25
1966	1,458	105	323	0.07	0.22
1967	1,015	79	236	0.08	0.23
1968	1,136	108	311	0.10	0.27
1969	1,740	177	482	0.10	0.28
Average	1,408	120	353	0.09	0.25
1970	2,027	193	498	0.10	0.25
1971	1,259	126	311	0.10	0.25
1972	1,362	169	403	0.12	0.30
1973	1,815	231	520	0.13	0.29
1974	1,667	227	459	0.14	0.28
Average	1,626	189	438	0.12	0.27
1975	1,137	177	329	0.16	0.29
1976	1,335	268	470	0.20	0.35
1977	1,919	473	781	0.25	0.41
1978	1,940	422	647	0.22	0.33

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1979	1,311	316	436	0.24	0.33
Average	1,528	331	532	0.22	0.34
1980	2,760	693	841	0.25	0.30
1981	1,867	519	571	0.28	0.31
1982	1,297	348	360	0.27	0.28
1983	1,140	332	333	0.29	0.29
1984	2,250	640	616	0.28	0.27
Average	1,863	506	544	0.27	0.29
1985	1,649	538	500	0.33	0.30
1986	1,303	470	429	0.36	0.33
1987	1,374	480	422	0.35	0.31
1988	853	322	272	0.38	0.32
1989	640	281	227	0.40	0.35
Average	1,164	418	370	0.36	0.32
1990	390	169	129	0.43	0.33
1991	454	160	118	0.35	0.26
1992	443	207	148	0.47	0.33
1994	171	89	60	0.52	0.35
Average	342	152	109	0.44	0.33
1995	319	229	150	0.72	0.47
1996	407	262	167	0.64	0.41
1997	683	457	285	0.67	0.42
Average	470	316	201	0.67	0.43
Grand Average	1,308	264	369	0.20	0.30

Table 7.5. Selected statistics pertaining to blue crab landings in Louisiana, 1960-1997. Deflated values and prices were derived using the 1982-1984 Consumer Price Index (Bureau of Labor Statistics 1999).

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	10,050	497	1,680	0.05	0.17
1961	11,910	514	1,720	0.04	0.14
1962	9,523	462	1,531	0.05	0.16
1963	7,982	447	1,461	0.06	0.18
1964	5,692	379	1,223	0.07	0.21
Average	9,031	460	1,523	0.05	0.17
1965	9,284	635	2,017	0.07	0.22
1966	7,986	537	1,659	0.07	0.21
1967	7,559	520	1,556	0.07	0.21
1968	9,551	807	2,320	0.08	0.24
1969	11,602	1,072	2,921	0.09	0.25
Average	9,196	714	2,095	0.08	0.23
1970	10,254	928	2,392	0.09	0.23
1971	12,186	1,256	3,110	0.10	0.25
1972	15,083	1,777	4,251	0.12	0.28
1973	23,080	2,811	6,331	0.12	0.27
1974	20,640	2,701	5,480	0.13	0.27
Average	16,249	1,895	4,311	0.12	0.26
1975	17,144	2,510	4,665	0.15	0.27
1976	15,211	3,061	5,379	0.20	0.35
1977	16,154	3,765	6,213	0.23	0.38
1978	15,074	3,189	4,892	0.21	0.32
1979	21,334	4,776	6,579	0.22	0.31
Average	16,983	3,460	5,546	0.20	0.33
1980	18,183	4,327	5,252	0.24	0.29
1981	16,237	4,469	4,916	0.28	0.30
1982	17,284	4,843	5,019	0.28	0.29
1983	19,616	6,366	6,392	0.32	0.33
1984	29,603	8,188	7,880	0.28	0.27
Average	20,185	5,639	5,892	0.28	0.29
1985	29,848	8,387	7,794	0.28	0.26
1986	31,611	9,301	8,487	0.29	0.27
1987	52,345	20,134	17,724	0.38	0.34
1988	53,554	21,447	18,130	0.40	0.34
1989	33,387	14,781	11,920	0.44	0.36
Average	40,149	14,810	12,811	0.37	0.31
1990	38,886	14,209	10,872	0.37	0.28

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1991	51,088	17,468	12,825	0.34	0.25
1992	51,744	26,666	19,006	0.52	0.37
1993	45,847	24,039	16,636	0.52	0.36
1994	36,665	22,090	14,906	0.60	0.41
Average	44,846	20,895	14,849	0.47	0.33
1995	36,914	29,055	19,065	0.79	0.52
1996	39,902	23,965	15,274	0.60	0.38
1997	43,440	27,144	16,912	0.62	0.39
Average	40,085	26,721	17,084	0.67	0.43
Grand Average	23,775	8,409	7,537	0.35	0.32

Table 7.6. Selected statistics pertaining to blue crab landings in Texas, 1960-1997. Deflated values and prices were derived using the 1982-1984 Consumer Price Index (Bureau of Labor Statistics 1999).

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1960	2,867	176	596	0.06	0.21
1961	2,875	178	594	0.06	0.21
1962	4,473	289	957	0.06	0.21
1963	2,980	200	652	0.07	0.22
1964	2,484	175	566	0.07	0.23
Average	3,136	204	673	0.07	0.22
1965	3,622	286	908	0.08	0.25
1966	2,778	228	703	0.08	0.25
1967	2,625	223	667	0.09	0.25
1968	4,084	329	946	0.08	0.23
1969	6,343	600	1,634	0.09	0.26
Average	3,890	333	972	0.09	0.25
1970	5,525	509	1,311	0.09	0.24
1971	5,810	567	1,400	0.10	0.24
1972	6,464	653	1,561	0.10	0.24
1973	6,881	830	1,870	0.12	0.27
1974	6,088	832	1,688	0.14	0.28
Average	6,154	678	1,566	0.11	0.25
1975	5,992	948	1,762	0.16	0.29
1976	6,668	1,179	2,073	0.18	0.31
1977	8,249	1,947	3,212	0.24	0.39
1978	7,470	2,004	3,073	0.27	0.41

Year	Pounds (x 1000)	Value		Price ($/lb)	
		Current ($1,000s)	Deflated ($1,000s)	Current	Deflated
1979	8,312	2,146	2,956	0.26	0.36
Average	7,338	1,645	2,615	0.22	0.35
1980	8,953	2,456	2,981	0.27	0.33
1981	6,952	1,928	2,121	0.28	0.31
1982	8,010	2,375	2,461	0.30	0.31
1983	8,829	3,250	3,263	0.37	0.37
1984	7,729	2,252	2,167	0.29	0.28
Average	8,095	2,452	2,599	0.30	0.32
1985	9,722	3,309	3,075	0.34	0.32
1986	9,482	3,170	2,892	0.33	0.31
1987	11,688	4,763	4,193	0.41	0.36
1988	10,428	4,224	3,571	0.40	0.34
1989	9,123	3,972	3,204	0.44	0.35
Average	10,089	3,888	3,387	0.39	0.34
1990	8,599	3,295	2,521	0.38	0.29
1991	6,123	2,271	1,668	0.37	0.27
1992	6,161	2,784	1,984	0.45	0.32
1993	8,286	3,960	2,740	0.48	0.33
1994	5,094	3,006	2,028	0.59	0.40
Average	6,853	3,063	2,188	0.45	0.32
1995	5,447	3,854	2,529	0.71	0.46
1996	6,311	4,211	2,684	0.67	0.43
1997	5,739	3,671	2,287	0.64	0.40
Average	5,832	3,912	2,500	0.67	0.43
Grand Average	6,456	1,922	2,039	0.30	0.32

Table 7.7. Relative contribution to Gulf of Mexico reported landings (Q) and value (V) by state, 1960-1997.

Years	Florida		Alabama		Mississippi		Louisiana		Texas	
	% Q	% V	% Q	% V	% Q	% V	% Q	% V	% Q	% V
1960-1964	50	47	3	4	6	7	31	30	11	13
1965-1969	46	41	7	8	5	5	30	31	13	15
1970-1974	31	27	5	6	4	5	44	47	16	17
1975-1979	32	28	4	5	4	4	42	43	18	20
1980-1984	26	23	5	6	4	4	46	47	19	20
1985-1989	15	14	5	5	2	2	62	63	16	16
1990-1994	12	14	5	4	1	1	72	71	11	10
1995-1997	16	17	3	5	1	1	68	68	10	10

Note: Totals may not sum to 100 due to rounding.

7.1.2.1 Florida Landings and Value

Reported production of blue crabs in Florida (west coast) in the early 1960s averaged slightly less than 15 million lbs (Table 7.2). In general, Florida's landings (based on five-year averages) declined over the last 38 years. While average landings reached a low in the early 1990s, Florida landings began an increasing trend even though they were more than 15% below their 38-year average. Florida's blue crab production in the early 1960s represented 50% of the total landings in the Gulf of Mexico (Table 7.7). By the early 1990s, the proportion of the Gulf total contributed by Florida (west coast) had fallen to 12%. The recent contribution to total Gulf landings was about 16%.

The average value of Florida's reported blue crab landings over the last 38 years has increased from less than $1.0 million to almost $7.0 million (Table 7.2). However, the average deflated value of Florida's blue crab landings increased by almost 80%, rising from $2.4 to $4.3 million. Considering the general decline in Florida landings overall, the increase in the deflated value was attributed to an increase in the real, or deflated, price of the landed product which increased $0.16-$0.44/lb from the 1960s to present. This represents an increase of 175% (Table 7.2). In addition, Florida's contribution to the total Gulf value increased less through the late 1980s than the state's contribution to total Gulf landings (Table 7.7). This suggests that prior to this period, the price for the Florida product was less than that of the total Gulf average. Since 1990, the Florida dockside price has slightly exceeded the price in the other Gulf states.

7.1.2.2 Alabama Landings and Value

Alabama's reported blue crab landings recently averaged 3.1 million lbs which is approximately three times greater than the average landings in the early 1960s (Table 7.3). While highly variable (based on five-year averages), there was a general trend of increased landings in the state and a 3%-5% increase in the Alabama contribution to the total Gulf landings (Table 7.7). The value of Alabama's reported blue crab landings increased from an average of $58,000 in the early 1960s to roughly $1.9 million in the late 1990s (Table 7.3).

7.1.2.3 Mississippi Landings and Value

Landings and value have declined in the Mississippi fishery over the 38-year period (Table 7.7). In the early 1960s, Mississippi contributed 6% to the total Gulf landings and 7% to the total Gulf value. Mississippi's contribution to the total Gulf landings and value averaged about 1% since 1990. Since the early 1960s, Mississippi's landings declined from 1.7 million lbs to less than 0.5 million lbs in the late 1990s (Table 7.4). The average deflated value of Mississippi's reported blue crab landings fell approximately 40% over the last 38 years from $340,000 to $200,000.

7.1.2.4 Louisiana Landings and Value

The reported annual harvest of blue crabs in Louisiana averaged just over nine million lbs in the 1960s (Table 7.5), and the state's contribution to the Gulf total averaged about 30% (Table 7.7). By the 1970s, annual production had increased to over 16 million lbs, and the state's contribution to the Gulf total increased to over 40%. A large increase in production began in the mid 1980s. Since 1985 production averaged in excess of 40 million lbs, and the state's contribution to the total Gulf production during the 1990s was approximately 70%. Overall, the recent average production of 40.1 million lbs exceeded the average early 1960s production of 9.0 million lbs by more than 300%.

The current annual value of blue crab landings increased from less than $1.0 million in the early 1960s to almost $27 million during late 1990s. When adjusted for inflation, the dockside value increased by a factor of almost ten from an annual average of $1.5 to $17.1 million. The substantial increase in the deflated dockside value reflects both a large increase in quantity of product and a large increase in the deflated price of the landed product. Overall, Louisiana's contribution to the total Gulf value approximates the state's contribution by weight (Table 7.7).

7.1.2.5 Texas

Reported blue crab landings in Texas increased from an average of 3.1 million lbs in the early 1960s to 10.1 million lbs in the late 1980s and declined sharply to present (Table 7.6). Similarly, the deflated dockside value of these landings peaked at an average of $3.4 million in the late 1980s, representing a five-fold increase since the early 1960s. Since the late 1980s, the average deflated value declined 26% to roughly $2.5 million.

Overall, the contribution of Texas landings to the total for the Gulf ranged from 10% to 19% based on a five-year average (Table 7.7). The contribution to the total Gulfwide value by Texas paralleled the landings contribution.

7.1.3 Seasonal Landings and Value

The average 1990-1997 monthly landings and dockside values associated with Gulf blue crab harvest are presented in Table 7.8. Peak landings occurred from May through August and averaged 7.3 million lbs/month. The value of landings for this four-month period averaged $3.5 million/ month. Lowest landings occurred from December through February and averaged 2.36 million lbs worth $1.84 million/month. December through February landings were approximately one-half of the reported value of landings for May through August. While dockside value tended to be positively correlated with volume landed, there exists a strong inverse correlation between price/lb and landings. During the four-months when the quantity produced was high (May through August) the dockside price averaged $0.48/lb, expressed on a current dollar basis. By comparison, from December through February, price/lb averaged $0.65 or around 35% more than when seasonal landings were at a maximum.

Table 7.8. Monthly reported blue crab harvest and value from the Gulf of Mexico, 1990-1997 average.

Month	Quantity (1,000 lbs)	Value ($1,000)		Price ($/lb)	
		Current	Deflated	Current	Deflated
January	2,460	1,668	1,145	0.68	0.47
February	2,500	1,721	1,187	0.69	0.47
March	3,017	2,011	1,389	0.67	0.46
April	4,553	2,813	1,934	0.62	0.42
May	6,956	3,618	2,463	0.52	0.35
June	7,921	3,589	2,431	0.45	0.31
July	7,847	3,453	2,340	0.44	0.30
August	6,369	3,192	2,151	0.50	0.34
September	5,671	2,992	2,017	0.53	0.36
October	5,418	2,889	1,947	0.53	0.36
November	4,855	3,083	2,062	0.63	0.42
December	3,555	2,134	1,436	0.60	0.40

7.1.4 Gulf of Mexico Production in Relation to Chesapeake and United States

The United States production of blue crabs increased sharply during the 38-year analysis (Table 7.9). The 217 million lbs reported for the last three years represented an increase of about 65 million lbs, on average, when compared to the reported total production for 1960-1964.

Table 7.9. Summary statistics pertaining to Gulf of Mexico, Chesapeake, and United States blue crab landings, 1960-1997.

Year	Gulf		Chesapeake[a]		United States	
1960-1964	29,367 (19.2)[b]	1,546 (16.6)	71,098 (46.5)	3,986 (42.9)	153,005 (100)	9,297 (100)
1965-1969	30,886 (21.3)	2,281 (20.6)	73.383 (50.9)	5,630 (51.0)	144,279 (100)	11,050 (100)
1970-1974	37,311 (25.7)	4,070 (27.3)	67,013 (46.2)	6,418 (43.1)	144,928 (100)	14,902 (100)
1975-1979	40,255 (29.8)	8,056 (30.6)	55,784 (41.3)	10,744 (40.8)	134,973 (100)	26,307 (100)
1980-1984	43,664 (23.1)	12,063 (24.9)	87,724 (46.3)	22,711 (46.9)	189,421 (100)	48,424 (100)
1985-1989	64,306 (32.2)	23,601 (33.9)	85,443 (42.8)	29,969 (43.1)	199,645 (100)	69,546 (100)
1990-1994	62,317 (29.0)	29,378 (29.2)	86,104 (40.0)	41,752 (41.3)	214,984 (100)	100,679 (100)
1995-1997	59,132 (27.2)	39,471 (26.3)	74,665 (34.4)	54,607 (36.4)	217,112 (100)	149,972 (100)

[a]Includes only hard crabs.
[b]Numbers in parenthesis represent contribution to United States total by respective regions.

The Gulf contribution to total United States landings generally ranged from about 20%-30% (Table 7.9). The Chesapeake's share to the total United States landings declined from roughly 50% on average in the mid 1960s to around 36% recently. Overall, recent average production in the Chesapeake region represented a reduction of almost 12 million lbs annually when compared to average landings in the early 1990s. This reduction may explain (in part) the sharp increase in the Gulf of Mexico dockside price in recent years.

7.2 Fishing Income

Steele and Perry (1990) reported gross income per fisherman and trap for 1971-1986. Changes in collection of effort data since the early 1990s preclude an updated analysis.

7.3 Blue Crab Price Analysis

Blue crab dockside prices appear to be unresponsive to changes in landings. Prochaska and Taylor (1982) found that a 10% change in Florida landings translated into less than a two percent change in the Florida blue crab dockside price. Rhodes (1982) concluded that a 10% change in Gulfwide blue crab landings resulted in about a 4% change in Gulf of Mexico dockside price. Rhodes also noted that changes in Chesapeake blue crab landings, traditionally the nation's largest producer, did not significantly affect the Gulf of Mexico price. However, recent studies suggest that Chesapeake production was a significant factor explaining the Southeast (Gulf and South Atlantic) deflated dockside blue crab price (Keithly unpublished data). The deflated Southeast price was more responsive to Chesapeake landings than to Southeast landings. In other words, a one million lb change in blue crab harvest in the Chesapeake impacted the Southeast price more than a similar increase in Southeast landings.

7.4 Blue Crab Marketing

Blue crab products move through various outlets and undergo significant transformation before reaching the final consumer. With the exception of the work conducted in Louisiana by Keithly et al. (1988), analysis of marketing activities associated with blue crab products is limited. This analysis is over a decade old and may not reflect current marketing activities. The results discussed below should be interpreted with some caution when attempting to extrapolate to current marketing activities in each state.

7.4.1 Procurement

Dealers who do not process the raw product are referred to as wholesalers. In Louisiana, wholesalers usually procured raw product directly from local fishermen. The wholesalers interviewed purchased about 1.6 million lbs of live crabs on average (Keithly et al. 1988).

Because processors often require very large raw product supplies, procurement tends to take many more forms than that reported among wholesalers. Approximately 40% of the product supply among processors in 1986 was via direct purchases from local fishermen (Keithly et al. 1988). About 25% of the raw product supply was derived from the processors having crabs trucked to the respective plants by independent truckers or crabbers. Another 20% of raw product was secured by processors making routine trucking routes to procure the product. Finally, the remaining product (≈20%) was procured via sales from wholesalers to processors.

In addition to purchases by Louisiana dealers, Keithly et al. (1988) estimated that about 15% or more of Louisiana crabs left the state bypassing Louisiana marketing channels by direct purchases at the docks by out-of-state buyers. Most of this production was not reflected in the landings data (Keithly et al. 1988).

7.4.2 Utilization, Outlets, and Distribution

Keithly et al. (1988) found that approximately 60% of the live crabs purchased by Louisiana dealers in 1986 was processed in the state and the remaining 40% was sold live. Over 95% of the live product was directed to out-of-state markets in the Southeast and likely processed by out-of-state processors (Section 7.5).

Of the product processed by Louisiana dealers, in-state processed sales represented approximately one-third of the total. Approximately 70% of the out-of-state sales was directed to the northeastern and mid-Atlantic states. The Louisiana processed blue crab was marketed in three forms—fresh (88%), frozen (8%), and pasteurized (less than 5%). Approximately 65% of the processed volume constituted body meat while the remaining 35% constituted claw meat. By value, however, body meat accounted for almost three-quarters of total sales while claw meat accounted for only one-quarter of the total.

7.5 Domestic Processing Sector

The majority of blue crab landings are processed upon arrival at the dock. Ward (1990) noted that processing technology has changed little since the turn of the century. 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. Processing activities are examined below for 1973-1997 based on annual surveys conducted by the NMFS.

7.5.1 Aggregate Processing Activities

The number of Gulf processors increased from an average of 82 in the mid 1970s to 105 in the early 1990s (Table 7.10). Since the early 1990s, however, a sharp decline in the number of processors has occurred. In 1997, only 73 processors were in operation in the Gulf. This represented the lowest number in the last 23 years.

Table 7.10. Production of processed blue crab in the Gulf of Mexico, 1973-1997.

		Processed Poundage (x 1000)				Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Edible Meal Weight	Live Weight	Pounds Landed (x 1,000)	Current	Deflated	Current	Deflated[a]
1973	84	9,657	6,955	49,647	43,473	16,654	48,983	1.72	5.07
1974	83	9,431	7,026	50,151	40,354	17,384	45,989	1.84	4.88
1975	79	8,166	6,011	42,904	38,718	17,866	43,365	2.19	5.31
Average	82	9,085	6,664	47,567	40,848	17,302	46,113	1.90	5.08
1976	89	9,249	6,267	44,728	36,561	22,841	52,388	2.47	5.66
1977	84	9,899	6,732	48,043	44,328	24,790	53,427	2.50	5.40
1978	83	10,464	6,826	48,708	38,172	23,864	47,824	2.28	4.57
Average	85	9,870	6,608	47,160	39,687	23,832	51,213	2.41	5.19
1979	74	10,465	6,799	48,514	43,495	24,576	44,281	2.35	4.23
1980	76	10,212	6,812	48,613	42,729	28,603	45,330	2.80	4.44
1981	80	9,445	6,739	48,098	42,306	28,976	41,692	3.07	4.41
Average	77	10,041	6,784	48,408	42,843	27,385	43,768	2.73	4.36
1982	87	10,813	7,023	50,117	36,728	30,570	41,422	2.83	3.83
1983	97	12,557	8,577	61,208	40,334	40,837	53,592	3.25	4.27
1984	96	15,700	11,037	78,768	56,224	54,642	68,732	3.48	4.38
Average	93	13,024	8,879	63,384	44,429	42,016	54,582	3.23	4.19
1985	90	14,700	9,946	70,983	55,753	49,971	60,645	3.40	4.13
1986	94	16,145	11,716	83,617	52,926	59,685	71,139	3.70	4.41
1987	97	15,895	12,543	89,531	78,339	57,482	66,148	3.62	4.16
Average	94	15,580	11,402	81,377	62,339	55,713	65,977	3.58	4.23
1988	102	15,603	10,756	76,766	79,117	54,008	59,678	3.46	3.82
1989	103	14,024	10,910	77,880	55,394	64,025	67,466	4.57	4.81
1990	92	15,609	11,283	80,533	58,341	60,932	60,932	3.90	3.90
Average	99	15,079	10,983	78,393	64,284	59,655	62,692	3.96	4.16
1991	105	13,553	9,754	69,580	66,538	54,252	52,066	4.00	3.84
1992	108	12,637	9,875	70,471	69,578	62,243	58,008	4.93	4.59

Year	No. of Firms	Processed Poundage (x 1000) Product Weight	Edible Meal Weight	Live Weight	Pounds Landed (x 1,000)	Value ($1,000s) Current	Deflated	Price ($/lb) Current	Deflated[a]
1993	101	10,560	7,963	54,726	65,378	47,165	42,839	4.47	4.06
Average	105	12,250	9,197	64,926	67,165	54,554	50,971	4.45	4.16
1994	88	10,017	NA	50,583	53,891	44,805	39,650	4.47	3.95
1995	84	10,325	NA	57,962	53,925	74,748	64,106	7.24	6.21
1996	80	8,310	NA	49,574	62,250	59,302	49,418	7.14	5.95
Average	84	9,551	NA	52,706	56,689	59,618	51,058	6.24	5.35
1997	73	6,902	NA	42,227	62,584	46,836	38,140	6.79	5.53

[a]Value and price deflated using the 1990 Consumer Price Index (i.e., 1990=100)

The quantity processed is reported in three categories—product-weight, estimated edible meat-weight, and estimated live-weight (Table 7.10). 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 edible meat-weight basis is expressed in terms of lbs of blue crab meat. The live weight has been estimated based on various conversion factors provided by the NMFS and is used to express the estimated pounds of live blue crabs used in processing activities. Since both the edible meat and the live weight figures are estimates based on various 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 processed quantity, expressed on either a product weight or a live weight basis, increased from 1973 to 1990 (Table 7.10). Since 1990, however, the processed quantity fell sharply. The average annual reported processed weight of 9.55 million lbs (product weight) in the mid 1990s, for example, averaged about 80% of the 15.1 million lbs in the 1980s. The 6.9 million lbs reported in 1997 was the lowest quantity dating back to 1982. While undocumented, at least some of the decline in processing activities in the Gulf during recent years may be attributable to reduced production in the Chesapeake (Table 7.9). Shipments of live Gulf of Mexico blue crabs to the Chesapeake may be increasing to meet local demand.

The current annual value of blue crab processing activities in the Gulf of Mexico expanded from an average of $17.3 million in the mid 1970s to approximately $60 million in the late 1980s. However, no long-term increase in current value was evident since 1990. The deflated annual value of blue crab processing activities increased by almost 45% from $46.1 million in the mid 1970s to $66 million in the mid 1980s. Since 1987, however, the deflated value of processing activities has fallen sharply. The most recent average annual deflated processed value of $51 million was only about three-quarters of that ten years ago. The $38 million deflated value in 1997 was considerably lower than that estimated for any of the individual years dating back to 1973. This decline in the deflated value was primarily in response to a reduction in processed quantity rather than a decline in the deflated price per processed pound (Table 7.10). The deflated price of the processed product, which fell sharply throughout the 1980s, increased significantly during the past couple of years.

The Gulf of Mexico processed blue crab quantity, expressed on a live-weight basis, exceeded pounds landed from 1988 to 1990 (Table 7.10). In recent years, however, the reported landings exceeded the estimated live weight of processed blue crabs. In 1997, the estimated weight of live crabs used in processing activities equaled only two-thirds of the landings. Increased demand for Gulf of Mexico harvested product in the Chesapeake may be responsible for much of the increasing difference in recent years.

7.5.2 Processing Activities by Product Form

For purposes of discussion, Gulf of Mexico processed blue crab activities were segmented into three primary categories: 1) meats, 2) breaded products, and 3) "other" products (which include claws, gumbos, soups). Some of the relevant information pertaining to this exercise is presented in Table 7.11.

7.5.2.1 Meat Products

Sixty to 80 processors were responsible for crab meat production from 1973 to 1997. Annual production of meats averaged 5.7 million lbs. When examined in three-year intervals, the processed weight of meat ranged from a low of approximately four million lbs during both mid 1970s to the early 1980s to an average of more than 7.5 million lbs in the mid to late 1980s. After peaking in the mid 1980s, production decreased to 6.2 million lbs in 1997.

The current annual value of 1973-1997 processed meat activities in the Gulf of Mexico averaged $33.7 million (Table 7.11). The deflated value of the processed meat products, after peaking at about $50 million annually during the late 1980s (adjusted for inflation based on the 1990 Consumer Price Index), gradually decreased to coincide with the decrease in quantity of meats produced. The most recent average deflated price of $7.72 per product weight pound was, however, relatively high when compared to 1976. The deflated price for the meat products fell from a peak of $8.75/lb during the late 1970s to $6.41/lb during the early 1990s before increasing substantially.

Meat products accounted for about one-half of the total processed product weight in the mid 1970s but almost three-quarters of the total value (Tables 7.10 and 7.11). In recent years, processed meat products accounted for 60% of the total processing activities by product weight and more than 85% of total Gulf of Mexico blue crab processing activities by value.

7.5.2.2 Breaded Products

The number of firms that processed breaded blue crab products in the Gulf ranged from seven in 1980 to 16 in the early 1970s. Average production of breaded products equaled 5.4 million product weight lbs. Pounds processed exhibited substantial variation ranging from 3.2 million lbs in recent years to 7.5 million lbs from 1982 to 1987. A clear decline in breaded processing activities occurred after 1985. The 1997 production of 1.7 million lbs was less than a third of the 25-year average and was the lowest production figure on record since 1973.

The deflated value of processed blue crab breaded products increased from an average of $9.5 million in the mid 1970s to $16.4 million in the mid 1980s. Since 1984, however, the deflated price has fallen sharply. In general, the increase in deflated value during the mid 1970s can be attributed to an increase in processed poundage since the deflated price during the period fell by almost 20%. The decline in the deflated value after 1984 reflects a decline in both the processed quantity and the deflated price of the processed product. The average annual deflated value of breaded products ($5.7 million) in recent years was one-half of the 25-year average of $11.4 million while the deflated value of $2.9 million in 1997 equaled one-quarter of the long-term average.

During the mid 1970s, breading activities accounted for 40% of the total Gulf of Mexico blue crab processing activities by product weight but only 20% of the total by value. In recent years, breaded products fell to a third on the basis of quantity and just slightly more than 10% when expressed on a value basis.

Table 7.11. Gulf of Mexico processed blue crab production by product form, 1973-1997.

Year	Meat					Breaded					Other (claws, soups, gumbos)				
			Value		Price			Value					Value		
	No. of Firms	Pounds (x 1000)	Current	Deflated	Deflated	No. of Firms	Pounds (x 1000)	Current	Deflated	$/lb	No. of Firms	Pounds (x 1000)	Current	Deflated	$/lb
1973	64	4,914	12,571	36,973	7.52	16	3,866	3,581	10,533	2.72	10	878	502	1,477	1.68
1974	66	4,971	12,684	33,555	6.75	16	3,552	3,512	9,291	2.62	6	908	1,188	3,143	3.46
1975	62	4,214	13,606	33,025	7.84	16	3,247	3,513	8,527	2.63	9	704	747	1,813	2.57
Avg.	64	4,700	12,954	34,518	7.34	16	3,555	3,535	9,450	2.66	8	830	813	2,145	2.58
1976	71	4,109	16,526	37,904	9.23	15	4,904	5,887	13,502	2.75	9	236	428	982	4.16
1977	67	4,114	17,318	37,322	9.07	11	5,511	6,872	14,810	2.69	13	274	601	1,295	4.73
1978	68	3,902	15,425	30,912	7.92	11	6,454	8,204	16,442	2.55	6	107	235	471	4.39
Avg.	69	4,042	16,423	35,380	8.75	12	5,623	6,988	14,918	2.65	9	206	421	916	4.45
1979	64	3,664	14,643	26,384	7.20	8	6,706	9,704	17,484	2.61	5	95	229	413	4.34
1980	68	3,923	17,868	28,316	7.22	7	6,221	10,605	16,806	2.70	4	68	131	208	3.05
1981	67	4,466	21,967	31,607	7.08	11	4,871	6,681	9,613	1.97	9	108	328	472	4.38
Avg.	66	4,018	18,159	28,769	7.16	9	5,933	8,997	14,635	2.47	6	90	229	364	4.03
1982	72	3,787	19,952	27,035	7.14	12	6,974	10,397	14,088	2.02	9	52	221	299	5.74
1983	82	5,168	28,596	37,528	7.26	15	7,316	11,873	15,581	2.13	7	74	367	482	6.55
1984	83	6,962	37,749	47,483	6.82	15	8,375	15,496	19,492	2.33	10	364	1,397	1,757	4.83
Avg.	79	5,305	28,766	37,349	7.04	14	7,555	12,589	16,387	2.17	9	163	662	846	5.19
1985	78	5,813	32,970	40,012	6.88	13	8,531	15,480	18,786	2.20	10	356	1,521	1,846	5.19
1986	81	7,898	46,314	55,201	6.99	14	8,009	12,452	14,842	1.85	5	238	919	1,096	4.60

Year	Meat					Breaded					Other (claws, soups, gumbos)				
			Value		Price			Value					Value		
	No. of Firms	Pounds (x 1000)	Current	Deflated	Deflated	No. of Firms	Pounds (x 1000)	Current	Deflated	$/lb	No. of Firms	Pounds (x 1000)	Current	Deflated	$/lb
1987	82	9,592	47,388	54,531	5.69	14	6,011	8,849	10,183	1.69	8	292	1,246	1,433	4.92
Avg.	80	7,768	42,224	49,915	6.43	14	7,517	12,261	14,604	1.94	8	295	1,229	1,458	4.94
1988	86	6,956	41,514	45,872	6.59	13	8,311	12,009	13,269	1.60	7	335	486	537	1.60
1989	81	8,457	52,482	55,302	6.54	13	4,888	9,993	10,530	2.15	14	678	1,551	1,634	2.41
1990	70	7,670	47,283	47,283	6.16	11	6,858	10,728	10,728	1.56	16	1,082	2,921	2,921	2.70
Avg.	79	7,694	47,093	49,486	6.43	12	6,686	10,910	11,509	1.72	12	698	1,653	1,697	2.43
1991	83	6,745	43,367	41,619	6.17	12	5,877	9,344	8,968	1.53	15	930	1,541	1,479	1.59
1992	85	7,654	52,994	49,389	6.45	13	3,977	7,322	6,824	1.72	16	1,006	1,927	1,796	1.79
1993	78	5,286	38,638	35,094	6.64	12	3,771	6,180	5,613	1.49	18	1,503	2,347	2,132	1.42
Avg.	82	6,562	45,000	42,034	6.41	12	4,542	7,616	7,135	1.57	16	1,146	1,938	1,802	1.57
1994	71	4,828	34,874	30,753	6.37	13	4,325	7,678	6,777	1.57	9	781	2,148	1,894	2.42
1995	68	6,404	65,568	56,233	8.78	13	3,261	7,731	6,630	2.03	10	590	1,360	1,166	1.98
1996	67	5,846	53,909	44,924	7.68	11	2,098	4,427	3,689	1.76	9	351	940	783	2.23
Avg.	69	5,693	51,450	43,970	7.72	12	3,228	6,612	5,699	1.77	9	574	1,483	1,281	2.23
1997	62	5,054	42,487	34,599	6.85	10	1,662	3,611	2,941	1.77	8	182	730	594	3.26

7.5.2.3 "Other" Products

Production of "other" blue crab processed products (e.g., claws, soups, gumbos) has traditionally been minor in the Gulf of Mexico. When examined in three-year intervals, production ranged from a low of 230,000 lbs in the late 1970s to almost two million lbs in the early 1990s. The deflated price of "other" processed blue crab products varied considerably and ranged from $1.57 per product-weight pound during the early 1990s to $5.19 per product-weight pound in the early 1980s. Much of the variation in the deflated per pound price 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.

7.5.3 Processing Activities by State

Blue crab processing activities by the individual states in the Gulf of Mexico are briefly examined in this section of the report. As a result of confidentiality concerns, only the aggregate processing activities by state, rather than activities by product form, are presented.

7.5.3.1 Florida (West Coast) Blue Crab Processing Activities

The number of reported blue crab processors in Florida (west coast) peaked at 28 during the early 1980s followed by a sharp decline thereafter to a low of eight in the mid 1990s (Table 7.12). Overall, Florida blue crab processors represented almost 30% of the Gulf total in the mid 1970s but only 10% by the mid 1990s.

Table 7.12. Production of processed blue crab in Florida west coast, 1973-1997.

		Processed Poundage (x 1,000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1,000)	Current	Deflated	Current	Deflated[a]
1973	23	2,474	12,303	9,599	4,667	13,726	1.89	5.55
1974	23	2,466	13,192	10,134	4,838	12,800	1.96	5.19
1975	22	1,539	10,731	12,807	4,677	11,353	3.04	7.37
Average	23	2,160	12,075	10,845	4,727	12,626	2.19	5.85
1976	26	2,451	12,369	12,049	7,047	16,163	2.88	6.60
1977	23	1,781	11,013	15,832	5,496	11,845	3.09	6.65
1978	23	1,868	10,770	11,679	4,829	9,677	2.59	5.18
Average	24	2,033	11,384	13,187	5,791	12,562	2.85	6.18
1979	21	1,754	11,364	11,199	5,137	9,255	2.93	5.28
1980	21	1,679	10,639	11,276	5,990	9,493	3.57	5.65
1981	26	1,922	12,840	14,788	7,943	11,429	4.13	5.95
Average	23	1,785	11,614	12,421	6,357	10,059	3.56	5.64
1982	23	2,683	13,185	8,871	7,887	10,687	2.94	3.98
1983	29	2,275	13,244	9,337	10,473	13,744	4.60	6.04
1984	31	2,325	12,779	12,912	10,300	12,956	4.43	5.57
Average	28	2,428	13,069	10,373	9,553	12,462	3.94	5.13

Year	No. of Firms	Processed Poundage (x 1,000) Product Weight	Live Weight	Pounds Landed (x 1,000)	Value ($1,000s) Current	Deflated	Price ($/lb) Current	Deflated[a]
1985	27	2,299	13,048	12,273	9,569	11,613	4.16	5.05
1986	27	2,187	12,676	7,644	9,486	11,306	4.34	5.17
1987	23	4,102	27,139	10,413	13,146	15,128	3.20	3.69
Average	26	2,863	17,621	10,110	10,734	12,682	3.75	4.43
1988	21	2,846	11,908	10,386	8,743	9,661	3.07	3.39
1989	24	2,351	10,551	8,159	9,462	9,907	4.00	4.21
1990	20	3,034	12,272	6,878	8,046	8,046	2.65	2.65
Average	22	2,744	11,577	8,474	8,731	9,205	3.18	3.35
1991	19	1,421	11,908	5,213	3,499	3,358	2.46	2.36
1992	18	1,923	10,551	7,619	5,471	5,099	2.84	2.65
1993	11	1,808	12,272	8,437	4,384	3,982	2.42	2.20
Average	16	1,718	11,577	7,090	4,452	4,146	2.59	2.41
1994	10	1,752	6,747	8,407	4,647	4,098	2.65	2.34
1995	7	1,548	5,933	8,636	5,109	4,382	2.92	2.83
1996	6	317	2,153	11,140	2,713	2,261	8.56	7.13
Average	8	1,206	4,944	9,394	4,156	3,580	3.45	2.97
1997	7	296	2,025	9,246	2,597	2,115	8.77	7.14

[a]Value and price deflated using the 1990 Consumer Price Index (i.e., 1990=100).

Until recently, annual Florida production of processed crab products ranged from approximately 1.7 million lbs to 2.9 million lbs when examined in three-year intervals. 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 mid 1990s and reported landings exceeded processing activities, expressed on a live-weight basis, by almost 50%.

Florida accounted for approximately one-quarter of the Gulf of Mexico blue crab processing activities on the basis of both quantity and value during the mid 1970s (Table 7.13). The state's share, however, declined considerably over the last 25 years. By the mid 1990s, Florida's share had fallen to 13% on the basis of product weight and to only seven percent when expressed on a value basis. Florida apparently has increased its relative share of the less expensive processed products (e.g., breaded products).

Table 7.13. Proportion of the Gulf of Mexico processed blue crab poundage and value contributed by individual states.

Years	Florida			Alabama			Mississippi			Louisiana			Texas		
	%Q[a]		%V[b]	%Q		%V	%Q		%V	%Q		%V	%Q		%V
	PW	LW		PW	LW		PW	LW		PW	LW		PW	LW	
1973-75	24	25	27	37	27	26	9	12	12	21	23	21	9	13	14
1976-79	21	24	24	54	41	34	4	5	5	15	20	24	6	9	12
1980-81	18	24	23	60	47	42	3	5	5	12	16	19	7	10	12
1982-84	19	21	23	61	50	44	2	3	3	12	18	21	6	8	10
1985-87	18	22	19	56	44	39	2	3	3	20	27	33	3	4	5
1988-90	18	15	15	45	38	32	1	1	1	25	32	38	11	14	15
1991-93	14	18	8	44	40	37	3	3	3	36	43	48	3	4	4
1994-96	13	9	7	43	40	36	4	2	2	35	42	50	6	7	5
1997	4	5	6	53	47	48	3	2	2	16	26	25	17	20	20

[a]%Q represents proportion of the Gulf of Mexico total processed poundage contributed by individual states expressed on a product weight basis (PW) and a live-weight basis (LW).
[b]%V represents proportion of the Gulf of Mexico total processed value contributed by individual states.

7.5.3.2 Alabama Blue Crab Processing Activities

The number of blue crab processors in Alabama increased from an average of 13 in the mid 1970s to 29 in recent years (Table 7.14). The annual processed poundage, when evaluated in three-year intervals, peaked at 8.7 million lbs in the mid 1980s but declined to an average of 4.1 million lbs in recent years. In the Gulf of Mexico, Alabama accounts for 50% of the live weight landings and 60% of the product value (Table 7.13).

The contribution of Alabama to the Gulf total was significantly higher in terms of product weight than in value (Table 7.14). 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 decline from the late 1980s, the deflated price increased from an average of $2.93 per product weight pound to an average of $4.53 per product weight pound in recent years.

Table 7.14. Production of processed blue crab in Alabama, 1973-1997.

Year	No. of Firms	Processed Poundage (x 1000) Product Weight	Live Weight	Pounds Landed (x 1000)	Value ($1,000s) Current	Deflated	Price ($/lb) Current	Deflated[a]
1973	13	3,307	12,861	2,099	4,201	12,357	1.27	3.74
1974	13	2,993	11,673	1,826	3,989	10,554	1.33	3.53
1975	14	3,667	14,171	1,640	5,218	12,664	1.42	3.45
Avg.	13	3,322	12,902	1,855	4,470	11,858	1.35	3.57
1976	13	4,309	15,800	1,299	6,529	14,975	1.52	3.48
1977	16	5,609	20,465	2,174	8,795	18,955	1.57	3.38
1978	15	6,122	21,748	2,009	9,197	18,430	1.50	3.01
Avg.	15	5,347	19,338	1,827	8,174	17,453	1.53	3.26
1979	17	6,793	24,375	1,341	11,944	21,520	1.76	3.17
1980	20	6,283	22,475	1,557	12,738	20,186	2.03	3.21
1981	19	5,147	18,901	2,462	9,455	13,605	1.84	2.64
Avg.	19	6,074	21,917	1,787	11,379	18,437	1.87	3.04
1982	24	5,906	21,225	1,266	10,654	14,437	1.80	2.44
1983	27	7,682	29,470	1,412	16,326	21,425	2.13	2.79
1984	28	10,364	45,121	4,216	28,336	35,643	2.73	3.44
Avg.	26	7,984	32,029	2,298	18,439	23,835	2.31	2.99
1985	26	9,430	37,123	2,261	23,155	28,100	2.46	2.98
1986	26	9,531	39,508	2,886	23,683	28,227	2.48	2.96
1987	25	7,258	31,029	2,496	18,812	21,648	2.59	2.98
Avg.	26	8,740	35,887	2,548	21,883	25,992	2.50	2.97
1988	27	8,074	33,690	3,869	20,511	22,664	2.54	2.81
1989	25	5,456	24,813	4,090	16,788	17,690	3.08	3.24
1990	20	6,891	30,070	3,303	19,443	19,443	2.82	2.82
Avg.	24	6,807	29,524	3,754	18,914	19,933	2.78	2.93
1991	26	6,582	28,427	2,731	18,303	17,565	2.78	2.67
1992	27	4,870	25,433	3,550	21,860	20,373	4.49	4.18
1993	29	4,635	23,548	2,554	20,677	18,781	4.46	4.05
Avg.	27	5,363	25,743	2,945	20,280	18,906	3.78	3.53
1994	28	4,920	23,790	2,688	22,669	19,992	4.61	4.06
1995	29	3,655	18,978	2,520	21,191	18,174	5.80	4.97
1996	29	3,762	19,822	3,129	21,216	17,673	5.64	4.70
Avg.	29	4,112	20,863	2,809	21,692	18,613	5.28	4.53
1997	28	3,656	19,814	3,476	22,674	18,464	6.20	5.05

[a]Value and price were deflated using the 1990 Consumer Price Index (i.e., 1990=100)

The processed quantity reported for Alabama, expressed on a live-weight equivalent basis, greatly exceeded reported landings in the state (Table 7.14). During the mid 1980s, for example, the annual processed poundage (live weight equivalent) was almost 36 million lbs while average reported landings were 2.5 million lbs. Alabama is a large net importer of live crabs for use in processing activities.

7.5.3.3 Mississippi Blue Crab Processing Activities

Mississippi has historically contributed only marginally to the Gulf of Mexico blue crab processing activities. Overall, the number of processing establishments in the state declined from an average of nine during the mid 1970s to only four in recent years (Table 7.15). The annual processed poundage, examined on a product-weight basis, ranged from a high of 823,000 lbs in the mid 1980s to less than 150,000 lbs in the late 1990s.

Table 7.15. Production of processed blue crab in Mississippi, 1973-1997.

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
1973	11	723	5,155	1,667	1,754	5,158	2.43	7.13
1974	11	1,091	7,736	1,626	2,471	6,537	2.27	5.99
1975	10	655	4,665	1,137	2,129	5,168	3.25	7.89
Avg.	11	823	5,852	1,477	2,118	5,621	2.57	6.83
1976	10	378	2,693	1,335	1,268	2,909	3.36	7.71
1977	9	362	2,576	1,919	1,258	2,711	3.47	7.49
1978	9	343	2,447	1,940	1,268	2,542	3.70	7.41
Avg.	9	361	2,572	1,731	1,265	2,720	3.51	7.54
1979	7	285	2,037	1,311	1,141	2,055	4.00	7.20
1980	6	340	2,428	2,760	1,372	2,174	4.03	6.39
1981	6	331	2,364	1,867	1,394	2,006	4.21	6.06
Avg.	6	319	2,277	1,979	1,302	2,079	4.08	6.52
1982	6	235	1,675	1,297	1,076	1,458	4.58	6.21
1983	5	211	1,509	1,140	1,016	1,334	4.81	6.31
1984	5	370	2,641	2,250	1,579	1,986	4.27	5.37
Avg.	5	272	1,942	1,562	1,224	1,593	4.50	5.86
1985	6	302	2,157	1,649	1,446	1,755	4.79	5.81
1986	6	452	3,230	1,303	2,376	2,832	5.25	6.26
1987	6	340	2,426	1,374	1,734	1,995	5.10	5.87

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
Avg.	6	365	2,604	1,442	1,852	2,194	5.08	6.01
1988	5	183	1,309	853	1,061	1,172	5.78	6.39
1989	5	131	938	640	883	930	6.72	7.08
1990	4	108	774	390	559	559	5.16	5.16
Avg.	5	141	1,007	628	834	887	5.91	6.29
1991	6	382	1,847	454	1,248	1,198	3.26	3.13
1992	5	437	1,928	443	1,412	1,316	3.23	3.01
1993	6	459	1,959	253	1,512	1,374	3.30	2.99
Avg.	6	426	1,911	383	1,391	1,296	3.26	3.04
1994	4	334	1,133	171	758	668	2.27	2.00
1995	4	314	1,133	319	1,641	1,407	5.23	4.48
1996	5	409	1,577	407	1,068	890	2.61	2.18
Avg.	4	352	1,281	299	1,156	988	3.28	2.81
1997	4	217	966	683	776	632	3.58	2.91

[a]Value and price were deflated using the 1990 Consumer Price Index (i.e., 1990=100).

When examined on a live-weight basis, Mississippi's annual processing quantity ranged from a high of almost six million lbs in the mid 1970s to only about one million lbs during the late 1980s (Table 7.15). While relatively small compared to other Gulf states, these figures suggest that Mississippi is a net importer of live crabs to cover processing requirements.

On the basis of product weight, Mississippi's share of the Gulf of Mexico's blue crab processing activities fell from an average of nine percent in the mid 1970s to only one percent in the late 1980s (Table 7.13). Thereafter, however, the share did increase to an average of four percent in recent years.

7.5.3.4 Louisiana Blue Crab Processing Activities

The average number of Louisiana blue crab processors ranged from 23 to 28 prior to 1990 (Table 7.16). The number more than doubled to an average of 50 in the early 1990s and then declined sharply to 27 in the mid 1990s.

Table 7.16. Production of processed blue crab in Louisiana, 1973-1997.

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
1973	30	2,915	12,486	23,080	3,580	10,529	1.91	4.80
1974	28	1,872	10,392	20,639	3,406	9,009	2.11	4.81
1975	25	1,752	9,442	17,144	3,917	9,506	2.54	5.43
Avg.	28	1,940	10,774	20,288	3,634	9,682	2.15	4.99
1976	29	1,504	9,643	15,211	5,350	12,270	3.79	8.16
1977	27	1,545	9,765	16,154	6,505	14,019	4.31	9.07
1978	29	1,509	9,359	15,074	5,461	10,944	4.02	7.25
Avg.	28	1,520	9,589	15,480	5,772	12,411	4.04	8.17
1979	23	1,035	6,471	21,334	3,378	6,086	3.89	5.88
1980	23	1,195	7,965	18,183	5,245	8,313	4.45	6.96
1981	22	1,372	9,185	16,237	6,673	9,601	4.98	7.00
Avg.	23	1,201	7,874	18,585	5,099	8,000	4.48	6.66
1982	26	1,180	8,260	17,284	6,307	8,546	5.50	7.25
1983	27	1,651	11,506	19,616	8,882	11,656	5.45	7.06
1984	20	1,978	13,602	29,603	10,697	13,455	5.46	6.80
Avg.	24	1,603	11,123	22,168	8,629	11,219	5.47	7.00
1985	21	2,013	14,046	29,848	11,711	14,212	5.92	7.06
1986	27	3,460	24,607	31,611	21,251	25,329	6.07	7.32
1987	37	3,757	26,334	52,345	21,901	25,202	5.67	6.71
Avg.	28	3,077	21,662	37,935	18,288	21,581	5.88	7.01
1988	41	3,622	23,960	53,554	19,587	21,644	5.27	5.98
1989	42	3,926	26,556	33,387	24,745	26,075	6.07	6.64
1990	41	3,813	25,034	38,886	23,000	23,000	5.90	6.03
Avg.	41	3,787	25,183	41,942	22,444	23,573	5.79	6.22
1991	48	4,633	30,028	51,088	27,856	26,733	6.04	5.77
1992	52	5,018	32,731	51,744	31,350	29,217	6.20	5.82

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
1993	50	3,467	20,864	45,847	19,734	17,924	5.63	5.17
Avg.	50	4,373	27,874	49,560	26,313	24,625	5.99	5.63
1994	40	2,191	13,120	36,665	13,564	11,961	6.19	5.46
1995	38	4,331	28,633	36,914	42,782	36,691	9.88	8.47
1996	34	3,501	23,987	39,902	32,209	26,829	9.20	7.66
Avg.	37	3,341	21,913	37,827	29,518	25,160	8.84	7.53
1997	27	1,533	10,885	43,440	11,588	9,436	7.56	6.15

[a]Value and price were deflated using the 1990 Consumer Price Index (i.e., 1990=100).

During the mid 1970s, annual production averaged 1.9 million lbs and accounted for 21% of the total processed quantity and 21% of total value of blue crab products in the Gulf (Table 7.13). Average processed production peaked at almost 4.4 million lbs during the early 1990s and accounted for 36% and 50% of the Gulf processing activities by weight and value, respectively.

The price of Louisiana's processed blue crab was relatively high when compared to the Gulf average (Tables 7.16 and 7.10). 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 deflated price received for the Louisiana processed product occurred in the late 1970s with a value of $8.17 per pound. After falling to only $5.63 per product weight pound in the early 1990s, the price advanced to $7.53 in the mid 1990s.

Louisiana is a net exporter of live crabs to other Gulf of Mexico states for processing; landings used for processing were approximately one-half of total landings. In the late 1980s, processed poundage converted to a live-weight equivalent basis averaged 7.9 million lbs while reported harvest for the same period, by comparison, averaged 18.6 million lbs. In the early 1990s, 28 million lbs were processed while approximately 50 million lbs were harvested.

7.5.3.5 Texas Blue Crab Processing Activities

In general, blue crab processing activities in Texas have been more stable over the last 30 years than in any other Gulf state. Number of processors ranged from six to ten based on three-year averages (Table 7.17). Similarly, with two exceptions in the late 1980s and early 1990s, the weight of processed blue crab has fallen in the relatively narrow range of 500,000 to 800,000 lbs.

As in Louisiana, blue crab products in Texas are relatively high priced because they tend to be largely meat-based products. The deflated price of product in Texas peaked at nearly $10/lb in the mid 1970s, then declined steadily to less than $5/lb in the mid 1990s. Based on total volume of product, Texas generally contributed less than 10% to the total Gulf weight based on three-year averages, ranging from 3%

in the mid 1980s to 11% in the late 1980s. Because of the high price of Texas blue crab products, their contribution to the total Gulf value has exceeded their contribution to total Gulf product by weight.

Table 7.17. Production of processed blue crab in Texas, 1973-1997.

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
1973	7	958	6,841	6,088	2,453	7,214	2.56	7.53
1974	8	1,009	7,158	6,154	2,680	7,089	2.65	7.02
1975	8	552	3,895	5,992	1,926	4,674	3.49	8.46
Avg.	8	840	5,965	6,078	2,353	6,325	2.80	7.53
1976	11	607	4,222	6,668	2,647	6,072	4.36	10.00
1977	9	601	4,224	8,249	2,736	5,897	4.55	9.81
1978	7	622	4,383	7,470	3,109	6,231	5.00	10.02
Avg.	9	610	4,277	7,462	2,831	6,057	4.64	9.94
1979	6	598	4,267	8,312	2,977	5,364	4.98	8.98
1980	6	715	5,105	8,953	3,259	5,164	4.56	7.22
1981	7	673	4,808	6,952	3,511	5,052	5.21	7.50
Avg.	6	662	4,727	8,072	3,249	5,193	4.91	7.84
1982	8	810	5,772	8,010	4,645	6,294	5.73	7.77
1983	9	738	5,209	8,829	4,140	5,432	5.61	7.37
1984	12	663	4,626	7,229	3,731	4,692	5.62	7.07
Avg.	10	737	5,202	8,023	4,172	5,473	5.66	7.43
1985	10	656	4,609	9,722	4,092	4,966	6.24	7.57
1986	8	514	3,595	9,482	2,889	3,444	5.62	6.70
1987	6	438	2,604	11,688	1,889	2,174	4.32	4.97
Avg.	8	536	3,603	10,297	2,957	3,528	5.52	6.58
1988	8	877	5,898	10,428	4,106	4,537	4.68	5.17
1989	7	2,159	15,203	9,123	12,207	12,863	5.65	5.96
1990	7	1,762	12,384	8,599	9,885	9,885	5.61	5.61
Avg.	7	1,600	11,102	9,383	8,733	9,095	5.46	5.69
1991	6	534	3,564	6,123	3,346	3,211	6.27	6.02

		Processed Poundage (x 1000)			Value ($1,000s)		Price ($/lb)	
Year	No. of Firms	Product Weight	Live Weight	Pounds Landed (x 1000)	Current	Deflated	Current	Deflated[a]
1992	6	388	2,412	6,161	2,150	2,004	5.54	5.17
1993	5	190	1,016	8,286	857	779	4.52	4.11
Avg.	6	370	2,331	6,857	2,118	1,998	5.72	5.39
1994	6	820	5,794	5,094	3,167	2,793	3.86	3.41
1995	6	476	3,224	5,447	4,026	3,453	8.46	7.25
1996	6	321	2,036	6,311	2,095	1,746	6.53	5.44
Avg.	6	539	3,685	5,617	3,096	2,664	5.74	4.94
1997	7	1,201	8,538	5,739	9,201	7,493	7.66	6.24

[a]Value and price were deflated using the 1990 Consumer Price Index (i.e., 1990=100).

7.5.4 Structure and Conduct

Information in this section is taken from unpublished data of W. Keithly. The structure and conduct of any industry can be examined using several criteria. One of the most commonly used criterion is that of concentration. In the blue crab fishery, the five largest Southeast (Gulf and South Atlantic) processors historically (1973-1993) accounted for about 25% of total processed blue crab sales. The ten largest processors accounted for 35%-40% of total processed blue crab sales, and the 20 largest processors comprised 50%-55%. These figures suggest that individual establishments have little ability to control output prices in any meaningful manner.

Approximately 15%-20% of all Southeast blue crab processors have depended on processed blue crab sales for 50% or less of total processed seafood sales. Another 15%-20% of the establishments depended on processed blue crab sales for 50%-95% of total processed seafood sales. Finally, more than 60% of all establishments relied on processed blue crab sales for more than 95% of total processed seafood sales.

A strong relationship exists between age of establishment and processed blue crab sales. For example, in 1993 a total of 155 establishments in the Southeast reported blue crab processing activities. Of these, 46 initiated blue crab processing operations in or before 1978. Processed blue crab sales among these firms averaged $1.28 million a piece in 1993. Another 20 processors began operation between 1979 and 1984. Average 1993 processed blue crab sales among this group of firms equaled $710,000 per firm. The 33 processors that initiated blue crab processing operations between 1985 and 1990 reported processed blue crab sales averages in 1993 of $580,000 per establishment. Finally, 56 firms initiated blue crab processing activities between 1991 and 1993. Sales among this group of processors averaged $450,000. These figures suggest that processed blue crab sales are, on average, strongly dependent on the age of the establishment.

7.6 Crab Imports

Crab imports (primarily from Mexico, Venezuela, Thailand, and Indonesia) compete with domestic blue crab products. In 1997, United States imports of fresh and frozen crabmeat was 14.5 million lbs, valued at $67 million. In addition, 16 million lbs of canned crabmeat, valued at $67 million, was imported. Blue crab products are not distinguished from other crab imports, so there is no way to determine the weight or value of United States imports of blue crab products.

Exports to the United States from Mexico tripled between 1990 and 1997 from approximately 700,000 - 2.1 million kg (Table 7.18). Approximately 45% of Mexico's crab exports to the United States in 1997 represented crab meat in airtight containers.

Exports to the United States from Venezuela were 1.1 million kg in 1997 compared to 879,000 kg in 1990 (Table 7.19). This represents an increase of approximately 30% over eight years. As with Mexico, a large portion of the U.S. imports from Venezuela is crab meat in airtight containers.

Information pertaining to two of the major Asian exporters of crab products to the United States, Thailand, and Indonesia, are included in Tables 7.20 and 7.21, respectively. Thailand's exports remained relatively stable at roughly 1.5 million kg per year. Indonesia's exports, however, increased from about 100,000 kg in 1990 to more than 2 million kgs in 1997. Exports from both countries are heavily dominated by crab meat products in airtight containers.

The relevance of these imported products with respect to the domestic markets for the domestic blue crab product depends upon the ability of the imported products to compete and substitute for the domestic product in the market place. Significant price increases in Gulf dockside blue crab price over the past several years suggests that competition of the foreign product with the domestic blue crab product may be somewhat limited.

Table 7.18. United States imports of selected crab products from Mexico, 1990 and 1997.

Year	Product	Kilograms	Value
1990	Crab NSPF Frozen	242,261	832,666
	Crab NSPF Live/Fresh/Salted/Brine	21,798	75,671
	Crabmeat NSPF Fresh/Dried/Salted/Brine	32,680	321,573
	Crabmeat NSPF Frozen	26,953	205,999
	Crabmeat NSPF in ATC	154,053	1,125,956
	Crabmeat NSPF other preparations	230,112	2,067,521
TOTAL		707,857	4,629,386
1997	Crab NSPF Frozen	262,044	1,012,219
	Crab NSPF Live/Frozen/Salted/Brine	73,887	497,241
	Crabmeat NSPF Fresh/Dried/Salted/Brine	253,541	2,646,538
	Crabmeat NSPF Frozen	186,633	2,346,095
	Crabmeat NSPF in ATC	962,289	9,854,589
	Crabmeat NSPF other preparations	384,313	3,983,237
TOTAL		2,122,707	20,339,919

Table 7.19. United States imports of selected crab products from Venezuela, 1990 and 1997.

Year	Product	Kilograms	Value
1990	Crab NSPF Frozen	520	5,763
	Crab NSPF Live/Fresh/Salted/Brine	90,282	82,580
	Crabmeat NSPF Fresh/Dried/Salted/Brine	456,521	4,126,229
	Crabmeat NSPF Frozen	51,772	503,074
	Crabmeat NSPF in ATC	11,835	51,675
	Crabmeat NSPF other preparations	267,623	2,195,382
TOTAL		878,553	6,964,703
1997	Crab NSPF Frozen	5,961	103,520
	Crab NSPF Live/Frozen/Salted/Brine	218,063	351,967
	Crabmeat NSPF Fresh/Dried/Salted/Brine	56,424	910,581
	Crabmeat NSPF Frozen	26,058	375,374
	Crabmeat NSPF in ATC	523,378	6,602,414
	Crabmeat NSPF other preparations	318,536	5,268,421
TOTAL		1,148,420	13,612,277

Table 7.20. United States imports of selected crab products from Thailand, 1990 and 1997.

Year	Product	Kilograms	Value
1990	Crab NSPF Frozen	927	3,800
	Crab NSPF Live/Fresh/Salted/Brine	0	0
	Crabmeat NSPF Fresh/Dried/Salted/Brine	110,642	497,048
	Crabmeat NSPF Frozen	7,480	56,177
	Crabmeat NSPF in ATC	1,336,089	6,549,868
	Crabmeat NSPF other preparations	6,226	41,490
TOTAL		1,461,364	7,148,383
1997	Crab NSPF Frozen	45,518	464,528
	Crab NSPF Live/Frozen/Salted/Brine	0	0
	Crabmeat NSPF Fresh/Dried/Salted/Brine	0	0
	Crabmeat NSPF Frozen	80,729	1,128,363
	Crabmeat NSPF in ATC	1,337,778	11,183,383
	Crabmeat NSPF other preparations	26,650	121,498
TOTAL		1,490,675	12,897,772

Table 7.21. United States imports of selected crab products from Indonesia, 1990 and 1997.

Year	Product	Kilograms	Value
1990	Crab NSPF Frozen	8,505	8,505
	Crab NSPF Live/Fresh/Salted/Brine	0	0
	Crabmeat NSPF Fresh/Dried/Salted/Brine	8,160	65,395
	Crabmeat NSPF Frozen	0	0
	Crabmeat NSPF in ATC	81,826	448,291
	Crabmeat NSPF other preparations	0	0
TOTAL		98,491	522,191
1997	Crab NSPF Frozen	0	0
	Crab NSPF Live/Frozen/Salted/Brine	0	0
	Crabmeat NSPF Fresh/Dried/Salted/Brine	296,351	2,020,779
	Crabmeat NSPF Frozen	53,525	553,135
	Crabmeat NSPF in ATC	1,708,938	12,410,294
	Crabmeat NSPF other preparations	4,309	15,171
TOTAL		2,063,123	14,999,379

8.0 SOCIOCULTURAL CHARACTERIZATION OF THE GULF OF MEXICO COMMERCIAL BLUE CRAB FISHERY

8.1 Background

Changes in marine fisheries regulations may be associated with financial strains and difficult psychological and social adjustments by commercial fishermen and their families. However, marine fisheries policy-makers often do not consider these human costs when designing programs and making policies or setting regulations. While attention to social science issues may be simply ignored in some cases, there may also have been an absence of appropriate research on social and cultural aspects of marine fishery regulations.

Few studies have focused on the sociology of the commercial blue crab fishery in the Gulf of Mexico. Earlier studies included a survey of blue crab fishermen (Pesson 1974) that provided an overview of the general practices, attitudes, and social characteristics of the blue crab fishermen of Louisiana. This study is now over two decades out of date and does not consider what has become a significant underlying source of social change in this fishery — the influx of Southeast Asian refugees into the coastal fisheries of the Gulf. A study by Paredes et al. (1977) in a small community of northeast Florida also provided considerable details of the blue crab fishery as it existed more than twenty years ago. A study by Forbus et al. (1989) on the blue crab industry of Alabama provided a more current and useful historical footing for the present sociological study effort. More recently, a symposium was held in 1993 dealing with conflicts in the Gulf blue crab fishery (GSMFC 1995).

While it is clear that the early blue crab fishery was organized around a narrow group of traditional fishing families, the industry recently underwent major changes with the recent shift in ethnic and economic organization. Inter- and intra-ethnic conflict over fishing patterns, economic organization, and regulatory oversight have resulted and, to some extent, continue today. Vietnamese, Cambodian, and Laotian fishermen represent the largest minority components of the blue crab fishery. The entry of these ethnic groups into the fishery in the mid 1970s resulted in conflicts—social, cultural, and economic. Problems in communication (multiple non-English-speaking populations), the tendency of refugees to cluster in small tightly-knit social communities and in economically limited rural areas, unfamiliarity with local social norms and ignorance of prevailing rules and regulations, and their entry into an already burdened fishery are among the early and, to some degree, continuing social and cultural problems of this fishery.

This section is intended to provide the reader with an understanding of the demographic and social composition of the Gulf of Mexico commercial blue crab fishery. This section is based on the results of three analytic tasks: 1) review, evaluation, and integration of findings of published and unpublished literature pertaining to the social and cultural context of the blue crab fishery in the Gulf of Mexico; 2) implementation and analysis of a survey of blue crab fishermen designed to establish key demographic, statistical, and fisherman opinion information, and 3) completion of focused key informant telephone interviews designed to provide a more complete picture of the social and cultural context of the fishery (GSMFC unpublished data).

8.2 Methodology

A questionnaire was developed for the mail survey (Figure 8.1). Each selected license holder was mailed a questionnaire along with a cover letter and a stamped, self-addressed envelope. The following week, a combination thank you and reminder were mailed to each individual. The population was sampled, and the number of mail-outs and number and percent of returns are provided in Table 8.1. Approximately 23% of those sampled completed and returned the survey. It should be noted, however, that the number of

Figure 8.1. Gulf of Mexico blue crab fisherman mail survey instrument.

BLUE CRAB FISHERMAN SURVEY

With pencil or pen, please darken all boxes that apply: [1-5] **(For computer scoring)**

1. **How many years have you been crabbing?** [1-5] [6-10] [11-15] [16-20] [21-25] [26-30] [31-35] [36-40] [40+]

2. **Which other members of your immediate family/friends crew for you? Please mark total number of each that apply: Father/Mother** [1] [2] **Wife** [1] **Husband** [1] **Brothers** [1] [2] [3] [4] **Sisters** [1] [2] [3] [4] **Son/Daughters** [1] [2] [3] [4] [5] **Cousins/uncles/in-laws** [1] [2] [3] [4] [5] **Friends** [1] [2] [3] [4] [5]

3. **Who first introduced you to crab fishing? Father/Mother** [1] **Wife** [2] **Husband** [3] **Brother** [4] **Sister** [5] **Son/Daughter** [6] **Cousin** [7] **Friend** [8] **In-laws** [9] **Other** [10]

4. **Are you? Caucasian** [1] **Asian-American** [VIET] [LAO] [CAM] [THAI] **Hispanic-American** [3] **African-American** [4] **Native American** [5] **Other** [6]

5. **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+]

6. **Are you? Single** [1] **Married** [2] **Divorced** [3] **Widowed** [4]

7. **Indicate highest level education completed: Elementary** [6] **Middle School** [9] **High School/GED** [12] **Some College** [14] **College Degree** [16] **Graduate School Degree** [20]

8. **How satisfied are you with crabbing as an occupation?: Highly satisfied** [5] **Mostly satisfied** [4] **Satisfied** [3] **Not very satisfied** [2] **Unsatisfied** [1]

9. **How many boats do you use? 10-18 ft.** [1] [2] [3] **19-26.** [1] [2] [3] **27-32.** [1] **33-38** [1] **39+ft.** [1]

10. **Please indicate the number of each of the following gear you are running: Traps ____ Peeler gear ____ Trotline/bait ____ Trotline/bush ____ Trawl ____**

11. **Please estimate what percentage of your annual *fishing income* comes from the following: Hard crab____ Soft crab____ Shrimp____ Oysters ____ Finfish ____ Other ____ (100%)**

12. **Please estimate what percentage of your annual *total income* comes from *fishing*:** [10%] [20%] [30%] [40%] [50%] [60%] [70%] [80%] [90%] [100%]

13. **In a typical crab fishing year, what *percentage* of your fishing expenditures are for the following? Bait ____ Fuel ____ New Gear ____ Gear/Boat Maintenance ____ Licenses ____ Other ____ (total 100%)**

14. **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] **All Months** [13]

15. **During the *busiest part* of your fishing season, about how many crabbing trips do you make per week?**
[1] [2] [3] [4] [5] [6] [7]

16. **During the *slowest part* of your fishing season, about how many crabbing trips do you make per week?**
[1] [2] [3] [4] [5] [6] [7]

17. **Each year, what percentage of your catch do you sell to: Dealers** [%] **Processing plants** [%] **Wholesaler** [%] **Directly to Restaurants** [%] **Private individuals** [%] **Others** [%] **(total 100%)**

Issues of Concern: From your experience, how much of a problem are the following factors:
Not a Problem [N] **Potential Problem** [PP] **Problem** [P] **Significant Problem** [SP] **Or Major Problem** [MP]

18. ***Environmental conditions*:** **(leave blank if not applicable)**

Coastal water pollution	[N] [PP] [P] [SP] [MP]	**Increased vessel traffic**	[N] [PP] [P] [SP] [MP]
Crab disease	[N] [PP] [P] [SP] [MP]	**Salinity/water temp**	[N] [PP] [P] [SP] [MP]
Vessel pollution	[N] [PP] [P] [SP] [MP]	**Red tide**	[N] [PP] [P] [SP] [MP]
Industry discharge	[N] [PP] [P] [SP] [MP]	**Other ____________**	[N] [PP] [P] [SP] [MP]

19. ***Commercial/economic conditions*:**

Number of buyers	[N] [PP] [P] [SP] [MP]	**Local competition**	[N] [PP] [P] [SP] [MP]
Shipping costs	[N] [PP] [P] [SP] [MP]	**Operational costs**	[N] [PP] [P] [SP] [MP]
Crab meat imports	[N] [PP] [P] [SP] [MP]	**Peeler crab availability**	[N] [PP] [P] [SP] [MP]
Processing costs	[N] [PP] [P] [SP] [MP]	**Other ____________**	[N] [PP] [P] [SP] [MP]

20. ***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 undersized crab**	[N] [PP] [P] [SP] [MP]
Poaching/theft	[N] [PP] [P] [SP] [MP]	**Other ____________**	[N] [PP] [P] [SP] [MP]

21. ***Potential sources of conflict*; *other fishermen and recreational users*:**

Shrimp fishermen	[N] [PP] [P] [SP] [MP]	**Dredgers**	[N] [PP] [P] [SP] [MP]
Recreational fishermen	[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]

22. *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

23. In what city do you live? ____________________________

24. From which port, harbor, or landing area do you normally fish? _________________________

25. If you were in charge of blue crab management in your state, what changes would you recommend?

Table 8.1. Blue crab sociocultural survey results using mail and phone interviews.

State	Total Population/ Records (est.)	Total Mailed Out	Total Received	Return Rate Mailed/Received
Louisiana	2,550	2,480	574	23%
Alabama	176	151	49	32%
Texas	553	540	115	21%
Florida	715	700	261	37%
Mississippi	119	110	24	22%
Totals	4,113	3,981	1,023	26%

license holders also includes individuals who never fished commercially. For example, it was estimated that in Louisiana, 30% of 1996 license holders were not active in the fishery (Guillory 1998c). This implies that the response rate was considerably higher.

Additional sociocultural information was obtained from focused telephone interviews with two dozen key informants or surveyed license holders who volunteered to provide additional information.

8.2.1 Age Characteristics

The survey indicated that approximately 75% of the Gulf fishermen were between 31 and 59 years of age. Approximately 16% of the blue crab fishermen were over the age of 60; while only 9% of the fishermen were under the age of 30. Overall, this distribution was fairly consistent across the five states and underscores an important characteristic of the Gulf blue crab fishing population. They tend to be recruited into the fishery later in life and continue to actively fish into their late 60s and 70s.

8.2.2 Gender

While the gender of survey respondents was not queried, it was estimated that the overwhelming majority (~95%) of blue crab fishermen were male. Anecdotal reports of fishermen licensing additional family members, including daughters and wives, to increase the number of traps that could be legally employed, if true, would tend to overstate the number of female participants.

8.2.3 Education

Gulf of Mexico blue crab fishermen represented an unusual distribution of educational attainment. While the majority (41%) completed high school, approximately 30% of the fishermen attained less than a high school education, and 28% completed at least two years of college. It was also notable that an equal number of fishermen (8%) completed college as completed only elementary school (8%).

8.2.4 Race/Ethnicity

The vast majority (87%) of the Gulf blue crab fishermen were Caucasian, and the largest minority population was Vietnamese (7%). The minority population of the Texas fishery was composed largely of Vietnamese fishermen, whereas Cambodian and Laotian fishermen represented the principal minority populations in Alabama. Early post-Vietnam War immigration patterns resulted in a distribution which precipitated the current minority profile in the Gulf.

8.2.5 Marital Status

Approximately 77% of the Gulf blue crab fishermen were married, 11% single, 10% divorced, and 2% widowed. The strong inclination towards marriage was consistent Gulfwide, and is consistent with trends among commercial fishermen in general.

8.3 Fishing History and Characteristics

8.3.1 Years Crabbing

The largest group of blue crab fishermen (24%) were active in the fishery for less than five years. In addition, 20% had been involved for six to ten years, resulting in a total of 44% of the fishermen having less than ten years experience. It is notable that more than 28% of the fishermen had fished in excess of 20 years.

8.3.2 Crew Size and Composition

The largest percentage of fishermen fished alone (29%), 27% fished with their husbands or wives, 13% with their sons or daughters, 9% with their fathers, and 12% with friends.

8.3.3 Entry into the Fishery

The largest percentage of fishermen (35%) were introduced to the fishery by their parents. The second most common source of introduction to the fishery was friends (33%). Another 15% were introduced either by a brother, cousin, or other relative. This pattern is characteristic of traditional fisheries where the father passes his experience and occupation on to his sons. The role of non-relative, non-friend sources of introduction (non-traditional sources) appears to be increasing over time (J. Petterson personal communication).

8.3.4 Vessel Size(s)

Approximately 39% of the blue crab fleet consisted of vessels less than 19 ft in length, while 44% consisted of 19-26 ft vessels, and the remaining 15% ranged from 27 ft to over 39 ft. It was notable that nearly 20% of the fleet consisted of second and third vessels.

8.3.5 Number of Traps

The number of traps fished ranged from 25 to more than 2,000, with 33% using less than 200, and 29% using between 200-299 traps. Seventeen percent used 300-399 traps, 9% used 400-499 traps, and the remaining 12% used over 500 traps. Sixty-two percent of the fishermen used less than 299 traps.

8.4 Annual/Monthly Fishing Pattern

8.4.1 Seasonal Frequency

Approximately 50% of the respondents indicated they fished every month of the year and 25% fished six months or less.

8.4.2 Frequency Per Week

Approximately 74% of the fishermen fished three or less days during their reported low season work week. This low season varied among fishermen; some preferred to fish less during certain winter months, while others reduced effort during spring and fall months.

During their reported peak season, the number of fishing days per week increased to six or seven days, with approximately 57% of the fishermen working six or more days per week and was consistent Gulfwide. While this indicates a clear distinction between peak and low seasons, it is not clear whether this reflects a single peak of activity or multiple peaks throughout the year.

8.5 Socioeconomic Importance

8.5.1 Dependence on the Blue Crab Fishery

Two kinds of dependence were evaluated in our survey: 1) dependence on fishing as an occupation and 2) dependence on blue crab fishing as an element of this overall dependence on fishing. Over half (55%) of the blue crab fishermen indicated that they had earned 100% of their income from fishing, while a total of only 26% earned less than 50% of their income from fishing.

Of this total, the average commercial blue crab fisherman relied on hard shell blue crab for 64% of their fishing income, soft shell blue crab for 4%, shrimp for 12%, oysters for 2%, and finfish and other harvests for the remaining 18% of their fishing income. This represents a high level of dependence on the blue crab fishery.

8.6 Investment/Expenditure Patterns

8.6.1 Expenditure Patterns

Bait (20%), fuel (18%), gear (18%), and maintenance (14%) expenses represented the principal costs associated with blue crab fishing. This pattern was fairly consistent Gulfwide, with the exception of Florida, where fishermen reported license fees represented 20% of their costs.

8.6.2 Market Patterns

Gulf blue crab fishermen sold their catch primarily to dealers (40%) with the remainder sold to wholesalers (20%), local plants (14%), private parties (13%), restaurants (8%), and other (5%).

8.6.3 Occupational Satisfaction

Approximately 78% of fishermen indicated they were satisfied, mostly satisfied, or highly satisfied with their fishery experience. The largest percentage (35%) indicated they were satisfied with the occupation, while 25% indicated they were mostly satisfied. As many fishermen (17%) indicated "highly satisfied" as indicated "not very satisfied" (16%). This was consistent with field interviews which indicated that while there were many problems and issues confronting the fishery, fishermen continued to be satisfied with their occupation.

8.7 Environmental and Regulatory Concerns

8.7.1 Environmental Conditions

Industry discharge was the only environmental condition identified as a "major" problem in the fishery. Industry discharge affects the nearshore environment where blue crab are caught. These sources of pollution are easily recognizable by local fishermen and affect their choice of fishing areas and quality of catch. No problems were identified as "significant," and only increased vessel traffic was identified as a "problem."

8.7.2 Commercial/Economic Conditions

Crab meat imports were identified as the only "major" commercial/economic problem in the fishery. Import taxes and other barriers were suggested as protective measures. Operational costs and local competition were identified as "problems" for the fishery. This was reflected in fishermen recommendations concerning limited entry and trap limitation programs for the Gulf. This general perception that the larger economic conditions were "not a problem" appeared to be consistent throughout the Gulf. Fishermen, in general, were concerned with the impact of crab imports on the larger market, but considered these issues *external* to the fishery itself.

8.7.3 Potential Sources of Conflict: Other Commercial Crab Fishermen

Two potential sources of conflict with other commercial crab fishermen were identified as "major problems" in the blue crab fishery: 1) poaching/theft and 2) the taking of undersized crabs. Each of these areas of conflict occurred within different domains, and it would not be appropriate to rate or scale the relative importance of the various responses. However, poaching/theft was one of the most frequently identified problems in response to the open-ended survey question and in our telephone discussions with fishermen. Gulf fishermen were convinced that the taking of undersized crabs is a "major problem" that needs to be addressed, and some Caucasian fishermen argued that Asian fishermen play a disproportionate role in the taking of undersized crabs. The lack of enforcement of existing regulations was a persistent theme during telephone discussions and the focus of many suggested solutions (e.g., technological, enforcement, seasons, area restrictions). No problems were identified as "significant" problems. Gulf fishermen also reported gear conflicts as a problem in the fishery, particularly in high productivity or easily accessible areas.

8.7.4 Potential Sources of Conflict: Other Fishermen and Recreational Users

Among the potential sources of conflict with other fishermen, poaching and theft were identified by blue crab fishermen as a "major problem." The question remains whether the traps are lost to other crab fishermen, recreational fishermen, passing vessels, or to errant shrimp or trawl gear. Certainly, some pots are removed or pillaged intentionally, and some are lost to shrimp gear. However, weather, misplaced traps, poor locations, lost buoys, and other causes probably account for a considerable percentage of the annual loss of traps. Moreover, the fishermen acknowledge the difficulty of implementing a cost-effective means of preventing the actual theft of traps or of preventing gear conflict. Better trap identification was often suggested by fishermen as one measure that could improve both monitoring and enforcement.

Shrimp fishermen, recreational fishermen, and boaters were all identified as "problems" for the blue crab fishery. Many of the recommendations centered on how to control the activity of the shrimp fishermen who were seen as "the pillagers of the shallows." The conflict between blue crab fishermen and shrimp fishermen occurs in several areas. First, the peak seasons occur at roughly the same time and in the same areas for both shrimp and blue crab. Second, the use of both shrimp gear and crab pots in the same area can result in significant loss of gear and fishing time for both. Finally, shrimp gear was viewed as destructive to blue crab fishing grounds.

Conflicts with recreational fishermen were purported by commercial fishermen to arise in several different ways. Recreational fishermen were also believed to be the major source of blue crab that commercial fishermen argue enters the market through clandestine channels and thereby depresses the market price paid per pound of catch. Commercial fishermen claim that "recreational fishermen harvest one-fifth to two-thirds of the all the Gulf's blue crabs." Additional conflicts reported with recreational fishermen and boaters arise from an increased number of boats and disregard for navigational channels, commercial fishing areas and practices, and established local customs on fishing grounds. Hostility to recreational users is also fueled by the belief that the recreational lobby exerts a far more powerful and (in the fishermen's mind) inappropriate control over the legislature. Fishermen contend that laws will tend to favor recreational fishermen, a bias introduced by the perception that recreational use is less detrimental to the resource than commercial use.

8.7.5 Potential Sources of Conflict: Regulations and Enforcement

Blue crab fishermen identified three "major" sources of conflict regarding regulations and enforcement: 1) excessive regulations, 2) state legislators, and 3) inadequate enforcement. While there was considerable variability between states, fishermen overall considered *excessive regulations* to be a "major problem" for the fishery. The problem of excessive regulations was an opinion held strongly only by Louisiana fishermen, who numerically dominated this statistic. Fishermen did not identify *excessive enforcement* as even a potential problem, but identified inadequate enforcement as a "major problem." Fishermen felt overburdened with rules and regulations that legitimate fishermen are obligated to know and obey, while fishermen who violate the rules are rarely subject to enforcement actions.

Blue crab fishermen also identified state legislators as a "major problem." Again, this represents primarily the perspective of Louisiana and Texas fishermen who believed that management of the fishery had succumbed to political conflict and the views of regulatory agencies rather than the needs of the fishery or fishermen. From their perspective, instead of basing policy on good biological and economic studies, decisions were made on the basis of political expediency.

The most common concern for fishermen was the need to improve enforcement of existing rules and regulations. Many of the problems and issues confronting fishermen were derived from actions that are violations of established rules or regulations. The harvest and sale of undersized crab, trap and crab poaching, closed areas, etc. all involve violations of existing regulations. Fishermen also recognized that the cost of enforcing and prosecuting certain violations may be excessive relative to the nature of the violation.

The linkage between agency responsiveness and inadequate enforcement appeared strong, with fishermen concerned that the appropriate regulatory agencies are not enforcing existing rules and regulations. This was a particular problem for highly competitive fishermen who lumped those who steal traps, loot crab pots, crowd prime fishing grounds, and take undersized crab as "violators" of existing regulations and who benefit from lack of enforcement. They perceive these violations as unfairly costing honest commercial fishermen.

8.8 Leading Fisherman Recommendations

Blue crab fishermen were most concerned with issues affecting equity in the fishery. They favored stable rules that were enforceable and allowed the best fisherman to make the most money. They perceived a fishery with adequate but poorly enforced rules which rewarded "cheaters" at the expense of honest fishermen. The fishermen suggested a variety of ways to improve equity: 1) by limiting the number of traps per vessel, license, or fisherman (31%) and 2) by enforcing the rules that currently exist, in particular, those rules concerning poaching and theft, and those designed to ensure the future economic and biological viability of the fishery (19%). Other fishermen recommendations were centered around size limits (9%), seasonal restrictions (8%), trap specifications (7%), female or peeler crab limits (7%), and bureaucratic control (6%).

8.8.1 Trap Limitation

The most common recommendation (31%) from fishermen was to limit the number of traps for each fisherman (or boat or license). Suggestions ranged from 200 traps per license holder to 400 traps per vessel. This is a patent example of the fisherman's desire that the fishery be conducted in a fair and equitable manner. They were not opposed to one fisherman, through hard work, harvesting and selling more crabs. They were, however, opposed to fishermen who exploited regulatory loopholes and/or enforcement gaps and reaped unfair profits from the common resource. Fishermen were concerned not so much with the health of the biological resource but with the economic and social equity of the fishery. Their perceived overcapitalization of the fishery represents, for many fishermen, the intermediate stages of an eventual collapse of their livelihood and way of life.

8.8.2 Law Enforcement

The second most common recommendation among blue crab fishermen was to improve enforcement of existing rules and regulations. As one fisherman simply put it, "We need better enforcement of stricter theft laws!" Many of the problems and issues confronting blue crab fishermen were derived from actions that are violations of established rules or regulations. The harvest and sale of undersized crabs, trap and crab poaching, etc. all involve violations of existing regulations. Fishermen recommended stronger sanctions for law violators including revocation of fishing privileges and higher fines.

9.0 MANAGEMENT CONSIDERATIONS

9.1 Definition of the Fishery

The fishery includes the harvest activities for the blue crab, *Callinectes sapidus* Rathbun, in the coastal waters of the United States Gulf of Mexico.

9.2 Management Unit

The management unit is the population of blue crab occurring in the coastal waters of the United States Gulf of Mexico.

9.3 Management Goal

The goal of this plan is to provide a management strategy that allows for maintenance of the stocks and provides for stability of the fishery over the long term.

9.4 Management Objectives

In consideration of relevant habitat, biotic, and fishery-related characteristics, the objectives of blue crab management in the Gulf of Mexico are:

1. To identify and encourage conservation, restoration, and enhancement of essential blue crab habitats.
2. To reduce incidental fishing mortality on juvenile crabs.
3. To implement and complete appropriate research studies and acquire fishery dependent and independent-data to provide necessary information to assess the status of the stock.
4. To enhance the social and economic benefits derived from the use of the resource.
5. To reduce wasteful harvesting practices in the fishery.
6. To reduce conflicts between commercial blue crab fishermen and other groups.
7. To provide for a program of plan evaluation in which the biological, social, and economic impact of existing and proposed fisheries management regulations are assessed.
8. To encourage the adoption of a Gulfwide management strategy.

9.5 Stock Assessment

Stock assessment of blue crabs in the Gulf of Mexico was hampered by an inadequate fishery dependent data base. There was neither reliable catch-and-effort data nor information on the age structure for the commercial fishery. Because of these shortcomings, the assessment was conducted using less data intensive techniques than several other techniques currently in use. Four indicators of stock status were used in the assessment—landings history, estimates of relative abundance, total mortality rates, and mean carapace width. Consensus information from these four indicators was used to determine stock condition.

No credible CPUE data were available nor was there information on population age structure in the commercial fishery. In addition to lack of reliable effort data, stock assessment was hampered by inadequate data on hard crab harvest and the lack of information on recreational catch. Traditional aging techniques were difficult to apply to blue crabs as they lack somatic hard parts found in fish, and tag recapture is difficult because of ecdysis. These obstacles limit the options available for assessing stock status and place restrictions on interpretation of results.

The von Bertalanffy (1938) growth equation was fitted to 14 blue crab data pairs. Once the von Bertalanffy growth coefficient was estimated, it was used in Hoenig's (1983) size-based formula for estimating annual rates of instantaneous total mortality. Polynomial model building was used to determine long and short term trends in landings and estimates of relative abundance. Long term trend analysis included all available data, and short term analysis included only the most recent five years. Simple linear regression was used to detect general long term trends (i.e., linearly increasing or decreasing). Analyses were performed for each state since the blue crab is essentially an estuarine species, and management decisions were considered most likely to be implemented as deemed appropriate by each state. Stock assessment procedures are presented in greater detail in Appendix 14.2.

9.5.1 Stock Assessment Summaries by State

No signs of stock stress were detected in the analysis of Florida data. Excluding 1998 data, there was no significant increase in total mortality rates and no significantly declining trends in estimates of relative abundance, mean carapace width, percent frequency of occurrence, and landings.

Consistent signs of stock stress were not detected in the analyses of Alabama data. Landings increased significantly, but this did not result in a significant increase in total mortality rates. Estimates of relative abundance were relatively stable with no significant, declining long-term trends except for the post-recruit size class. Percent frequency of occurrence declined significantly, but this did not translate into a significant declining trend in CPUE. No significant declines were observed in long term analysis of mean carapace width indicating there was no systematic decrease in the size of blue crabs.

Mississippi's landings history indicated a potential decline in stock health. The decrease in landings from 1987 to 1994 appears alarming, but Perry et al. (1998) attributed this decline not to a declining population but to: 1) the introduction of management regulations restricting harvest and fishing area, 2) increased product being landed out of state, 3) a loss of processing capacity, and 4) the economic interdependency of the crab fishery with other fisheries. None of the other indicators of stock status showed signs of concern. There was no significant increase in total mortality rates and no significant decrease in CPUE, frequency of occurrence, and mean carapace width.

Assessing the blue crab population in Louisiana waters was difficult because of somewhat contradictory results. Although a significant increase in total mortality rates, a significant decline in CPUE of crabs fully-recruited to the fishery, and a decrease in average crab size suggest a cautionary interpretation of these data; other positive indicators may ameliorate these concerns. For example, a significant increase in CPUE of the recruit size class accounts for the decline in average size. Additionally, landings have generally increased since 1966, and the frequency of occurrence in samples indicated no significant trend over time.

Indicators of stock status suggest that the blue crab population of Texas is not currently under stress. Landings generally declined from 1985 to present, although landings have increased four of the last five years. Total mortality rates increased significantly for a period of time (1982-1992) but are now on the decrease. Estimates of relative abundance and percent frequency of occurrence declined for all categories since 1989 but have increased over the last four years. Mean carapace width data indicated no signs of alarming trends, and the composite data resulted in a significantly increasing short term trend.

9.5.2 Stock Assessment Summary for the Gulf

The von Bertalanffy (1938) growth equation was fitted to 14 blue crab widths-at-ages to estimate the mean carapace width of very old Gulf crabs (CW_{∞}=276 mm) and the von Bertalanffy growth coefficient

(K=0.663). These estimates were then used in Hoenig's (1987) formula for estimating annual rates of total instantaneous mortality. Correlation analysis was performed between mortality estimates and CPUE estimates for recruits to determine if increases in total mortality were due to an influx of recruits rather than an increase in death rates. Polynomial model building was used to determine long and short term trends in total mortality rates, estimates of relative abundance, percent frequency of occurrence, mean carapace width, and landings history. Csirke and Caddy's (1983) method of surplus production modeling was used to estimate maximum sustainable yield (MSY) but was abandoned due to a lack of relationship between total mortality and landings.

There was little uniform indication of stock stress for any indicator of stock health. Alabama and Louisiana were the only states to show significant declines in post-recruit CPUE. The Alabama decline did not result in a significant increase in total mortality estimates, and the Louisiana decline was counteracted by a significant increase in recruit CPUE. Louisiana was the only state with a significant decline in mean carapace width, but this may not be due to a systematic decrease in somatic size but to the combined effect of significantly increasing numbers of recruits and significantly decreasing numbers of post-recruits. Mississippi was the only state resulting in a significant decline in landings, but this was probably due to socio-economic conditions and management regulations rather than a decline in population size. Louisiana was the only state with significantly increasing total mortality rates which was consistent with the increased landings and declining post-recruit CPUE; however, these results should be considered in conjunction with significantly increasing recruit CPUE.

Inconsistencies as highlighted in the above stock indicators illustrate the need for collection of appropriate fishery dependent and fishery independent data across the Gulf. Collection of these data would facilitate a more comprehensive assessment of blue crab stocks in the future.

9.6 Environmental and Biological Parameters Relevant to Management

9.6.1 Habitat

9.6.1.1 Essential Habitat

Areas of particular concern are all habitats required during the blue crab life cycle. These include offshore waters used for spawning and larval development, estuarine nursery grounds, and the access routes used by crabs between areas. Estuarine nursery grounds range from barrier island/Gulf shoreline inland to the freshwater marshes (Section 4.4). Nursery habitats of critical concern are intertidal marshes; sub-tidal grass beds; and unvegetated, soft sediment shoreline habitats. Drop net sampling data (Thomas et al. 1990; Zimmerman et al. 1990a, 1990b) and tethering experiments on blue crabs and other brachyurans (Heck and Thoman 1981, Ruiz et al. 1993, Hines and Ruiz 1995) have verified the importance of the shallow, marsh-water interface as a refuge and foraging area. Studies have found a significant relationship between production of blue crabs (Orth and van Montfrans 1990) or other estuarine species (Turner 1977, 1979; Deegan et al. 1986) and total-vegetated habitat among the Gulf states. Unvegetated soft sediment areas adjacent to mainland beaches also provide habitat (Rakocinski et al. 1999).

9.6.1.2 Habitat Quality/Habitat Loss

Essential marine/estuarine habitats in the Gulf of Mexico have undergone dramatic changes (Section 4.3). Substantial marsh habitats across the Gulf of Mexico have been lost or altered, and chronic pollution of estuarine habitats from urban and agricultural runoff and industrial discharges are present, although largely unquantified. Access routes that crabs use to move between offshore waters and estuarine bays, bayous, and marshes are vital. Water control structures can block access to nursery habitats if they are closed during periods of crab immigration.

There is little doubt that blue crab production in the Gulf depends on the quantity and quality of estuarine marshes, mangrove areas, submerged vegetation, and nearshore soft sediment habitats. These areas not only provide postlarval, juvenile, and subadult crabs with food and protection from predation but also help to maintain an essential buffer between fresh and salt water. Although the quantity of marsh acreage has not declined in some areas, the quality of the marsh as habitat for juvenile blue crabs has diminished.

Marsh loss has reached crisis levels in some Gulf of Mexico estuaries. This loss occurred due to both natural (subsidence, sea level rise) and man-induced (reduction in freshwater and sediment input, dredging of transportation channels and location canals for oil exploration, saltwater intrusion, pipeline construction, etc.) factors. The impact of marsh loss on blue crab production may not be initially evident. Biological productivity tends to increase temporarily in deteriorating marshes due to increased shallow marsh-water interface habitat and increased detrital input associated with deteriorating marshes (Gagliano and Van Beek 1975). Marine biologists generally acknowledge that estuarine carrying capacity, however, will eventually decrease as the conversion of marsh to open water continues and edge habitats in suitable salinity regimes decline below a critical point. Browder et al. (1989) postulated that land-water interface in the Terrebonne-Barataria estuaries would begin to decline by the mid 1990s, after which brown shrimp (*Penaeus aztecus*) production would decline sharply.

The chronic, long term effects of pollution on estuarine organisms are difficult to quantify. Potential sources of toxic contaminants (e.g., pesticides, herbicides, other organics, and heavy metals) into estuaries include urban and agricultural runoff, drilling fluids, produced water, and oil spills from petroleum and other industries. Some life history characteristics make the blue crab more susceptible to accumulation of toxins (preference for feeding on bottom-dwelling organisms such as filter feeding bivalve mollusks and burying into sediments in extremely cold weather) while the short life span and migratory habits render the species less susceptible (Williams and Duke 1979, Fishery Management Plan Workgroup 1996). The effects of various pollutants/toxins have been documented under laboratory conditions (reviewed in Guillory et al. 1996, Van Heukelem 1991), and there have been mortalities of blue crabs along the Atlantic coast associated with Kepone, DDT, or other pesticides (Newman and Ward 1973, Van Engel 1982). However, there are insufficient data to assess the impacts of toxicants on blue crabs in Gulf of Mexico estuaries.

Eutrophication, resulting from the addition of nutrients, has been greatly accelerated by human activity. Eutrophic waters are characterized by frequent algal blooms and periodic hypoxia or low levels of dissolved oxygen. There is evidence that eutrophication has increased in recent decades in the Barataria and Terrebonne estuaries of Louisiana (Rabalais et al. 1995c), and anoxic bottom conditions have been reported in Mobile Bay (May 1973; Tatum 1980, 1982); Mississippi Sound (Gunter and Lyles 1979); and Tampa, Sarasota, and Florida bays (P. Steele personal communication). Extensive areas (1,650,000 ha) of low bottom oxygen levels (<2 ppm) occur annually during the summer in coastal waters of Louisiana and Texas (Rabalais et al. 1991, 1997).

9.6.1.3 Carrying Capacity

Carrying capacity is the maximum stable population size that a particular estuary can support over a long period of time. Orth and van Montfrans (1990) linked production of blue crabs to the quantity and quality of suitable habitat, and data from Gulf studies lend support to their conclusions. Postsettlement biotic processes linked to availability and suitability of habitat have been identified as major factors regulating population levels of juveniles in northern Gulf estuaries. Interspecific and intraspecific predation appear to regulate abundances of early stage blue crabs, and the importance of habitat as refuge is paramount (Sections 3.2.8.3 and 4.5.2). 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). Intraspecific predation also appears to be a strong regulator of juvenile population abundance. Mansour (1992) found cannibalism common and noted its frequency increased with increasing crab size and was predominant during the period of juvenile recruitment. Peery (1989) noted that “the potential of larger crabs to cannibalize juveniles is great enough to produce strong density-dependent regulation of juveniles.” Identification of critical habitat and recognition of the importance of habitat to production are crucial to maintenance of populations.

9.6.2 Biotic Factors

9.6.2.1 Genetics

Recent genetics research (Section 3.2.1.3) supports the recommendation that a Gulf-wide strategy for blue crabs is appropriate. There is a low level of genetic variation among Gulf populations, and genetic exchange is not impeded by physical or physiological barriers in the region (McMillen-Jackson et al. 1994, Berthelemy-Okazaki and Okazaki 1997).

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 (Section 3.2.2.3). 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. Life history characteristics of female blue crabs (terminal anecdysis and size at 50% sexual maturity, 125-130 mm CW), size-selective harvesting gear, and intense fishing pressure suggest the possibility that genetic selection could occur in this fishery. Because some fraction of the population is consistently reproducing at a smaller size, these individuals may contribute disproportionately to the stock. The direct selective force is for small size at reproduction, thus, there may be a selection for smaller individuals.

9.6.2.2 r-selected Characteristics

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 r-selection) 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 density-independent 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."

9.6.2.3 Spawner-Recruit Relationship

Management of blue crabs in the Gulf of Mexico has included protection of egg-bearing females as a measure to ensure sustainable harvest even though a spawner-recruit relationship has not been established, and blue crabs in the Gulf are not recruitment limited (Sections 3.2.5.1, 3.2.8.3, 4.5.2). Although egg-bearing females are protected in all but one Gulf state, the commercial blue crab fishery continues to exhibit wide, annual fluctuations in harvest. Blanket protection of egg-bearing females is not biologically justified. In the regional blue crab FMP, Steele and Perry (1990) noted the 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."

Population abundances are influenced by post-settlement processes that affect juvenile survival (Livingston et al. 1976, Heck and Coen 1995, van Montfrans et al. 1995, Perry et al. 1998).

9.6.2.4 Megalopal Settlement/Post-settlement Survival

Blue crabs recruit to Gulf estuaries as megalopae. Megalopal settlement is episodic within an estuary and asynchronous among coast wide sites (Section 3.2.4.2.3). There is little settlement in spring and early summer; daily settlement usually begins in July with settlement peaks observed in late summer/early fall. Although significantly higher blue crab postlarval settlement rates (10-100 times greater) occur in northern Gulf estuaries (Rabalais et al. 1995a) than in Atlantic coast estuaries (van Montfrans et al. 1995), levels of juvenile abundance are similar (Heck and Coen 1995). Heck and Coen (1995) attributed the similarities in population levels of juveniles to higher predation rates for post-settlement blue crabs in Gulf estuaries (Section 3.2.8.3). Other studies support the contention that blue crab population size is determined by density-dependent, post-megalopal settlement processes associated with predation (habitat complexity, crab density, and size) and estuarine carrying capacity (Morgan et al. 1996, Pile et al. 1996). Noting the magnitude of megalopal immigration and the upward trend in early juvenile abundance in trawl samples from several states, Guillory et al. (1998) and Guillory (1997a) concluded that estuaries in the northern Gulf of Mexico were not recruitment limited and that factors related to survivorship of juveniles in the estuary were primary determinants of abundance of late stage juveniles. Both Perry et al. (1998) and Guillory (1997b) observed that high initial densities of post-settlement blue crabs did not necessarily result in proportionally elevated levels of later-stage juveniles or adults.

Estuarine survivorship of juveniles appears to be the major determinant of year-class strength. In general, analyses of long term trawl and/or seine data sets for blue crabs from Gulf coast estuaries show an upward trend in abundance of early juveniles with stable population levels in larger juvenile size classes. Continued maintenance of juvenile populations is dependent on preservation of suitable habitats that afford both food and refuge from predation and on reducing sources of juvenile mortality.

9.6.2.5 Parasites and Diseases

Although massive 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, Newman and Ward 1973). Of the parasites that infect blue crabs in the Gulf of Mexico, the influence of the rhizocephalan barnacle, *Loxothylacus texanus*, on blue crab stocks is of particular concern (Sections 3.2.2.3 and 3.2.6.3). Rate of growth, size at maturity, and reproductive capacity of blue crabs may be affected by this parasite, and the fishery implications of rhizocephalan infection may be significant. Because of the high levels of infection recorded in some northcentral Gulf of Mexico estuaries (Adkins 1972b, Ragan and Matherne 1974, Overstreet 1978) and the occurrence in these areas of populations of small mature crabs, the effect of rhizocephalan infection on growth and molting needs to be established.

9.7 Fishery-Related Parameters Relevant to Management

9.7.1 Inadequate Fishery Data

9.7.1.1 Fishery-Independent Data

All states have fishery-independent monitoring programs; however, sampling protocol and methodologies are inconsistent among Gulf states and should be standardized. Important components of these programs should include: size and weight, sex, maturity, parasitic infection, and molt cycle stage. Standardized sampling would allow for compilation of a consistent regional data base allowing more effective stock assessment and Gulfwide data comparability.

Data on sex composition and maturity would provide for estimates of size at 50% sexual maturity; currently these data are only available for Louisiana and Mississippi (Guillory and Hein 1997b, Perry unpublished data) (Section 3.2.2.3). It would also provide information on seasonality of spawning and spawning history. Parasites have been known to affect growth and development (Overstreet 1978, 1983) (Sections 3.2.2.3, 3.2.6.3). Overstreet (1978) implicated the rhizocephalan barnacle, *L. texanus,* as the causative agent for the occurrence of "dwarf" or "button" crabs in the northern Gulf. With infection rates of up to 40% within selected size classes in some Louisiana estuaries, distribution and abundance of this parasite could have a decided impact on numbers and size of harvestable adults. Information on molt cycle stage will provide temporal and spatial data on pre-molt/post-molt crabs.

9.7.1.2 Fishery-Dependent Data

There are inadequate catch data and no reliable effort data in the Gulfwide commercial and recreational fisheries. In addition, there are no data on size and sex composition of commercial landings and no information on age structure (Sections 9.5, 6.1.5, and 6.2.4).

9.7.1.3 Fishery Information Network (FIN) Activities

The Gulf of Mexico and Caribbean coastal states (Texas, Louisiana, Mississippi, Alabama, Florida, Puerto Rico, and United States Virgin Islands); the NMFS; the USFWS; the NPS; the Gulf of Mexico and Caribbean Fishery Management Councils; and the GSMFC have initiated a state-federal cooperative program to collect, manage, and disseminate statistical data and information on the marine commercial and recreational fisheries of the Southeast Region called the Fisheries Information Network (FIN). The goals of the program are to plan, manage, and evaluate commercial and recreational fishery data collection activities; to implement a marine commercial and recreational fishery data collection program; to establish and maintain a commercial and recreational fishery data management system; and to support the establishment of a national data collection and management program. Under this program, the GSMFC, the Gulf states, and the NMFS have begun and will continue to conduct activities to improve the quantity and quality of data available for fisheries management.

9.7.2 Increasing Effort/Gear Saturation

The NMFS surveys provide the only comprehensive Gulfwide data on fishing effort. Although the data base is incomplete and inadequate for some analyses, long-term trends can be examined. The fishery is currently operating at a low level of economic efficiency with a relatively constant harvest divided into increasing numbers of gear units. The total number of commercial blue crab fishermen in the Gulf states has risen dramatically, with an increase between 1980 (1,516 fishermen) and 1991 (4,028 fishermen) of 166%. Increased effort in the blue crab fishery has led to overcapitalization and catch per fisherman has declined in most Gulf states (Section 6.1.5). Total landings in an open-access fishery generally increase but at a decreasing rate with successive unit increases in effort. Eventually, a point is reached where no further increase in landings is realized. Consequently, catch (and revenue) per fisherman will eventually decrease in an expanding fishery. Steele and Perry (1990) suggested that while gross income in the fishery was relatively constant when evaluated on a deflated basis, profitability may be declining because of increased operating costs to the fishermen.

9.7.3 Declining Catch Rates

Summary data from individual states using license records or number of trips as an index of fishing effort also show long term downward trends in catch rates of commercial fishermen in Florida (Steele and Bert 1998), Alabama (Heath 1998), Mississippi (Perry et al. 1998), Louisiana (Guillory and Perret 1998), and Texas (Hammerschmidt et al. 1998). Declining commercial catch rates typically occur in a fishery as it matures and fishing effort increases (Caddy 1984). Although no quantitative data are available, recreational crab fishermen have expressed concern about declining catch rates in some states.

9.7.4 Capture and Harvest of Sublegal Crabs

Retention of sublegal (<127 mm CW) blue crabs in traps has been recognized since the introduction of the gear (Davis 1942, Green 1952) (Section 6.1.3). The increasing use of 1.5" square mesh traps, which retain smaller crabs than do hexagonal mesh traps, has contributed to even greater catches of undersize crabs (Guillory 1996, Guillory 1998c, Guillory and Prejean 1997, Guillory and Hein 1998b).

Directed fishing mortalities from illegal harvest and sale of sublegal blue crabs and capture and handling mortalities associated with culling undersize individuals should be reduced. Increased harvest and sale of sublegal crabs may reduce catches of larger, more-desirable crabs, and because smaller crabs are less likely to be processed, this portion of the resource is wasted at the processing level. Injuries and/or physiological stress from trap capture and handling results in delayed mortalities and reduced future growth rates in many decapods (Murphy and Kruse 1995). McKenna and Camp (1992) documented a 7% delayed mortality of trap-caught blue crabs in North Carolina. Substantial injuries may occur in the trap or during culling. Eldridge et al. (1979) found that 57% of the crabs in his study had damaged appendages. Multiple limb loss and chelotomy significantly reduce the growth increment at molting (Smith 1990, Ary et al. 1987, respectively). Small blue crabs may suffer high immediate mortality rates in traps due to conspecific predation by larger individuals.

9.7.5 Bycatch of Blue Crabs

An average of 82 million blue crabs were captured annually from 1990 to 1994 in the Texas inshore shrimp fishery (Hammerschmidt et al. 1998) (Section 6.4). Based upon an estimated 1989 catch of 227.8 million lbs 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 20.5 million lbs; considering that much smaller individuals are captured in trawls, skimmer nets, and wing nets than in crab traps, the number of blue crabs captured in the shrimp fishery exceeds that number harvested by commercial crab fishermen. Comprehensive, quantitative data on incidental catch of blue crabs in other Gulf fisheries are lacking.

Research has indicated that capture in shrimp gear and subsequent culling have significant effects on blue crab survival. The average mortality rate of blue crabs captured in trawls was 36% overall, 26% 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 unpublished data and ADCNR unpublished data), increases in delayed mortality may result from prolonged exposure and repeated dips; additionally, other more toxic chemicals may be added to the brine solution. Considering the number of crabs which are harvested and the high mortality rates associated with capture and handling in the shrimp fishery, future increases in harvestable stock may be dependent on reducing this and other sources of juvenile mortality.

9.7.6 Bycatch In Traps/Impingement

Bycatch of other species also occurs in blue crab traps. Seigel and Gibbons (1995) concluded that drowning in crab traps is a major threat to diamondback terrapin (*Malaclemys terrapin*) populations, and otters (*Lutra canadensis*) have drowned in crab traps (E. Holder personal communication). Guillory (1993) and Whitaker (1979) collected 11 and 13 species of finfish in monitored ghost traps in Louisiana and South Carolina, respectively. Manatees (*Trichechus manatus*) in Florida have been injured after becoming entangled in crab trap buoy lines (P. Steele personal communication).

9.7.7 Ghost Fishing

Substantial numbers of crab traps are abandoned or lost due to uncontrollable factors (i.e., tides, currents, storm surges), negligence by the fishermen in properly assembling and maintaining buoys and attachment lines, inadvertent clipping of float lines by vessel propellers, and the use of plastic jugs or bottles as floats which may become brittle and deteriorate with weathering.

Overall mortality of blue crabs in ghost traps is substantial when the number of ghost traps and mortality rate per trap are considered. Casey (1990) estimated that annual trap loss in the Chesapeake Bay blue crab fishery ranged from 10% to 30%. The number of ghost traps added each year in Louisiana may be as high as 45,000, if a conservative annual trap loss estimate of 10% and total trap number of 450,000 (Guillory and Perret 1998) are assumed. Guillory (1993) estimated mortalities of 25 crabs/trap/yr in ghost traps. In addition, he found that "autobaited" ghost traps (traps containing dead incidental catch) continue to attract crabs at about 35/trap/yr. Arcement and Guillory (1993) found that mortality of blue crabs was significantly less in vented (5.3/trap) than in unvented (17.3/trap) traps because they retained significantly lower numbers of sublegal blue crabs.

The number of ghost traps and the potential impacts of ghost fishing mortality will rise if the number of traps increases and use of square mesh traps becomes more common. Square mesh traps capture more sublegal crabs and are constructed of a longer lasting, heavier gauge wire than hexagonal mesh traps (Guillory 1998c, Guillory and Hein 1998b, Guillory and Prejean 1997), and ghost trap mortality increases directly with the numbers of sublegal crabs (Arcement and Guillory 1993). Ghost traps can also be serious navigational hazards in shallow estuarine waters where they are commonly used.

9.8 Sociologic and Economic Issues Relevant to Management

9.8.1 Sociological

9.8.1.1 User Group Conflicts

Water-related activities in the Gulf have increased dramatically, exacerbating user group conflicts. All user groups have a right to public waters and should accept responsibility for alleviating conflicts. Conflicts may occur between commercial trap fishermen and waterfowl hunters, recreational fishermen, landowners, pleasure boat operators, recreational crab fishermen, and waterfront property owners. 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. One of the more volatile issues is the conflict between shrimp and crab fishermen. Crab fishermen have seen increased numbers of traps lost, damaged, or misplaced due to shrimping activities. Conversely, crab traps caught in shrimping gear can cause damage and loss of catch. Reports of friction and conflicts between these two commercial user groups have escalated in recent years.

9.8.1.2 Theft of Traps and Crabs

Theft of traps or their contents is considered by fishermen among the two most important problems in the fishery according to the sociological survey of commercial blue crab fishermen (Section 8.7.3). While there is a question regarding the extent of trap loss, perceptions that other fishermen are stealing traps creates unnecessary conflict. Increased enforcement may not resolve the problem, since crab and trap theft are difficult to identify and prosecute, even where theft is witnessed and citations issued.

9.8.1.3 Cultural Differences

While the vast majority of the blue crab fishermen are Caucasians, the Texas fishery includes a large minority of Vietnamese fishermen, and the Alabama fishery includes a significant percentage of Laotian and Cambodian fishermen. These cultural differences are seen as a source of conflict by a large number of fishermen, both between Caucasian fishermen and Asian-American fishermen, and between Vietnamese, Cambodian, and Laotian fishermen.

9.8.1.4 Perceived Problems by the Commercial Fishing Sector

Understanding peoples' beliefs and expectations about natural resources is important in fisheries management, as fisheries administrators largely manage fish populations by regulating the actions of the people who catch the fish (Voiland and Duttweiler 1984). Effective and successful fisheries management is thus dependent not only upon biological variables but also upon social, economic, and political issues. This section presents a brief listing of the views and perceptions of a representative portion of the commercial fishermen surveyed in the blue crab fishery as reported in Section 8.0. The following issues were identified by respondents as problems in the fishery:

- Industry discharge/pollution
- Crab meat imports
- Operational costs
- Local competition
- Poaching/theft of crabs and traps
- Harvest of undersized crabs
- Inadequate enforcement of existing regulations
- Too many traps
- User group conflicts
- Illegal sales by recreational fishermen
- Excessive regulations
- State legislators

9.8.2 Economic

9.8.2.1 Economic Profile of the Commercial Sector

No economic profile of the commercial fishing sector currently exists. Information pertaining to: 1) costs and returns by state and boat size, 2) interdependency among fisheries, 3) capacity of the fleet, and 4) current investment in the harvesting sector would be useful to help evaluate the benefits and costs of current and proposed regulations. Given the paucity of economic information on the fishery, any current attempt to analyze benefits and costs associated with management actions is seriously hampered.

9.8.2.2 Imports

Imports of crab products to the United States have increased substantially in recent years. Better reporting of imported crab products would provide the needed data to assess the degree of substitutability between the imported product and the domestically-harvested product. This information is important in examining the gains (losses) in consumer and producer surplus associated with alternative management measures.

9.8.2.3 Recreational

The economic contribution of the recreational component of the Gulf of Mexico blue crab fishery is lacking. Analysis of the economic contribution of the recreational component will provide information that can be used to address issues of allocation.

10.0 MANAGEMENT RECOMMENDATIONS

This management plan is broad and comprehensive in scope and addresses all relevant aspects of the biology of and fishery for blue crabs. It is intended to provide a framework for conservation of the resource and economic viability of the fishery. Detailed rationale for these management recommendations are found in Section 9.

Based on Jamieson's (1986) definitions of management strategies, management of blue crabs in the Gulf of Mexico has been "preventative." Protection of spawning stock, size restrictions, area and seasonal closures, gear restrictions, and protection of nursery grounds have been implemented to maintain fishery yield and conserve the stock. There is no evidence of a long-term decline in blue crab populations in all Gulf states (Sections 9.5 and 14.2.4). The commercial fishery, however, is overcapitalized from an economic perspective, and the high number of traps has resulted in increased user conflicts.

Blue crabs possess unique life history traits, and these species-specific attributes must be considered in establishment of harvest policy. Blue crabs are an r-selected species (Section 9.6.2.2), meaning they are highly productive, can sustain high exploitation rates, and will recover rapidly should overfishing ever occur. Present management strategies emphasize the total protection of egg-bearing females as necessary for recruitment success and the maintenance of stocks. While spawning stock must be sufficient to ensure recruitment, total protection of egg-bearing females is not biologically justified and has not increased harvest beyond the carrying capacity of Gulf estuaries. In contrast to the Chesapeake Bay blue crab fishery, the fishery in the Gulf is not recruitment limited (Sections 3.2.5.1, 3.2.8.3, and 9.6). Blue crab populations in the Gulf are limited by postsettlement biotic processes that influence survival of small juveniles. Protection of essential habitat must be an integral part of the management strategy to maintain current harvest levels. In addition, management policies should address sources of juvenile blue crab mortality.

Management agencies should commit to the improvement of fishery dependent data. There are no reliable Gulfwide data on catch and effort in the commercial and recreational fisheries, no data on size and sex composition of commercial landings, and no information on age structure. Because these traditional stock assessment parameters are unavailable for this fishery, stock assessment models must rely on fishery-independent data combined with commercial landings. Collection of these data will allow for a more rigorous assessment of stock status and will provide the baseline information necessary to assess the long-term impacts that '2-S' and '3-S' management strategies have on blue crab size (Section 3.2.2.3).

A commitment must also be made to improving the collection of fishery-independent data. All states have fishery-independent monitoring programs; however, sampling protocol and methodologies are inconsistent among Gulf states and should be standardized. Important components of these programs should include: size and weight, sex, maturity, parasitic infection, presence and absence of eggs, and molt cycle stage. Adoption of standardized fishery-independent sampling protocols and methodologies would: 1) allow for development of regional and/or Gulfwide data sets to evaluate fluctuations in juvenile abundance indices, 2) provide for estimates of size at 50% sexual maturity, 3) provide data on seasonality of spawning and spawning history, 4) provide data on infection rates of *L. texanus*, and 5) provide temporal and spatial data on pre-molt/post-molt crabs.

While there are problems in the blue crab fishery specific to individual states, there are major problems that transcend geographic boundaries. This section identifies Gulfwide problems, makes recommendations, and provides rationale in support of these recommendations.

10.1 Habitat Loss, Degradation, and Alteration

Essential marine/estuarine habitats (Sections 4.4 and 9.6.1.1) of the Gulf of Mexico have undergone dramatic changes (Section 9.6.1.2). Changes in the amount and timing of freshwater inflow may have a deleterious effect on that portion of the blue crab life-cycle taking place in the estuary. Limiting freshwater inflow through damning of rivers, channelization, and pumping water for redistribution affects salinity, reduces nutrient inputs and decreases wetland acreage. Substantial marsh habitats across the Gulf of Mexico have been lost or altered. In addition, chronic pollution of estuarine habitats from urban and agricultural runoff and industrial discharges is present, although not quantified.

10.1.1 Recommendations

1. Support those programs that identify, preserve, and/or restore essential blue crab habitat and assess and discourage projects which negatively alter blue crab habitat or impede access by crabs to essential habitats.

2. Support efforts to reduce estuarine/marine pollution.

10.1.2 Rationale

Habitat conservation, protection, access, and restoration are essential to the maintenance and stability of the fishery. Orth and van Montfrans (1990) found a significant relationship between production of blue crab and habitat, and production of other estuarine species has been linked to total vegetated habitat in Gulf states (Turner 1977, 1979; Deegan et al. 1986). Loss of essential habitat associated with reduced freshwater inflow decreases carrying capacity and limits production. The chronic, long-term effects of pollution on estuarine water quality are difficult to quantify but could potentially impact blue crab populations.

10.2 Harvest of Egg-Bearing Females

Blue crab management in the Gulf of Mexico has been directed toward protection of egg-bearing females. This strategy assumes a density-dependent relationship between spawning stock and recruitment levels that would be expected to produce a more stable population. Although egg-bearing females have been protected in all but one Gulf state, the fishery continues to exhibit wide annual fluctuations in harvest. The harvest of egg-bearing females should not be prohibited based on biological considerations.

10.2.1 Recommendations

The states should evaluate the socio-economic impacts of total prohibition of harvest of egg-bearing females.

10.2.2 Rationale

No spawner-recruit relationship has been established for blue crabs in the Gulf of Mexico, and total protection of egg-bearing females is not biologically justified. The blue crab population in the Gulf of Mexico is not recruitment limited (Sections 3.2.5.1 and 9.6). Population abundance is influenced by post-settlement processes associated with juvenile survival—quantity and quality of juvenile habitat (food and refuge) and juvenile mortality associated with capture and handling in the shrimp fishery (Sections 3.2.8.3, 4.5.2, 6.4, 9.6, and 9.7.5).

10.3 Lack of Accurate Harvesting Sector Statistics

Commercial and recreational blue crab catch and effort data are inadequate. Under reporting of hard crab landings in the Gulf of Mexico has been documented (Sections 6.1.5 and 6.2.4), and the inadequacy of recreational data noted (Section 9.7.1). Soft crab production values are poor estimates of actual production. Caffey et al. (1993) and Supan (unpublished data) have estimated actual production to be 14 to 19 times greater than reported landings in Louisiana. In addition, commercial crab license sales may not be indicative of the actual number of crab fishermen. Guillory (1998b) found that approximately 30% of Louisiana license holders in 1996 did not crab commercially for a number of reasons. Comprehensive recreational surveys have not been conducted, and recreational effort and harvest data are lacking. Development of stock assessment models in the Gulf of Mexico blue crab fishery is severely hindered by inadequate data.

10.3.1 Recommendations

1. Implement or expand existing fishery-dependent monitoring programs in each Gulf state. These programs should provide consistent data on commercial and recreational fishing effort, participation, and harvest in the hard and soft-shell blue crab fishery. Peeler crab landings should be reported separately from soft crab production.

2. Collect data that will allow for determination of CPUE in the commercial hard crab fishery, defined as pounds per trap day. A trip ticket system like Florida's which provides for collection of data on number of traps fished, soak time, and catch is recommended.

3. Enhance data by expanding state fishery surveys to include recreational crabbing.

4. The states should pursue full implementation of the FIN which will meet the monitoring and reporting requirements of this FMP.

10.3.2 Rationale

Catch and effort data are necessary to assess the status of the fishery using stock assessment models, to monitor changes in the fishery, and to manage fishery effort.

10.3.3 Size and Sex Composition in the Fishery

There are no data on size and sex composition of the commercial and recreational catch of blue crabs in the Gulf of Mexico.

10.3.3.1 Recommendations

The states should implement programs to obtain biological information on the commercial and recreational catch. This information should include size, sex, maturity, and spawning condition.

10.3.3.2 Rationale

These data would allow for use of more rigorous stock assessment models. Information on size of crabs from the total harvest would; 1) broaden the data pool for determination of size at 50% sexual maturity, 2) provide data required for determination of spawning potential and 3) broaden and improve baseline data for future evaluation of current management strategies. Biological characteristics of female blue crabs (size at 50% sexual maturity, terminal anecdysis), size-selective harvesting gear, and high fishing effort may be selecting for smaller maximum size. Although the data are scant, there is some evidence that genetic selection may be occurring in other brachyuran fisheries that share similar life history traits and fishery-related parameters with blue crabs.

10.4 Inadequate Fishery Independent Data

Biological data obtained on blue crabs from fishery independent sampling programs are inconsistent.

10.4.1 Recommendation

The following data should be obtained for blue crabs: size, sex, rhizocephalan infections, sexual maturity (females), presence of eggs, molt condition (i.e., hard, soft, buster, etc.), and weight when possible.

10.4.2 Rationale

Standardized data components would allow for the completion of a consistent data base that will facilitate stock assessments or determination of certain critical life history parameters.

10.5 Gear Saturation

From an economic perspective, the commercial blue crab fishery of the Gulf of Mexico is overcapitalized. The high number of traps has resulted in user group conflicts and increased ghost trap fishing. The overall catch per fisherman is declining suggesting that although the fishery may be able to tolerate additional fishing pressure, the fishery would become less profitable to individual fishermen. The relatively low-fixed investment requirements and high resource abundance, coupled with other economic and sociological factors, resulted in a dramatic increase in blue crab fishing effort in the Gulf of Mexico during the middle 1980s. Gross income in the fishery is relatively constant when evaluated on a deflated basis, and profitability may be declining because of increased operating costs to the fishermen.

10.5.1 Recommendations

Reduce fishing effort by reducing the number of fishermen and the number of traps allowed. Several options exist including licensing moratoriums, qualifying income and license criteria, license buyback programs, trap limitations, and trip quotas.

10.5.2 Rationale

Total landings in an open access fishery generally increase but at a decreasing rate with successive unit increases in effort. Eventually, a point is reached where no further increase in landings is realized. Consequently, catch (and revenue) per fisherman will eventually decrease in an expanding fishery. Catch per fisherman has declined in the Gulf states over time (Section 9.7.3). Reduction of fishing effort by limited entry is increasingly being employed in various fisheries throughout the United States and the world. Programs to reduce the number of fishermen are in effect in Florida and Texas and were in effect in Louisiana from 1996 to 1998. However, a reduction in the number of fishermen must be accompanied by a simultaneous reduction in the number of traps per fishermen to be effective. Trap number is currently restricted only in Texas. Limited entry and trap limitation are mechanisms that could enhance profitability within the fishery. A reduction in fishing effort would increase economic return to the fishermen through decreased operational expenses (gear, bait, and fuel) and an expected increase in catch per trap (Section 9.7.2). Trap limitation was the most common recommendation from commercial blue crab fishermen surveyed for the sociologic profile (Section 8.8.1).

10.6 Wasteful Harvesting Practices

10.6.1 Capture and Harvest of Sublegal Crabs

The capture and subsequent sale of sublegal crabs is a problem in some states. One contributing factor is increased use of 1.5" square mesh traps, which catch significantly higher numbers of undersize crabs than hexagonal mesh traps (Guillory 1998c, Guillory and Hein 1998b, Guillory and Prejean 1997).

10.6.1.1 Recommendations

1. Require liability for those in possession of sublegal crabs.

2. Require use of escape rings. Each crab trap should include three unobstructed escape rings (2.375" minimum inside diameter) located on the outside walls of the upper or outer chamber flush with the floor or baffle. Exceptions to the use of escape rings may be necessary for peeler traps.

3. Require minimum mesh size restrictions. Minimum outside wall mesh sizes of 1.5" (measured from corner to corner on the base) for hexagonal and 1.75" (measured from corner to corner) for square mesh should be adopted for hard crab traps. Minimum outside wall mesh size of one inch may be allowed in peeler traps.

10.6.1.2 Rationale

Catch of sublegal crabs may increase mortality through trap/handling stress. There is evidence that injuries and/or physiological stress from trap capture and handling results in delayed mortalities and reduced future growth rates in many decapods (Murphy and Kruse 1995). A seven percent delayed mortality of trap-caught blue crabs was documented in a North Carolina study (McKenna and Camp 1992). Capture related injuries may also reduce future growth rates. Multiple limb loss and chelotomy significantly reduce the growth increment at molting (Smith 1990, Ary et al. 1987, respectively). Substantial injuries occur in the trap or during culling; Eldridge et al. (1979) found that 57% of the crabs in his study had damaged appendages. Additionally, the sale of sublegal crabs is an enforcement problem and an inefficient use of the resource. Harvest of sublegal crabs results in a reduction of processed and total yield (harvest weight) from the fishery. Holding possessors of sublegal crabs liable would provide incentive to comply with size restrictions. Escape rings (Guillory and Hein 1998a) and/or minimum mesh restrictions (Guillory 1998c) would reduce the catch of sublegal crabs. Escape rings are currently mandated in Florida, Louisiana, and Texas and a minimum mesh restriction (1.5" minimum) for hard crab traps is present in Florida.

10.6.2 Bycatch of Blue Crabs and Incidental Trap Catch

Studies of shrimp trawl bycatch in Texas and Louisiana indicate that substantial numbers of blue crabs, especially juveniles, are captured. Hammerschmidt et al. (1998) estimated that an average of 82 million blue crabs were captured annually from 1990-1994 in the Texas inshore shrimp fishery. Using data from Adkins (1993), an estimated 20.5 million lbs of crabs were captured in the 1989 Louisiana shrimp fishery. Bycatch of other species in crab traps may also pose a problem in some areas.

10.6.2.1 Recommendations

1. Encourage adoption of bycatch separation practices that reduce non-directed fishing mortality (standardized salt box protocols, reduction of tow and culling time), particularly in shallow water nursery habitats.

2. In localized areas where incidental catch of terrapins is a concern, impose appropriate measures to reduce mortality (e.g., degradable panels, excluder devices, or area/seasonal closures).

10.6.2.2 Rationale

Both onboard and delayed mortality may impact population levels of juvenile and adult crabs taken as bycatch. According to a North Carolina study, delayed mortalities of blue crabs captured in trawls was 20% in the cooler months and 80% in the warmer months (McKenna and Camp 1992). Data on use of salt boxes to separate bycatch from shrimp is conflicting. Studies in Texas (Colura and Bumguardner, in press) and Alabama found that survival of crabs subjected to salt box separation was more affected by tow and culling time than by immersion in brine. In fact, Colura and Bumguardner (1997) suggested that the use of salt boxes significantly reduced catch separation in controlled experiments and that salt box use could possibly reduce total mortality by speeding catch separation time. These studies, however, did not address increases in delayed mortality from prolonged exposure to the brine solution or repeated dippings. Adkins (1993) recommended the elimination of salt boxes because in some instances, chemicals other than sodium chloride were added to the mixture to increase specific gravity of the liquid.

There are no standardized protocols for salt box use: salinities are highly variable and the practice of adding other chemicals to the solution is undocumented. Bumguardner and Callirhoe (1997) reported salinities in salt boxes in the Texas shrimp fleet ranged from 35 to 92‰. In both, the Texas and Alabama studies an average salt box salinity (calculated from data from the shrimp fishery) was used to determine survivorship and there are no data on values in excess of the average. Extreme hypersaline conditions may result from failure to regulate target concentrations due to evaporation of water over time. Considering the number of crabs which are harvested (Adkins 1993, Hammerschmidt et al. 1998) and the high mortality rates associated with capture and handling in the shrimp fishery (Callirhoe and Bumguardner, in press), future maintenance and enhancement of the harvestable portion of the stock may be dependent on reducing this and other sources of juvenile mortality.

Seigel and Gibbons (1995) concluded that drowning in crab traps is a major threat to diamondback terrapin (*Malaclemys terrapin*) populations. Degradable escape panels will reduce ghost fishing of other species captured in crab traps.

10.6.3 Ghost Traps

Mortality of blue crabs and finfish in ghost traps is a concern. Substantial numbers of crab traps are abandoned or lost due to uncontrollable factors (i.e., tides, currents, storm surges), negligence by the fishermen in properly assembling and maintaining buoys and attachment lines, inadvertent clipping of float lines by vessel propellers, and the use of plastic jugs or bottles as floats which may become brittle and deteriorate with weathering. Crab mortality in ghost traps varies based on area, season, and length of time in the water. Guillory (1993) found average mortality rates in ghost traps in Louisiana of 25.8 crabs/trap over a one year period. In a related study, Arcement and Guillory (1993) found an average mortality of 17.3 crabs/trap over three months. Guillory (1993) and Whitaker (1979) collected 16 and 13 species of finfish in monitored ghost traps in Louisiana and South Carolina, respectively.

The number of ghost traps and the potential impacts of ghost fishing mortality will rise if the number of traps in the fishery increases and square mesh traps become more common. Square mesh traps capture more sublegal crabs and are constructed of a heavier-gauge wire which resists corrosion for a longer period of time than traps made of lighter gauge wire (Guillory 1998c, Guillory and Hein 1998b, Guillory and Prejean 1997).

10.6.3.1 Recommendations

1. Require the use of degradable escape panels or tie-down straps (Sections 5.2.1.7.3 and 5.2.5.7.3).

2. Encourage crab fishermen to remove inactive traps from the water.

3. Require the use of six-inch minimum diameter or equivalent solid floats and a ¼" minimum diameter nonfloating, nonmetallic buoy line.

4. Prohibit use of plastic jugs or bottles as floats.

5. Require escape rings. Each crab trap should include three unobstructed escape rings (2.375" minimum inside diameter) located on the outside walls of the upper or outer chamber flush with the floor or baffle. Exceptions to the use of escape rings may be necessary for peeler traps.

6. Require minimum mesh size. Minimum outside wall mesh sizes of 1.5" (measured from corner to corner on the base) for hexagonal and 1.75" (measured from corner to corner) for square mesh should be adopted for hard crab traps. Minimum outside wall mesh size of one inch may be allowed in peeler traps.

7. Encourage derelict trap removal programs.

10.6.3.2 Rationale

Degradable escape panels or tie-down straps will allow blue crabs and finfish captured in ghost traps to escape after a certain period of time. Removal of inactive crab traps from the water will reduce ghost fishing mortality. The use of floats and buoy lines as recommended will reduce trap loss. Reduction in lost crab traps will benefit both fishermen and the resource by reducing ghost fishing mortality. Escape rings and minimum mesh size requirements will reduce both the catch of sublegal crabs and ghost fishing mortality. Some states may require regulatory changes to allow removal of derelict traps by individuals other than the original trap owner. A derelict trap removal program will reduce the number of abandoned traps and associated ghost fishing mortality and reduce gear encounters and may diminish user group conflicts.

10.7 Peeler Crab Availability

Since the widespread adoption of closed, recirculating seawater systems reduced the problem of poor estuarine water quality in open, flow-through systems, the availability of premolt crabs has become the primary limiting factor in soft crab shedding operations (Guillory 1996, Perry et al. 1982).

10.7.1 Recommendation

Each Gulf state should exempt peeler crabs held for shedding from the minimum five-inch carapace width size limit for hard blue crabs.

10.7.2 Rationale

A five-inch size limit for hard crabs significantly reduces the harvest of peeler crabs because most peeler crabs taken for shedding are smaller than five inches.

10.8 User Group Conflicts

Water-related activities have increased dramatically, exacerbating user group conflicts. All user groups have a right to public waters and should accept responsibility for alleviating conflicts. Conflicts may occur between commercial trap fishermen and waterfowl hunters, recreational fishermen, landowners, pleasure boat operators, recreational crabbers, and those people concerned about visual aesthetics. 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.

One of the more volatile issues is the conflict between shrimp and crab fishermen. Crab fishermen have seen increased numbers of traps lost, damaged, or misplaced due to shrimping activities. Conversely, crab traps caught in shrimping gear can cause damage and loss of catch. Reports of friction and conflicts between these two commercial user groups have escalated in recent years.

10.8.1 Recommendations

1. Reduce fishing effort in the blue crab fishery by decreasing the number of fishermen and traps allowed. Several options exist including licensing moratoriums, qualifying income and license criteria, license buyback programs, and trap limits.

2. Implement area, seasonal, or gear restrictions in regions of high user group conflict. These measures could apply to any or all user groups.

3. Require crabbers to remove all inactive traps from the water.

4. Allow onshore disposal or recycling of ghost traps caught in shrimp gear.

5. Encourage recycling programs for abandoned/discarded traps.

6. Educate user groups to take responsibility for their actions on public waters. Reduction of user group conflicts can be promoted through outreach programs supported by local, state, and federal resource agencies and local, state, and national conservation and fishing organizations.

10.8.2 Rationale

Public waters are shared by numerous user groups and as interaction between these groups increases, conflict is more likely to occur. Education has been shown to be an effective tool to reduce user conflicts on public waters. Additionally, measures that minimize encounters between user groups and facilitate removal of inactive and/or unserviceable traps (ghost traps) will aid in reduction of conflicts.

10.9 Trap and Crab Theft

Theft of traps or their contents has always been a problem in the fishery, but escalated when the fishery began to expand dramatically during the mid 1980s, resulting 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.

10.9.1 Recommendations

1. A trap tagging system coupled with vessel identification should be adopted to facilitate enforcement efforts.

2. Stricter penalties and/or fines for trap or crab theft violations should be applied. Penalties should include license suspension or revocation.

10.9.2 Rationale

Trap tagging and vessel identification would facilitate enforcement efforts to curtail thefts. Combined trap/vessel identification systems are required in Florida, Mississippi, and Texas. Increased penalties or fines may act as a deterrent to theft.

10.10 Resource Management

Good resource management is closely linked with adequate law enforcement. Enforcement issues include biological parameters associated with harvest (size and sex), seasonal and area closures, and theft of crabs and traps. Biological issues include lack of financial resources dedicated to specific research needs. Additionally, the negative public perception of the fishery has masked its economic importance.

10.10.1 Recommendation

Agencies charged with management, research, and enforcement should be afforded those resources necessary to accomplish their objectives. States should review the current level of financial support being received for research, management, and enforcement to determine the adequacy of current funding levels.

10.10.2 Rationale

Responsible management of the fishery will require long-term continuation of ongoing research and monitoring programs, implementation of needed, special projects, and enforcement of blue crab regulations.

11.0 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 long-range planning, coordination, and funding for interstate research programs and standardized, Gulf-wide fishery independent and fishery dependent data collection programs. These categories do not reflect any order of priority.

11.1 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.

11.2 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 Gulfwide 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 Fishery Statistics Survey (MRFSS).

11.3 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.

11.4 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.

12.0 REVIEW AND MONITORING OF THE PLAN

12.1 Review

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.

12.2 Monitoring

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 10 on an annual basis.

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14.0 APPENDIX

14.1 Glossary of Terms

Modified from: Wallace, R.K., W. Hosking, and S.T. Szedlmayer. 1994. Fisheries Management for Fishermen: A manual for helping fishermen understand the federal management process. Auburn University Marine Extension & Research Center.

Abundance - See relative abundance and absolute abundance.

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.

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.

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.

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.

Directed Fishery - Fishing that is directed at a certain species or group of species. This applies to both sport fishing and commercial fishing.

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.

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.

Euryhaline - Organisms that live in a wide range of salinities.

Ex-vessel - Refers to activities that occur when a commercial fishing boat land 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.

Fecundity - A measurement of the egg-producing ability of an organism. Fecundity may change with the age and size of the crab.

Fishery - All the 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.

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.

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.

Incidental Catch - See bycatch.

Instantaneous Mortality - See fishing mortality, natural mortality, and total mortality.

Juvenile - A young individual that has not reached sexual maturity.

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.

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.

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 study 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.

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.

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.

Open Access Fishery - A fishery in which any person can participate at any time.

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 greater than which will meet the management goal.

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).

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.

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.

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.

Sport Fishery - See recreational fishery.

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.

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.

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 ofindividuals in a cohort at various ages.

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.

Year-Class - Individuals spawned and hatched in a given year.

Yield - The production from a fishery in terms of numbers or weight.

14.2 Stock Assessment Models for Blue Crabs in the Gulf of Mexico

14.2.1 Introduction

Stock assessment of Gulf of Mexico blue crab was limited by an absence of reliable fishery dependent data. No credible catch per unit of effort data (CPUE) were available, and there is no information on the population age structure in the commercial fishery. Blue crab fishing effort data is only collected by Florida where a trip ticket system was initiated in 1985. A potential source for estimating effort was through the number of licenses and traps sold; however, although each Gulf state requires crab fishermen to be licensed, licenses do not reveal the number of traps fished or how intensively they have been fished. Also, Guillory (1998c) reported that 30% of licensed crab fishermen in Louisiana in 1996 did not crab commercially; therefore, the number of licenses may not accurately reflect the number of active fishermen.

In addition to lack of reliable effort data, stock assessment was hampered by inadequate data on hard crab harvest and the lack of information on recreational catch. Blue crab landings are poor estimates of actual harvest. According to Lyles (1976), Moss (1982), and Meeter et al. (1979), blue crab landings do not necessarily reflect population abundance but may be driven by socio-economic conditions in the fishery. Additionally, crabs are often shipped to out-of-state buyers with little or no accountability. Crabs sold in the "basket trade," to the general public, and to restaurant and retail outlets often go unreported. However, accuracy of landings may have improved in recent years as states began individual programs to collect fishery-dependent harvest data.

A very important component of contemporary stock assessment is knowing the age structure of the species under study. Finfish species are commonly aged through three methods; the interpretation of calcified tissue (e.g., dermal scales, otoliths or other bones, and fin spines), return data from tagging experiments, and assigning age classes to modes in size frequency distributions. These techniques were difficult to apply to blue crabs as they lack somatic hard parts found in fish, and tag recapture is difficult because of ecdysis. Assigning age classes to distributional modes also presents problems. Blue crabs experience discrete rather than continuous growth. Additionally as blue crabs mature, molt interval increases, and there is a terminal molt in females at age one. Finally, the spawning season in the Gulf is protracted (March to November), and spawning may take place year round in warm winters. The continuing recruitment and overlap of modal groups complicates the assigning of age classes without corroborative information. Consequently, it is difficult to assign ages to modal groups in size frequency distributions.

These obstacles limit the options available for assessing stock status and place restrictions on interpretation of results. Virtual population analysis (VPA) is currently a popular assessment tool but was not used in this study because it is an age structured, data-intensive technique. Gulland and Rosenberg (1992) also stated that VPAs are excellent for looking at the history of long-lived fish but are less useful for short-lived fish (blue crab is a short-lived invertebrate). Holistic models, however, do not require data on the age structure of the stock and CPUE; therefore, this approach was used in conjunction with other indicators of stock status to assess the blue crab population of the Gulf of Mexico. Although holistic models are less data demanding, they require some assumptions not supported by blue crab life history parameters in the Gulf (e.g., discrete growth, terminal anecdysis in females, and constant natural mortality); thus caution should be exercised when interpreting holistic models. Extensive development of models to define population characteristics has created a perception of precision beyond that warranted by the data. Indicators of stock status used to assess the blue crab population of the Gulf of Mexico included long-term sustainable yield (LSY, or landings history) and the following fishery independent indicators: estimates of relative abundance, length based estimates of total mortality, mean carapace width, and capture frequency. CPUE and mean carapace width data were categorized into recruits (<127 mm carapace width), post-recruits (>127 mm carapace width), males and females. Sex information was not collected in Texas and were collected in

Alabama for years 1983-1989. Since all the Gulf states now collect data on crab carapace width as part of their fishery independent monitoring programs, width frequency analysis played a major role in the assessment. This report represents the first attempt to assess blue crab populations in the Gulf of Mexico.

14.2.2 Materials and Methods

Data for all methodologies were obtained from fishery independent monitoring and assessment programs in each state, and fishery-dependent commercial landings (NMFS Commercial Fisheries Statistics internet site) which included hard, soft, and peeler crabs for the Gulf only. Fishery independent data from 16- and 20-foot otter trawls were used for population abundance, size, and mortality estimates. Annual indices of relative abundance were expressed as catch per unit of sampling effort (CPUE) and percent frequency of occurrence in samples.

The von Bertalanffy (1938) growth equation was used to model blue crab growth rate,

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

where CW_t is the carapace width at time t; CW_∞ 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_∞, widths at ages, and maximum age.

CW_∞ was estimated by the modified Wetherall et al. (1987) technique,

$$(\overline{CW} - CW') = \beta_0 + \beta_1(CW')$$

where $\overline{CW}$ was the mean carapace width of crabs CW' in width and larger, CW' the lower bound of a size interval in a size frequency distribution, and β_0 and β_1 represent the estimated y-intercept and slope of the fitted line, respectively. Calculating $\overline{CW}$ by starting with the largest size class and fitting a straight line to the above data pairs provided an estimate of CW_∞ as the point where the fitted line intercepted the x-axis,

$$CW_\infty = -\frac{\beta_0}{\beta_1}$$

A second estimate of CW_∞ was obtained through Beverton's (1963) technique of dividing the maximum size occurring in a well sampled stock by 0.95,

$$CW_\infty = \frac{CW_{max}}{0.95}$$

This approach is based on the observation that, in general, the oldest individuals of a stock grow to reach about 95 percent of their asymptotic length.

Carapace widths at ages were based on Tagatz (1968b) study in the St. Johns River in Florida, a similar latitude of the Gulf of Mexico. Average monthly carapace width measurements were used for crabs hatched in April, July and October.

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 (1921) presumed 6 years from anecdotal evidence. Rothschild and Ault (1992) also assumed a maximum age of six years in their assessment of Chesapeake Bay blue crabs.

Once the von Bertalanffy growth model was developed, CW_∞ and K were used in Hoenig's (1987) formula to compute annual estimates of instantaneous total mortality rate, Z.

$$Z = \log_e \left[\frac{(e^{-K}(\overline{CW} - CW_\infty)) + CW_\infty - CW_r}{(\overline{CW} - CW_r)} \right]$$

where CW_r was the carapace width at full recruitment to the sampling gear and $\overline{CW}$ was the mean carapace width of crabs measuring CW_r and greater. Caution should be used in interpretating Z since it's assumed that von Bertalanffy growth is similar for both sexes and Helser and Kahn (1999) reported that this formula may be sensitive to recruitment fluctuations While the von Bertalanffy growth curve may accurately describe growth for both sexes up to age one it may not accurately describe females beyond one year. Also, an influx of recruits decreases the value of $\overline{CW}$ thereby increasing Z; therefore, large values of Z may indicate high recruitment rather than high mortality. Correlation analysis was performed between recruitment CPUE and Z to determine if this problem was present.

Fishing mortality is traditionally estimated by subtracting natural mortality from total mortality. Most methods for estimating natural mortality require fishing effort or tag return data. Because these data are lacking in the Gulf blue crab fishery, the International Council for the Exploration of the Sea (ICES) convention of dividing three by the maximum age (Anthony 1982, Vetter 1985) was considered. However, while the ICES approach may work well for long lived, cold water, finfish species; its applicability to short lived, warm water, invertebrates is unknown; therefore, total mortality was not broken down into component parts because fishing mortality and natural mortality were not required in the surplus production modeling process.

Csirke and Caddy's (1983) technique to model surplus production was used as an approach to estimate maximum sustainable yield, MSY. Their model fits a convex parabola to a plot of landings versus instantaneous rates of total mortality,

$$Y = \beta_0 + \beta_1 Z + \beta_2 Z^2$$

where Y=yield (i.e. landings). MSY is then estimated as,

$$MSY = \beta_0 - \frac{\beta_1^2}{4\beta_2}$$

and the instantaneous rate of total mortality corresponding to MSY, Z_{MSY}, by

$$Z_{MSY} = -\frac{\beta_1}{2\beta_2}$$

This approach assumes that: 1) landings represent a relatively constant fraction of total removals, 2) estimates of total mortality are reliable, and 3) a relationship exists between landings and total mortality. There are problems with applying these assumptions to the blue crab fishery. As previously stated, landings may be more reflective of socio-economic conditions in the fishery rather than actual population abundance, and parameters used to calculate total mortality (maximum carapace width, maximum age, carapace widths at age, and non-sex specific growth rates) are somewhat arbitrary or non-existent.

Yearly estimates of instantaneous rates of total mortality, reported commercial landings, indices of relative abundance, mean carapace width, and percent frequency of occurrence were subjected to polynomial regression model building to inspect for long and short term trends through time (all available data and five most recent years, respectively). The convention consists of fitting a simple linear model and testing for a significantly fitting model. Increasing powers of the independent variable are entered step-wise into the model and tested for a significant improvement in fit at each step by testing the additional sum of squares accounted for by entering additional terms into the model. This process is continued until two consecutive non-significant improvements in fit are achieved. The "best" fitting model is the last model to achieve a significant improvement in fit. Simple linear regression was used to model long term data to detect general trends (i.e. linear increasing or decreasing). Statistical hypothesis testing was performed at the $\alpha=0.05$ level of significance.

14.2.3 Results and Discussion

The first step in the assessment procedure was estimating the von Bertalanffy growth parameters for blue crabs gulf-wide. An initial esitmate of CW_∞ is required which is further refined by the model fitting procedure. One estimate was derived using the Wetherall et al. (1987) technique by grouping blue crab carapace width measurements into five millimeter (mm) size classes and, beginning with the largest class, computing mean carapace widths for crabs larger than the lower limits of the respective class boundaries (Table 14.1). Only data points which appeared to lie in a straight line (Table 14.1, data pairs 3 through 11) were used in the regression analysis (Figure 14.1). The equation for the fitted line was,

$$(\overline{CW} - CW') = 155.800 - 0.582(CW')$$

which resulted in an estimate of $CW_\infty = 268$ mm.

A second, comparative estimate of CW_∞ was derived from Beverton's (1963) technique of dividing maximum carapace width of a well sampled population by 0.95. The maximum carapace width occurring in the data base which was considered to be a reliable measurement was 260 mm; therefore, this approach yielded an estimate of 274 mm, a value similar to the one achieved by the Wetherall et al. (1987) method. The Wetherall et al. (1987) result was used in subsequent analysis since this estimate relied on a greater number of data points and Sparre et al. (1989) considered this approach the best estimate of CW_∞.

Carapace widths at ages derived from Tagatz (1968b) revealed varying growth rates depending on the month hatched, but since general growth increments were required, monthly carapace width measurements were averaged across hatching months (Table 14.2). This procedure yielded twelve monthly growth increments from larval stage to age one. Additional width at age values included 1) age 2 = 179 mm and 2) maximum age = 6 years with a corresponding width of CW_∞=268 mm. Thus 14 data points (Figure 14.2) were used to fit the von Bertalanffy growth equation,

$$CW_t = 276(1 - e^{-0.663(t - 0.169)})$$

This estimate of $K = 0.663$ is slightly greater than those reported by Rothschild et al. (1991) and Rugolo et al. (1997) who estimated $K = 0.506$ and 0.587, respectively for Chesapeake Bay blue crabs. However, blue crab growth is temperature dependent and occurs only above 9°C causing Bay crab growth to cease in November and begin again the following April (Miller and Houde 1998). Thus Gulf crabs may reach maximum size within the first year but Chesapeake Bay crabs may not reach maximum size until their second summer (Smith 1997) thereby explaining the greater growth coefficient for the Gulf. The values of $K = 0.663$ and $CW_{\infty} = 276$ were then used as input for Hoenig's (1987) technique of estimating rates of total instantaneous mortality for each state.

Estimates of MSY were attempted using the surplus production model; however, regressing landings on total mortality estimates did not result in the required convex parabola. This was primarily due to narrow ranges of total mortality estimates and relatively few years of data. Therefore, it was impossible to determine the position of the data points on the desired parabolic shape (ascending arm, peak, or descending arm). This problem was encountered for all states; therefore, attempts to estimate MSY were discontinued.

14.2.3.1 Florida

Ten years of fishery independent data were available from the Tampa Bay and Charlotte Harbor regions. These data yielded length-based estimates of total instantaneous mortality rates ranging from 0.935 to 1.153 (Table 14.3) and indicated no significant inter-annual trends (Figure 14.3). Correlation analysis between recruit CPUE and Z resulted in no significant relationship indicating that mortality estimates were independent of recruitment levels.

Estimates of relative abundance ranged from 2.3 to 14.4 individuals per tow. The 14.4 estimate for 1998 appears to be an anomaly as this figure is more than triple the next highest estimate. It should be noted that sampling effort was reduced from an average of 614 tows per year from 1989 to 1997, to 248 in 1998 which may have influenced the estimate. Omitting the 1998 data resulted in no significant relationships between years and CPUE (Figures 14.4 and 14.5). Inclusion of the 1998 data, resulted in significant long term relationships for all categories (recruits, post-recruits, males, females and composite data) thus this data point was very influential in the analysis. No significant short-term trend was detected for any category either with or with the 1998 data.

Percent frequency of occurrence ranged from 35.1 to 81.1%. The 81.1% value was for 1998 and helps to explain the unusually high CPUE estimates mentioned previously. Although sampling intensity was reduced in this year, the selected sampling locations apparently fell in areas favorable to blue crab occurrence as they were caught in an unusually high number of samples. No significant trends through time were detected in long- nor short-term analyses (Figure 14.6). Annual mean carapace widths ranged from 91.9 to 111.5 mm. No significant trends through time were detected in long- nor short-term analyses for any category (Figures 14.7 and 14.8).

Reported landings ranged from 684,400 lbs in 1950 to 20,609,200 lbs in 1965. A cubic polynomial best described the landings trend through years (Figure 14.9). Landings generally increased from 1950 until they peaked in 1965. Landings decreased to a recent minimum in 1991 and generally increased thereafter. No short term trend was detected and there was no drastic decline from which there was no recovery. Reported landings averaged 10,173,398 lbs (SE=626,059) for the 49 year period.

No signs of stock stress were detected in the analysis of Florida data. Excluding 1998 data, there was no significant increase in total mortality rates and no significantly declining trends in estimates of relative abundance, mean carapace width, percent frequency of occurrence nor landings.

14.2.3.2 Alabama

Fifteen years of fishery independent data were available for the state of Alabama. Length-based estimates of total mortality ranged from 1.003 to 1.259 (Table 14.4, Figure 14.10) and showed no significant correlation with years or recruit CPUE.

Estimates of relative abundance ranged from 0.2 to 1.6 individuals per tow with the 1.6 value for 1984 appearing to be unusually high, almost twice the next highest value. Omitting this value in trend analysis resulted in no long term trends for any category except post-recruits which exhibited a significantly decreasing trend (Figure 14.11). Including this datum in the analysis resulted in significantly declining trends for recruits, post-recruits, and composite data with no significant trend persisting for males and females. It's important to note that collection of sex data for blue crabs in Alabama discontinued in 1989, and only seven years of data were available (Figure 14.12). No short-term trends were detected for recruits, post-recruits nor composite data. Males and females were not analyzed for short term results since the analyses would have been meaningless with respect to most recent information.

Percent frequency of occurrence ranged from 38.8 to 74.7%. The maximum value occurred in 1984 and may help to explain the relatively high CPUE estimates for this year. Apparently there was strong recruitment in 1984 as blue crabs occurred in an unusually large number of samples which resulted in unusually large estimates of CPUE. No short-term trend was detected (Figure 14.13).

Mean carapace width varied little ranging from 50.2 to 73.2 mm. The post-recruit size class resulted in a significantly fitting fourth-degree polynomial describing the relationship between carapace width and years (Figure 14.14). However, it's important to note that although statistical analysis detected significant fluctuations among years, there was no significant linear trend. This indicates that although mean carapace width varied upward and downward during the 15 year time series there has been no overall significant increase nor decrease in mean carapace width for this category from 1983 to present. No significant trend through years was detected for the composite data nor the recruit size class and no short-term trend was detected for any category (Figure 14.15).

Landings ranged from 498,800 lbs in 1960 to 4,216,125 lbs in 1984. A linear model with an increasing slope best described the long- and short-term trends through years (Figure 14.16). There was no decline in landings from which there was no recovery. Landings averaged 1,984,056 lbs (SE=137,688) for the period 1950 - 1998.

Consistent signs of stock stress were not detected in the analyses of Alabama data. Landings increased significantly, but this did not result in a significant increase in total mortality rates. Estimates of relative abundance were relatively stable with no siginificant declining long-term trends except for the post-recruit size class. Percent frequency of occurrence declined significantly, but this did not translate into a significant declining trend in CPUE. No significant declines were observed in long-term analysis of mean carapace width indicating there's been no systematic decrease in the size of blue crabs.

14.2.3.3 Mississippi

Twenty six years of fishery independent data were analyzed to assess the blue crab population in Mississippi (Table 14.5). Estimates of total mortality ranged from 0.875 to 1.866 and indicated no significant trend through years (Figure 14.17). Mortality estimates were positively correlated with recruitment levels but the fitted line accounted for only 22.0% of the variability between mortality estimates and years, and high mortality estimates occurred during years of relatively low as well as high recruitment.

Estimates of relative abundance ranged from 0.7 to 14.5 individuals per tow. The estimates for 1978 and 1979 appear to be anomalies as these figures were relatively higher than other years. Omitting these data points resulted in no significant relationships between years and CPUE for any category (Figures 14.18, 14.19). Including these data resulted in significantly declining trends for all categories except post-recruits thus these data were very influential in the analysis. In general, CPUE estimates were relatively stable after 1981. No short-term trend was detected for any category.

Percent frequency of occurrence ranged from 33.3 to 81.2% and resulted in no significant trend through time (Figure 14.20). Mean carapace widths ranged from 35.3 to 77.6 mm and resulted in no significant trends through years except for males which resulted in a significantly increasing trend (Figures 14.21 and 14.22). Landings ranged from 171,667 lbs in 1994 to 4,040,100 lbs in 1950 and averaged 1,482,410 lbs (SE=113,176). Trend analysis resulted in significantly declining landings over the long term but a significantly increasing short-term trend (Figure 14.23).

Landings history indicated a potential decline in stock health. The decrease in landings from 1987 to 1994 appears alarming but Perry et al. (1998) attributed this decline not to a declining population but to: 1) the introduction of management regulations restricting harvest and fishing area, 2) increased product being landed out of state, 3) a loss of processing capacity, and 4) the economic interdependency of the crab fishery with other fisheries. None of the other indicators of stock status showed signs of concern. There was no significant increase in total mortality rates and no significant decrease in CPUE, frequency of occurrence, or mean carapace width.

14.2.3.4 Louisiana

Louisiana data spanned the longest time series, 32 years. Estimates of total mortality from 1967 to 1998 ranged from 0.558 to 0.894 (Table 14.6) and resulted in a significantly increasing linear trend (Figure 14.24). There was no significant correlation between total mortality estimates and estimates of relative abundance for recruits.

Estimates of relative abundance ranged from 3.3 to 14.7 individuals per tow. Mean CPUE estimates decreased significantly for recruits and increased significantly for post-recruits with the combined effect resulting in no significant trend for the composite data (Figure 14.25). CPUE estimates for 1980, 1990 and 1991 appeared to be unusually large but removing these data had no effect on the results of statistical tests. The significant increase in recruit CPUE may be due to the short-term effect of estuarine degradation occurring in Louisiana coastal wetlands. As estuaries erode and subside, there is an increase in shallow marsh-edge habitat (Browder et al. 1989), a favorable area for growth and survival of early juvenile blue crabs. The significant decline in post-recruit CPUE may best be explained by the significant increase in estimates of total mortality. If natural mortality is assumed to be constant then the significant increase in total mortality is due to a significant increase in fishing mortality. Percent frequency of occurrence ranged from 48.7 to 79.9% and averaged 67.5% over the 32 year time series. There was no significant trend through years (Figure 14.26).

Recruits and post-recruits both resulted in significantly declining linear trends in mean carapace width with significant curvilinear fluctuations through years (Figure 14.27). These results indicated the importance of not restricting trend lines to the linear form. According to the linear trend (r^2=0.192, p=0.0154), mean carapace width for recruits was estimated to be 53 mm in 1967 and 46 mm in 1998, a difference of 7 mm. According to the third degree polynomial (r^2=0.454, p=0.0011), mean carapace width was estimated to be 54 mm in 1967 and 38 mm in 1998, a much larger difference (16 mm) than provided by the linear. Post-recruits showed a more drastic difference. The linear trend (r^2=0.174, p=0.0218), provided estimates of 154 mm for 1967 and 150 for 1998, a decline of 4 mm. But the third degree polynomial

(r^2=0.523, p=0.0004) indicated an increase rather than a decrease in mean carapace width, 151 mm for 1967 and 154 mm for 1998. Therefore, if one is interested in generalizing trends by using the linear form, it is recommended that the best fitting model also be considered.

Although linear trends indicated a significant decline in mean carapace width, this result must also consider better fitting, curvilinear models. Mean carapace width for fully-recruited crabs declined 2.4% according to the linear model but increased 1.8% according to the curvilinear. This result may due to the significant increase in abundance of recruits coupled with the significant decrease in abundance of post-recruits and not to a systematic decrease in crab size. Mean carapace width can be affected by three conditions: 1) increased numbers of small crabs, 2) decreased numbers of large crabs, or 3) a systematic reduction in somatic size. The situation in Louisiana currently consists of significantly increasing estimates of relative abundance for recruits and significantly decreasing estimates for post-recruits. For example, an additional correlation analysis was conducted between mean carapace width (composite data) and recruit CPUE, and results indicated that mean carapace width was indeed significantly correlated (negatively) with recruit CPUE.

Landings ranged from a low of 5,891,600 lbs in 1964 to a high of 53,716,989 lbs in 1988. The average landings for the 49 year period was 21,440,027 lbs (SE=2,087,395). A fourth-degree polynomial best described the long term trend through time (Figure 14.28). In general, landings increased slightly from 1950 to 1955, dropped slightly until 1966, then increased at a considerable rate until a peak was reached in 1988. Although landings have generally declined from 1987 to present, there's been a significant increase in landings over the past five years.

Assessing the blue crab population in Louisiana waters was difficult because of somewhat contradictory results. Although the significant increase in total mortality rates, significant decline in CPUE of crabs fully-recruited to the fishery, and decrease in average crab size suggest a cautionary interpretation of these data; other positive indicators may ameliorate these concerns. For example, the significant increase in CPUE of the recruit size class accounts for the decline in average size. Additionally, landings have generally increased since 1966, and the frequency of occurrence in samples indicated no significant trend over time.

14.2.3.5 Texas

Seventeen years of fishery independent data from the Texas coast yielded total mortality estimates ranging from 0.886 to 1.201 (Table 14.7) and resulted in a significant quadratic trend. In general, mortality estimates increased from 1982 to 1992 then decreased from then to present. There was no significant correlation between mortality estimates and recruit CPUE.

Estimates of relative abundance ranged from 1.8 to 4.8 individuals per tow. Trend analyses resulted in significant quadratic trends for recruits and composite data, and a significantly declining linear trend for post-recruits. In general, CPUE estimates for recruits and composite data increased from 1982 to 1989 and then began declining. Although there was no significant short-term trend, there has been a steady increase in estimates during the last four years for all categories.

Percent frequency of occurrence ranged from 40.6 to 59.3% and indicated a significantly decreasing linear trend. Although there was no significant short-term trend, there was a steady increase in estimates for the last four years for all categories.

Mean carapace width ranged from a low in 1994 of 66 mm to a high of 90 mm in 1984. Recruits showed no significant trend through years while a fourth-degree polynomial best described the post-recruit relationship. The post-recruit class showed no significant linear relationship. The composite data resulted in no significant long-term trend but a significantly increasing short-term trend. Again, it is interesting to note an increase in estimates over the last four or five years.

Landings ranged from 195,400 lbs in 1956 to 11,688,000 lbs in 1987 ($\bar{x}$=5,226,291; SE=458,893 lbs). A cubic polynomial best described the landings trend through years. Landings generally increased from 1950 to a peak in 1987 and have declined since then. There was a short-term increase in landings from 1994 to 1998 which would have been significant, if 1997 was excluded.

Indicators of stock status suggest that the blue crab population of Texas is not currently under stress. Landings generally declined from 1985 to present, although four of the last five years have increased. Total mortality rates increased significantly for a period of time (1982-1992) but are now on the decrease. Estimates of relative abundance and percent frequency of occurrence declined for all categories since 1989 but have increased over the last four years. Mean carapace width data indicated no signs of alarming trends, and the composite data resulted in a significantly increasing short-term trend.

14.2.4 Summary and Conclusions

The von Bertalanffy (1983) growth equation was fitted to 14 blue crab widths-at-ages to estimate the mean carapace width of very old Gulf crabs (CW_∞=276 mm) and the von Bertalanffy growth coefficient (K=0.663). These estimates were then used in Hoenig's (1987) formula for estimating annual rates of total instantaneous mortality. Correlation analysis was performed between mortality estimates and CPUE estimates for recruits to determine if increases in total mortality were due to an influx of recruits rather than an increase in death rates. Polynomial model building was used to determine long- and short-term trends in total mortality rates, estimates of relative abundance, percent frequency of occurrence, mean carapace width and landings history. Csirke and Caddy's (1983) method of surplus production modeling was used to estimate MSY but was abandoned due to a lack of relationship between total mortality and landings.

There was little uniform indication of stock stress for any indicator of stock health. Alabama and Louisiana were the only states to show significant declines in post-recruit CPUE. The Alabama decline did not result in a significant increase in total mortality estimates, and the Louisiana decline was counteracted by a significant increase in recruit CPUE. Louisiana was the only state to result in significant declines in mean carapace width, but this result may not be due to a systematic decrease in somatic size but to the combined effect of significantly increasing numbers of recruits and significantly decreasing numbers of post-recruits. Mississippi was the only state resulting in a significant decline in landings, but this was probably due to socio-economic conditions and management regulations rather than a decline in population size. Louisiana was the only state with significantly increasing total mortality rates which was consistent with the increased landings and declining post-recruit CPUE; however, these results should be considered in conjunction with significantly increasing recruit CPUE.

Table 14.1. Blue crab carapace width data used in the Wetherall et al. (1987) procedure to estimate CW_∞, the mean carapace width of very old Gulf blue crabs. CW' is the lower boundary of 5-mm size classes, and CW is the mean carapace width of blue crabs CW' and larger.

Data Pair	CW′	CW	CW -CW′
1	205	231.051	26.051
2	210	240.000	30.000
3	215	246.875	31.875
4	220	247.628	27.628
5	225	248.986	23.986
6	230	251.591	21.591
7	235	253.800	18.800
8	240	255.962	15.962
9	245	257.717	12.717
10	250	261.323	11.323
11	255	262.500	7.500

Table 14.2. Carapace widths (mm) by month of St. Johns River, Florida blue crabs hatched in April, July and October (Tagatz, 1968b) ([1] Larvae).

Month	Month Hatched			Mean Carapace Width
	April	July	October	
1	1[1]	1[1]	1[1]	1.0
2	5	5	5	5.0
3	12	12	8	10.7
4	23	23	10	18.7
5	46	46	12	34.7
6	58	46	15	39.7
7	90	58	29	59.0
8	113	58	46	72.3
9	113	72	72	85.7
10	113	90	90	97.7
11	113	113	113	113.0
12	142	142	142	142.0

Table 14.3a. Estimated total mortality rates, indices of relative abundance (CPUE), percent frequency of occurrence of blue crab for the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

Year	Total Mortality (Z)	CPUE					Percent Frequency of Occurrence
		Recruits	Post-recruits	Males	Females	All	
1989	1.050	2.930	1.499	1.970	2.106	4.429	49.8
1990	1.013	2.089	0.773	1.199	1.391	2.862	43.5
1991	1.024	1.720	0.609	1.082	1.115	2.329	35.1
1992	1.109	2.414	0.920	1.592	1.629	3.334	55.2
1993	1.123	2.687	0.938	1.718	1.758	3.626	54.5
1994	1.143	1.930	0.590	1.263	1.183	2.520	45.6
1995	0.935	1.576	0.785	1.093	1.227	2.361	40.8
1996	1.039	3.075	1.598	2.612	1.947	4.673	63.0
1997	1.128	2.428	0.645	1.336	1.484	3.073	47.9
1998	1.153	11.202	3.181	7.643	5.994	14.383	81.1
Mean	1.072	2.703	1.018	1.799	1.728	3.722	49.8
SE	0.022	0.107	0.040	0.067	0.068	0.130	0.007

Table 14.3b. Mean carapace width and reported landings (lbs) of blue crab for the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

Year	Mean Carapace Width (mm)					Landings
	Recruits	Post-recruits	Males	Females	All	
1989	91.813	150.427	115.828	111.776	111.460	8,197,383
1990	74.444	149.477	105.857	90.030	95.074	6,914,878
1991	72.482	153.241	90.013	99.156	93.607	5,234,967
1992	84.224	149.212	105.604	102.396	102.192	7,653,632
1993	83.367	147.074	101.317	100.145	99.895	8,458,739
1994	82.349	146.593	98.872	98.650	97.554	8,463,934
1995	78.067	154.142	104.770	103.419	103.376	8,691,292
1996	86.223	149.038	110.937	105.669	107.724	11,199,662
1997	76.268	150.534	100.673	90.992	91.920	9,321,590
1998	79.491	147.745	100.040	95.663	94.584	12,659,531
Mean	82.145	148.376	103.535	99.391	99.736	8,679,561
SE	0.289	0.294	0.487	0.495	0.343	657,968

Table 14.4a. Estimated total mortality rates, indices of relative abundance (CPUE), percent frequency of occurrence of blue crab for the state of Alabama, 1983-1997.

Year	Total Mortality (Z)	CPUE					Percent Frequency of Occurrence
		Recruits	Post-recruits	Males	Females	All	
1983	1.158	0.434	0.050	0.219	0.264	0.484	58.4
1984	1.042	1.332	0.222	0.680	0.874	1.554	74.7
1985	1.065	0.424	0.073	0.221	0.276	0.497	61.1
1986	1.116	0.435	0.060	0.228	0.267	0.495	53.0
1987	1.206	0.227	0.023	0.112	0.138	0.250	39.7
1988	1.258	0.360	0.022	0.191	0.189	0.382	38.8
1989	1.176	0.779	0.068	0.029	0.035	0.848	50.0
1990	1.126	0.347	0.042			0.389	50.7
1991	1.106	0.448	0.046			0.495	51.5
1992	1.003	0.190	0.037			0.228	46.8
1993	1.092	0.232	0.026			0.257	42.1
1994	1.207	0.305	0.028			0.333	41.8
1995	1.253	0.287	0.021			0.308	42.1
1996	1.157	0.166	0.018			0.185	39.8
1997	1.216	0.349	0.025			0.374	48.0
Mean	1.145	0.426	0.052	0.255	0.312	0.478	49.2
SE	0.020	0.027	0.003	0.024	0.025	0.028	2.534

Table 14.4b. Mean carapace width and reported landings (lbs) of blue crab for the state of Alabama, 1983-1997.

Year	Mean Carapace Width (mm)					Landings
	Recruits	Post-recruits	Males	Females	All	
1983	46.775	151.648	51.390	62.488	57.382	1,411,629
1984	54.759	149.321	67.498	69.442	68.594	4,216,125
1985	48.826	156.472	65.820	63.611	64.595	2,260,826
1986	51.469	152.349	61.619	66.732	64.007	2,886,211
1987	42.130	149.824	51.960	52.006	51.938	2,495,632
1988	44.996	147.229	51.272	50.200	50.873	3,869,458
1989	48.444	142.849			56.011	4,090,476
1990	58.361	145.120			68.289	3,302,889
1991	40.068	148.414			50.254	2,731,120
1992	59.102	144.796			73.169	3,550,370
1993	63.706	146.300			72.035	2,554,158
1994	56.249	147.639			63.823	2,687,961
1995	53.842	151.809			60.893	2,520,268
1996	56.837	149.136			66.025	3,218,948
1997	48.609	149.016			55.537	3,486,851
Mean	51.808	149.391	62.589	65.774	63.158	3,047,574
SE	0.267	0.413	0.743	0.654	0.352	185,196

Table 14.5a. Estimated total mortality rates, indices of relative abundance (CPUE), percent frequency of occurrence, mean carapace width and reported landings of blue crab for the state of Mississippi, 1974-1998.

Year	Total Mortality (Z)	CPUE					Percent Frequency of Occurrence
		Recruits	Post-recruits	Males	Females	All	
1974	1.163	7.513	0.445	2.785	3.929	7.958	58.3
1975	1.168	8.536	0.089	3.277	3.628	8.625	52.1
1976	1.279	13.156	0.341	3.735	6.286	10.208	56.2
1977	1.060	4.646	0.333	2.021	1.708	4.979	56.2
1978	0.954	13.527	0.952	5.551	7.688	14.479	66.7
1979	1.112	12.827	0.902	5.459	7.119	13.729	81.2
1980	1.078	8.750	0.854	3.260	3.923	9.604	68.8
1981	0.733	0.562	0.292	0.271	0.479	0.854	37.5
1982	0.921	2.333	0.562	1.250	1.188	2.896	43.8
1983	0.904	0.625	0.083	0.271	0.375	0.708	33.3
1984	0.772	3.667	1.021	1.452	2.922	4.688	50.0
1985	1.004	5.438	0.479	1.903	2.676	5.917	58.3
1986	1.155	3.203	0.193	0.840	1.688	3.396	52.1
1987	1.168	1.417	0.146	0.625	0.688	1.562	54.2
1988	1.083	7.705	0.233	2.408	3.798	7.938	58.3
1989	0.888	4.125	0.646	1.979	2.229	4.771	75.0
1990	1.059	3.812	0.271	1.229	2.146	4.083	70.8
1991	0.893	8.208	0.104	1.630	4.365	8.312	50.0
1992	1.025	0.917	0.021	0.417	0.396	0.938	37.5
1993	0.842	0.958	0.104	0.333	0.708	1.062	33.3
1994	1.030	1.646	0.354	0.875	1.021	2.000	54.2
1995	0.889	2.500	0.458	1.292	1.375	2.958	54.2
1996	0.928	2.438	0.625	1.479	1.375	3.062	60.4
1997	1.195	3.724	0.464	1.550	1.843	4.188	70.8
1998	1.208	2.062	0.167	0.833	0.958	2.229	50.0
Mean	1.020	4.889	0.401	1.903	2.607	5.290	56.5
SE	0.029	0.774	0.057	0.297	0.439	0.802	2.551

Table 14.5b. Mean carapace width and reported landings (lbs) of blue crab for the state of Mississippi, 1974-1998.

Year	Mean Carapace Width (mm)					Landings
	Recruits	Post-recruits	Males	Females	All	
1974	45.035	143.750	61.060	56.415	51.000	1,667,000
1975	34.141	154.250	42.000	40.838	35.342	1,136,600
1976	53.559	153.467	54.497	60.257	57.119	1,334,500
1977	43.798	148.063	65.454	60.780	50.778	1,918,600
1978	53.666	148.886	67.090	59.452	60.468	1,942,300
1979	49.719	152.310	69.226	51.288	57.252	1,311,450
1980	39.666	152.780	64.860	57.792	50.158	2,759,600
1981	49.482	152.643	91.462	88.826	84.707	1,866,550
1982	52.009	147.444	88.400	69.474	70.547	1,297,100
1983	53.733	159.750	76.615	67.500	66.206	1,139,690
1984	51.316	153.918	70.391	80.885	73.861	2,250,342
1985	53.032	152.870	69.296	64.744	61.474	1,648,901
1986	44.801	152.222	78.180	43.378	51.247	1,302,812
1987	62.559	153.143	68.067	83.242	71.013	1,374,048
1988	45.825	145.909	54.398	49.231	49.101	853,094
1989	58.066	152.323	80.421	70.103	70.825	658,899
1990	50.858	151.769	74.237	61.252	57.551	394,228
1991	36.458	160.600	53.000	43.249	38.231	455,684
1992	55.386	138.000	75.300	52.421	57.222	444,892
1993	56.739	147.400	57.625	70.765	65.628	253,463
1994	53.316	152.176	78.667	69.653	70.823	171,667
1995	51.742	153.045	84.871	62.758	67.437	320,844
1996	57.906	154.300	90.014	71.439	77.578	408,525
1997	47.307	156.045	72.549	64.181	60.032	684,598
1998	42.667	150.875	67.850	45.696	50.757	593,182
Mean	49.311	150.998	69.602	61.046	59.659	1,153,964
SE	1.382	1.046	2.440	2.527	2.350	136,162

Table 14.6a. Estimated total mortality rates, indices of relative abundance (CPUE), percent frequency of occurrence of blue crab for the state of Louisiana, 1967-1998.

Year	Total Mortality (Z)	CPUE					Percent Frequency of Occurrence
		Recruits	Post-recruits	Males	Females	All	
1967	0.572	3.254	1.758			5.012	66.8
1968	0.715	3.933	1.066			5.000	68.6
1969	0.797	4.440	0.892			5.333	74.1
1970	0.694	4.122	1.265			5.386	79.9
1971	0.782	6.629	1.525			8.154	71.5
1972	0.694	6.250	1.436			7.686	68.3
1973	0.649	5.812	1.544			7.357	66.1
1974	0.610	4.974	1.897			6.871	71.1
1975	0.701	4.074	1.321			5.395	65.2
1976	0.675	2.524	0.800			3.323	48.7
1977	0.781	2.502	0.748			3.249	60.2
1978	0.805	4.374	0.751			5.126	64.7
1979	0.713	8.252	1.120			9.372	76.7
1980	0.739	13.001	1.697			14.698	74.2
1981	0.679	5.331	1.202			6.533	66.9
1982	0.789	7.485	0.907			8.393	72.4
1983	0.804	7.717	1.012			8.729	75.0
1984	0.702	5.719	1.429			7.148	75.3
1985	0.679	5.372	1.134			6.506	71.7
1986	0.682	6.147	1.081			7.228	70.9
1987	0.789	6.333	0.786			7.119	69.8
1988	0.704	7.269	0.798			8.068	64.6
1989	0.698	7.048	0.836			7.883	60.9
1990	0.634	10.946	1.505			12.450	72.2
1991	0.654	11.753	1.302			13.055	74.6
1992	0.915	6.708	0.519			7.227	59.6
1993	0.807	8.586	0.588			9.174	66.9
1994	0.859	9.076	0.398			9.474	67.0
1995	0.940	4.404	0.205			4.610	55.3
1996	0.913	4.800	0.295			5.095	56.0
1997	0.869	5.371	0.356			5.728	61.9
1998	0.885	4.909	0.428			5.337	61.5
Mean	0.748	6.222	1.019			7.241	67.5
SE	0.017	0.439	0.080			0.460	1.227

Table 14.6b. Mean carapace width and reported landings of blue crab for the state of Louisiana, 1967-1998.

Year	Mean Carapace Width (mm)					Landings
	Recruits	Post-recruits	Males	Females	All	
1967	56.739	153.838			92.277	7,705,000
1968	49.512	150.465			71.684	9,834,800
1969	47.451	153.222			65.096	11,798,500
1970	52.017	153.796			76.037	10,343,800
1971	46.650	152.021			66.140	12,312,600
1972	50.698	152.075			70.479	15,184,800
1973	54.778	155.247			75.549	23,199,600
1974	55.945	155.062			84.412	20,735,500
1975	50.185	151.762			73.692	17,254,300
1976	51.277	158.750			78.524	15,299,200
1977	45.786	156.373			73.692	16,379,000
1978	43.128	151.235			59.041	15,207,400
1979	52.716	154.286			64.945	21,477,880
1980	44.282	154.313			57.339	18,299,697
1981	57.077	150.255			74.491	16,326,057
1982	48.165	150.342			60.220	17,381,803
1983	47.350	148.663			59.185	19,666,648
1984	51.800	151.549			71.414	29,678,305
1985	52.508	151.078			69.474	29,930,590
1986	51.123	149.252			65.699	31,690,272
1987	55.122	147.301			65.291	52,483,872
1988	52.013	152.176			62.811	53,716,989
1989	49.167	146.729			59.240	33,559,087
1990	51.964	148.762			63.335	39,135,733
1991	52.648	150.494			62.311	51,287,672
1992	43.858	150.064			50.522	51,984,138
1993	41.341	150.611			48.321	45,945,372
1994	40.313	152.610			44.969	36,764,750
1995	42.954	153.374			47.870	36,966,523
1996	39.493	152.778			46.014	40,001,240
1997	42.261	152.479			49.068	43,525,813
1998	40.421	152.567			49.523	43,656,898
Mean	48.773	151.985			64.333	27,772,932
SE	0.907	0.453			2.042	2,558,605

Table 14.7a. Estimated total mortality rates, indices of relative abundance (CPUE), percent frequency of occurrence of blue crab for the state of Texas, 1982-1998.

Year	Total Mortality (Z)	CPUE					Percent Frequency of Occurrence
		Recruits	Post-recruits	Males	Females	All	
1982	0.886	2.333	0.588			2.921	55.6
1983	1.040	2.393	0.572			2.966	55.1
1984	1.123	2.407	0.530			2.937	56.8
1985	1.159	2.621	0.550			3.171	59.3
1986	1.063	2.310	0.523			2.833	53.2
1987	0.970	2.157	0.667			2.824	53.7
1988	1.163	3.819	0.482			4.301	50.6
1989	1.186	2.946	0.366			3.312	46.9
1990	1.170	2.880	0.386			3.266	50.5
1991	1.201	3.901	0.455			4.356	50.6
1992	1.164	4.285	0.539			4.824	53.1
1993	1.039	2.917	0.688			3.605	52.4
1994	1.166	3.572	0.416			3.989	48.4
1995	1.178	1.557	0.196			1.753	41.4
1996	1.114	1.548	0.270			1.818	40.6
1997	1.136	1.795	0.302			2.097	48.0
1998	1.002	1.814	0.473			2.288	49.7
Mean	1.103	2.662	0.471			3.133	50.9
SE	0.022	0.202	0.033			0.214	1.202

Table 14.7b. Mean carapace width and reported landings (lbs) of blue crab for the state of Texas, 1982-1998.

Year	Mean Carapace Width (mm)					Landings
	Recruits	Post-recruits	Males	Females	All	
1982	51.964	158.213			77.430	8,010,000
1983	67.370	150.785			86.743	8,829,000
1984	78.312	147.610			90.028	7,229,000
1985	66.222	147.547			78.672	9,722,000
1986	71.172	149.008			85.859	9,482,000
1987	70.862	149.760			89.694	11,688,000
1988	65.000	150.282			74.831	10,428,000
1989	65.078	150.360			75.062	9,123,291
1990	69.075	144.332			78.169	8,598,652
1991	57.520	148.079			67.286	6,123,207
1992	55.031	151.552			66.256	6,160,647
1993	67.877	149.825			83.980	8,286,418
1994	56.039	149.239			66.093	5,094,314
1995	57.608	149.646			68.246	5,447,088
1996	65.896	149.933			78.925	6,310,547
1997	61.487	150.426			74.755	5,738,680
1998	64.293	153.742			83.050	6,981,424
Mean	64.165	150.020			77.946	7,827,642
SE	1.653	0.702			1.919	491,757

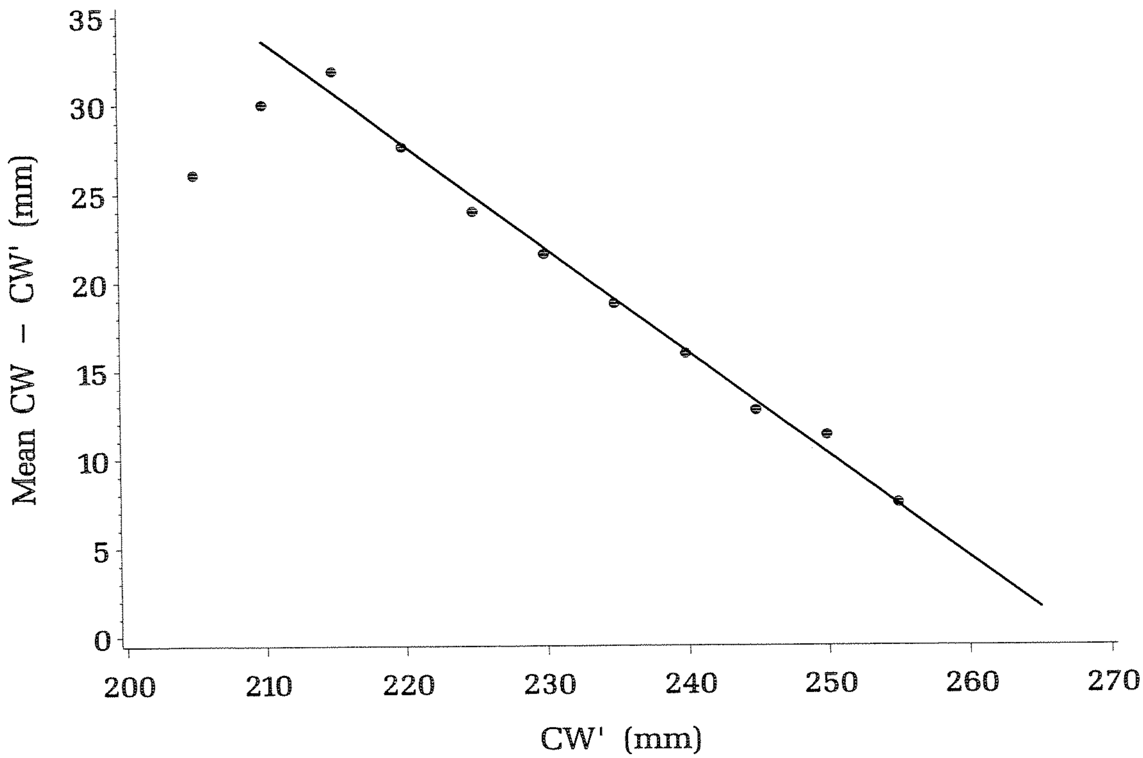

Figure 14.1. Wetherall et al. (1987) plot used to estimate CW_∞, the average carapace width of very old Gulf of Mexico blue crabs.

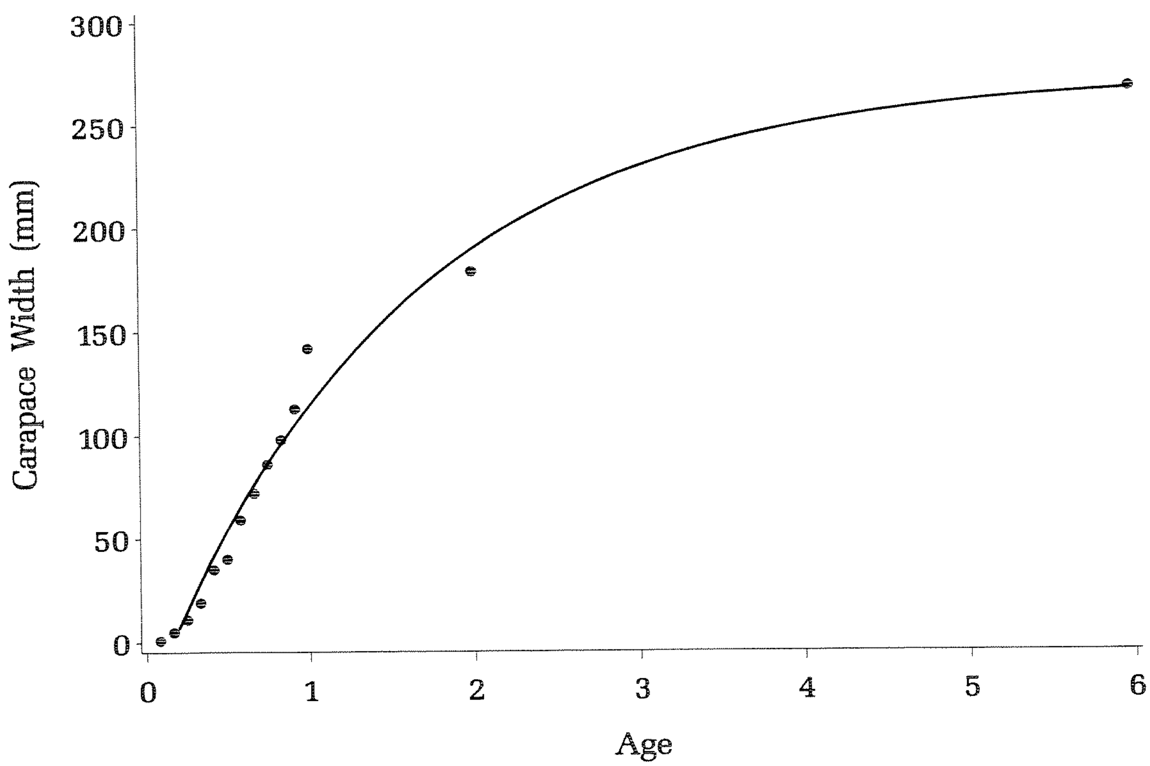

Figure 14.2. VonBertalanffy growth curve for Gulf of Mexico blue crabs.

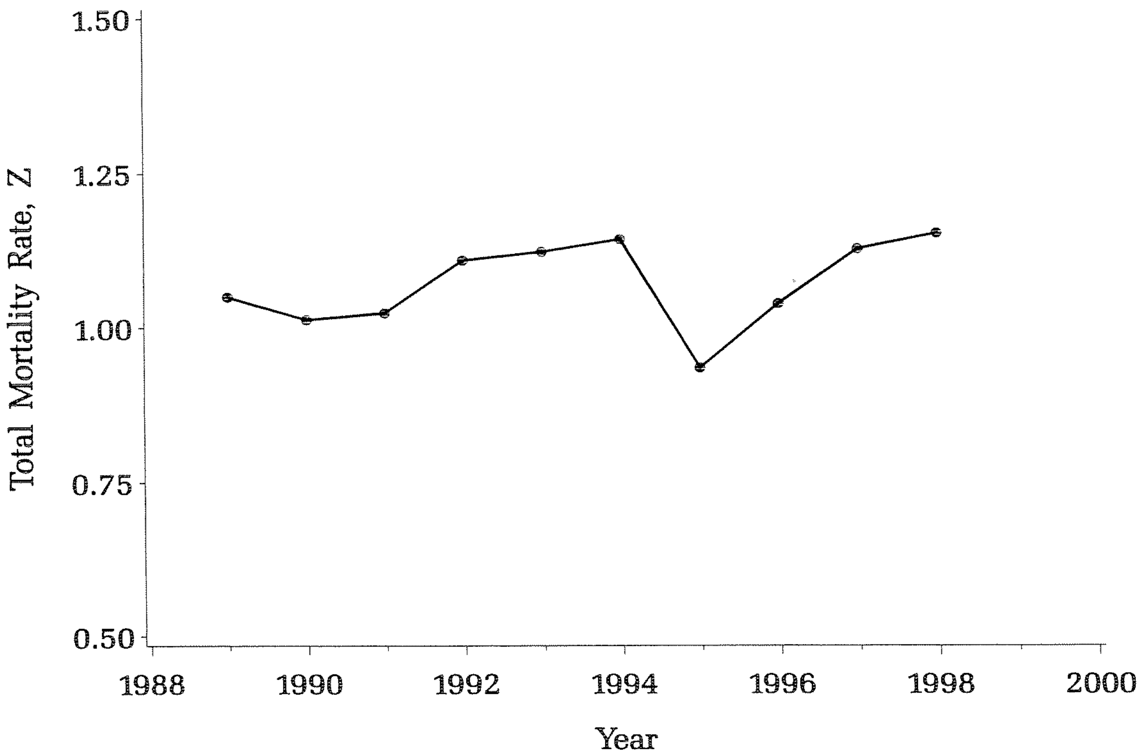

Figure 14.3. Scatter plot of estimated annual rates of instantaneous total mortality for blue crabs of the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

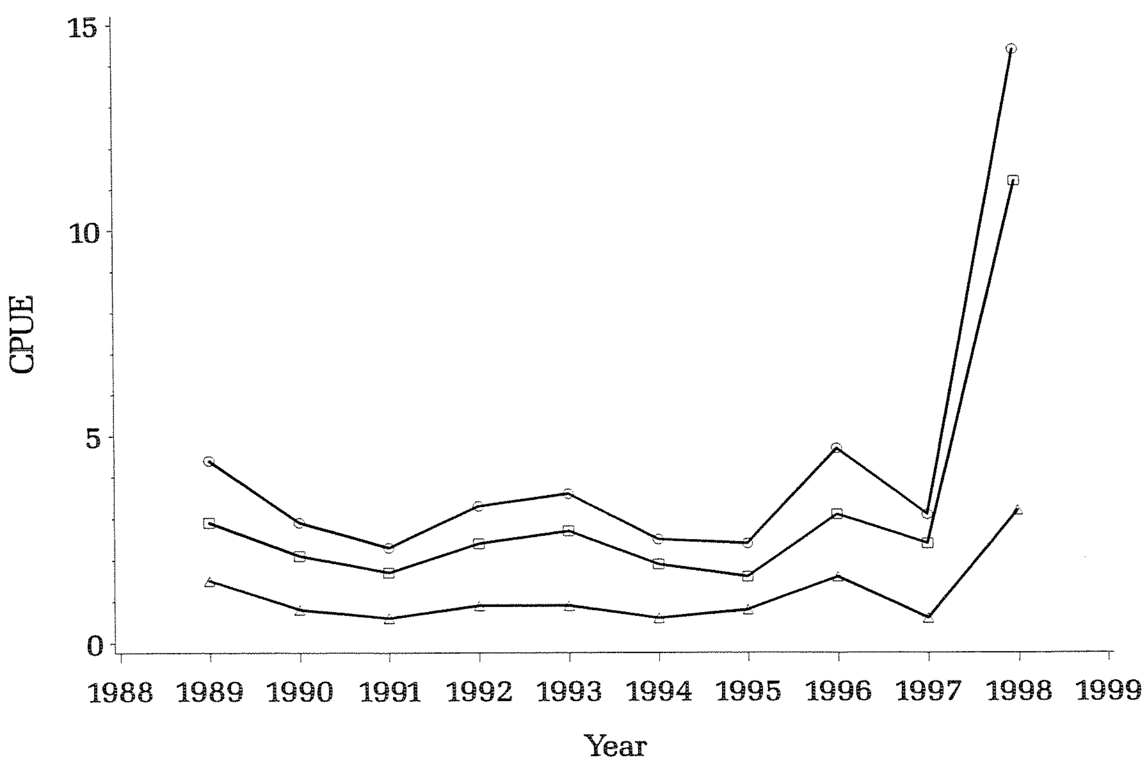

Figure 14.4. Scatter plot of catch-per-unit-effort for recruits (squares), post-recruits (triangles), and composite data (circles) for blue crabs of the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

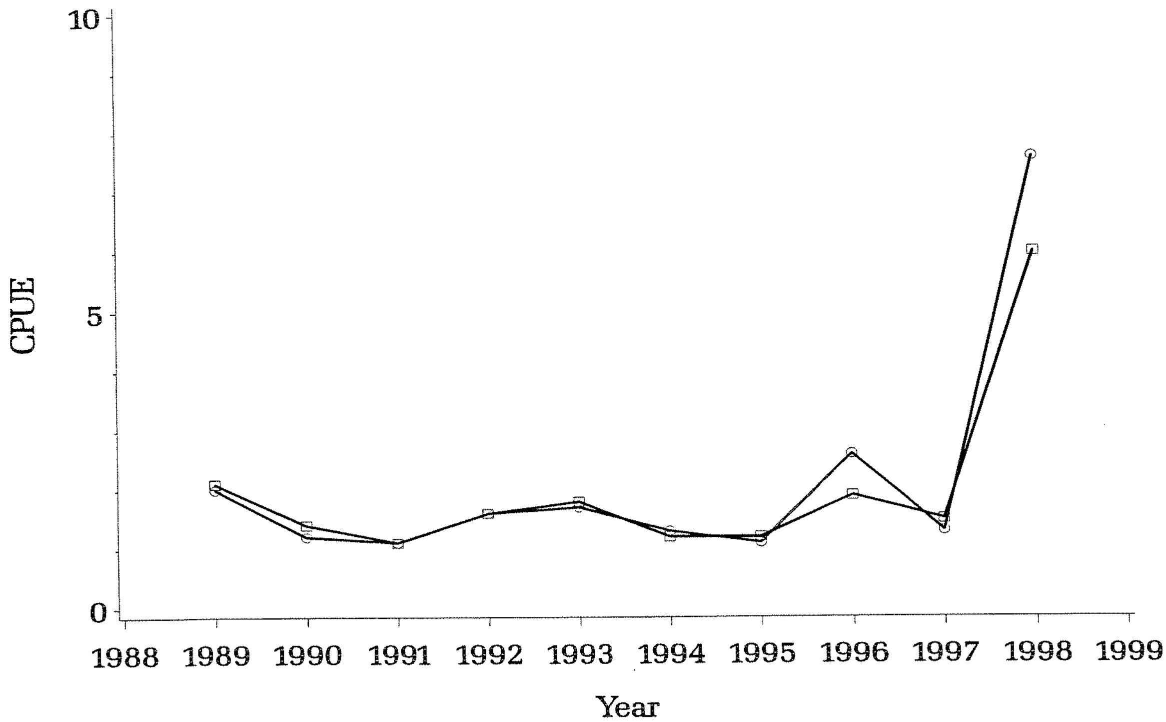

Figure 14.5. Scatter plot of catch-per-unit-effort for male (circles) and female (squares) blue crabs for the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

Figure 14.6. Scatter plot of frequency of occurrence of blue crabs in trawl samples of the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

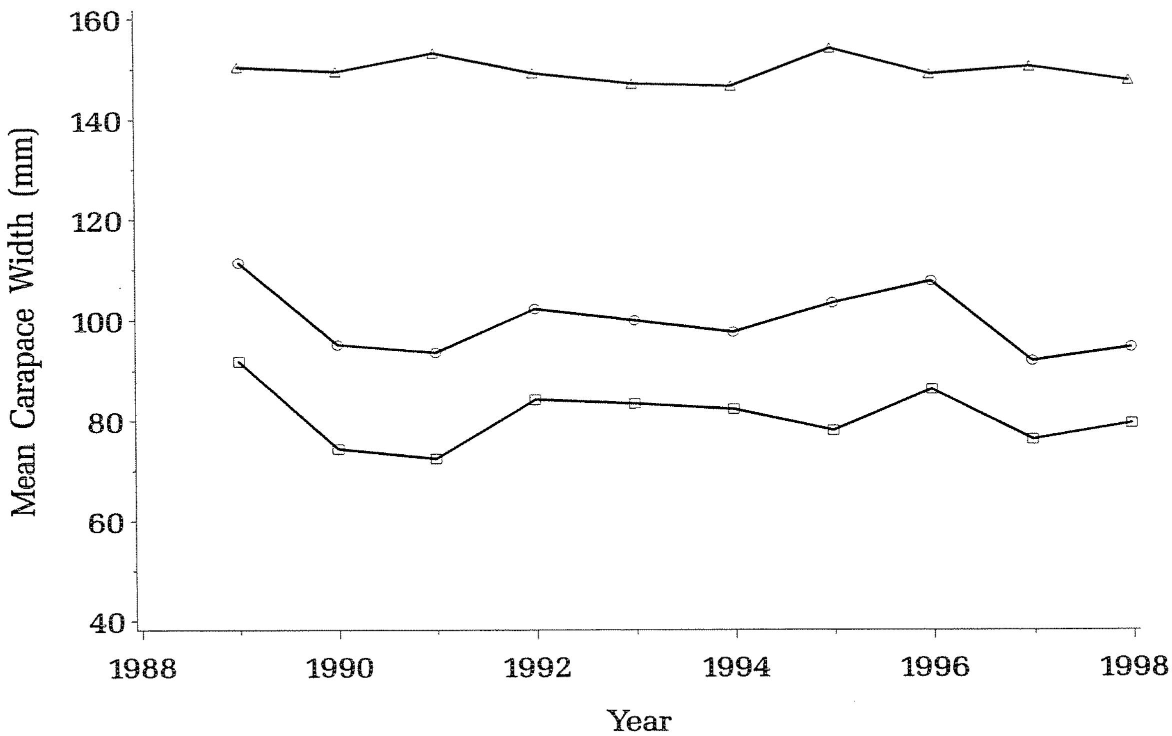

Figure 14.7. Scatter plot of mean carapace width of recruits (squares), post-recruits (triangles) and composite data (circles) for blue crabs of the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

Figure 14.8. Scatter plot of mean carapace width of male (circles) and female (squares) blue crabs of the Tampa Bay and Charlotte Harbor regions of Florida, 1989-1998.

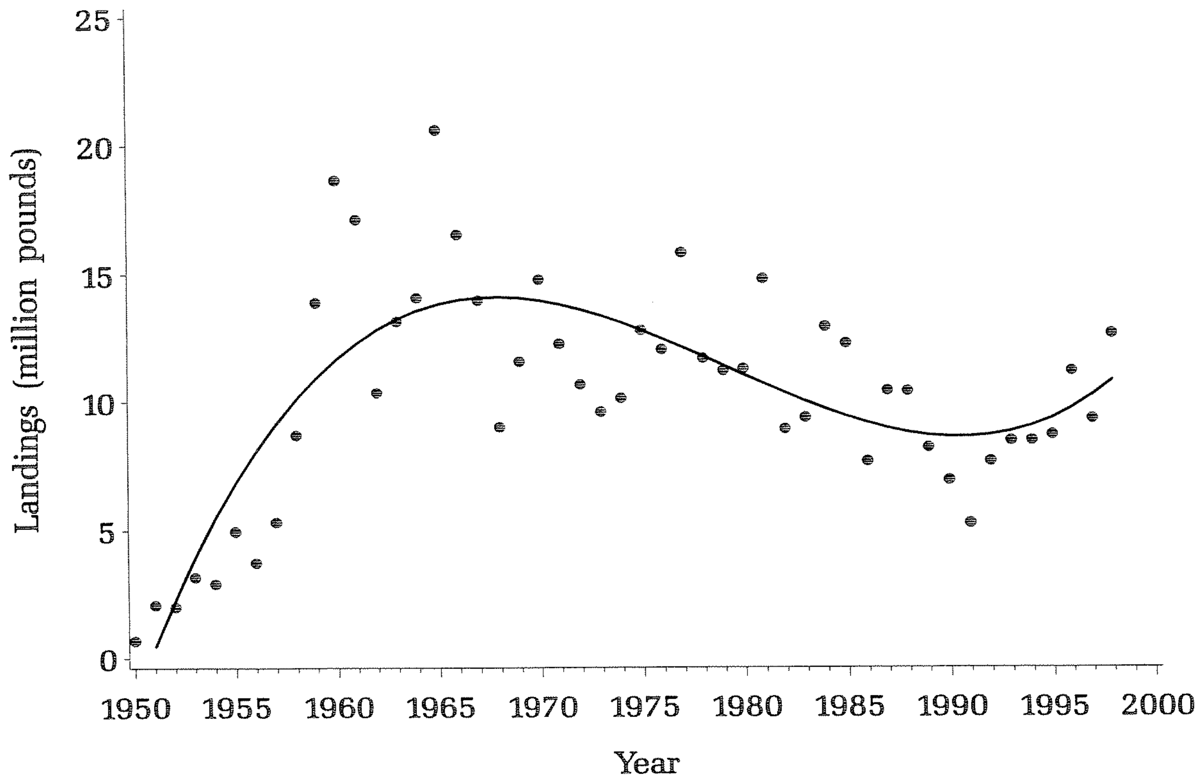

Figure 14.9. Scatter plot and trend line of Florida west coast blue crab landings, 1950-1998.

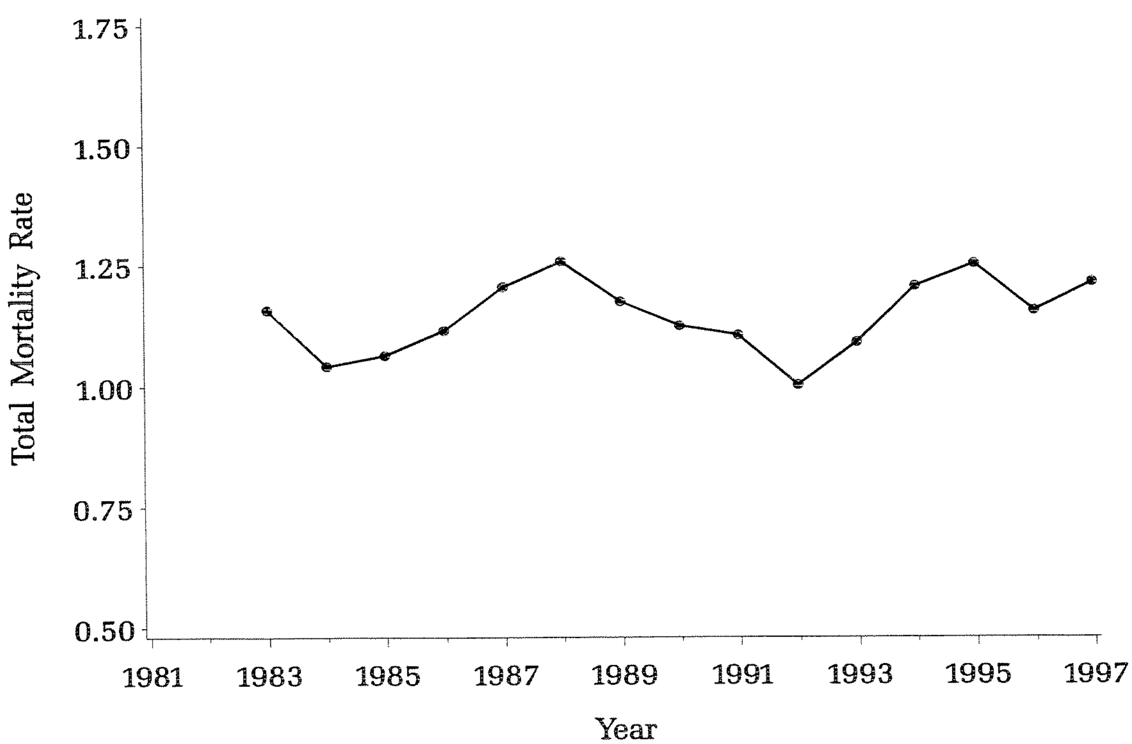

Figure 14.10. Scatter plot of estimated annual rates of instantaneous total mortality for Alabama blue crabs, 1983-1997.

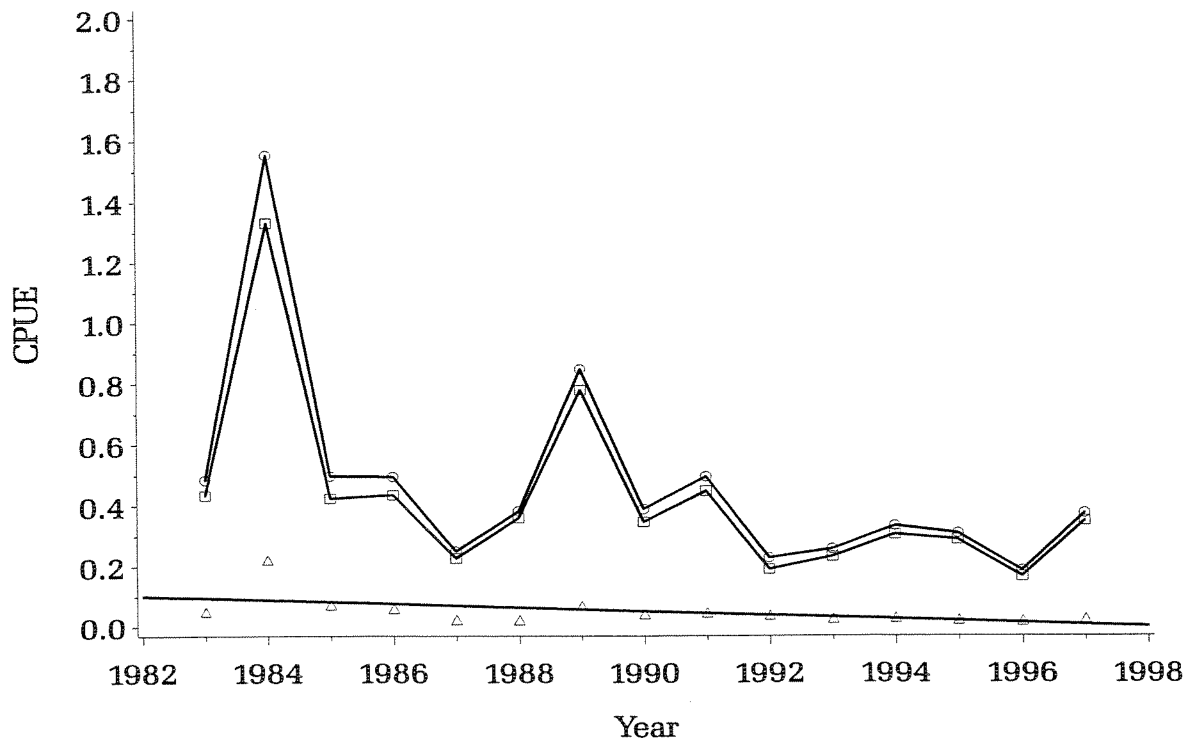

Figure 14.11. Scatter plot of catch-per-unit-effort for recruits (squares), post-recruits (triangles), and composite data (circles) for Alabama blue crabs, 1983-1997.

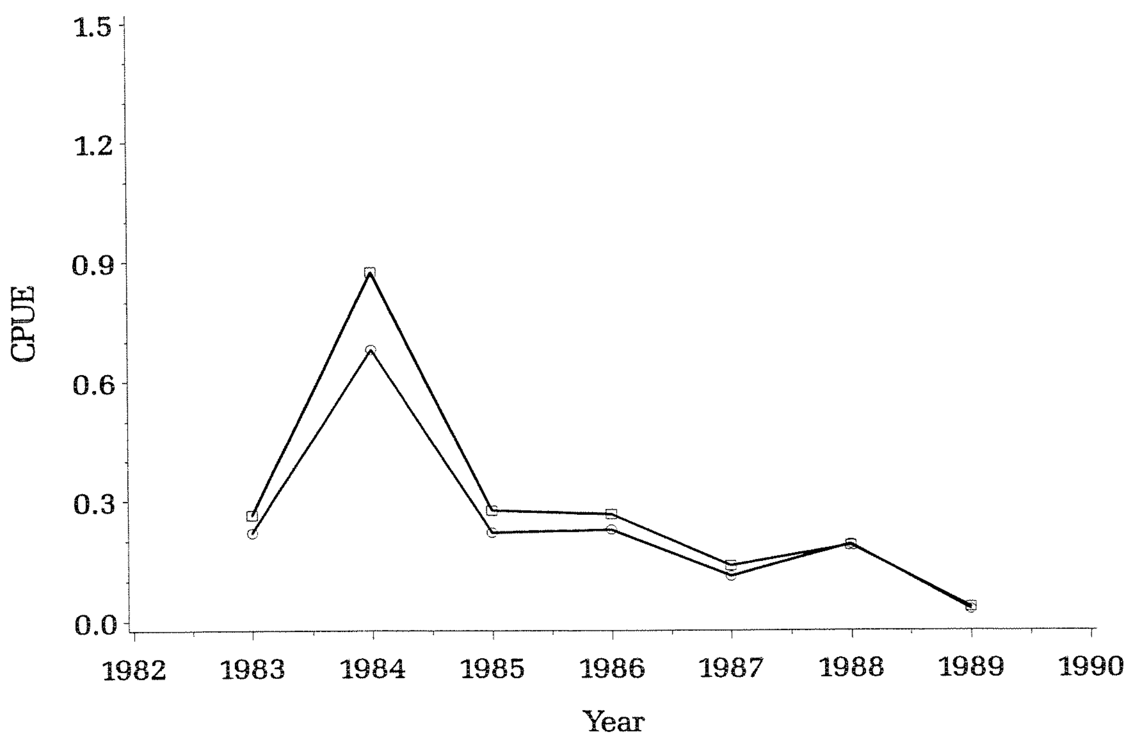

Figure 14.12. Scatter plot of catch-per-unit-effort for Alabama male (circles) and female (squares) blue crabs, 1983-1989.

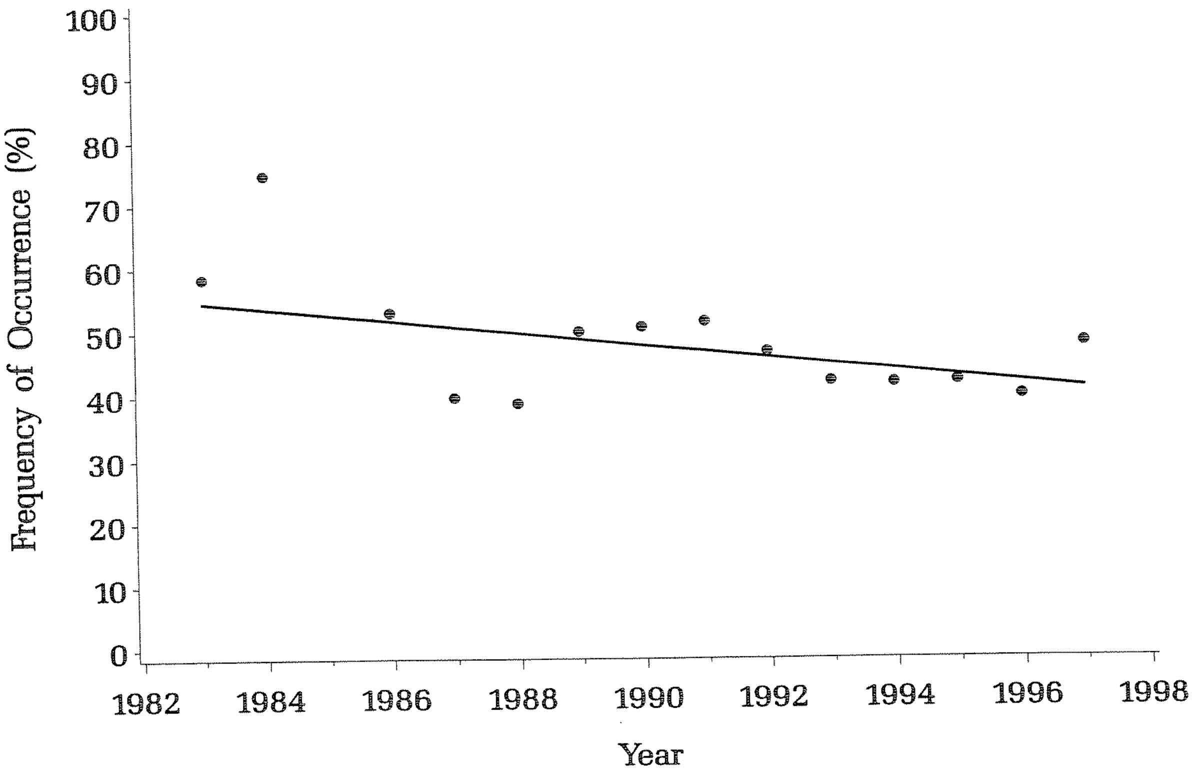

Figure 14.13. Scatter plot of frequency of occurrence of blue crabs in Alabama trawl samples, 1983-1997.

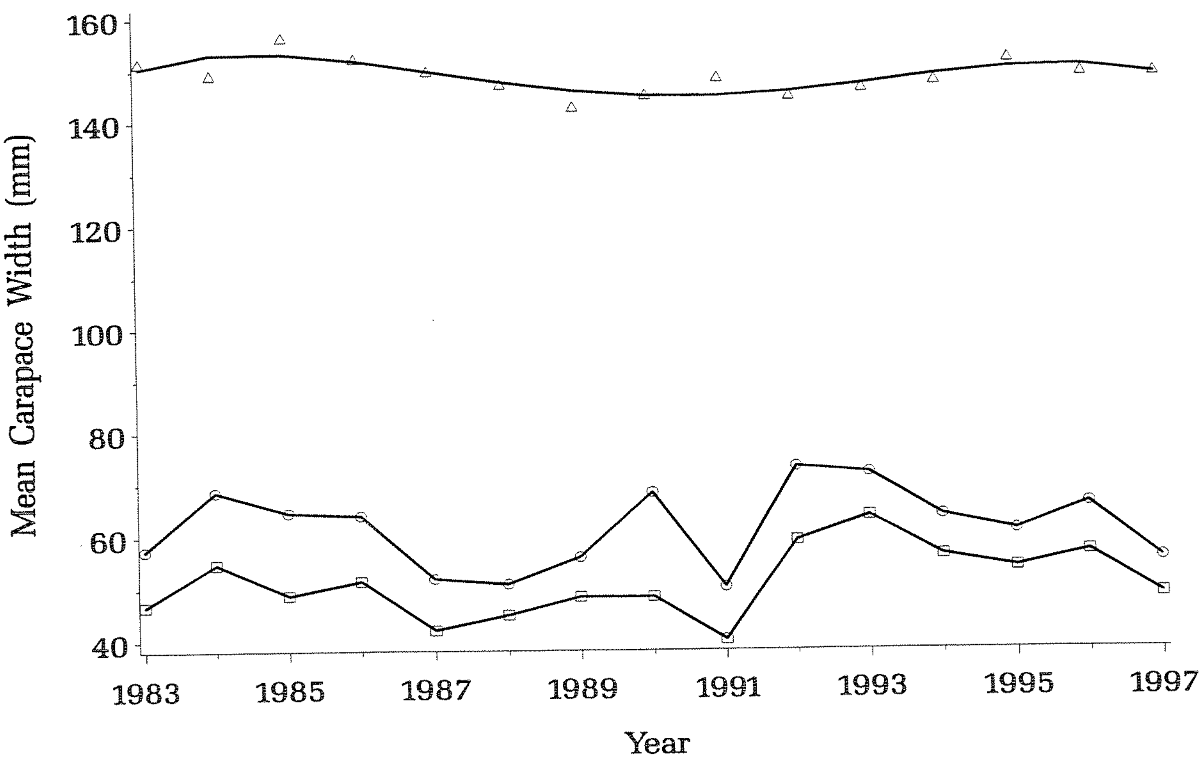

Figure 14.14. Scatter plot of mean carapace width of recruits (squares), post-recruits (triangles) and composite data for Alabama blue crabs, 1983-1997.

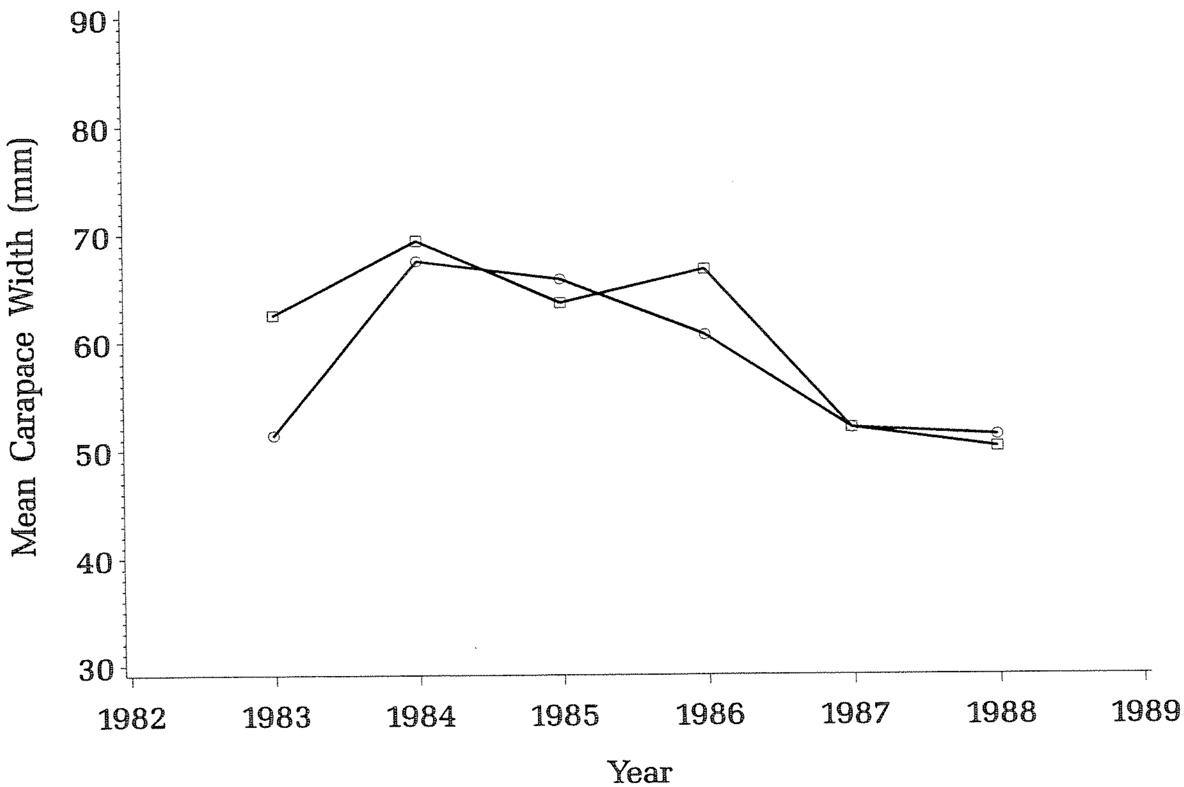

Figure 14.15. Scatter plot of mean carapace width of Alabama male (circles) and female (squares) blue crabs, 1983-1988.

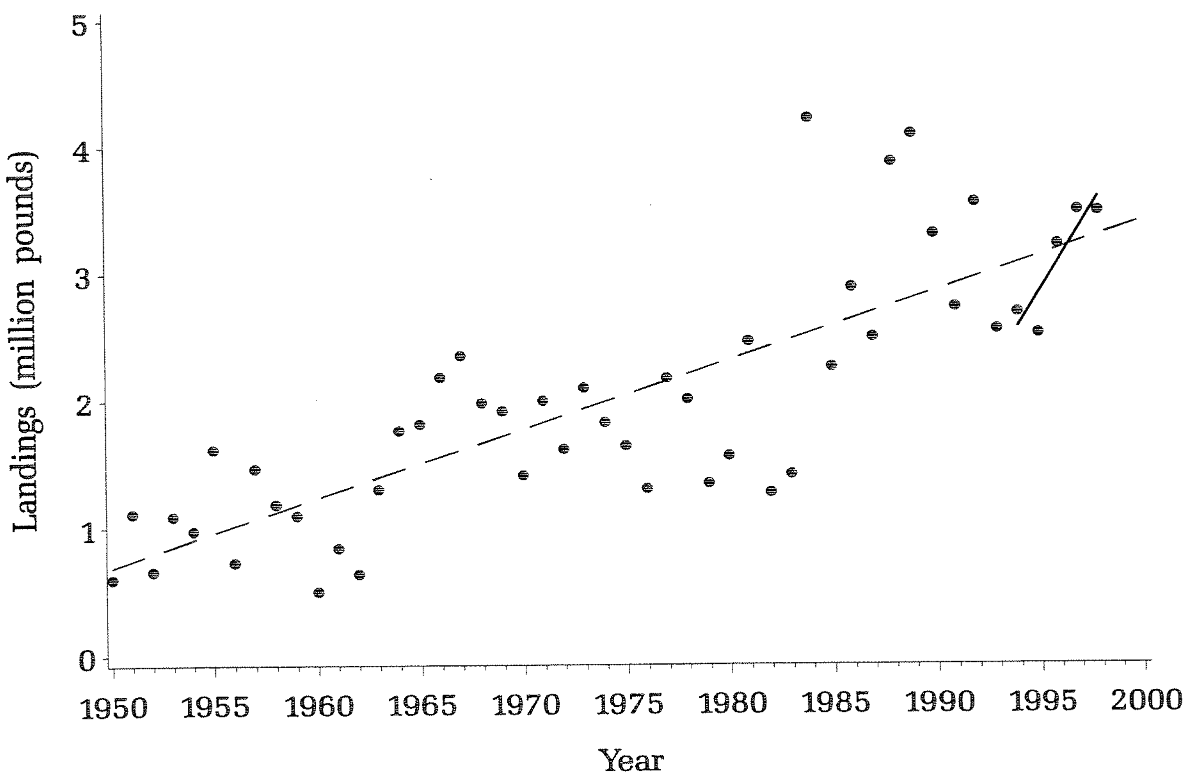

Figure 14.16. Scatter plot and trend lines of Alabama blue crab landings, 1950-1998.

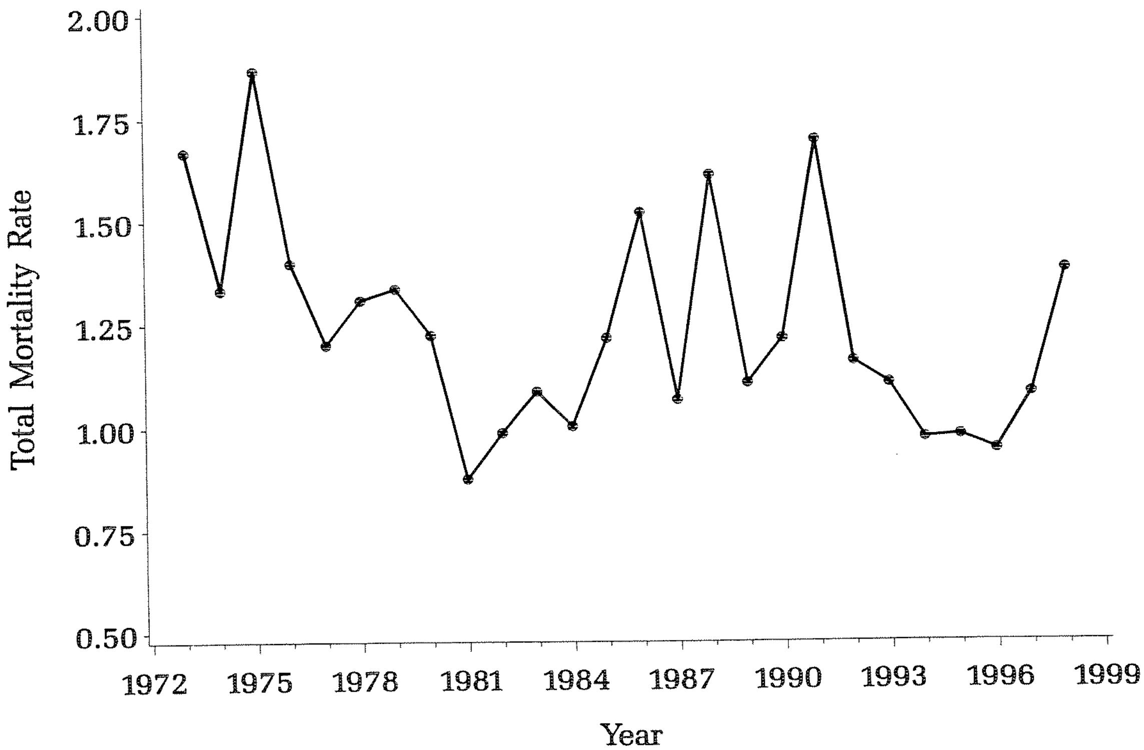

Figure 14.17. Scatter plot of estimated annual rates of instantaneous total mortality for Mississippi blue crabs, 1973-1998.

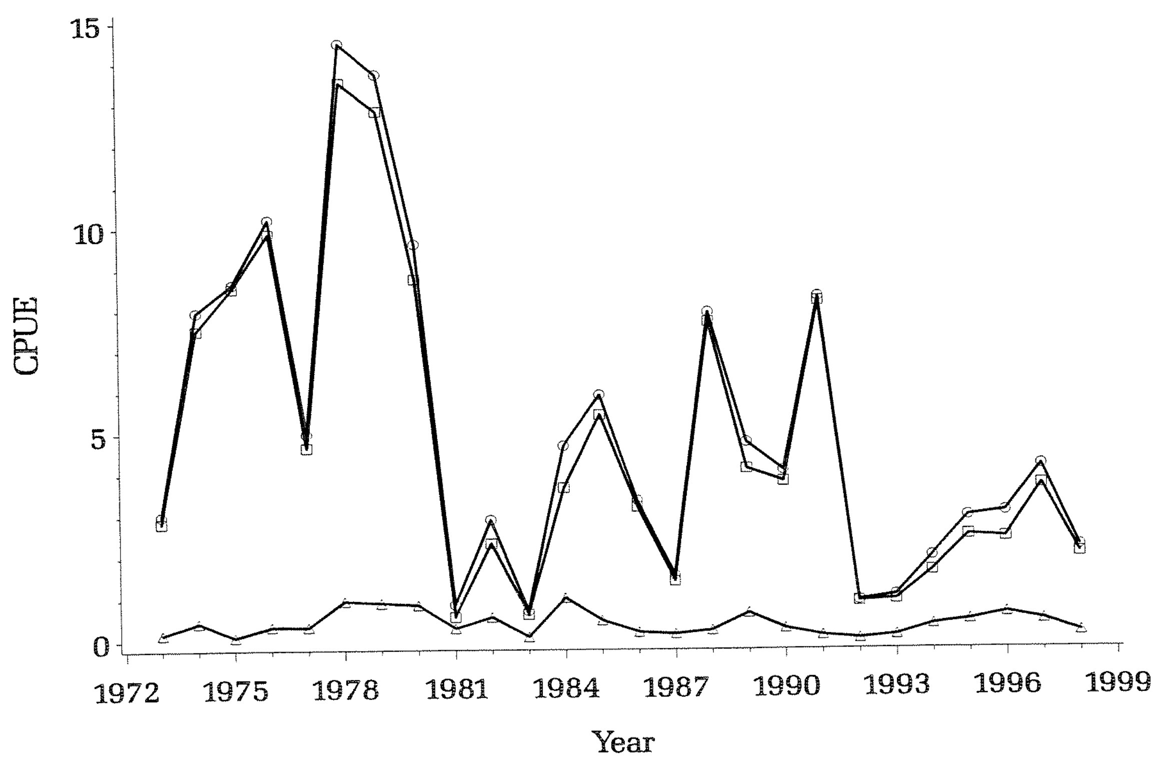

Figure 14.18. Scatter plot of CPUE for recruits (squares), post-recruits (triangles) and composite data (circles) for Mississippi blue crabs, 1973-1998.

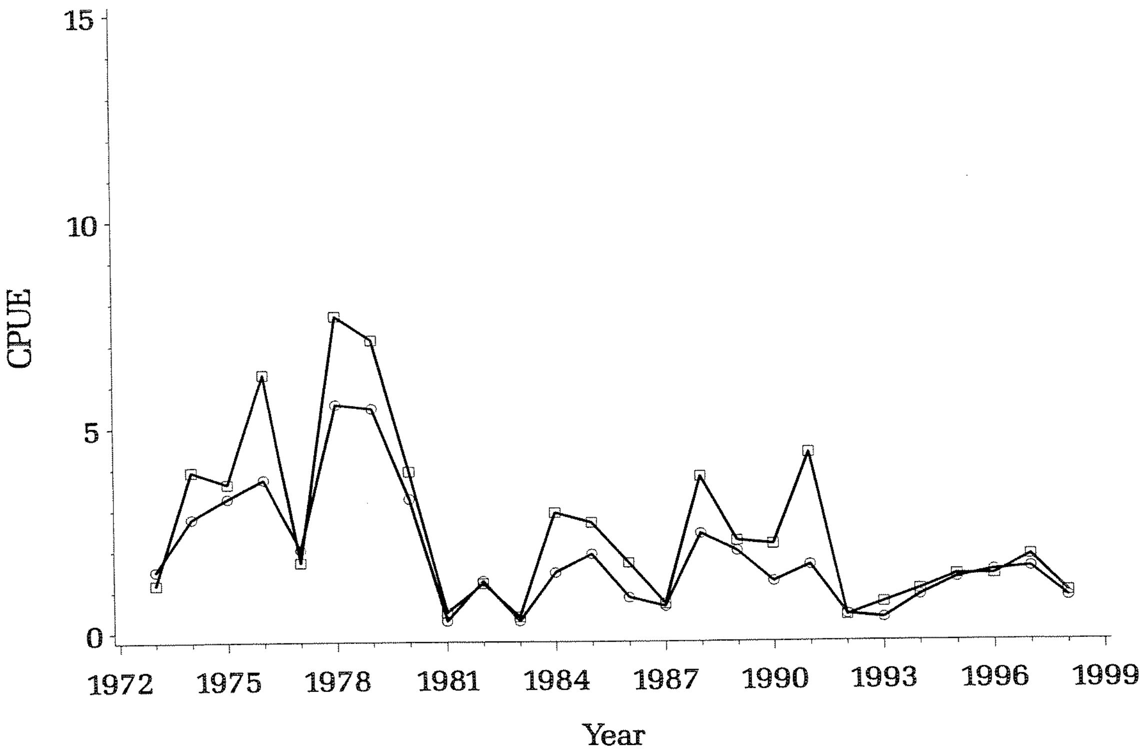

Figure 14.19. Scatter plot of CPUE for Mississippi male (circles) and female (squares) blue crabs, 1973-1998.

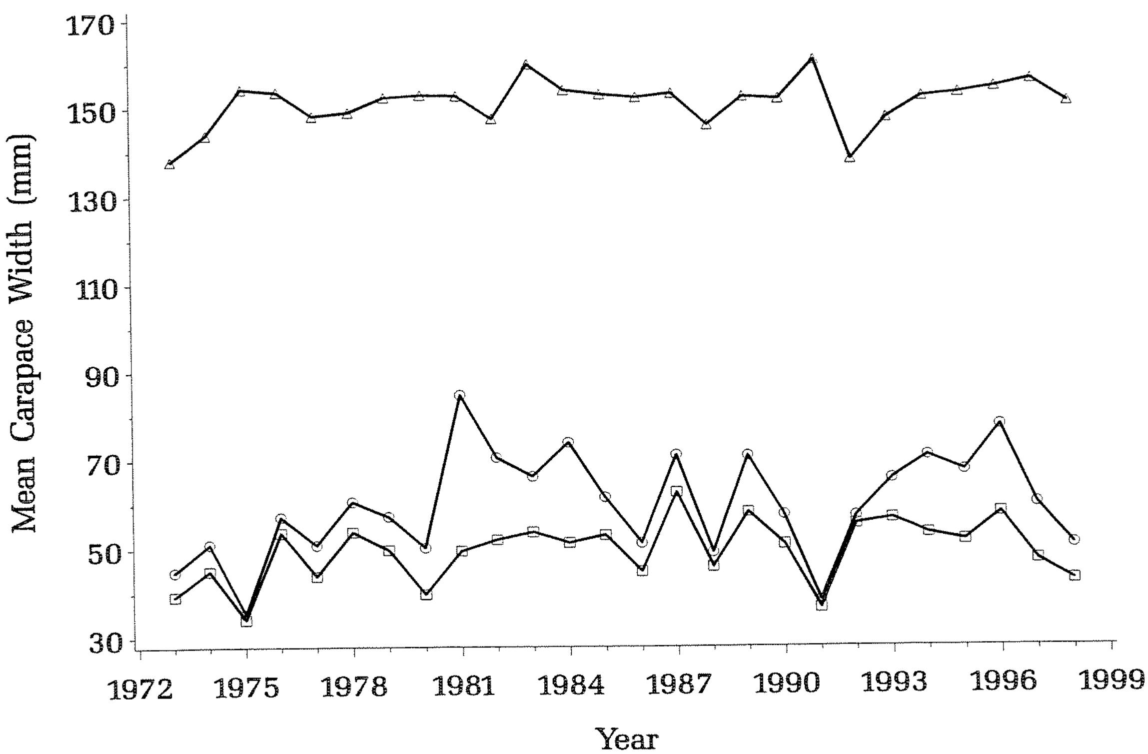

Figure 14.20. Scatter plot of mean carapace width of recruits (squares), post-recruits (triangles) and composite data for Mississippi blue crabs, 1973-1998.

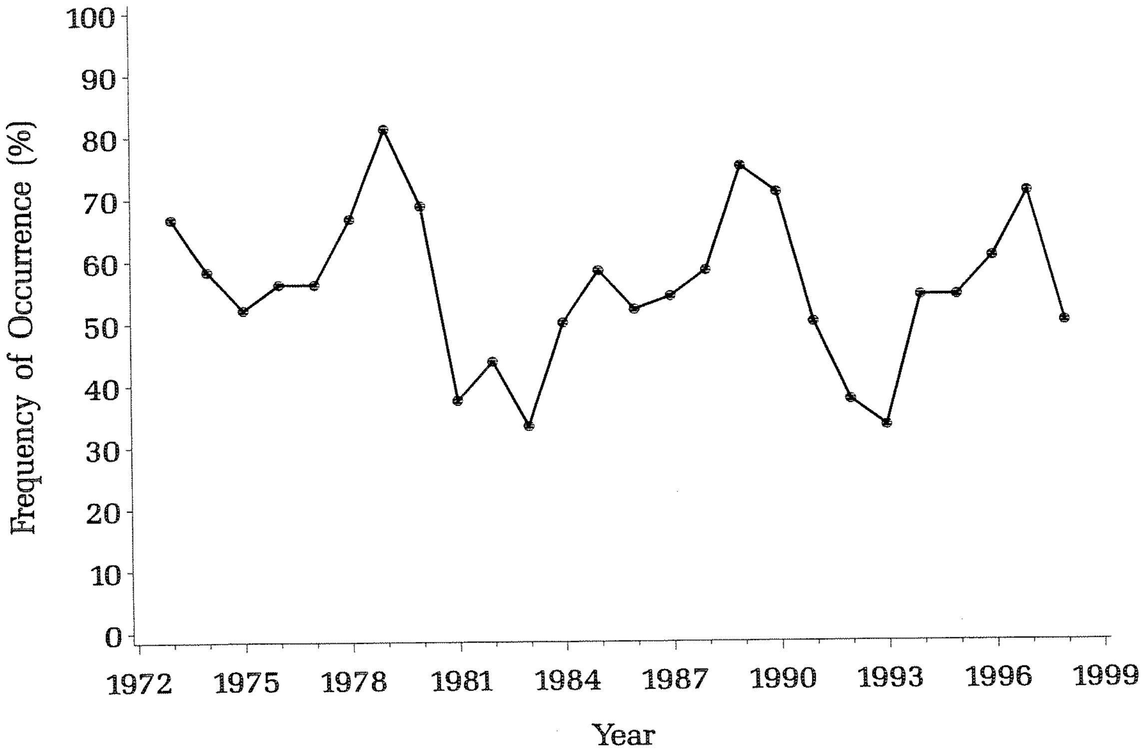

Figure 14.21. Scatter plot of frequency of occurrence of blue crabs in Mississippi trawl samples, 1973-1998.

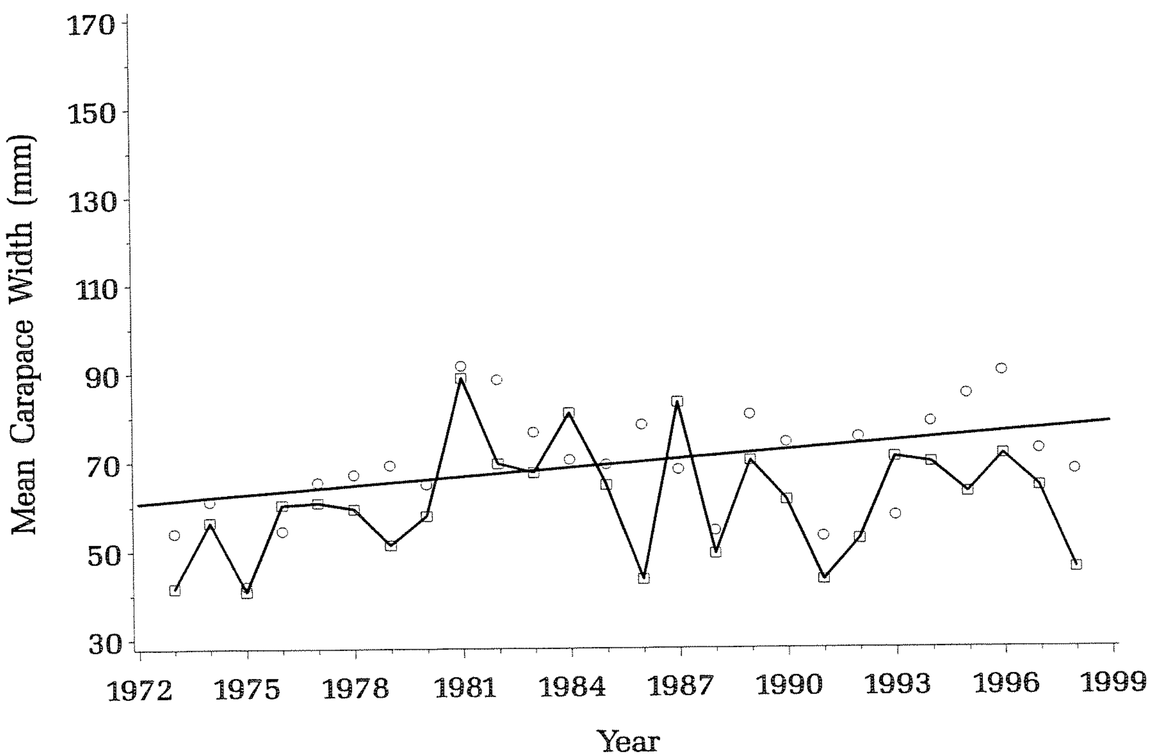

Figure 14.22. Scatter plot of mean carapace width of Mississippi male (circles with trend line) and female (squares) blue crabs, 1973-1998.

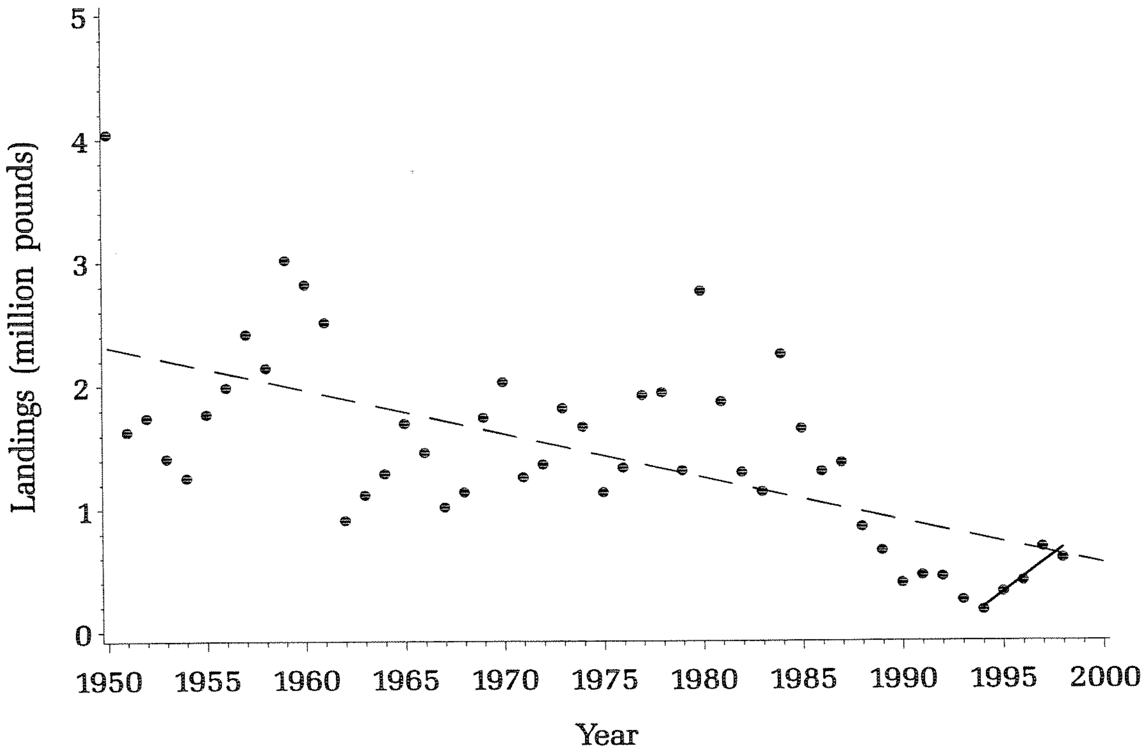

Figure 14.23. Scatter plot and trend lines of Mississippi blue crab landings, 1950-1998.

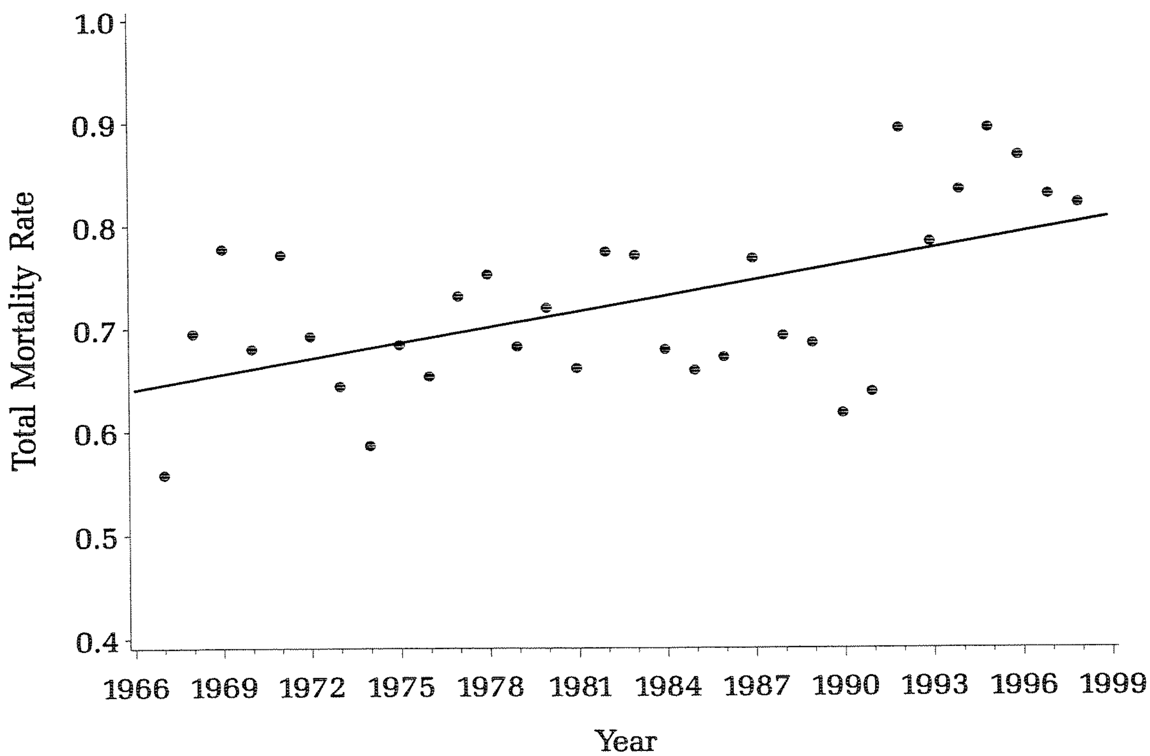

Figure 14.24. Scatter plot and trend line of estimated annual rates of instantaneous total mortality for Louisiana blue crabs, 1967-1998.

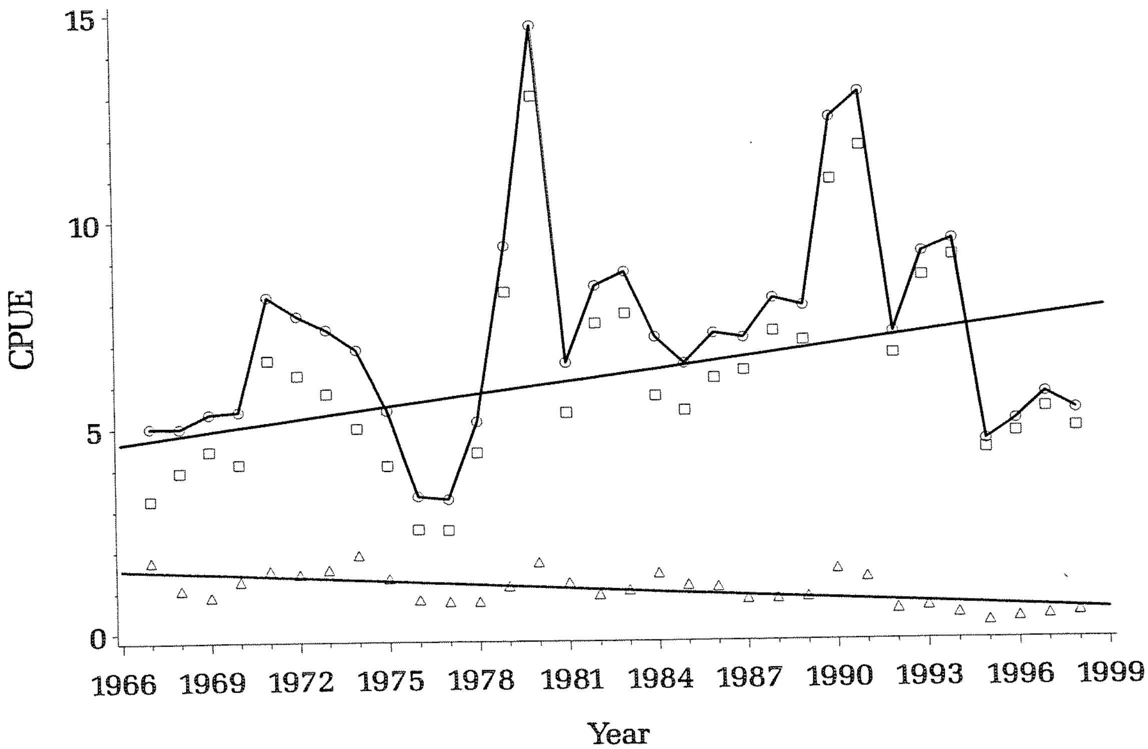

Figure 14.25. Scatter plot of catch-per-unit-effort for recruits (squares with trend line), post-recruits (triangles with trend line) and composite data (circles) for Louisiana blue crabs, 1967-1998.

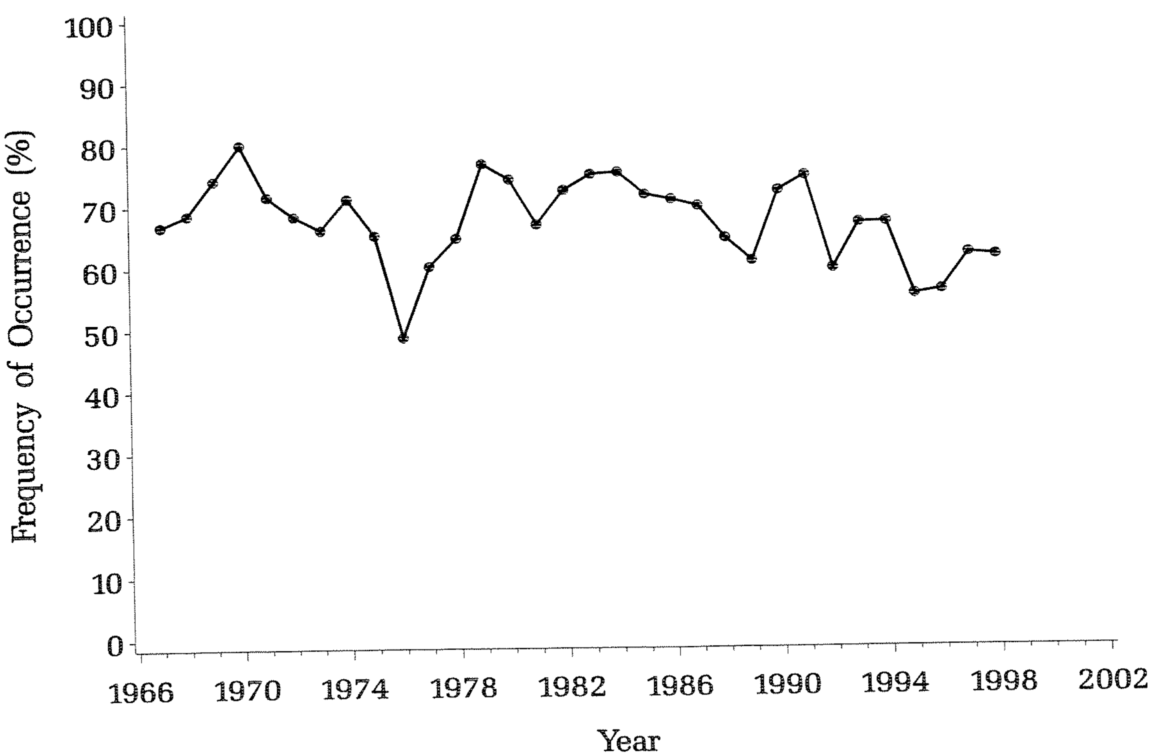

Figure 14.26. Scatter plot of frequency of occurrence of blue crabs in Louisiana trawl samples, 1967-1998.

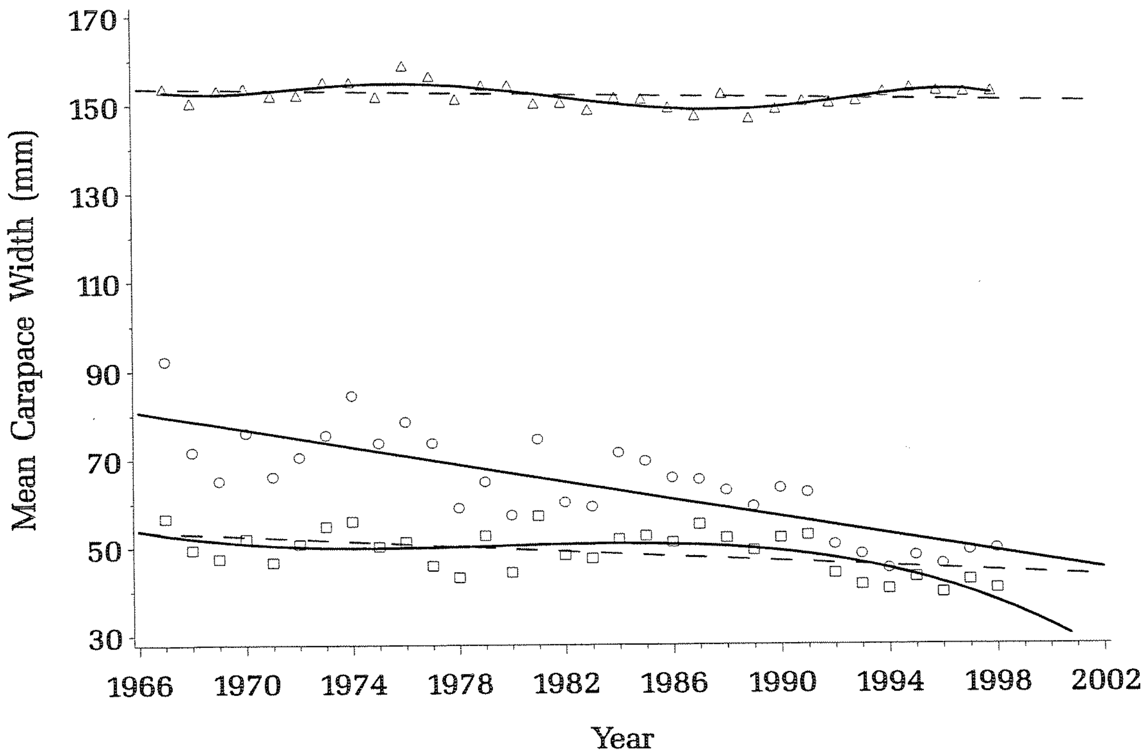

Figure 14.27. Scatter plot and trend lines of mean carapace width of recruits (squares), post-recruits (triangles) and composite data (circles) for Louisiana blue crabs, 1967-1998.

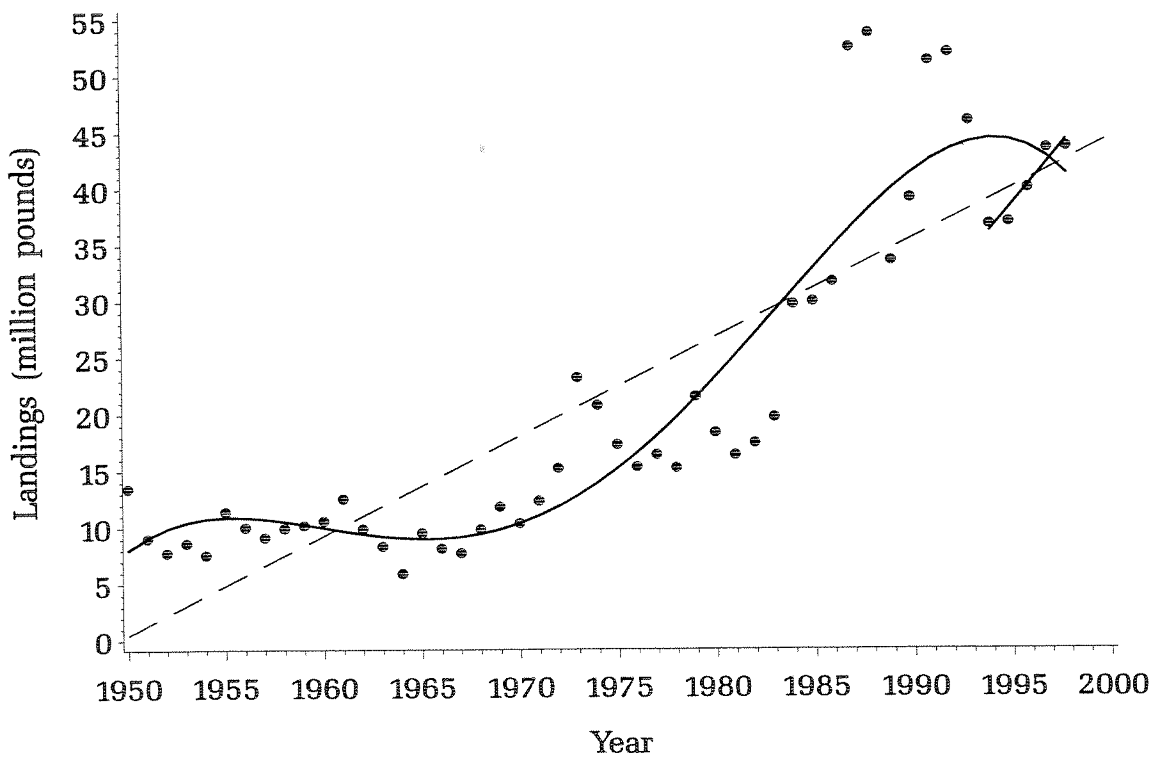

Figure 14.28. Scatter plot and trend lines of Louisiana blue crab landings, 1950-1998.

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