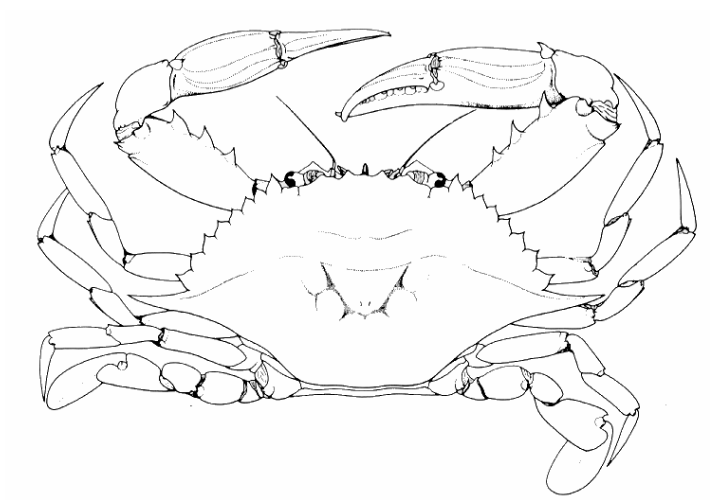
A stock assessment for blue crab, *Callinectes sapidus*, in Florida waters



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Executive Summary

In this second quantitative assessment for blue crabs in Florida we provide separate, detailed population analyses for blue crabs inhabiting waters along the gulf and Atlantic coasts. Although we treat these populations as separate, there may be a relatively high movement of blue crab from the gulf to the Atlantic population. Updated information is provided on key aspects of their life history (age, growth, and reproduction), habitat requirements, and population dynamics (genetic stock structure and natural mortality).

During the 1930's and 1940's, statewide blue crab landings were about 4.5 to 7.0 million pounds with about 1.0 million pounds reported on the gulf coast. The landings remained relatively constant through the 1950's and 1960's on the Atlantic coast, whereas gulf coast landings increased to about 7 millions pounds during the late 1950's then to 15 million pounds during the 1960's. Since 1965, the commercial landings of blue crab on both coasts have declined with the lowest landings reported occurring in 2001 (gulf) and 2002 (Atlantic). Through 2005, landings and commercial catch rates have rebounded somewhat. Landings were about 7.4 million pounds on the gulf coast and 4.2 million pounds on the Atlantic coast during 2005.

There are no estimates of the recreational harvest of blue crabs, making the conclusions of this assessment suspect if these landings are, as suspected, substantial.

Fishery-independent indices of abundance were variable at the start of these surveys (1989 or 1990) and showed a depression in abundance during the early 2000's on both coasts that mirrors the commercial catch rate trends. These abundance indices have rebounded through 2005.

All three assessment models indicate that fishing mortality rates have recently trended downward, since 2003 on the gulf coast and since about 2000 on the Atlantic coast. The analyses differ somewhat in the historical level of fishing mortality but all show a rapid increase in fishing prior to the 1960's then a general slow increase during the period 1960-1999 before the recent decline.

Estimated abundances of blue crabs appear to have responded to the recent declines in fishing mortality by increasing since the early 2000's. Historic trends in abundance show a general decline in biomass from the 1950's through the 1980's, a possible increase in abundance and biomass during the early to mid 1990's before a significant drop is seen during the late 1990's. All three analyses indicate a rebound in abundance in recent years.

The results of the three analyses point to somewhat different results for the status of the blue crab stocks in Florida. The catch-survey analysis indicated that overfishing was not occurring during 2002-2005, with respect to a rough estimate of the potential overfishing benchmark $F_{0.1}$. The biomass dynamic model indicated that the fishery has been overfishing the stock on both coasts since the mid 1960's or early 1970's with respect to F_{MSY}. This has apparently reduced the stock size below the biomass associated with maximum sustainable yield (MSY). Conversely, the stochastic stock reduction analysis shows that, though highly uncertain, the stocks on both coasts were most likely not being overfished during 2002-2005. A common feature in all of these analyses is the finding that blue crabs in Florida appears to be very resilient to high fishing rates. Estimates of MSY were consistent between these models at about 17.5 million pounds on the gulf coast and 7.5 million pounds on the Atlantic coast.

There are troubling gaps in our knowledge about blue crab and its fishery that could lead to a high degree of bias in these analyses. The ages of blue crab are not known and may lead to a biased estimate of natural mortality rate. There is some information to suggest that commercial discard mortality could be high and that the recreational catch could be significant. Neither of these is included in the analyses due to lack of any meaningful time series of these data.

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1.0 Introduction

This report follows the Standard Stock Assessment Report format recommended by the Atlantic States Marine Fisheries Commission (2005).

1.1 Management Unit Definition

The Florida Fish and Wildlife Conservation Commission (FWC) manages the Florida blue crab stock as one management unit. In this assessment we provide separate, detailed population analyses for the gulf and Atlantic coast regions. These populations are defined geographically as the gulf population, including all blue crabs within and offshore of Florida coastal counties from Escambia east and south through Monroe, including Atlantic waters off Monroe County. The Atlantic population is comprised of all blue crabs in and adjacent to Miami-Dade through Nassua Counties. Blue crabs also occur well inland in major waterways (e.g., St. Johns River) so inland counties in which landings have been reported were divided between the two population according to major watersheds contained in each county, as gulf Counties: Leon, Washington, Alachua, Gadsen, Madison, Columbia, Desoto, Highlands, Holmes, Polk, Sumter, and Suwannee; and Atlantic Counties: Clay, Putnam, Bradford, Marion, Lake, Orange, and Seminole. There may be some minor population misclassification of landed blue crabs because of the high mobility of blue crab fishers. Though genetic information suggests one unit stock of blue crabs occurs in Florida waters (see 2.4 Stock Definition), the short-term dispersal of blue crabs appears to be localized so that the gulf and Atlantic populations likely respond independently to fishing pressures within their respective regions.

1.2 Regulatory History

The first blue-crab specific regulation in Florida was enacted in 1941 and included a 5 ½ inch carapace width minimum size limit and a May 15 – August 15 prohibition of the possession of egg-bearing females. In 1947, the closed season was removed making it legal to harvest egg-bearing females year-round. However, in 1963, the take or possession of egg-bearing females from waters east of the Aucilla River was prohibited. More regulations were added in 1973 when requirements for possessing and displaying the number of a current state permit and escape gap regulation were passed. It was also deemed unlawful to offer for sale any egg-bearing females taken from state waters. In 1978, the minimum carapace-width size limit was reduced to five inches The possession of undersized blue crabs, for the purpose of sale, in quantities greater than 10% of the total catch, was prohibited unless authorized by a special permit for the soft-shell crab or bait trade. A variety of permitting and trap marking regulations were made during the 1980's.

The near-current regulations to blue crab harvest were first developed by the Florida Marine Fisheries Commission in 1994 when they designated blue crab as a restricted species, retained the minimum size limit of five inches for commercial harvest, repealed the 10% tolerance for undersized crabs, allowed a bycatch possession limit of 200 pounds of blue crabs per trip on shrimp trawls, prohibited all harvest and possession of egg-bearing blue crabs, and established a daily recreational bag limit of ten gallons of blue crabs. Numerous other gear design and provisions to regulate fishing activities were also included. By the middle of 1994, there were changes to some of these regulations that allowed some retention of undersized crabs and mandated the use of three escape rings larger than 2 3/8 inch inside-diameter in each trap. Finally, by the end of 1994, standards for biodegradable trap components were enacted to prevent "ghost-fishing" by lost traps. The development of a peeler-trap fishery that used small-meshed traps without escape rings led to late 1995 regulations that only blue crab traps with larger, 1 ½ inch mesh required escape rings and that only live male crabs could be used as "bait" in peeler traps. In 1998, the use of blue crab traps to harvest blue crabs in federal waters adjacent to Florida was prohibited, mainly as a way to eliminate the use of these traps to catch finfish. Also, a moratorium was placed on the issuance of new blue crab endorsements beginning in June 1998 and this has been extended through June 2007 in preparation for an effort management plan that involves limiting the number of fishers and the number of traps they are allowed to possess. In order to eliminate the take of stone crabs in blue crab traps prior to the opening of the stone crab fishery, the waters three to nine nautical miles offshore of the area north of the Suwannee River were closed to blue crab traps during September 20 – October 4 each year beginning in 2004. In 2005, this closure was extended to all of the gulf coast of Florida.

1.3 Assessment History

The only previous quantitative, Florida-specific stock assessment of blue crab in Florida is the precursor to the current assessment (Murphy *et al.* 2001). Their findings were highly dependent on the apparent maximum age achieved by unexploited blue crabs and the natural mortality rate implied from this life span. Under the assumption of a six-year maximum life span, their analysis suggested that overfishing (in the sense of $F_{0.1}$) was occurring on both the gulf and Atlantic coasts during the most recent years they examined (1999/2000). Under what was judged a more likely assumption of a shorter three-year maximum life span, overfishing was not occurring on either coast. This latter finding was similar to that from a gulf-specific assessment exercise conducted for each gulf coast state blue crab population (Gillory *et al.* 1999). Their findings were that, except for 1998, there was no significant increase in total mortality rates and no significant declining trends in relative abundance, mean carapace width, percent frequency occurrence or landings.

2.0 Life History

Much of the biological and fishery information summarized herein was taken from studies of blue crabs conducted in Florida and summaries of available data (Laughlin 1982; Tagatz 1968; Steele 1979, 1991; McMillen-Jackson et al. 1994; Steele and Bert 1994, 1998; McMillen-Jackson et al. 2003a; McMillen-Jackson et al. 2003b; McMillen-Jackson and Bert 2004). Unpublished data derived from FWC Fish and Wildlife Research Institute (FWRI) blue crab studies around Florida were also used. Additional information was taken from studies of blue crab in Chesapeake Bay (Rothschild and Ault 1992), Galveston Bay (Pullen and Trent 1970), and Lake Pontchartrain, Louisiana (Darnell 1961). Synopses of biological data (Millikin and Williams 1984; Williams 1984; Guillory *et al.* 2001) also provided useful information on blue crab biology. Information on blue crab fisheries summarized herein was excerpted from FWC management and regulations documentation (see http://myfwc.com/marine).

2.1 Age

Crustacean generally are aged by assigning age classes to modes in size-frequency distributions. The method is complicated by the following factors: 1) crustaceans experience discrete growth by means of ecdysis (molting), rather than continuous growth, and 2) the time period between molts increases with age, while the proportional increase in size per molt decreases. The relationship between age and size is more problematic in blue crabs than in some other crustacean species because blue crab size (generally measured as carapace width including the lateral spines) at age is highly variable; females undergo a terminal molt when they mature at about age one, after which they no longer grow in size; and the blue crab spawning season in the gulf is protracted and seasonal growth rates may differ, thereby confounding the identification of cohorts according to size modes.

Recently developed biochemical methods have provided better estimates of blue crab ages and population demographics. Lipofuscin is a fluorescent pigment that accumulates in neural tissues over time. Histological analyses of lipofuscin concentrations have been used for age determination in several species of crustaceans. Ju *et al.* (1999; 2001) devised a biochemical analysis to quantify lipofuscin accumulation in blue crabs. Ju *et al.* (2003) used this method to conduct a large-scale demographic assessment of blue crabs in Chesapeake Bay. Lipofuscin analysis provided four modes for which they could assign age classes, compared with the two modes provided by size distributions. The data indicated that the majority of the adult crabs captured in a winter dredge survey were less than two years old, although several crabs were estimated to be greater than three years old. Secor *et al.* (2003) evaluated age structure and estimated mortality parameters for use in stock assessments using lipofuscin data from blue crabs collected from Chesapeake Bay during the 2001/2002 winter season.

Lipofuscin is a byproduct of metabolism and the rate of accumulation may vary with regard to environmental factors, principally temperature (Ju *et al.* 1999, 2001; Ju and Harvey 2002). Thus, the Chesapeake aging data is not directly applicable to Florida blue crabs. Development of a project to biochemically analyze lipofuscin levels in Florida blue crabs is underway. This project will provide a method of aging crabs that is more reliable than size measurements. Accurate data on Florida blue crab maximum age and population demographics are essential to producing a meaningful stock assessments.

The maximum observed age of blue crabs is presumed to be 3-6 years (Van Engel 1958; Rothschild and Ault 1992). Mark-recapture studies have provided some of the best estimates of blue crab maximum age. In the St. Johns River, Florida, tagging data indicated that few blue crabs live for longer than one year (Tagatz 1968a). However, several crabs were recaptured two and three years after tagging (their age at tagging was assumed to be approximately one year), suggesting a maximum age of four years. Maximum age of four or five years was derived from tagging data in North Carolina (Fischler 1965 in Miller et al. 2005). Rothschild and Ault (1992) estimated a maximum age of six years for crabs in Chesapeake Bay based on a recapture of blue crabs four years after tagging; the crab were assumed to be about two years old when tagged.

2.2 <u>Growth</u>

Blue crabs have a hard exoskeleton consisting mainly of chitin. To allow for growth, the crab must shed this layer and produce a new exoskeleton through the process of ecdysis (molting). Underneath the hard exoskeleton, the new soft exoskeleton develops. After the crab molts, the new exoskeleton expands and hardens, allowing for growth. Environmental conditions such as temperature (Leffler 1972), salinity (Tagatz 1965), and lunar cycle (Ryer et al. 1990) influence the timing and frequency of molting (Steele 1979). The crab requires 18-20 postlarval molts to reach maturity (Van Engel 1958 in Steele 1979). Females are assumed to undergo a terminal molt when they mature, after which they no longer grow in size. However, Steele and Bert (1994) noted that the average size of ovigerous female blue crabs caught in traps in Tampa Bay, Florida, was significantly larger (by approximately 20 mm) than the average size of newly mature females, suggesting that some female blue crabs may molt subsequent to maturation. Molting and pre-molt mature female have been observed in other studies (Abbe 1974; Olmi 1984; Milikin and Williams 1984 in Guillory *et al.* 2001), but their frequency is presumed to be low. However, at least some blue crabs, both females and males, seem to have terminal molts; Tagatz (1968a) tagged adult blue crabs in the St. Johns River, Florida, and recovered three females about two years after release, and two males about three years after release. Because the tags were attached to the carapace and would be lost at molting, these crabs had not molted.

Blue crab growth rates are difficult to estimate because molting results in discrete rather than continuous growth. Also, the time period between molts (molt interval) increases with age, while the proportional increase in crab body size per molt (growth increment) decreases. Molt intervals for juvenile blue crabs vary with crab size, ranging from three to five days for crabs less than half an inch, to one to two months for a four-inch crab (Van Engel 1958 in Oesterling 1976). Tagatz (1968b) raised juvenile blue crabs in outdoor floats in the St. Johns River, Florida, and found that although growth per molt was similar over the winter and summer (average temperatures of 14˚ C and 26˚ C, respectively), molt intervals increased at lower temperatures. Growth increments were highly variable, ranging from approximately 8% to 50%. In another study (Tagatz 1968a), he found that most crabs in the St. Johns River reached maturity and full size within one year of hatching. Size at maturity was variable; the size of the smallest mature female was 99-mm carapace width (CW) and the largest immature female was 177-mm CW. The size overlap of immature and mature females was wider in Tampa Bay, where the smallest mature female captured in a trapping study was 47-mm CW and the largest immature female was 174-mm CW (FWC-FWRI unpublished data). Tagatz (1968a) found that males in the lower St. Johns River reached 50% maturity at 125-129-mm CW and nearly 100% maturity at 165-169-mm CW. In the lower salinity upper river, males reached maturity at larger sizes; at 150-154-mm CW 50% of the males were mature, but at the 165-169-mm CW size (the largest size class he reported), only 76% were mature. The Florida maturity-at-size values were intermediate to those obtained from blue crabs in Louisiana and Mississippi (Guillory and Hein 1997b and Perry unpublished data, respectively, in Guillory *et al.* 2001).

Carapace-width-to-weight relationships have been estimated for blue crabs sampled from estuaries throughout much of their range in the eastern United States. In Florida, two sets of estimates derived, one using both juvenile and adult blue crabs, and the other using only legal-sized crabs. For the first set of estimates, carapace-width-to-weight relationships were analyzed for female (n = 1,358) and male (n = 3,433) blue crabs caught during a trapping study in Tampa Bay (FWC-FWRI unpublished data). Only live, uninjured, premolt or intermolt crabs greater than 15 grams in weight were used in the analyses; crabs less than 15 grams could not be weighed accurately. Carapace widths ranged 24-196 millimeters for females and 18-233 millimeters (mm) for males. Crab weights (W) ranged 16-330 grams for females and 16-600 grams for males.

Female: $W = 0.01573 * CW^{1.863}$; $r^2 = 0.954$
Male: $W = 0.006036 * CW^{2.104}$; $r^2 = 0.954$.

Analyses also were performed on commercially caught, legal-sized (>127 mm CW) blue crabs throughout Florida (FWC-FWRI unpublished data). Crabs were measured quarterly either at fish houses or directly off the fishing boat, at six locations around the state; data from legal-sized crabs from the Tampa Bay trapping study also were used. Measurements included carapace width, carapace length, and body weight. Only live, mature crabs with two claws were used in the analyses. The carapace-width (mm)-to-weight (g) relationships for all crabs (females: n = 2,254, males: n = 3,050) were:

Female: $W = 0.0000551 * CW^{1.8660}$; $r^2 = 0.620$
Male: $W = 0.0000397 * CW^{2.1430}$; $r^2 = 0.602$.

Significant interactive effects of region and season were found for both sexes, so pairwise analyses were performed. Significant pairwise differences in regression line intercepts (crab size) were more common than differences in slopes (growth rate), but these differences were infrequent and showed few consistent spatial or temporal patterns. Thus, these two sex-specific size-weight relationships for legal-sized blue crabs can be applied to crabs caught throughout the state.

In the Chesapeake Bay, a relationship of carapace width (millimeters) to weight (grams) was estimated for 5,000 blue crabs of each sex that were collected during the winter dredge survey conducted (Rothschild and Ault 1992). The sex-specific weight-at-carapace-width relations were:

Female: $W = 0.0034865 * CW^{2.1165}$
Male: $W = 0.00022105 * CW^{2.7208}$.

Pullen and Trent (1970) collected blue crabs during a shrimp trawl survey in Galveston Bay, Texas and estimated the carapace-width (millimeters) to weight (grams) relations:

Female: $W = 0.00028743 * CW^{2.6395}$
Male: $W = 0.00018135 * CW^{2.7748}$.

Tagatz (1965) did not supply a regression equation for the carapace-width-to-weight relation for blue crabs found in the St. Johns River, Florida, but his data were comparable to the findings by Pullen and Trent (1970) in Galveston Bay. Pullen and Trent (1970) noted that blue crabs of a given sex and carapace width from Virginia and Florida weighed less than those sampled from Galveston Bay, Texas, but when compared with the Tampa Bay data, this was only true for the larger size classes (>175-mm CW for females and 190-mm CW for males).

2.3 Reproduction

Blue crabs mate nearly year round in Florida waters. In the St. Johns River, Tagatz (1968) found mating common from March-July and October-December. In Tampa Bay, mating pairs were found year round, with the highest frequencies February-July, and lower frequencies September-January; little mating was found to occur in August (FWC-FWRI unpublished data). Males mate during the last three or four stages (molt cycles) of growth. Female blue crabs are thought to mate only once in their lifetime immediately following their pubertal molt. However, Steele and Bert (1994) noted that the mean size of ovigerous females in Tampa Bay was significantly larger than the mean size of post-pubertal molt females, suggesting that females may molt after maturity. Size at maturity is highly variable with environmental conditions such as temperature and salinity (Tagatz 1968a, b). Mature females ranged 100-240 mm CW in the St. Johns River (Tagatz 1968), and 47-196 mm CW in Tampa Bay (FWC-FWRI unpublished data). There is a large overlap in sizes of immature and mature female blue crabs; the largest immature female caught in the St. Johns River was 177 mm CW, and in Tampa Bay was 174 mm CW.

Mating occurs in low-salinity waters. The pre-pubertal female releases pheromones that are detected by the males via the aethetasc sensilla in the outer flagellum of the antennules (Alexander 1999). This is a cue for the male to begin precopulatory behavior. Pairing with a pre-pubertal female, the male carries her around until she molts. Copulation occurs immediately following the pubertal molt before the exoskeleton hardens. Precopulatory pairing maximizes reproductive success for the males when mating is limited to a brief period of time in the female's life cycle, and provides protection for the female while in the vulnerable molting process. After mating, the males tend to remain in the estuaries while the mature females migrate to higher salinity waters to spawn.

In Florida, female blue crab migration patterns differ between the Atlantic and gulf coasts. On the Atlantic coast, female blue crab spawning migrations generally follow an inshore/offshore pattern, similar to those seen in blue crabs throughout the rest of their U.S. range (Cargo 1958; Judy and Dudley 1970). However, tagging studies have shown that females on the Florida gulf coast migrate northward along the coast prior to spawning. Oesterling and Adams (1982) reported that nearly 25% of tagged female blue crabs were recovered more than 48 kilometers from their release sites on the Florida gulf coast, and that some crabs traveled as far as 499 kilometers. Steele (1991) had similar results; tagged female blue crabs released in Tampa Bay were recovered up to 800 km north of their release sites, and crabs released as far south as Charlotte Harbor were recaptured in Apalachee Bay. Oesterling and Adams (1982) proposed that the females migrate north toward a common spawning ground in the Apalachicola Bay region, from where larvae are dispersed along the entire west Florida coast. Steele (1991), however, suggested that the outflow from the Apalachicola River acts as a barrier to westward dispersal for these crabs.

Spawning typically occurs during the spring and summer. The female broods the eggs in a sponge-like mass on the pleopods. The eggs hatch as zoea larvae and development occurs in offshore waters. While in the planktonic stage, the larvae may be distributed by currents. After 31-49 days, the zoea develop into megalopae, which return to the estuaries and settle as benthic juveniles (Costlow and Bookhout 1959 in Tagatz 1968). Juvenile blue crabs are found in nearshore shallow waters and within the estuaries, and move back into lower salinity waters.

Female blue crabs may spawn multiple times as the sperm are viable for at least one year. Females captured from the Indian River Lagoon produced up to six fertile broods over a six-month period from April to October (Hines *et al.* 2003). Although these females were tank reared throughout this period, the data provides perspective on blue crab reproductive capabilities. Dickinson *et al.* (2006) reported that some female blue crabs maintained in bay waters during the spawning period produced more than seven clutches of eggs over 18 weeks. The larger crabs produced more eggs per clutch, but the smaller crabs produced clutches more often, and they concluded that reproductive output was similar for most size groups.

2.4 Stock Definitions

The blue crab, *Callinectes sapidus*, inhabits estuarine and nearshore coastal habitats throughout the western Atlantic and Caribbean from northern Massachusetts to northern Argentina (Williams 1984; Steele and Bert 1994).

Blue crabs in the eastern Gulf of Mexico and the western Gulf of Mexico are genetically dissimilar, and the exchange of individuals between these regions, and between the Gulf of Mexico and the Atlantic Ocean, may be low. These differences are not so pronounced that we would consider these populations to be different genetic stocks. However, limited localized dispersal could delay the re-establishment of overfished populations by immigrant larvae, juveniles and adults leaving geographically distant populations.

2.5 Genetic Information

Genetic analyses of proteins and mitochondrial DNA (*mt*DNA) of blue crabs along the Atlantic Ocean and Gulf of Mexico coasts of the United States revealed no distinct genetic structuring of populations. However, gradual changes in a protein allele frequency along the Atlantic coast (McMillen-Jackson *et al.* 1994) and in *mt*DNA diversity along the Atlantic and gulf coasts (McMillen-Jackson and Bert 2004) suggested that most short-term dispersal of blue crabs is localized, and that long-distance genetic exchange occurs over long periods of time. Although the regional exchange of individuals may be low, these differences are not so pronounced to consider these populations to be different genetic stocks. Local dispersal by blue crabs was confirmed by a *mt*DNA sequence analysis of Gulf of Mexico blue crabs (Darden 2004). Although this analysis detected significant genetic differences between blue crabs in the eastern and western Gulf of Mexico and among western Gulf of Mexico blue crabs, blue crabs along the west Florida coast were genetically homogeneous.

Two comprehensive studies on the population genetics of blue crabs in Florida and throughout their range in the eastern United States have been conducted (McMillen-Jackson *et al.* 1994; McMillen-Jackson and Bert 2004). In the first study, McMillen-Jackson *et al.* (1994) used protein electrophoresis to analyze blue crabs collected at 16 locations from New York to Texas, including six locations in Florida: Cape Canaveral, Florida Bay, Tampa Bay, Chassahowitzka River, Apalachicola Bay, and Pensacola. In the second study, McMillen-Jackson and Bert (2004) used restriction fragment length polymorphism analysis of the blue crab *mt*DNA genome to analyze blue crabs collected at 14 locations from New York to the Yucatan Peninsula, Mexico, including five locations in Florida: Jacksonville, the Keys, Tampa Bay, Cedar Key, and Apalachicola Bay. In both studies, they determined the level of genetic diversity overall and for each collection, level of genetic variance among all collections and between pairs of collections, genetic distances between pairs of collections, and genetic relationships among collections. No significant differences in genetic composition (i.e., nuclear gene allele or *mt*DNA haplotype frequencies) occurred within the Florida collections; thus, blue crabs on the east and west coasts of Florida appear to comprise a single genetic stock. However, the data derived from both studies suggest that short-term dispersal and gene flow (the genetic integration of individuals into non-natal populations) in blue crabs are regional in scale, and that long-distance gene flow (which is related to migration and dispersal) occurs in a stepping-stone manner over long time periods. Thus, a depleted populations is more likely to be repopulated from nearby locations than from distant locations. In addition, a difference in *mt*DNA genetic variability (the number of different alleles or haplotypes in each collection) between blue crabs in the Florida Keys (low genetic variability) and in Jacksonville, Florida (high genetic variability), suggests that blue crab dispersal and gene flow between the coasts may be asymmetrical. Blue crab dispersal and gene flow appears to be relatively high from the gulf to the Atlantic (likely due to larval transport via the Florida Straits), and much lower in the opposite direction.

In a third study, Darden (2004) sequenced a highly variable region of the *mt*DNA *cytochrome c oxidase subunit I* gene to analyze population structure in blue crabs collected at 11 Gulf of Mexico locations from Naples, Florida to Brownsville, Texas, including five locations in Florida: Goodland, Port Charlotte, Tampa Bay, Apalachicola, and Pensacola. Analysis of molecular variance – which considers both the differences in genetic composition (*mt*DNA haplotype frequencies) between collections, as well as the differences between individual haplotypes within a collection – defined two genetically differentiated Gulf of Mexico regions: the western Gulf of Mexico, consisting of the collections from Pensacola, Florida to Texas; and the eastern Gulf of Mexico, consisting of the collections from Apalachicola, Florida to southwest Florida. Within the western Gulf of Mexico, all but one of the pair-wise comparisons between collections showed significant genetic differentiation, confirming the results of the previous study that blue crabs dispersal is limited and long-distance gene flow is low. Conversely, no significant genetic differences were evident among the eastern Gulf of Mexico blue crab collections, indicating that blue crabs along the west Florida coast experience high gene flow among themselves.

The results of these genetic analyses are consistent with blue crab migration behaviors. Throughout most of their U.S. range, blue crab migrations are limited: male blue crabs generally remain within an estuary, while female blue crabs migrate to higher salinity nearshore waters to spawn. Movement tends to be inshore-offshore, rather than alongshore. This results in localized patterns of dispersal, where the exchange of individuals is highest between adjacent geographic locations, and decreases with distance. Consequently, populations that are geographically close to one another will be more genetically similar than are populations that are geographically far apart, resulting in the stepping-stone patterns of gene flow and gradients in allele frequencies and genetic diversities. The exception to these general migration behaviors is seen in blue crabs along the gulf coast of Florida; in this region, female blue crabs migrate relatively long distances north as far as Apalachee Bay (Oesterling 1976; Steele 1991). Long-distance migrations tend to genetically homogenize geographically separated populations, as seen in Darden's (2004) results for the eastern Gulf of Mexico blue crab collections.

2.6 <u>Natural Mortality</u>

A range of estimates for instantaneous natural mortality (M) were used in the Murphy *et al.* (2001) assessment and these were based on different assumptions about blue crab maximum life span. The maximum observed age of blue crabs is 3-6 years (Van Engel 1958; Rothschild and Ault 1992). Using the relation M=3.0/maximum age for an exploited population (International Council for the Exploration of the Seas [ICES] convention), this range of observed maximum ages gives M's ranging from 0.5 to 1.0 yr^{-1}. Given little information on the annual or age-specific changes in natural mortality, Murphy *et al.* (2001) assumed a constant 6-month rate of 0.25 or 0.50 yr^{-1}, though this parameter was highly influential in the status determination for blue crab.

Guenther *et al.* (per. comm. FWC-FWRI and In Prep.) estimated year-specific estimates of natural mortality for blue crabs in Tampa Bay during 1989-2004. These were derived from an ECOPATH/ECOSIM modeling exercise that included a hydrodynamic model for the input of nutrients and a predator-prey model for the predation pressure. The ranges of M estimates were from 0.96 to 1.67 yr^{-1} suggesting higher rates than those derived through the ICES convention.

3.0 Fishery Description

3.1 Brief Overview of Fisheries

The commercial fishery for blue crabs is conducted almost exclusively using blue crab traps. Information on the recreational fishery is lacking but various small traps, dip nets, and lines are used to catch blue crabs. Commercial landings have shown a general decreasing trend since the mid 1980’s (Table 3.1.1, Fig. 3.1.1). Superimposed on this pattern are large oscillations often related to extended years of drought when blue crab production is apparently low and wet years when blue crab production is apparently high.

Various observations describing characteristics of the fishing effort in the Florida blue crab fishery have been documented (Steele and Bert 1998; McMillen-Jackson *et al.* 2003). McMillen-Jackson *et al.* (2003) conducted a mail survey of 855 Florida commercial blue crab fishers. The survey consisted of 14 questions focused on individual fishing effort, trap usage, trap loss, and fishing location. On average, blue crab fishermen reported fishing a total of 364 (standard deviation [SD] = 310) traps. About 43% reported fishing 200 or fewer traps, and 80% fished 500 or fewer traps. Only 6% reported fishing 1,000 or more traps, and one respondent reported fishing 3,000 traps.

Survey respondents reported actively fishing an average of 193 traps per day (SD = 117). Overall, they reported fishing 10-900 traps per day. About 72% reported fishing 200 or fewer traps per day. This question did not specify how many fishers were fishing, so the higher numbers of traps may have been fished by more than one fishers. Most (67% of survey respondents) of the fishers reported that they fished their blue crab traps alone. About 27% fished with one other person, and fewer than 6% fished with two or more people.

Taking into consideration the number of traps fished daily, as reported by the survey respondents, and the number of fishers in the work group, it was estimated that nearly 90% of Florida blue crab fishers who reported working alone actively fished 200 or fewer traps per day (mean = 164 traps fished per day, SD = 85, range = 10-500). More fishers generally worked more traps per day. Two fishers fished an average of 203 traps per day (SD = 167, range 10-900). The largest reported work group – five fishers – averaged 325 traps fished per day (SD = 248, range = 150-500).

About 90% of survey respondents reported fishing their blue crab traps three or fewer days after baiting (soak time), with the highest percentage (46%) reporting a two-day soak time. The range of soak times was 1-15 days, but only two respondents reported soak times of more than one week.

About 80% of survey respondents reported that they fished for blue crabs 3-6 days per week. Overall, respondents averaged four days of fishing per week (SD = 1.5), although about 12% reported fishing seven days per week. Survey respondents reported fishing for blue crabs an average of 41 weeks per year (SD = 13). More than 65% fished 40 or more weeks per year, and about 50% of those individuals (33% of all survey respondents) reported fishing for blue crabs 52 weeks per year.

An average of seven blue crabs caught per trap (SD = 5.4) was reported by survey respondents. Overall, respondents reported per-trap catches of 0-40 blue crabs. Although most reported catches of 1-6 crabs, nearly 25% reported averaging ten or more blue crabs per trap.

3.2 Current Status

The current status of the blue crab fisheries in Florida is uncertain though commercial landings have rebounded in recent years from a low period of landings in the early 2000's. There is no information on the recreational blue crab fishery.

4.0 Habitat Description

4.1 Brief Overview of Habitat Requirements

Blue crabs are dependent on estuaries throughout much of their life history, particularly in the postsettlement and reproduction phases (Guillory *et al.* 2001a). Though postsettlement blue crabs are most abundant in estuaries, they can be found in freshwater and shallow ocean along the shore and out to 295 feet (90 meters), but prefer depths of 115 feet (35 m) or less (Williams 1984; Hamer *et al.* 1991; Steele and Bert 1994). They have been reported as far as 190 miles (305 km) upstream in the Atchafalaya River in Louisiana and in hypersaline waters up to 60 ppt (Guillory *et al.* 2001a). In general, postsettlement blue crabs are associated with inshore and nearshore areas utilizing a range of habitat types including sandy and muddy bottoms to high density vegetative areas.

Blue crab survival and production are positively related to habitat quality (Engel and Thayer 1998; Guillory *at al*. 2001). The estuaries with the highest blue crab production in Florida – Apalachee Bay and Suwannee Sound/Waccasassa Bay – have large tidal marsh and submerged vegetation acreage (Guillory *et al.* 2001). Turner and Boesch (1988) saw declines in blue crab fishery production with wetland habitats loss (in Guillory *et al.* 2001). Habitat loss and degradation are a concern throughout the Gulf of Mexico, particularly in Florida where coastal regions are being converted for development (Guillory *et al.* 1998; Engel and Thayer 1998; Guillory *et al.* 2001). Alteration of estuarine and coastal habitat increase nutrient and chemical loading through nonpoint-source runoff, turbidity, and changes freshwater inflow (Engel and Thayer 1998). Blue crab populations have been adversely affected by domestic, agricultural, and industrial pollutants, as well as drainage alteration and dredge and fill operations (Guillory *et al.* 2001).

High-salinity waters are essential for the early blue crab life stages. Spawning occurs in nearshore waters where larvae are exported via oceanic tides to the continental shelf for zoeal development and megalopal metamorphosis. Optimal salinity for hatching ranges from 23 to 30 ppt and will not occur below 15 ppt, and larvae rarely survive the first molt in salinities less than 20 ppt (Guillory *et al.* 2001). In northeast Florida, larval zoeal stages were found up to 160 km offshore (Nichols and Keney 1963 in Tagatz 1968a). Planktonic postlarval megalopae recruit into Gulf of Mexico and Atlantic Ocean estuaries typically during summer and fall months, where they settle into nursery and shoreline habitats and metaphorpose into the first-crab juvenile stage (Futch 1965; Rabalais *et al.* 1995; Guillory *et al.* 2001; ASMFC 2004). Tagatz (1968a) observed waves of juvenile blue crabs entering the St. Johns River approximately five months after spawning began, continuing from summer through early winter. Blue crab recruitment may be influenced by wind- and storm-driven transport (Rabalais *et al.* 1995, Etherington and Eggleston 2000).

Blue crab postlarvae are five times more abundant in areas with submerged aquatic vegetation (SAV) than unvegetated areas and prefer that SAV habitat over mud and oysters (USEPA 1997; Moksnes and Heck 2006). Juvenile blue crabs utilize salt marsh and seagrass habitats as nursery grounds but eventually disperse from these areas and are most abundant in low to intermediate salinities in the upper and middle estuaries (Guillory *et al.* 2001; Forward *et al.* 2004). Tagatz (1968a) found that juveniles less than 1.57 inches (40 mm) carapace width (CW) preferred habitats in shallow water and mud in the St. Johns River, Florida. In Tampa Bay, Florida, Steele and Bert (1994) identified areas of soft sand-mud interspersed with turtle grass as important juvenile habitat. Heck and Spitzer (2001) suggested that smaller juvenile crabs survive better in low density vegetation while larger juveniles survive better in high density vegetated habitats though they tend to locate in all bottom habitat types (Moody 2001; Guillory *et al.* 2001). This habitat partitioning by juveniles is most likely related to predation avoidance including cannibalism, food availability, reproductive success, and growth (Guillory *et al.* 2001). Hovel and Lipcius (2002) found complexity of seagrass habitat influenced juvenile blue crab survival though intraspecific predation largely affects spatial distribution.

Adult blue crabs use various habitat types including submerged vegetation, unvegetated sediments and marsh areas. Blue crabs are distributed throughout the estuary but are partitioned seasonally with respect to salinity and sex (Steele and Bert 1994). Juveniles of both sexes and adult male blue crabs prefer brackish waters of the upper and middle estuary while adult females tend to concentrate in the lower reaches of the bay in waters of higher salinity (>30 ppt). In tagging studies, Tagatz (1968) found that most of the male crabs remained in the estuarine environment while the females moved further out into the coastal waters to spawn. Prey availability has been shown to be another factor driving adult blue crab distribution in the estuarine system (Seitz *et al.* 2003).

Female blue crab habitat preferences change with life stage. In Tampa Bay, pre-pubertal females are found in low-salinity waters of the mid and upper bay, where mating occurs during molting (Steele and Bert 1994). After copulating, the females migrate to higher salinity waters to spawn. Salinity is an important factor in the hatching of blue crab eggs and survival of the larvae. Costlow and Bookhout (in Steele and Bert 1998) noted that larvae require salinities above 22 ppt to survive. By moving to higher salinity waters offshore before their eggs hatch, the females enhance larval dispersal and reduce osmoregulatory stress and predation (Hines *et al.* 1987 in Steele and Bert 1994).

Blue crabs are opportunistic, benthic omnivores, feeding on fish, aquatic vegetation, mollusks, crustaceans, and annelid worms (Darnell 1961; Muller 1999). Little information is available on the food of larval blue crabs, but in captivity they feed on yellow dinoflagellates (Sandoz and Rogers 1944 in Tagatz 1968b) and *Artemia* nauplii (brine shrimp) and *Arbacia* eggs (Costlow and Bookhout 1959 in Tagatz 1968b). Blue crab megalopae (final larval stage before first crab stage) are omnivorous and feed on pieces of fish, shellfish, and aquatic plants (Van Engel 1958 in Tagatz 1968). Dittel *et al.* (2006) saw changes in dietary patterns with crab size; plant materials composed a large proportion (up to 26% in some habitats) of the diets of small crabs, but not larger crabs. Also, prey items were habitat specific; similar-sized juveniles had different diets in marsh, sand flat, and seaweed bed habitats.

In Apalachicola Bay, Laughlin (1982) found that blue crabs fed on fishes, xanthid crabs, smaller blue crabs, and mollusks such as American oysters, *Mercenaria* sp. hard clams, coot clams, mussels, *Rangia*, and periwinkles (Millikin and Williams 1984; Williams *et al.* 1990). Tagatz (1968) examined the stomach contents of 695 blue crabs captured in the St. Johns River, Florida. Blue crabs (5-200-mm CW) ate the same general diet regardless of the crab size, area, or season feeding primarily on mollusks (clams and mussels), fish, and crustaceans (amphipods and crabs).

Blue crabs play an important role in the marine trophic system, as prey and predators. Mammals, birds, and larger fish prey on blue crabs (Darnell 1959; Bateman 1965; Day *et al.* 1973 in Steele 1979). Their primary predators include raccoon (*Procyon lotor*), blue heron (*Ardea herodias*), common merganser (*Mergus merganser*), and hooded merganser (*Lophodytes cucullatus*). Juvenile blue crabs are eaten by larger fish such as spotted seatrout (*Cynoscion nebulosus*), red drum (*Scianops ocellatus*), Atlantic croaker (Micropogonias undulatus), black drum (Pogonias cromis) and sheepshead (*Archosargus probatocephalus*). Florida pompano (*Trachinotus carolinus*) and other large fish and planktivores (Adkins 1972 in Steele 1979) consume larval blue crabs.

As predators, blue crabs can influence community composition and distribution. Blue crab predation affects the abundance and size distribution of the hard clam *Mercenaria mercenaria* on different substrates (Arnold 1984); plays a significant role in maintaining salt marsh habitat health by controlling densities of the periwinkle *Littoraria irrorata* (Silliman and Zieman 2001, Silliman and Bertness 2002); and serves to limit the abundance and distribution of introduced species such as the European green crab *Carcinus maenas* (deRivera *et al.* 2005) and rapa whelk *Rapana venosa* (Harding 2003).

5.0 Data Sources

5.1 Commercial

Commercial harvest information was obtained from the FWC's Marine Fisheries Information System and from Fisheries Statistics Division of the National Marine Fisheries Service (NMFS) for the years 1950-2005. These data include annual landings tallied from monthly dealer reports collected by the NMFS during the period 1950-85[1] and trip-specific commercial landings reported within the FWC trip ticket program during the period 1986-2005. Trip tickets included edited batches 1 – 937, which closed October 17, 2006, insuring that all data through 2005 were edited and final. Historic coast-specific commercial landings data (sporadic during 1897-1949) were also gathered from various reports of the U.S. Commissioner of Fisheries and subsequent agencies. The sizes of commercially landed blue crabs are not routinely monitored but some data on the size, weight, and sex of commercially harvested blue crabs landed from throughout the state have been collected under the Trip Interview Program and by the FWC-FWRI Crustacean Fisheries staff.

5.1.1 Data Collection Methods

5.1.1.1 Survey Methods

During the period 1950-1986, landings of both soft-shell and hard blue crab were reported to the NMFS (and predecessor Federal agencies) through monthly dealer reports made by major fish wholesalers in Florida. Prior to this time (late 1800's through 1949), commercial

[1] See http://www.st.nmfs.gov/st1/commercial/index.html.

landings were reported only occasionally by agents of the U.S. Commissioner of Fisheries. Since 1986, information on what is landed and by who in Florida's commercial fisheries comes from the FWC's Marine Resources Information System, commonly known as the trip-ticket program. Wholesale dealers are required to use trip tickets to report their purchase of saltwater products from commercial fishers. Conversely, commercial fishers must have Saltwater Products Licenses to sell saltwater products to licensed wholesale dealers. In addition, blue crab became a "restricted species" in 1995 so only fishers who have Restricted Species Endorsements on their Saltwater Products Licenses qualify to sell blue crab. Each trip ticket includes the Saltwater Products License number, wholesale dealer license number, date of the sale, fishing gear used, trip duration (time away from the dock), area fished, depth fished, number of traps or number of sets where applicable, species landed, quantity landed, and price paid per pound.

Biostatistics samplers charged with monitoring Florida's commercial landings of marine resources have occasionally sampled blue crabs, during 2000-2002 on the gulf coast and during 1997, 1998, 2000, 2001, 2003, and 2005 on the Atlantic coast. These samples are generally taken when animals are available and at the convenience of fish house operators. A special, FWC-FWRI Crustacean Fisheries biostatistics sampling effort for blue crabs landed in the commercial fishery was conducted during 2002-2004 at fish houses and on fishing boats in six regions of the state (Panhandle, Big Bend, Southwest, Southeast, Indian River, and Northeast). In each region, a minimum of 100 crabs were weighed and measured each quarter, often from the same fish house.

5.1.1.2 Sampling Intensity

The commercial landings based on monthly dealer reports prior to 1986 came from a subset of dealers that included all the large wholesale dealers operating in Florida. The FWC trip ticket program greatly expanded the coverage of the fishery to include all wholesale dealers operating in Florida and to include all transactions where marine resource products are purchased from a licensed commercial fisher. In recent years (2004-2005), the numbers of trips reporting blue crab landings has been about 25,000 on the gulf coast and 15,000 on the Atlantic coast (Table 3.1.1).

The biostatistics data for landed commercial blue crabs is available during the period 2000-2004 on the gulf coast and periodically since 1997 on the Atlantic coast. The number of blue crabs sampled for lengths was generally below the 100 lengths / 200 metric ton (MT) threshold used to define the adequate number of representative samples needed to describe the landings (National Marine Fisheries Service Northeast Fisheries Science Center rule-of-thumb). Exceptions occurred when adequate samples were collected for lengths on the Atlantic coast in 2002, (0.63 crabs/MT landed), 2003, and 2004 (Table 5.1.1.2.1). In terms of weight, at least 0.5 samples per metric ton were made on the Atlantic coast during 2000, 2003, and 2004.

5.1.1.3 Biases

The NMFS program to collect landings was seemingly most effective for fisheries where the majority of landings are made at the large-volume wholesale dealer outlets (fish houses). Blue crabs are most often landed in small amounts at both large and small fish houses so there is a potential negative bias in the early commercial landings. However during 1985 and 1986, when two data collection systems operated concurrently, the NMFS-reported landings of blue crab were often considerably higher than those reported through the trip ticket program. This was generally considered a result of the reluctance of fishers to participate in the trip ticket program during the early years (B. Muller, FWC-FWRI, pers. comm.) though some of the large-fish-house-sampling bias may still have been evident on the Atlantic coast in 1985. The General Canvass recorded 50% and 16% higher blue crab landings than did trip-tickets on the gulf coast during 1985 and 1986, respectively. On the Atlantic coast, the general-canvass reported blue crab landings were 14% lower than trip-ticket reported landings in 1985 and 44% higher in 1986. The General Canvass is generally considered the official commercial landings up through 1985 when it was displaced by the trip ticket system. It is assumed here that any mis-reporting by the official landings system is randomly distributed over the years. The mobility of the blue crab fleet may also introduce some bias into the reported landings, when blue crab caught on one coast are transported to the other coast and sold to a dealer without indicating the area fished on the trip ticket.

Biostatistics data collected under the TIPS program was generally collected from unsorted landings or the entire landings for a particular trip were sampled. The serendipitous encounter of blue crabs for sampling could have introduced an unknown bias. The biostatistics sampling that occurred statewide during 1997-2005 occasionally encountered landed blue crabs that some fishers or fish houses had sorted by sex, so the sex ratio of the crabs sampled may not be an accurate representation of the sex ratio of the catch. This FWC-FWRI Crustacean Fisheries survey also restricted sampling to live blue crabs, ignoring the small numbers of dead crabs in the landings. Any additional biases in this sampling are unknown.

5.1.1.4 Biological Sampling

Blue crabs landed at commercial fish houses were sampled for carapace width, weight, and sex under the Trip Interview Program (TIP). Sampling for blue crab was sporadic and usually occurred when fish house operators allowed sampling of live crabs and when targeted fish species were not available. Besides the above biostatistics measures, the commercial fishing trip’s general location, gear used, and trip duration were recorded and the disposition of the samples were noted (sorted, unsorted).

During 2002 through 2004, commercially caught blue crabs were sampled in six regions of the state: Panhandle, Big Bend, Southwest, Southeast, Indian River Lagoon, and Northeast. The crabs are measured either directly off the fishing boat or at fish houses. At least 100 crabs at each location were sexed, measured (carapace width: tip to tip of lateral spines) to the nearest millimeter, and weighed to the nearest gram. Lost claws and major injuries were noted, as well as crab condition (alive or dead). Sampling was conducted quarterly for most locations, although not all locations were sampled every quarter due to a lack of commercially caught crabs at a particular time (e.g. Southeast locations during the drought) or the inability to make adequate arrangements with local fishers or fish houses.

5.1.1.5 Aging Methods

No aging methods besides following modal progressions of length-classes (see Section 2.2 Growth) have been applied to blue crabs in Florida.

5.1.1.6 Development of Estimates

For the following analyses, the available data were used to estimate the number of traps pulled per trip, the numbers of blue crabs landed, and least squares mean estimates of annual catch per unit effort. While the first two types of information are occasionally available on the trip ticket for each commercial trip, the landings data are sometimes reported in pounds and the number of trap pulls is missing or seemingly impossible given the time duration of the trip. The reported commercial pounds of blue crabs landed were converted to numbers using a constant value of 0.41 pounds per crab. This is the statewide average reported for the 2002-2004 biostatistical survey of landed blue crabs in Florida and was similar to the average weights reported for samples occasionally taken under the TIP survey (Table 5.1.1.2.1). The number of traps pulled was estimated based on matching missing or inaccurate (bad) trip ticket records with complete and seemingly valid (good) trip ticket records that shared some trait with the bad records. The good trip ticket records were defined as any that showed saltwater products license numbers, measures of the time fished and the number of traps used and whose traps per time fished ranged from zero to 66 traps per hour. This more than encompassed the observed mean number of traps fished per hour by fishers interviewed in a fishery characterization study (McMillan-Jackson *et al.* 2005). In that study, the average number of traps pulled per hour was about 25. These good data were used to calculate the number of traps pulled per trip for the rest of the trip ticket data by matching them in a hierarchical pattern: first with mean monthly estimates of numbers of traps pulled per hour from those with matching SPL numbers, then with the average number of traps pulled per hour in that county, then with the average monthly number of traps used per hour in that fishing area, then finally with the overall monthly average number of traps pulled per hour. The total number of traps used on each trip was calculated as the hours fished times the traps per hour.

The Marine Resources Information System provides detailed information useful for the estimation of annual standardized landings per unit effort. Landings per trip, both in pounds and estimated numbers, were standardized using a Generalized Linear Model (GENMOD procedure in SAS version 8.02)) that assumed the pounds landed data represented a random, negative-binomial distributed variable that is a potential function of year, county, month, fishing location (bay or ocean), $\log_e$ of time fished, and $\log_e$ of the number of traps pulled. Final year-specific least-square means estimates and the standard errors of landings rate were used to generate distributions using a Monte Carlo simulation (500 Student's *t* distributed realizations) used to determine the median catch rates, quartiles and 95% confidence bounds. Diagnostics of the standardization included examination of the standardized deviance residuals for patterns and quantile-quantile plots of these residuals against a standard normal distribution.

5.1.2 <u>Commercial Landings</u>

Annual commercial landings of blue crabs prior to 1950 are not well documented but appear to have been substantial after the mid 1930's. Landings data gathered from various early publications of the U.S. Commissioner of Fish and Fisheries Reports indicate that statewide landings were over 4.0 million pounds during the late 1930's, higher on the Atlantic coast than on the gulf coast (Fig. 5.1.2.1). During the 1930's and 1940's, statewide landings were about 4.5 to 7.0 million pounds with about 1.0 million pounds reported on the gulf coast. The landings remained at relatively consistent levels through the 1950's and 1960's on the Atlantic coast, averaging about 7.0 million pounds (Table 3.1.1, Fig. 3.1.1). However, on the gulf coast the landings rose rapidly from an average of 2.2 million pounds during 1950-1954 to 7.3 millions pounds during 1955-1959, and 14.5 million during the 1960's. Since 1965, the commercial landings of blue crab on the gulf coast have varied widely but with a consistent declining trend (H_o:slope=0; H_a: slope<0, P<0.05). Over the same period on the Atlantic coast, blue crab landings have also been declining significantly, through they appear to have remain somewhat stable during the periods of the mid 1950's through late 1970's and again during the 1990's. The lowest landings reported on each coast since 1950 occurred in 2001 (gulf) and 2002 (Atlantic).

5.1.3 Commercial Discards/Bycatch

A blue crab trapping study conducted by FWC-FWRI in Tampa Bay during the period May 2000 through December 2006 showed that there is the potential for a sizeable mortality of crabs not landed by the commercial trap fishery. Of a total of 9,084 crabs caught in the study's traps, 495 were found dead (5.4% of total) as the traps were retrieved. Of the live crabs, 32.3% were smaller than the legal minimum carapace width and were released, 0.6% were ovigerous females and were released and 3.4% were soft crabs. The under-sized blue crabs were very active and it is believed that few of these would die after release (A. McMillan-Jackson, FWC-FWRI pers. comm). It seems likely that few of the soft-shelled crabs would survive release and that the less active ovigerous females would suffer a higher release mortality than the undersized crabs. Overall, it appears that an unreported mortality of blue crabs equal to about 10% of the reported landings could be missed in this assessment.

Blue crabs also comprise part of the bycatch of shrimp trawlers operating in nearshore and especially inland waters. In Florida, nearshore and inland shrimping activity was curtailed in 1996 following the Constitutional amendment that restricted large shrimp trawls to waters farther than one mile from the Atlantic coastline and farther than about three miles from the gulf coastline. Prior to this an unknown but probably significant number of blue crabs were caught and discarded by the shrimp trawl fishery. Any blue crabs that they landed would have entered the NMFS General Canvass or FWC trip ticket program and been included in the reported commercial landings.

Bycatch in other net fisheries was also potentially significant but at an unknown level prior to the 1996 elimination of entangling nets from inland waters or in more recent times with the use of cast nets and small seines.

5.1.4 Commercial Catch Rates (CPUE)

Commercial catch (meaning reported landings) rates are available only for the period when fishing effort has been available, since 1986. For this analysis, all trips landing blue crabs were assumed to have used blue crab trap gear and the number of traps pulled was reported or estimated as indicated in Section 5.1.1.6 "Development of estimates".

The annual landings weight for blue crab is positively related to the estimated fishing effort occurring during that year, both in terms of number of fishing trips and estimated number of traps pulled. On the gulf coast, the estimated number of traps pulled and pounds of landings were both at or near their observed minima in 1991 and 2001 (Table 3.1.1, Fig. 5.1.4.1). Over the observed range of about 4.0 to 7.5 million traps pulled in a year the landings of blue crabs on the gulf coast increased from about 4 million pounds to 13 million pounds. During 1996 and 1998, both the number of traps pulled and the landings were at or near the maximum observed values. On the Atlantic coast, fewer traps are pulled each year compared to the numbers pulled on the gulf coast but there was still a fairly close positive correlation between the numbers of traps pulled and the landings. An exceptional amount of blue crabs was landed in 1987 with an intermediate amount of fishing effort, measured either as traps pulled or fishing trips made.

The trends in standardized landings rate median values were significantly downward (H_o:slope=0; H_a: slope<0, P<0.05) on both coasts over the entire time frame analyzed, 1986-2005. The standardization process showed the significant impact that the number of traps pulled on a trip had on the number of crabs landed (Table 5.1.4.1) without significant impacts from the county where the crabs were landed, the reported location fished, or the month that fishing took place. The modeled YEAR effect also showed a significant impact on the landings, both in numbers and weight, on both coasts. The diagnostics of the model fit suggested some underestimation by the model at high observed landings amount, especially on the Atlantic coast (Figs. 5.1.4.1, 5.1.4.2). Also, the distribution of residuals are slightly skewed right for the gulf coast models. While these diagnostics suggest some violations of the assumptions used in the standardization, the overall trends in the medians are probably somewhat more robust to these departures than are measures of the precision of the expected values. The early trip-ticket data for gear type and amount were considerably sparse; therefore, to determine the sensitivity of the trend analysis to these data points the 1986 and 1987 data were dropped and the trend re-analyzed, still indicating a significantly downward trend on the gulf coast but not on the Atlantic. Landings rates on both coasts have increased since 2002.

5.1.5 Commercial Catch-at-Age

No aging methodology has been applied to commercially landed blue crabs in Florida.

5.2 Recreational

There is very limited information on the recreational fishery for blue crabs in Florida. It is thought that landings may be significant. Steele and Bert (1998) found that 18% of all tag returns made during a 1983 to 1985 blue crab tagging study were from recreational crabbers. Female blue crabs are often caught using dip nets at passes when they begin migrating out of the bays to spawn. Recreational harvesters do not have to possess a saltwater products license unless they are fishing from a boat. Blue crabs are also caught for bait and for use as food by recreational fishers using up to five recreational blue crab traps per fisher, as allowed by FWC regulations.

5.2.1 Data Collection Methods

5.2.1.1 Survey Methods

None.

5.2.1.2 Sampling Intensity

None.

5.2.1.3 Biases

None.

5.2.1.4 Biological Sampling

None.

5.2.1.5 Aging Methods

None.

5.2.1.6 Development of Estimates

None.

5.2.2 Recreational Landings

Unknown.

5.2.3 Recreational Discards/Bycatch

Unknown.

5.2.4 Recreational Catch Rates (CPUE)

Unknown.

5.2.5 Recreational Catch-at-Age

Unknown.

5.3 Fishery-Independent Survey Data

Fishery-independent-survey-based trends for young-of-the-year (defined as blue crabs 40-79 mm carapace width [CW]) and exploited-size blue crabs (127 mm CW and larger) were derived from data collected by the FWC's Fishery Independent Monitoring program's stratified random survey conducted along the gulf coast of Florida, in Apalachicola Bay, near the Cedar Keys, Tampa Bay, and Charlotte Harbor; and along the Atlantic coast of Florida in the southern and northern Indian River Lagoon and in the lower St. Johns River area.

5.3.1 Data Collection Methods

5.3.1.1 Survey Methods

The FWC's Fishery Independent Monitoring (FIM) program uses a stratified, random design to collect abundance and size-structure information from animal populations. Strata are primarily defined by depth, shore type (overhanging or not), and bottom vegetation (sea grass or not). Young-of-the-year (blue crabs measuring 40-79 mm CW) and exploited blue crab (127 mm CW and larger) indices were based on collections made using small seines, large seines, purse seines, gill nets, or trawls during two discrete periods of the year; April through May and October through November, and during the entire year. The former two time periods were used in the catch-survey analysis and the annual indices were used in the surplus production modeling.

5.3.1.2 Sampling Intensity

The level of sampling has varied over time since the initial fishery-independent surveys were conducted on the gulf coast in Tampa Bay and Charlotte Harbor during 1989 and in the northern Indian River during 1990. As the survey coverage has expanded to include other inland waters of the state, the coast wide number of sets has increased. On the gulf coast, April-May sampling increased from 97-127 sets made during 1989-1994 to generally more than 400 sets each year after 1996 (Table 5.3.1.2.1). During 1996, the statewide stratified sampling survey switched from a spring and fall seasonal survey to a monthly survey. On the Atlantic coast, the number of April and May sets varied from 16 to 138 during 1990-2000 before increasing to over 200 sets made each year as the northeast Florida sampling survey became fully operational. These same trends are apparent for the October-November period though the absolute sampling levels were generally higher than during April-May. The annual number of sets made statewide each year also increased markedly during 1996 when the program switched from seasonal to monthly.

5.3.1.3 Biases

The fishery-independent stratified random survey is designed to sample animals randomly within strata so bias should be minimal. There has been an expansion of the program over the years to include new times of the year and new areas and this may affect the coast wide average catch rates but the generalized linear modeling standardization framework was used to attempt to reduce any bias introduced by these changes in sampling frame. Some additional attempts to 'balance' the data included deleting some sampling in recently added grids, using only October and November trawl data on the gulf coast, and some lumping among habitat categories and gear type recorded for each sample. We assumed that gill nets operated similar to large seines for blue crabs, except that they attracted blue crabs rather than encircled them. Another issue, especially for small blue crabs, is the ability to distinguish them from other similar portunid crabs, though these other species occur in much lower abundances (Matheson, FWC-FWRI, personal communication). Over time it is possible that better discrimination has occurred in the field, introducing a negative bias to the abundance trends.

The migratory characteristics of 'sponged' female blue crabs may induce a bias in the relative abundance indices if their movement out of the estuaries into coastal waters is not proportional to abundance each year.

5.3.1.4 Biological Sampling

Size (carapace width) and sex information are obtained from all or a subsample of blue crabs captured in the fishery-independent survey program. In general, up to 20 individuals within each recognized size class were measured for carapace width and sexed. Since only size-specific stages of blue crab were required for this assessment, the distribution of carapace widths of sampled crabs were expanded to the total catch and summed within each sample. No finer scale width-specific information was necessary for the assessment analyses used below.

5.3.1.5 Aging Methods

No direct aging method has been applied to Florida blue crabs.

5.3.1.6 Development of Estimates

Standardized catch rates were estimated from the FIM young-of-the-year (recruit) and exploited-size blue crab data. Estimates were made for each year using each of the April-May, October-November, and January-December time frames. For standardization, a Generalized Linear Model (GENMOD) was used that combined the analysis of the binomial information on presence/absence with the Poisson-distributed positive catch data (a delta model, Lo *et al.* 1987). We assume that there are no substantial significant interaction terms with year in this model and consider only the main effects [showing Tables 5.3.1.6.1-8 variable names in parentheses]: season(yearmo) or calendar year (year), area (bayzone), vegetative shore cover (totShoreCover), sampling effort (effort), general sampling gear category (col_gear), surface water temperature (temperature), bottom vegetation cover (bvegCover), surface dissolved oxygen concentration (dissolvedO2), and salinity (salinity). A step-wise approach to developing the model used the criteria that a 1% reduction in the deviance-per-degrees-of-freedom relative to the null model, which included only the time variable, was necessary for including each additional term in the model. The median value for the distribution (generated through Monte Carlo simulation—see 5.1.1.6) of the back-transformed least-squares means for the time variable (season or year) provided indices of abundance for young-of-the-year and exploited-size blue crabs.

5.3.2 Catch Rates (Numbers)

The standardized fishery-independent survey results generally show high variability during the early years of the survey program and depressed abundance levels during the early 2000's. On the gulf coast, spring (April-May) young-of-the-year abundances were variable without trend though low levels were seen during the period 2000-2003 (Fig. 5.3.2.1). The fall (October-November) young-of-the-year abundances were less variable but showed an extreme high abundance in 1998. The year-to-year direction of the change in abundance of exploitable-sized blue crabs during the fall showed fairly good correspondence with the abundance changes seen earlier that year in young-of-the-year during the spring. Fourteen out of the possible 17 year-to-year changes showed similar directional response in abundance between the spring young-of-the-year and fall exploited-size blue crabs, with depressed levels in 1991, 1993, 1997, 1999, and 2002. Higher levels of abundance that corresponded between these groups occurred in 1992, 1996, 1998, and 2004. The correspondences between the fall young-of-the year and the following spring exploited-size blue crabs on the gulf coast was less than for the within-year spring to fall correspondence, though the changes seen in abundance of young-of-the-year in 1992, 1997, 1998, and 1999-2003 were followed by similar changes in abundance of exploited-size blue crabs during the following spring.

On the Atlantic coast, the spring and fall young-of-the-year estimates were higher and more variable before 2001, when the Northeast Florida fishery-independent survey was initiated (Figure 5.3.2.2). Correspondence between the spring young-of-the-year abundance changes and the fall exploited-size blue crab abundance changes was low on the Atlantic coast, with correspondence in abundance change occurring in 1996, 1997, 2000, and 2004 only. In contrast, the pattern of abundance change in spring exploited-sized blue crabs closely matched the changes seen in the previous fall's young-of-the-year abundance. In fact, from 1999 through 2004 the trends seen in young-of-the-year matched that of 2000 to 2005 spring abundances of exploited-size blue crabs.

Calendar year abundance estimates made for both young-of-the-year and exploitable-sized blue crabs showed little correspondence in trends between the young-of-the-year stage and the exploitable-size stage (Figure 5.3.2.3). This conforms to the assumption that growth between the two size groups occurs over a six-month period rather than over a one-year period, consistent with our understanding of blue crab recruitment and growth.

5.3.3 Length/Weight/Catch-at-Age

The size (carapace width) distribution of blue crabs was used to define two separate stages of their lives, young-of-the-year and exploited-size blue crabs. Young-of-the year were considered to be 40-79 mm CW while exploited-size blue crabs were equal to or larger than the minimum size limit, five inches (127 mm) CW.

5.3.4 Abundance Indices

The $\log_e$ values for the medians predicted for the fishery-independent survey catch rates (Table 5.3.4.1) through the standardization process described in Section 5.3.2 were assumed to be linearly related to abundance for each life stage (see Section Tuning Indices 6.2.1).

5.3.5 Biomass Indices

There are no fishery-independent biomass indices for blue crab at this time though they could be developed by applying the carapace width – weight relationships (see Section 2.2 Growth) to the size frequency information for the crabs captured in the fishery-independent survey. Commercial landings rates since 1986 may be considered in the future as indices of abundance but consideration needs to be given to the regulated changes to blue crab traps during the period 1986-2005.

5.4 Uncertainty and Measures of Precision

The life-stage specific indices of abundance estimated from the fishery-independent monitoring data were derived using a statistical framework that assumed the distribution of discrete positive catches would be Poisson and the presence/absence would be distributed as a binomial process. The combination of these models into a delta Poisson allows for the model to better capture the high number of zero catches in these data. The diagnostics used to investigate the validity of the assumed distribution and the qualities of the model fits to the data are presented in Figures 5.4.1 – 5.4.6.

The observed residuals from the binomial showed that most models generally fit the data well, though there were some patterns that showed the model underestimated the data during the early survey years, e.g. Fig. 5.4.1, April-May young-of-the-year. In addition, the residuals for the Atlantic coast models showed a much lower variance during the period 1998 through 2000 when low numbers of animals were encountered (Table 5.3.1.2.1). Residuals from the Poisson portion of the model for positive catches revealed some extreme outliers in the data. Though the residuals tended to cluster around the "zero line", there was a tendency for the model to underestimate the observed data, e.g., Fig. 5.4.2, October-November young-of-the-year.

The distributions of the residuals were generally skewed to the right reflecting the possible negative bias in the residuals (Figs. 5.4.1 – 5.4.6). The largest positive residuals (observed minus Normal expectation) were most often larger than expected such that the distribution of residuals was skewed to the right. Less frequently, the negative residuals were also larger values than expected, supporting the right skewed distribution.

6.0 Methods

6.1 Models

Three separate population dynamics models were utilized in this assessment: catch-survey analysis (Collie and Sissenwine 1983); non-equilibrium biomass dynamics modeling (Prager 1994); and stochastic stock reduction analysis (Walters *et al.* 2006). The catch-survey analysis used here is a two-stage, open-system depletion model that requires indices of abundance for under-sized and legal-sized blue crabs, catch data, and estimates of natural mortality (Murphy *et al.* 2001).Under-sized blue crabs are assumed to become available for harvest at the beginning of the following time unit. These indices are developed to relate to animal abundance at the beginning of each time unit across which catch in numbers is aggregated. An additional assumption is required about the relative effectiveness of the survey gear to capture the recruits compared with the effectiveness to capture the exploited-size crabs. Biomass dynamics or surplus production models capture the stocks ability to increase its biomass as a function of the stock size at different absolute abundances. The growth in biomass is a function of an intrinsic growth rate and a carrying capacity. These models require the catch, in weight, and indices of abundance and can be modified to include other inputs related to the stock of fishery dynamics, such as fishing effort and exploitation rate estimates. The stochastic stock reduction analysis is simply a population model that allows investigation of how a known series of catches could be removed from a stock so that it could persist through time and show recent abundance changes for which we have estimates. This is essentially an exploratory analysis that provides credible stock recruit dynamics given observed catches and indices of abundance. In this approach, an age-structured population model with Beverton-Holt stock-recruitment function is simulated forward in time from the start of the fishery, with exploitation rates calculated each year from observed catch divided by modeled vulnerable population (sum of vulnerabilities at age multiplied by modeled numbers at age). In stochastic SRA, recruitment is assumed to have had log-normally distributed annual anomalies (with variance estimated from assumed recruitment variability), and to account for the effects of these a very large number of simulation runs is made with anomaly sequences chosen from normal prior distributions (with or without autocorrelation). The resulting sample of possible historical stock trajectories is re-sampled using importance re-sampling (SIR), or a large sample is taken using Markov Chain Monte Carlo. Summing frequencies of occurrence of different values of leading population parameter values over this sample amounts to solving the full state-space estimation problem for the leading parameters.

6.2 Model Calibration

The catch-survey analyses were calibrated against absolute observations of commercial landings and blue crab trap fishing effort. Though each of these series of data was not assumed to be known without error, they scaled the final outputs of abundance and fishing mortality to represent the absolute scale. No independent estimates of either blue crab abundance or fishing mortality were used to calibrate the catch-survey analysis.

The non-equilibrium surplus production model (Northeast Fisheries Science Center NOAA Fisheries Toolbox, ASPIC, v.5.10.2) was calibrated with 1950-2005 commercial landings and the calendar-year indices of abundance from the fishery-independent survey data.

For comparison with the non-equilibrium surplus production and catch survey assessment models described above, we also ran a stochastic stock reduction analysis (SRA, Walters *et al.* 2006) on long-term blue crab catches (1908-2005) for the gulf and Atlantic coasts of Florida. The stochastic stock reduction analysis is calibrated against the commercial landings of blue crabs reported since the beginning of the fishery (Tables 3.1.1 and 5.1.2.1) and calendar-based indices of abundance for exploitable-size blue crabs.

6.2.1 Tuning Indices

The input data used to derive indices of the relative changes in abundance of blue crabs over seasons or years came from FWC-FWRI fishery-independent surveys (See Section 5.3 above). Log_e values of estimated catch-rate data were assumed to be linearly related to the abundance of blue crabs. For the catch-survey analyses, these standardized catch rates were derived separately for recruit-sized (40-79 mm CW) and exploited-size (127 mm CW and larger) blue crabs during the beginning of each of two six-month periods (Table 5.3.4.1). For the non-equilibrium surplus production model and the stochastic stock reduction analysis, calendar-year-specific standardized estimates of exploitable-sized blue crabs were used for tuning.

6.2.2 Input Parameters and Specifications

The catch-survey analysis was limited to the time frame represented by the extent of the fishery-independent monitoring program's operation on Florida's gulf and Atlantic coast. Because blue crabs show two apparent peaks in recruitment each year, during spring and again during fall, the year was split into six-month time frames, November-April and May-October. The life stages used in the assessment model represented young recruits who would grow into the exploited sizes at the beginning of the next six-month time period. Measures of recruitment were taken as the abundance of 40-79 mm CW blue crabs sampled during October-November for the November-April period and during April-May for the May-October period. Likewise, the relative abundance of exploited-size blue crabs was estimated from the fishery-independent catches made during each of these two-month periods. The extent of the survey data is from the May-October 1989 period to November 20005 – October 2006 period.

Estimates of instantaneous natural mortality rate (M) were provided for each life stage using overall M estimates from an ECOPATH model developed for Tampa Bay (Mahmoudi, FWC-FWRI personal comm., Guenther *et al.* in prep) which were partitioned by age using a weight-M relation (Lorenzen 1996). Average weights for blue crabs ages 0-3 used in the estimation procedure were 0.12, 0.53, 0.90, and 1.01 pounds. The estimation of age-specific M used the given average weight (in grams) in the Lorenzen's relation: $3.0\ W^{-0.288}$ and scaled this so that the cumulative natural mortality, $M_0+M_1+M_2+M_3$, equaled the cumulative M for a constant age-specific M equal to the value from the ECOPATH model that year. The final age-specific estimates of M were converted to stage-specific values using the geometric mean of the age-0 and age-1 M's as the estimate for 40-127 mm CW blue crabs and the geometric mean for age-2 and age-3 M's as the estimate for 127 mm and larger blue crabs. Because the time-steps used in the model were not calendar years the estimated stage-specific M's were calculated as the proportion of the calendar year included in each six-month period (Table 6.2.2.1).

The catch-survey analysis requires a measure of the relative vulnerability of the small, recruit blue crabs to that of the large, exploited size blue crabs. Without empirical estimates of this relative vulnerability, we use the simple assumption that each stage is equally available to capture. We also assume that the small, recruit blue crabs do not enter the fishery at any time during the six-month period they are considered recruits. Additionally, the relative error associated with the observed data, i.e. fishing effort and relative abundance of recruits and exploited-size, was assumed equal to the error associated with the population dynamics model (process error). The fitting scheme required determining the weights for each likelihood in the objective function such that the standard deviation of the standardized residuals of each component was at a similar level and close to a value of one.

The National Marine Fisheries Service Fisheries NOAA Fisheries Toolbox implementation of the non-equilibrium surplus production model ASPIC (version 5.10.2) was used as an additional way to derive comparable population dynamics parameters. Besides the data requirement, the model structure in this analysis was conditioned on yield for the reported commercial landings and the relative abundance implied by the fisheries-independent data series. The model fit was sensitive to initial estimates of the survey catchability coefficient and the ratio of the initial biomass (beginning of 1950) to the carrying capacity. These were chosen through trial and error so that the contrast and nearness indices were each approximately equal to one while the objective function was minimized.

The stochastic stock reduction analysis (SRA) was run for each coast of Florida for the period 1908 through 2005. The model is parameterized by taking U_{MSY} (annual exploitation rate producing MSY at equilibrium) and MSY as leading parameters, then calculating the Beverton-Holt stock-recruit parameters from these and from per-recruit fished and unfished eggs and vulnerable biomasses. Under this parameterization, we effectively assume a uniform Bayes prior for U_{MSY} and MSY, rather than a uniform prior for the stock-recruitment parameters. This is the age-structured version of the stock-recruitment parameterization in terms of policy parameters suggested by Schnute and Kronlund (1996).

Several input parameters needed for the stock reduction analyses were derived from scattered information on growth, reproduction and life span of blue crabs. Despite the actual stepwise growth of blue crabs from molt to molt, a continuous-growth von Bertalanffy model was developed from available known-size-at-age data and used in the SRA (Fig. 6.2.2.1). A coefficient of variation for the sizes predicted by the growth equation was set at 0.15 to produce what we judged as reasonable variation of length about age. Maturity of blue crabs was assumed to occur in a knife-edge fashion at age-1 or at a predicted size of 127 mm carapace width. The vulnerability of blue crabs to capture and take was modeled by a sigmoid, two-parameter function of age (Fig. 6.2.2.1). Finally, the instantaneous natural mortality coefficient was modeled as a uniform distribution bounded by the minimum and maximum estimates of M estimated in the 1989-2004 period used in the Tampa Bay ECOPATH/ECOSIM model.

7.0 Outputs/Results

7.1 Goodness of Fit of Model Used

The catch-survey analysis model fit the observed recruit indices (Fig. 7.1.1), observed exploited-size indices (Fig. 7.1.2), catch (Fig. 7.1.3), and fishing effort (Fig. 7.1.4) data better than they fit the predicted exploited-size indices (Fig. 7.1.5). The fit to the predicted exploited-size index showed a clear positive bias, especially on the gulf coast. These predicted values include a process error component, assumed to equal the measurement error, which may not be consistent with the population dynamics model and the observed data. On the gulf coast, the model predicted values that were close to the recruit indices with little apparent pattern in the residuals and a close correspondence of these residuals to a Normal distribution (Fig 7.1.1). The fits to the exploited-size indices showed good correspondence between the model and observed data except for the low observed spring1990 and 1992 indices. Exploited-size indices and fishing effort showed very similar patterns in residuals and q-q plots with low levels seen in spring 1990 and 1992. Conversely, the fit to catch was good except for the higher than expected levels during spring 1990 and spring 1992. On the Atlantic coast, recruitment indices were fit well though the residuals showed a slightly under-dispersed pattern relative to the Normal. Exploited-size blue crab indices and effort were fit equally as well though there were lower than expected levels in each during fall 1999. The catch was fit well also except for a higher than expected value during fall 1999. The weights chosen for the components of the objective functions produced standard deviations of the standardized residuals that were similar though less than one: gulf coast, process error (0.214), recruitment (0.365), exploited-size (0.202), effort (0.402), and catch (0.307); Atlantic coast, process error (0.496), recruitment (0.225), exploited-size (0.376), effort (0.386), and catch (0.340).

The ASPIC surplus production model provided a relatively good fit to the FWC-FWRI fishery-independent survey abundance indices used as indicators of trends in biomass (Fig. 7.1.6). However, the underlying population dynamics model was unable to capture the full variability seen in the fishery-independent indices, especially the very abundant 1998 year-class on the gulf coast and the 1992 and 1994 year classes on the Atlantic coast.

The stock reduction analysis is driven by the indices and observed level of catch to provide a profile of likely biomass levels associated with sustainable harvest. The indices were fit well by this exploratory process (Figure 7.1.7) and the catch is assumed known without error.

7.2 Parameter Estimates

7.2.1 Exploitation Rates

Estimates of instantaneous fishing mortality (F) for the six-month periods used in the catch-survey analysis were generally higher during the May-October period than during the November April period (Fig. 7.2.1.1). This is as expected result because blue crab activity slows during the colder months and they are less easily captured by the passive trap gear. On the gulf coast during the period 1989-2005, the six-month F's reached season-specific peaks of about 0.36 during May-October 1998 and 0.39 during November 1989-April 1990. Calendar-year estimates of annual F's show a slow but significant (Student's *t*, t=2.8, $P<0.05$) decline on the gulf coast during 1989-2005 but no significant linear trend on the Atlantic coast. Peak calendar-year fishing mortality rates occurred during 1998 on the gulf coast and during 1999 on the Atlantic coast.

Estimated biomass-based fishing mortality rates were generally similar to or greater than the catch-survey analysis estimates The biomass dynamic model showed absolute estimates of F that were higher than seen from the catch-survey analysis and did not show a significant downward trend on the gulf coast. However, this model did show a somewhat similar peak in F's during 1998-2000. On the Atlantic coast, the biomass dynamic model showed consistently higher estimates of F than those given by the catch-survey analysis but also showed that there was no significant linear trend in fishing mortality during 1990-2005.

The stock reduction analysis provided estimates of fishing mortality that were more similar to the biomass dynamics model results on the gulf coast and more similar to the catch-survey analysis on the Atlantic coast. Stochastic stock reduction analysis-based estimates of F peaked in 1994 on the gulf coast and during 2001-2005 averaged 0.61 yr^{-1}, similar to 0.56 yr^{-1} from the biomass dynamic model. On the Atlantic coast, extreme values of F were estimated for 1990 and 1999 (F = 2.66 yr^{-1} and 1.98 yr^{-1}, respectively), years for which very low indices of exploited-size blue crab abundance were observed. The estimated 2001-2005 average F's on the Atlantic coast were more similar between the catch-survey analysis (0.25 yr^{-1}) and the stock reduction analysis (0.28 yr^{-1}) than with the biomass dynamic model (0.38 yr^{-1}).

The long-term trends in fishing mortality showed somewhat different patterns. The pattern seen from the biomass dynamic model estimates indicate that by 1970 the fishery had attained levels of fishing mortality that were near what they were estimated to be in the early 1990's (Fig. 7.2.1.2). The stock reduction analysis appears to show an expansion of the fishery during the 1980's where fishing mortality reached levels seen in the 1990's. A combination of the estimates for all three analyses appears to show that recent fishing mortality rate estimates have trended downward, since 2003 on the gulf coast and since about 2000 on the Atlantic coast.

7.2.2 Abundance Estimates

Estimated exploited stock biomass of blue crabs generally declined slowly from the 1970's through the 1980's on both coasts (Table 7.2.2.1, Fig. 7.2.2.1). More recently, abundance of blue crabs has been variable on the gulf coast (Fig. 7.2.2.2) with a potentially rapid increase in vulnerable biomass during 1991-1998 followed by a large decline during 2000-2002. This was followed by a recovery of the stock from 7.7-12.1 million pounds during 2000-2002 to 15.1-24.3 million pounds in 2005. Exploitable biomass of blue crabs on the Atlantic coast may have increased after 1990 and maintained levels averaging 26.0 million pounds during 1991-1995 (supported by the catch-survey analysis and SRA) or remained a relatively constant levels of about 7.5 million pounds during this period (ASPIC result). In all three analyses, stock biomass or abundance increased after 2003 (Fig. 7.2.2.2).

7.2.3 Precision of Parameter Estimates

The precision of the estimated fishing mortality rates and abundances is difficult to capture due to the inclusion of uncertain input data that are represented as being without error in the models. For instance, the estimates of natural mortality used in the catch-survey analysis are taken at face value as certain though they are estimates themselves from a combination ECOPATH estimate in time and Lorenzen estimate across ages. Also, probable changes in vulnerability to the gear in recent years due to regulations (especially trap configurations) were not included in the analyses. The SRA model results for both coasts indicate wide uncertainty on historical (unfished) average biomass and on the extent of decline in stock biomass since the expansion of the fishery in the 1950's and 1960's (Fig. 7.1.7).

A major source of uncertainty in these analyses results from the lack of recreational catch data for blue crabs. It is clearly unrealistic to think that the harvest of blue crabs by recreational anglers is insignificant, though there are no data on this. The relative validity of these analyses rely more on the assumption that the angler catch of blue crabs did not change significantly over time. Of additional concern is the possible commercial discards that die that are not included in the data.

7.3 Projection Estimates

No projections were attempted within the framework of the catch-survey or non-equilibrium surplus production models. However, various scenarios of total catch were run through a projection of the SRA into the future to investigate the blue crab stocks resilience to fishing. Probability distributions for future blue crab stock biomass under various Total Allowable Catch (TAC) levels including zero catch and the current average catch were simulated for both coasts using results from the stochastic stock reduction analysis modeling (Fig. 7.3.1). Projection results through the year 2015 show that blue crabs on the gulf coast appear to be more resilient to fishing than do those on the Atlantic coast. If no catches were taken from blue crabs on the gulf coast, the stock's vulnerable (in the historic sense) biomass would increase by 26%; however, if the current catch was doubled or nearly tripled the vulnerable biomass would, on average, only decrease by 4% or 7%, respectively (Fig. 7.3.1). This broad peak of the likelihood profiles suggests there is a high level of uncertainty to these projections. On the Atlantic coast, the vulnerable stock's biomass would increase 17% if the fishery were closed. If the current catch was doubled or quadrupled, the vulnerable biomass would decline by 39% and 50%, respectively.

We caution that these results for the stochastic stock reduction analysis are driven largely on a reconstructed (not raw data) time series of total catches estimated from a variety of sources. There is particularly high uncertainty about commercial catches prior to 1950. We caution also that the model does not fully represent changes in vulnerability at age.

7.4 Sensitivity Analysis

The catch-survey analysis was run using an instantaneous natural mortality (M) of 1.0 per year for both life stages and across all years. This was consistent with the higher value of M used in the last assessment (Murphy *et al.* 2001). This value was generally lower than the year-specific estimates provided by the Tampa Bay ECOPATH model and resulted in higher estimates of instantaneous fishing mortality from the CSA run using a constant M. Estimates of abundance were generally unaffected. It was deemed more realistic to use the ECOPATH-based estimates and the stage-specific estimates derived through the Lorenzen relationship, so the constant M sensitivity runs are not reported here.

The ASPIC model was quite sensitive to the starting values input for the B1/K (initial biomass to carrying capacity) ratio and for the catchability coefficient for the catch per unit effort series. Guidance for selecting suitable starting values came from the size of the objective function value and the "contrast" and "nearness" values relative to their ideal values at 1.0.

7.4.1 Sensitivity to Model Configuration

Not explicitly determined.

7.4.2 Sensitivity for Input Data

Not explicitly determined.

7.5 Retrospective Analyses

No retrospective analysis was attempted for this assessment.

7.6 Selectivity

No selectivity estimates were made within the contexts of the catch-survey analyses (CSA) or the non-equilibrium surplus production model. The relative catchability of recruits and post-recruits was assumed to be unity in the CSA and the biomass estimates and fishery-independent indices used in the surplus production modeling were only for exploitable blue crabs. The stochastic stock reduction analysis required input of an empirical fishery selectivity for blue crabs (Fig. 6.2.2.1).

8.0 Biological Reference Points

8.1 Overfishing Definition

There is currently no overfishing definition for blue crabs that is sanctioned by the Florida Fish and Wildlife Conservation Commission. Most management is based on controlling the sizes of blue crabs harvested and the incidental mortality possibly inflicted by lost traps through the use of escape vents. In general, management has been summarized as preventative

(Jamieson 1986 in Steele and Bert 1998). Murphy *et al.* (2001) used a yield-per-recruit-based metric, $F_{0.1}$, as a measure of biological overfishing but had to derive it using a simple M/K ratio (Deriso 1987) relation and found that overfishing was not occurring during the 1999/2000 fishing year. At the newly derived instantaneous natural mortalities for exploited blue crabs used in this assessment (0.77-1.34 yr^{-1}, Table 6.2.2.1), the $F_{0.1}$ benchmark would be in the range of 0.77 – 1.61 yr^{-1} for blue crabs in Florida. Comparing the average 2003-2005 average F's to this benchmark, the status of blue crabs would be considered: gulf, no overfishing (average F's of 0.36 CSA, 0.65 ASPIC, 0.56 SRA); and Atlantic, no overfishing (average F's of 0.25 CSA, 0.38 ASPIC, 0.31 SRA).

An alternative biological benchmark that is calculated during the biomass dynamic modeling, ASPIC, or the stochastic stock reduction analysis is the maximum sustainable yield. Generally, this would be a less restrictive benchmark than the $F_{0.1}$ benchmark unless recruitment was high at relatively small stock sizes (see Section 8.4 below).

8.2 Stock Recruitment Analysis

There is little information in this assessment on the relationship between the spawning stock of blue crabs and the subsequently produced number of recruits. The fishery-independent indices of abundance of the two life stages, recruits and exploited size crabs, are used in the catch-survey analysis to link the recruit stage with the subsequent exploited-size abundances. It would seem unlikely that these data could be used to investigate the link between exploited-size blue crab abundance and the subsequent recruit-stage abundance because many of the spawning, sponged females become unavailable to the fishery-independent gear as they swim out of the estuaries to spawn.

The stochastic stock reduction analysis (SRA) provides some insight into the stock recruitment dynamics of blue crabs. On both coasts, the SRA predicted large recruitment anomalies that were seemingly independent of the magnitude of the vulnerable stock biomass. The compensation ratio estimates were quite low (visually interpreted as in the range of 1 to 3), indicating that there is little need for any compensatory increase in survival of recruits to counter the effects that the current level of fishing has in reducing the population size. It appears that density-independent factors drive the recruitment anomalies more strongly than does any density-independent effect in Florida blue crabs.

8.3 Yield and SSB per Recruit

No yield-per-recruit or spawning-stock-biomass-per-recruit analyses were conducted for this assessment. The growth of blue crabs is not known with any certainty because individual blue crabs cannot be aged; therefore, the inputs data necessary for an age-based YPR or SSBPR analysis are not available. The apparent high variability in growth rate between individuals, as seen in tagging studies, would also make length-based analyses highly uncertain.

8.4 Stock Production Model

The stock production or biomass dynamic model estimates of intrinsic growth rate indicate that blue crab populations can grow quite rapidly in a favorable environment when released from any density-dependent effects. The intrinsic rate of increase was estimated at 0.91 yr^{-1} on the gulf coast and 0.85 yr^{-1} on the Atlantic coast. The model also estimated carrying capacities of 58 and 32 million pounds on the gulf and Atlantic coasts, respectively. The stock production model is a simple model that fits general trends in the relative abundance data but was unable to mirror high degree of variability in the dynamics of blue crabs, e.g., estimates of exploitable biomass were less dynamic than those estimates for the more highly parameterized stochastic stock reduction analysis or as implied by the abundances estimated by the catch-survey analysis (Fig. 7.2.2.2).

Findings from the stock production modeling indicate that blue crabs have been consistently overfished (with respect to maximum sustainable yield) since at least the mid-1960's on the gulf coast and since about 1970 on the Atlantic coast, i.e. $B/B_{MSY}<1.0$. If adjustments for the high level of natural mortality were incorporated into this benchmark, e.g. $(1-M)B_{MSY}$ is the minimum stock size threshold defining the boundary of overfished/not overfished in some fisheries, then the status of the stock would likely change to not overfished. This provides an allowance for large swings in abundance often associated with short-lived animals that necessarily display high natural mortality levels. Over the same time frames, the fishing mortality increased to levels defined as "overfishing" since they were above that level needed to harvest maximum sustainable yield ($F/F_{MSY}>1.0$, Fig. 8.4.1).

Though less accurate than the relative values of the ratios of fishing mortality or exploited biomass to the maximum sustainable yield levels, absolute estimates of MSY ranged from 6.89 million pounds on the Atlantic coast to 13.07 million pounds on the gulf coast (Table 8.4.1). These levels of MSY coincided quite closely to the visually interpreted 'most-likely' estimates of maximum sustainable yield from the stochastic stock reduction analysis, i.e., 8.8 million pounds on the Atlantic coast and 13.8 million pounds on the gulf coast, though the broad, flat likelihood surface indicated these were highly uncertain (Fig. 7.2.2.3). Average yield during 2003-2005 were about 38-49% of the MSY levels on the Atlantic coast and 55-58% of this level on the gulf coast.

The instantaneous rate of fishing mortality at maximum sustainable yield, as estimated from the surplus production model, was 0.45 yr^{-1} and 0.43 yr^{-1} for the gulf and Atlantic coasts, respectively. This was much lower than the estimate derived from the stochastic stock reduction analysis that was visually interpreted as near 2.5 yr^{-1} on either coast (derived from the 'most likely' exploitation rate of 0.65, Fig. 7.2.2.3). The surplus production modeling has no direct information on the expected level of natural mortality for blue crabs and appears to underestimate the potential variability in the dynamics of this stock. Recall that it appeared to underestimate the variability seen in vulnerable biomass, as inferred from the changes in fishery-independent abundance indices. The stock reduction analysis was better able to capture these dynamics using available estimates of instantaneous natural mortality and stochastically generated recruitment anomalies based on stock performance over time.

8.5 Results

The results of the three analyses point to somewhat different results for the status of the blue crab stock in Florida but all indicate that the stock size is increasing in recent years. The data for the catch-survey analysis was limited to a period when the fishery for blue crabs was already fully developed and indicated that fishing during 2002-2005 was below a rough estimate of the biological benchmark $F_{0.1}$. The biomass dynamic model and the stochastic stock reduction analysis utilized a longer time series of data, beginning before exploitation was very high except for the fully developed fishery on the Atlantic coast in 1950, the beginning of the biomass dynamic analysis. The biomass dynamic model indicates that the stock on both coasts has been fished a levels higher than F_{MSY} since the mid 1960's or early 1970's. This has apparently reduced the stock size below the biomass associated with maximum sustainable yield where it has fluctuated with a significant downward trend since 1970 (gulf, Student's *t*, t=7.59; Atlantic, t=2.34; both df=34, $P<0.05$). The stochastic stock reduction analysis shows that there is a large uncertainty in the estimate of maximum sustainable yield and the exploitation needed to take that yield but the most likely estimates of these indicate that the stock is being fished below either during 2002-2005.

The blue crab stock in Florida appears to be very resilient to high fishing rates. Despite the status results from the biomass dynamic model, that analysis estimated that the intrinsic rate of increase for blue crabs was fairly high, showing that the population could increase 85-91% each year when released from environmental and density-related factors that restrict population growth. The stochastic stock reduction analysis indicated that maximum sustainable yield can be taken at very high fishing mortality levels, F's of about 2.5 yr^{-1}, and that large positive recruitment anomalies occur frequently.

8.5.1 Overfishing Definition

There is no officially accepted definition for overfishing of the blue crab resource in Florida, though two were chosen here depending on the type of model output information available. The operable definition applied to the catch-survey-based estimates of F is the $F_{0.1}$ yield-per-recruit benchmark deduced from Deriso's (1987) relation of M/K to $F_{0.1}$. For the biomass-based surplus production model and the stochastic stock reduction analysis, overfishing was demarcated as the level of F associated with maximum sustainable yield, F_{MSY}.

8.5.2 Overfished Definition

The overfished threshold was taken as the total stock biomass level associated with maximum sustainable yield, B_{MSY}. If the dynamic change in stock biomass is directly related to the instantaneous natural mortality rate, M, a pragmatic definition often used as the overfished threshold is B_{MSY} modified but the multiplier (1-M). This would indicate that even a very low biomass of blue crabs could be defined as not overfished because the 1-M modifier would put the overfished threshold at less than 23% of B_{MSY} (Table 6.2.2.1).

8.5.3 Control Rule

There is(are) no control rule(s) with the Florida Fish and Wildlife Conservation Commission's management framework that are associated with the biological benchmarks described above (section 8.5.1).

9.0 Recommendations and Findings

9.1 Evaluation of current status based on biological reference points

The current status of the blue crab stock remains uncertain but most evidence in these analyses suggest that it is either not being overfished in recent years or if it is, it has the resiliency to sustain its abundance at that level of overfishing. In all cases, the analyses indicate that the abundance or biomass of the blue crab stock has increased in recent years (2003-2005) following a number of years of depressed stock size. This period of low abundance coincided with a number of dry years that have been more recently followed by wet years associated with increased tropical storm and hurricane induced rains.

9.2 Research Recommendations

It is critical to this assessment that a monitoring program be routinely conducted to determine the extent of participation and harvest in the recreational blue crab fishery in Florida. Some short-term observations should also be made onboard commercial fishing operations to determine the amount of blue crabs discarded from the fishery and, if substantial, experiments need to be conducted to determine the numbers of blue crabs released that die. Age estimates should be determined by the best-available means for the Florida commercial and fishery-independent catches.

10.0 Minority Opinions

Not applicable at this time.

10.1 Descriptions of opinions

None.

10.2 Justification on why not adopted

Not applicable

11.0 Literature Cited

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12.0 Tables

Table 3.1.1. Commercial landings (lbs), estimated numbers landed, and estimated number of traps pulled for blue crab each calendar year on the Florida gulf and Atlantic coasts during 1950-2005. Landings from 1950-1985 were taken from the National Marine Fisheries Service General Canvass of fish dealer reports. Landings and estimated effort for 1986-2005 were derived from the FWC's Marine Resources Information System (through batch 937).

	Gulf coast				Atlantic coast			
Year	Trips	Traps	Number	Pounds	Trips	Traps	Number	Pounds
1950				684,400				5,482,400
1951				2,080,000				6,638,000
1952				1,998,800				6,150,600
1953				3,156,300				6,327,200
1954				2,903,300				6,927,300
1955				4,954,900				7,682,900
1956				3,729,500				8,050,700
1957				5,311,600				6,532,700
1958				8,694,200				7,996,500
1959				13,898,600				6,612,600
1960				18,652,500				6,962,400
1961				17,134,600				7,486,000
1962				10,356,500				7,868,800
1963				13,152,400				8,595,400
1964				14,081,500				6,952,900
1965				20,609,200				5,964,200
1966				16,548,000				7,323,200
1967				13,982,600				9,320,600
1968				9,008,100				6,615,600
1969				11,584,200				5,724,200
1970				14,786,600				7,778,700
1971				12,278,700				9,132,200
1972				10,673,300				6,287,500
1973				9,598,500				3,913,700
1974				10,133,800				7,471,800
1975				12,808,100				4,185,800
1976				12,048,500				4,024,200
1977				15,832,200				3,424,600
1978				11,700,913				3,810,923
1979				11,207,590				3,493,231
1980				11,292,607				4,602,149
1981				14,810,284				3,483,817
1982				8,924,302				5,393,479
1983				9,373,149				6,990,630
1984				12,939,930				6,737,726
1985				12,290,079				3,712,284
1986	23,172	4,964,782	19,015,137	7,792,425	9,998	2,437,983	8,432,637	3,458,670
1987	27,654	5,243,279	25,614,119	10,498,403	15,217	2,726,062	19,327,400	7,924,606
1988	30,435	5,426,703	25,531,157	10,462,466	16,741	3,712,004	11,824,307	4,836,404
1989	30,365	4,990,453	20,628,558	8,438,583	17,221	3,954,256	11,278,319	4,610,533
1990	26,030	5,065,105	17,401,124	7,123,477	23,759	4,213,486	17,257,467	7,059,049
1991	23,928	3,888,794	13,321,902	5,457,804	19,347	2,792,005	11,253,814	4,610,253
1992	29,373	5,068,733	20,192,657	8,279,882	20,160	2,963,513	16,665,634	6,821,238
1993	33,576	5,748,661	21,016,034	8,631,371	19,216	2,683,942	9,689,070	3,961,892
1994	39,932	6,411,828	20,795,096	8,535,817	22,864	3,352,690	13,425,708	5,477,880
1995	37,795	6,205,178	21,509,674	8,833,448	17,886	2,530,409	8,581,936	3,497,328
1996	43,497	7,576,188	30,444,252	12,519,583	20,684	3,271,059	13,746,055	5,621,640
1997	40,194	6,961,235	22,609,022	9,320,212	23,073	3,729,065	14,275,467	5,836,479
1998	40,730	7,438,805	31,226,818	12,861,822	19,356	3,206,839	11,291,079	4,622,120
1999	40,672	6,835,713	27,031,925	11,168,139	17,434	2,804,803	11,314,023	4,627,181
2000	29,978	5,010,044	15,845,048	6,571,394	17,283	2,998,086	11,897,948	4,861,508
2001	24,005	4,457,829	11,252,651	4,645,963	13,505	2,381,479	6,712,460	2,745,942
2002	26,620	5,048,013	13,481,983	5,566,542	12,328	2,085,284	5,700,832	2,326,810
2003	27,986	5,559,233	17,508,375	7,224,882	11,302	1,892,154	5,079,680	2,081,330
2004	25,605	5,639,140	19,605,112	8,082,667	13,077	2,033,460	9,335,428	3,838,511
2005	23,748	5,262,747	17,834,515	7,376,275	15,996	2,667,228	10,322,173	4,216,942

Table 3.1.2. Commercial landings (lbs), estimated numbers landed, and estimated number of traps pulled for blue crab during each season (May-October or November-April) on the Florida gulf and Atlantic coasts during 1986-2005. Landings and estimated effort were derived from the FWC's Marine Resources Information System (through batch 937).

May-October

	Gulf coast				Atlantic coast			
Year	Trips	Traps	Number	Pounds	Trips	Traps	Number	Pounds
1986	13,560	3,070,181	11,159,182	4,572,238	5,740	1,522,970	5,083,356	2,085,149
1987	17,211	3,303,970	17,294,808	7,087,934	8,996	1,665,851	11,107,846	4,554,982
1988	19,583	3,535,769	16,667,841	6,830,236	10,770	2,524,164	8,328,950	3,406,631
1989	17,985	2,838,967	11,702,385	4,783,640	10,263	2,311,116	7,673,032	3,144,340
1990	15,184	3,078,383	10,858,262	4,444,290	14,643	2,803,995	12,233,726	5,003,076
1991	14,278	2,333,723	7,930,516	3,249,486	12,717	1,890,156	8,190,032	3,354,465
1992	16,419	2,900,564	11,562,563	4,741,431	12,798	1,981,249	11,120,103	4,548,837
1993	19,365	3,422,580	12,811,614	5,261,245	12,323	1,745,178	6,310,127	2,576,199
1994	21,634	3,527,285	11,631,332	4,773,267	14,031	2,045,495	7,872,178	3,211,353
1995	21,247	3,532,436	13,191,286	5,423,023	11,195	1,608,970	5,658,686	2,298,518
1996	24,941	4,390,471	19,268,843	7,925,788	13,036	2,146,553	9,154,611	3,741,171
1997	20,193	3,528,297	11,232,298	4,637,529	13,647	2,238,121	8,481,830	3,467,335
1998	23,161	4,244,615	19,492,154	8,032,641	11,358	1,901,608	6,924,232	2,831,101
1999	19,929	3,293,996	11,403,590	4,720,933	10,001	1,640,494	6,952,252	2,841,299
2000	15,258	2,569,874	8,150,517	3,383,758	9,909	1,740,086	6,606,439	2,696,232
2001	12,760	2,351,939	6,143,688	2,530,444	7,956	1,429,518	4,351,798	1,778,980
2002	14,708	2,744,487	7,224,325	2,979,427	7,000	1,195,247	3,449,088	1,404,338
2003	15,992	3,198,244	10,435,324	4,308,264	6,639	1,101,452	3,050,632	1,249,848
2004	12,810	2,853,320	9,869,889	4,072,945	7,864	1,257,439	6,366,547	2,615,811
2005	12,464	2,776,967	8,922,007	3,706,008	9,640	1,626,004	6,734,666	2,749,438

November-April (showing November year)

	Gulf coast				Atlantic coast			
Year	Trips	Traps	Number	Pounds	Trips	Traps	Number	Pounds
1986	9,798	1,875,927	7,517,621	3,081,320	5,649	1,026,346	7,639,959	3,132,126
1987	10,451	1,767,765	7,384,353	3,025,934	5,880	1,094,559	4,079,447	1,668,484
1988	13,984	2,449,488	12,003,293	4,916,013	6,700	1,561,979	3,602,293	1,465,228
1989	10,366	1,805,895	5,780,442	2,366,827	8,697	1,368,562	4,744,948	1,942,231
1990	9,185	1,622,894	5,058,752	2,072,113	7,376	1,259,165	3,529,154	1,446,108
1991	12,453	2,052,341	8,412,895	3,448,756	7,141	918,566	5,264,292	2,157,338
1992	13,062	2,156,330	7,727,635	3,173,989	6,616	868,689	3,247,500	1,331,044
1993	18,142	2,917,946	9,642,681	3,958,506	8,582	1,243,795	5,692,764	2,324,065
1994	16,211	2,598,301	7,723,076	3,166,156	6,888	964,430	2,799,948	1,147,647
1995	17,934	2,995,608	9,892,457	4,067,126	7,442	1,062,580	4,080,147	1,671,343
1996	21,775	3,744,479	13,312,638	5,477,591	9,304	1,423,335	5,893,611	2,409,707
1997	14,753	2,646,353	7,574,700	3,120,222	8,377	1,415,329	4,820,922	1,977,539
1998	23,760	4,215,690	20,206,385	8,323,520	7,490	1,169,742	4,241,254	1,737,368
1999	15,309	2,500,018	8,099,932	3,355,416	7,880	1,313,068	5,796,619	2,371,080
2000	11,202	2,004,588	5,134,629	2,128,278	5,613	958,864	2,552,256	1,046,416
2001	12,357	2,390,625	6,201,279	2,563,380	5,625	939,399	2,444,010	1,000,829
2002	11,398	2,195,737	6,045,678	2,494,938	4,628	807,658	2,002,878	821,590
2003	13,344	2,851,845	9,853,603	4,058,634	5,265	783,489	2,547,888	1,050,031
2004	11,155	2,455,100	8,846,169	3,642,718	6,040	979,859	3,719,752	1,521,365
2005	11,095	2,454,166	9,906,961	4,081,157	6,086	990,737	3,255,096	1,329,674

Table 5.1.1.2.1. Numbers, mean carapace widths (CW mm) and mean weights (WT lbs) of blue crabs sampled on the gulf and Atlantic coasts of Florida during 1997-2005 under the TIPS biostatistics sampling program and under a special Crustacean Fisheries group survey. Standard errors (SE) are given for all means presented. The number sampled per metric ton of commercial landings (N/MT) is used to evaluate sampling adequacy (see text Section 5.1.1.2).

Carapace Widths

TIPS	Gulf coast				Atlantic coast			
	N	N/MT	Mean CW	SE	N	N/MT	Mean CW	SE
1997					158	0.06	141.2	0.97
1998					272	0.13	146.4	1.01
1999								
2000	341	0.11	156.4	0.90	1,384	0.63	148.2	0.98
2001	79	0.04	146.0	1.43	413	0.33	151.7	0.85
2002	419	0.17	154.0	0.73				
2003					66	0.07	145.5	1.19
2004								
2005					183	0.10	139.1	3.37

Crustacean	Gulf coast				Atlantic coast			
	N	N/MT	Mean CW	SE	N	N/MT	Mean CW	SE
2002	523	0.21	152.8	0.78	431	0.41	153.4	0.77
2003	1,531	0.47	153.4	0.37	1,109	1.17	145.5	0.46
2004	1,259	0.34	152.2	0.51	958	0.55	147.3	0.47

Whole weights

TIPS	Gulf coast				Atlantic coast			
	N	N/MT	Mean WT	SE	N	N/MT	Mean WT	SE
1997								
1998								
1999								
2000	27	0.01	0.372	0.0271	1,150	0.52	0.411	0.0033
2001	59	0.03	0.428	0.0149	413	0.33	0.406	0.0072
2002	419	0.17	0.393	0.0055				
2003								
2004								
2005								

Crustacean	Gulf coast				Atlantic coast			
	N	N/MT	Mean WT	SE	N	N/MT	Mean WT	SE
2002	523	0.21	0.421	0.0050	431	0.41	0.424	0.0053
2003	1,531	0.47	0.408	0.0025	1,109	1.17	0.371	0.0026
2004	1,259	0.34	0.403	0.0031	958	0.55	0.435	0.0036

Table 5.1.2.1. Historic landings reported (regular) or linearly interpolated (italics) for the commercial blue crab fisheries operating on the gulf and Atlantic coasts of Florida during the period 1897-1949. Historic landings data were used in the stochastic stock reduction analysis and were derived from various U.S. Fisheries Commission reports and related landings documents.

Year	Gulf	Atlantic	Year	Gulf	Atlantic
1897		3,999	1924	*9,193*	*75,600*
1898		*4,200*	1925	*10,119*	*79,381*
1899		*4,409*	1926	11,111	83,349
1900		*4,632*	1927	11,993	121,001
1901		4,861	1928	*14,396*	*121,199*
1902		6,067	1929	*17,284*	121,400
1903		*6,975*	1930	*20,745*	107,200
1904		*8,022*	1931	*24,890*	56,964
1905		*9,226*	1932	*29,850*	78,507
1906		*10,608*	1933	*35,825*	130,254
1907		*12,200*	1934	*42,989*	182,000
1908	2,006	*14,030*	1935	51,587	1,268,801
1909	*2,205*	*16,135*	1936	821,010	2,355,600
1910	*2,425*	*18,556*	1937	775,000	*2,473,380*
1911	*2,668*	*21,338*	1938	1,103,990	*2,597,048*
1912	*2,932*	*24,539*	1939	722,002	*2,726,900*
1913	*3,219*	*28,221*	1940	1,169,996	*2,863,247*
1914	*3,549*	*32,456*	1941	*1,228,505*	*3,006,409*
1915	*3,902*	*37,324*	1942	*1,289,925*	*3,156,728*
1916	*4,277*	*42,921*	1943	*1,354,431*	*3,314,566*
1917	*4,718*	49,358	1944	*1,422,134*	*3,480,293*
1918	*5,181*	*52,000*	1945	*1,493,254*	*3,654,310*
1919	*5,710*	*54,601*	1946	*1,567,901*	*3,837,024*
1920	*6,283*	*57,330*	1947	*1,646,318*	*4,028,876*
1921	*6,900*	*60,196*	1948	1,728,616	*4,230,320*
1922	*7,606*	63,205	1949	2,055,996	4,441,834
1923	*8,355*	72,000			

Table 5.1.4.1. Statistics used in the stepwise construction of the standardization model for commercial landings rates for blue crab (both by number and pounds) on the gulf and Atlantic coast of Florida during 1986-2005. Variables include year, ln(traps pulled), county, area fished (fishloc), and month. DF is degrees of freedom.

Gulf coast, numbers

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
Year	611,151	695,884.8	1.13865		20,307.0	<.0001
Year ltraps_pulled	611,150	678,146.4	1.10962	2.55	18,858.1	<.0001
Year county	611,137	687,277.0	1.12459	1.23	18,991.8	<.0001
Year fishloc	611,149	695,200.5	1.13753	0.10	18,580.3	<.0001
Year month	611,140	695,463.3	1.13798	0.06	19,289.9	<.0001
Year ltraps_pulled	611,150	678,146.4	1.10962		18,858.1	<.0001
year ltraps_pulled county	611,136	674,530.4	1.10373	0.52	16,531.9	<.0001
year ltraps_pulled month	611,139	677,776.2	1.10904	0.05	18,135.2	<.0001
year ltraps_pulled fishloc	611,148	677,790.1	1.10904	0.05	15,569.4	<.0001

Gulf coast, pounds

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	611,131	692,688.6	1.13345		20,542.8	<.0001
year ltraps_pulled	611,130	674,888.2	1.10433	2.57	18,963.9	<.0001
year county	611,117	684,140.9	1.11949	1.23	19,314.9	<.0001
year fishloc	611,129	692,004.9	1.13234	0.10	18,927.3	<.0001
year month	611,120	692,270.0	1.13279	0.06	19,516.6	<.0001
year ltraps_pulled	611,130	674,888.2	1.10433		18,963.9	<.0001
year ltraps_pulled county	611,116	671,485.2	1.09879	0.49	16,785.7	<.0001
year ltraps_pulled fishloc	611,128	674,530.0	1.10375	0.05	15,799.8	<.0001
year ltraps_pulled month	611,119	674,529.8	1.10376	0.05	18,220.0	<.0001

Atlantic coast, numbers

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	330,783	373,325.4	1.12861		14,778.4	<.0001
year ltraps_pulled	330,782	365,432.0	1.10475	2.11	14,191.4	<.0001
year county	330,780	371,841.6	1.12414	0.40	13,222.5	<.0001
year month	330,772	372,935.2	1.12747	0.10	15,384.0	<.0001
year fishloc	330,781	373,003.3	1.12764	0.09	16,885.0	<.0001
year ltraps_pulled	330,782	365,432.0	1.10475		14,191.4	<.0001
year ltraps_pulled county	330,779	364,954.8	1.10332	0.13	12,979.0	<.0001
year ltraps_pulled month	330,771	365,231.8	1.10418	0.05	14,460.6	<.0001
year ltraps_pulled fishloc	330,780	365,337.3	1.10447	0.02	13,474.9	<.0001

Atlantic coast, pounds

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	330,768	372,964.7	1.12757		14,827.0	<.0001
year ltraps_pulled	330,767	365,313.7	1.10444	2.05	14,108.9	<.0001
year county	330,765	371,570.1	1.12337	0.37	13,239.3	<.0001
year month	330,757	372,579.3	1.12644	0.10	15,428.9	<.0001
year fishloc	330,766	372,630.5	1.12657	0.09	17,044.0	<.0001
year ltraps_pulled	330,767	365,313.7	1.10444		14,108.9	<.0001
year ltraps_pulled county	330,764	364,922.6	1.10327	0.10	12,938.0	<.0001
year ltraps_pulled month	330,756	365,120.3	1.1039	0.05	14,377.4	<.0001
year ltraps_pulled fishloc	330,765	365,228.5	1.10419	0.02	13,557.2	<.0001

Table 5.3.1.2.1. Number of sets and number of young-of-the-year (YOY) and exploited-sized (EXPL) blue crabs captured during April-May, October-November, and January-December each year during 1989-2005 on the gulf coast and 1990-2005 on the Atlantic coast.

Gulf

	April-May			October-November			January-December		
Year	Sets	YOY	EXPL	Sets	YOY	EXPL	Sets	YOY	EXPL
1989	97	35	14	154	12	36	307	80	82
1990	119	47	28	183	4	22	340	58	50
1991	127	26	21	160	35	19	347	63	45
1992	119	62	16	161	49	26	341	126	64
1993	104	19	5	171	31	26	340	63	42
1994	110	30	14	168	21	14	333	54	28
1995	240	92	83	378	61	39	748	206	145
1996	294	127	129	442	68	169	2,068	512	707
1997	454	119	79	509	145	54	2,797	635	384
1998	385	182	76	532	554	471	2,608	2,189	1,716
1999	497	253	218	545	63	91	3,008	1,307	893
2000	497	154	67	557	39	95	3,038	571	444
2001	552	229	48	585	53	72	3,298	653	328
2002	537	129	114	585	23	46	3,250	367	350
2003	536	156	80	587	82	140	3,253	534	515
2004	541	297	118	589	53	140	3,273	990	718
2005	483	152	102	552	125	124	2,970	773	680

Atlantic

	April-May			October-November			January-December		
Year	Sets	YOY	EXPL	Sets	YOY	EXPL	Sets	YOY	EXPL
1990	16	2	9	77	8	6	111	12	21
1991	74	7	22	68	58	44	169	83	73
1992	67	34	76	70	3	7	169	64	152
1993	62	19	18	61	6	13	166	26	43
1994	74	14	81	76	12	25	172	28	127
1995	138	45	111	176	15	51	359	86	185
1996	74	7	51	76	5	7	453	43	125
1997	91	14	36	92	3	15	556	59	141
1998	56	15	25	86	2	3	366	76	59
1999	56	3	1	86	5	3	365	62	19
2000	56	6	23	86	2	6	366	19	60
2001	140	33	42	226	32	34	929	165	190
2002	197	120	28	226	19	26	1,210	424	166
2003	216	34	16	248	49	41	1,335	277	135
2004	218	143	65	248	61	99	1,342	513	511
2005	218	96	98	248	53	136	1,338	446	508

Table 5.3.1.6.1. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for recruit-size blue crabs on the gulf coast of Florida in April-May and October-November during 1989-2005. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	1,300	3,410.7	2.62361		455.9	<.0001
yearmo bayzone	1,284	3,239.2	2.52270	3.85	427.3	<.0001
yearmo effort	1,299	3,351.6	2.58017	1.66	431.0	<.0001
yearmo bvegCover	1,299	3,394.7	2.61331	0.39	450.5	<.0001
yearmo col_gear	1,299	3,395.0	2.61352	0.38	459.9	<.0001
yearmo salinity	1,299	3,400.7	2.61794	0.22	428.0	<.0001
yearmo dissolvedO2	1,299	3,404.4	2.62075	0.11	458.3	<.0001
yearmo temperature	1,299	3,404.9	2.62118	0.09	461.5	<.0001
yearmo totShoreCover	1,299	3,410.7	2.62560	-0.08	452.8	<.0001
yearmo bayzone	1,284	3,239.2	2.52270		427.3	<.0001
yearmo bayzone effort	1,283	3,186.2	2.48341	1.50	404.2	<.0001
yearmo bayzone col_gear	1,283	3,208.6	2.50083	0.83	441.6	<.0001
yearmo bayzone dissolvedO2	1,283	3,229.7	2.51730	0.21	429.7	<.0001
yearmo bayzone bvegCover	1,283	3,233.2	2.52003	0.10	425.6	<.0001
yearmo bayzone salinity	1,283	3,235.6	2.52189	0.03	396.7	<.0001
yearmo bayzone temperature	1,283	3,237.7	2.52356	-0.03	428.7	<.0001
yearmo bayzone totShoreCover	1,283	3,239.1	2.52462	-0.07	426.4	<.0001
yearmo bayzone effort	1,283	3,186.2	2.48341		404.23	<.0001
yearmo bayzone effort col_gear	1,282	3,149.1	2.45641	1.03	416.97	<.0001
yearmo bayzone effort bvegCover	1,282	3,177.2	2.47832	0.19	401.14	<.0001
yearmo bayzone effort dissolvedO2	1,282	3,178.1	2.47903	0.17	405.59	<.0001
yearmo bayzone effort salinity	1,282	3,178.5	2.47933	0.16	369.08	<.0001
yearmo bayzone effort temperature	1,282	3,183.9	2.48350	0.00	406.49	<.0001
yearmo bayzone effort totShoreCover	1,282	3,185.8	2.48503	-0.06	397.91	<.0001
yearmo bayzone col_gear effort	1,282	3,149.1	2.45641		416.97	<.0001
yearmo bayzone col_gear effort salinity	1,281	3,137.4	2.44917	0.28	381.62	<.0001
yearmo bayzone col_gear effort dissolvedO2	1,281	3,145.5	2.45550	0.03	416.69	<.0001
yearmo bayzone col_gear effort bvegCover	1,281	3,146.3	2.45609	0.01	413.89	<.0001
yearmo bayzone col_gear effort temperature	1,281	3,148.0	2.45744	-0.04	418.04	<.0001
yearmo bayzone col_gear effort totShoreCover	1,281	3,149.0	2.45822	-0.07	412.41	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	12,263	8,151.9	0.66475		291.96	<.0001
yearmo col_gear	12,262	7,985.7	0.65126	2.03	349.71	<.0001
yearmo bayzone	12,247	7,999.9	0.65321	1.74	283.02	<.0001
yearmo effort	12,262	8,087.0	0.65951	0.79	303.18	<.0001
yearmo salinity	12,262	8,121.8	0.66235	0.36	290.74	<.0001
yearmo totShoreCover	12,262	8,142.8	0.66407	0.10	280.29	<.0001
yearmo bvegCover	12,262	8,144.6	0.66422	0.08	296.2	<.0001
yearmo temperature	12,262	8,150.3	0.66468	0.01	293.55	<.0001
yearmo dissolvedO2	12,262	8,151.0	0.66473	0.00	291.57	<.0001
yearmo col_gear	12,262	7,985.7	0.65126		349.71	<.0001
yearmo col_gear bayzone	12,246	7,860.8	0.64190	1.41	339.21	<.0001
yearmo col_gear effort	12,261	7,904.1	0.64465	0.99	364.53	<.0001
yearmo col_gear salinity	12,261	7,962.1	0.64938	0.28	346.13	<.0001
yearmo col_gear bvegCover	12,261	7,984.0	0.65117	0.01	348.9	<.0001
yearmo col_gear temperature	12,261	7,985.0	0.65125	0.00	349.83	<.0001
yearmo col_gear dissolvedO2	12,261	7,985.4	0.65129	0.00	350.02	<.0001
yearmo col_gear totShoreCover	12,261	7,985.7	0.65131	-0.01	343.27	<.0001
yearmo col_gear bayzone	12,246	7,860.8	0.64190		339.21	<.0001
yearmo col_gear bayzone effort	12,245	7,754.5	0.63328	1.30	338.17	<.0001
yearmo col_gear bayzone salinity	12,245	7,850.5	0.64112	0.12	344.77	<.0001
yearmo col_gear bayzone bvegCover	12,245	7,851.7	0.64122	0.10	334.28	<.0001
yearmo col_gear bayzone temperature	12,245	7,858.6	0.64178	0.02	341.36	<.0001
yearmo col_gear bayzone totShoreCover	12,245	7,859.5	0.64185	0.01	330.02	<.0001
yearmo col_gear bayzone dissolvedO2	12,245	7,859.8	0.64187	0.00	339.79	<.0001
yearmo col_gear bayzone effort	12,245	7,754.5	0.63328		338.17	<.0001
yearmo col_gear bayzone effort salinity	12,244	7,740.8	0.63221	0.16	345.41	<.0001
yearmo col_gear bayzone effort bvegCover	12,244	7,742.9	0.63238	0.13	333.46	<.0001
yearmo col_gear bayzone effort totShoreCover	12,244	7,749.8	0.63294	0.05	322.55	<.0001
yearmo col_gear bayzone effort temperature	12,244	7,751.2	0.63306	0.03	341.35	<.0001
yearmo col_gear bayzone effort dissolvedO2	12,244	7,753.0	0.63321	0.01	338.92	<.0001

Table 5.3.1.6.2. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for exploited-size blue crabs on the gulf coast of Florida in April-May and October-November during 1989-2005. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	1,163	2,039.5	1.75364		250.66	<.0001
yearmo dissolvedO2	1,162	1,968.8	1.69430	3.38	230.59	<.0001
yearmo effort	1,162	1,998.6	1.71993	1.92	241.86	<.0001
yearmo bayzone	1,147	1,987.5	1.73279	1.19	237.30	<.0001
yearmo temperature	1,162	2,014.5	1.73361	1.14	228.39	<.0001
yearmo salinity	1,162	2,026.7	1.74417	0.54	246.04	<.0001
yearmo col_gear	1,162	2,034.2	1.75059	0.17	253.58	<.0001
yearmo bvegCover	1,162	2,037.3	1.75329	0.02	251.56	<.0001
yearmo totShoreCover	1,162	2,038.9	1.75468	-0.06	229.90	<.0001
yearmo dissolvedO2	1,162	1,968.8	1.69430		230.59	<.0001
yearmo dissolvedO2 effort	1,161	1,914.4	1.64895	2.59	212.19	<.0001
yearmo dissolvedO2 bayzone	1,146	1,922.8	1.67779	0.94	219.31	<.0001
yearmo dissolvedO2 temperature	1,161	1,956.4	1.68513	0.52	218.38	<.0001
yearmo dissolvedO2 salinity	1,161	1,960.4	1.68851	0.33	228.07	<.0001
yearmo dissolvedO2 totShoreCover	1,161	1,966.8	1.69402	0.02	211.66	<.0001
yearmo dissolvedO2 col_gear	1,161	1,967.7	1.69487	-0.03	231.59	<.0001
yearmo dissolvedO2 bvegCover	1,161	1,968.6	1.69564	-0.08	229.79	<.0001
yearmo effort dissolvedO2	1,161	1,914.4	1.64895		212.19	<.0001
yearmo effort dissolvedO2 bayzone	1,145	1,813.0	1.58337	3.74	207.10	<.0001
yearmo effort dissolvedO2 col_gear	1,160	1,867.1	1.60958	2.25	217.16	<.0001
yearmo effort dissolvedO2 salinity	1,160	1,883.2	1.62345	1.45	205.96	<.0001
yearmo effort dissolvedO2 totShoreCover	1,160	1,905.3	1.64247	0.37	177.15	<.0001
yearmo effort dissolvedO2 temperature	1,160	1,906.4	1.64348	0.31	200.53	<.0001
yearmo effort dissolvedO2 bvegCover	1,160	1,912.0	1.64828	0.04	213.13	<.0001
yearmo bayzone effort dissolvedO2	1,145	1,813.0	1.58337		207.10	<.0001
yearmo bayzone effort dissolvedO2 temperature	1,144	1,803.5	1.57649	0.39	199.51	<.0001
yearmo bayzone effort dissolvedO2 totShoreCover	1,144	1,804.3	1.57718	0.35	176.18	<.0001
yearmo bayzone effort dissolvedO2 col_gear	1,144	1,807.3	1.57981	0.20	206.84	<.0001
yearmo bayzone effort dissolvedO2 salinity	1,144	1,810.3	1.58242	0.05	198.73	<.0001
yearmo bayzone effort dissolvedO2 bvegCover	1,144	1,812.5	1.58433	-0.05	206.78	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	12,263	7,607.3	0.62035		243.08	<.0001
yearmo effort	12,262	7,259.9	0.59206	4.56	251.93	<.0001
yearmo col_gear	12,262	7,321.0	0.59705	3.76	282.57	<.0001
yearmo bayzone	12,247	7,430.8	0.60674	2.19	244.21	<.0001
yearmo salinity	12,262	7,569.3	0.61730	0.49	223.29	<.0001
yearmo dissolvedO2	12,262	7,573.8	0.61766	0.43	241.52	<.0001
yearmo temperature	12,262	7,584.1	0.61850	0.30	235.18	<.0001
yearmo bvegCover	12,262	7,597.1	0.61956	0.13	244.27	<.0001
yearmo totShoreCover	12,262	7,607.3	0.62040	-0.01	242.45	<.0001
yearmo effort	12,262	7,259.9	0.59206		251.93	<.0001
yearmo effort bayzone	12,246	6,799.4	0.55524	5.94	233.36	<.0001
yearmo effort col_gear	12,261	6,858.7	0.55939	5.27	294.64	<.0001
yearmo effort salinity	12,261	7,150.0	0.58315	1.44	238.07	<.0001
yearmo effort dissolvedO2	12,261	7,215.5	0.58849	0.58	246.08	<.0001
yearmo effort temperature	12,261	7,233.7	0.58998	0.34	238.06	<.0001
yearmo effort bvegCover	12,261	7,237.9	0.59032	0.28	255.15	<.0001
yearmo effort totShoreCover	12,261	7,259.0	0.59204	0.00	244.01	<.0001
yearmo bayzone effort	12,246	6,799.4	0.55524		233.36	<.0001
yearmo bayzone effort col_gear	12,245	6,539.5	0.53405	3.41	254.68	<.0001
yearmo bayzone effort dissolvedO2	12,245	6,778.8	0.55360	0.26	233.08	<.0001
yearmo bayzone effort totShoreCover	12,245	6,785.6	0.55415	0.17	226.17	<.0001
yearmo bayzone effort temperature	12,245	6,793.4	0.55479	0.07	228.41	<.0001
yearmo bayzone effort salinity	12,245	6,798.1	0.55517	0.01	232.22	<.0001
yearmo bayzone effort bvegCover	12,245	6,799.4	0.55528	-0.01	233.37	<.0001
yearmo col_gear bayzone effort	12,245	6,539.5	0.53405		254.68	<.0001
yearmo col_gear bayzone effort bvegCover	12,244	6,526.2	0.53301	0.17	255.10	<.0001
yearmo col_gear bayzone effort temperature	12,244	6,529.6	0.53329	0.12	244.07	<.0001
yearmo col_gear bayzone effort dissolvedO2	12,244	6,531.2	0.53342	0.10	253.34	<.0001
yearmo col_gear bayzone effort salinity	12,244	6,536.6	0.53386	0.03	247.27	<.0001
yearmo col_gear bayzone effort totShoreCover	12,244	6,539.3	0.53408	0.00	252.90	<.0001

Table 5.3.1.6.3. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for recruit-size blue crabs on the Atlantic coast of Florida in April-May and October-November during 1990-2005. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	382	89.2	1.80415		121.87	<.0001
yearmo bayzone	375	54.8	1.74617	3.21	122.50	<.0001
yearmo col_gear	381	68.8	1.75525	2.71	125.60	<.0001
yearmo dissolvedO2	381	78.1	1.77986	1.35	128.61	<.0001
yearmo temperature	381	79.4	1.78313	1.17	130.98	<.0001
yearmo salinity	381	82.5	1.79126	0.71	111.42	<.0001
yearmo bvegCover	381	83.6	1.79425	0.55	123.64	<.0001
yearmo totShoreCover	381	86.0	1.80052	0.20	124.87	<.0001
yearmo effort	381	87.4	1.80430	-0.01	121.70	<.0001
yearmo bayzone	375	54.8	1.74617		122.50	<.0001
yearmo bayzone col_gear	374	39.7	1.71053	1.98	120.53	<.0001
yearmo bayzone dissolvedO2	374	47.8	1.73208	0.78	127.74	<.0001
yearmo bayzone temperature	374	48.0	1.73262	0.75	128.71	<.0001
yearmo bayzone effort	374	52.1	1.74357	0.14	124.41	<.0001
yearmo bayzone salinity	374	52.8	1.74547	0.04	116.20	<.0001
yearmo bayzone totShoreCover	374	53.5	1.74736	-0.07	123.40	<.0001
yearmo bayzone bvegCover	374	54.8	1.75068	-0.25	119.92	<.0001
yearmo bayzone col_gear	374	39.7	1.71053		120.53	<.0001
yearmo bayzone col_gear temperature	373	31.3	1.69246	1.00	128.28	<.0001
yearmo bayzone col_gear effort	373	33.2	1.69767	0.71	122.63	<.0001
yearmo bayzone col_gear dissolvedO2	373	36.5	1.70634	0.23	123.70	<.0001
yearmo bayzone col_gear bvegCover	373	37.9	1.71032	0.01	122.23	<.0001
yearmo bayzone col_gear totShoreCover	373	38.0	1.71043	0.01	121.08	<.0001
yearmo bayzone col_gear salinity	373	38.9	1.71286	-0.13	113.91	<.0001
yearmo bayzone col_gear temperature	373	31.3	1.69246		128.28	<.0001
yearmo bayzone col_gear temperature dissolvedO2	372	18.8	1.66354	1.60	140.31	<.0001
yearmo bayzone col_gear temperature effort	372	26.2	1.68339	0.50	129.10	<.0001
yearmo bayzone col_gear temperature bvegCover	372	29.3	1.69156	0.05	130.18	<.0001
yearmo bayzone col_gear temperature totShoreCover	372	29.8	1.69289	-0.02	128.61	<.0001
yearmo bayzone col_gear temperature salinity	372	30.4	1.69452	-0.11	120.93	<.0001
yearmo bayzone col_gear temperature dissolvedO2	372	18.8	1.66354		140.31	<.0001
yearmo bayzone col_gear temperature dissolvedO2 effort	371	13.8	1.65435	0.51	141.07	<.0001
yearmo bayzone col_gear temperature dissolvedO2 bvegCover	371	16.1	1.66071	0.16	142.86	<.0001
yearmo bayzone col_gear temperature dissolvedO2 totShoreCover	371	17.5	1.66444	-0.05	140.49	<.0001
yearmo bayzone col_gear temperature dissolvedO2 salinity	371	17.7	1.66491	-0.08	132.53	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	3,838	2,481.1	0.64645		151.65	<.0001
yearmo bayzone	3,831	2,276.8	0.59431	8.07	153.95	<.0001
yearmo col_gear	3,837	2,301.6	0.59985	7.21	140.57	<.0001
yearmo bvegCover	3,837	2,377.4	0.61960	4.15	119.71	<.0001
yearmo temperature	3,837	2,448.3	0.63808	1.30	145.74	<.0001
yearmo totShoreCover	3,837	2,472.4	0.64435	0.32	115.00	<.0001
yearmo effort	3,837	2,477.2	0.64561	0.13	149.49	<.0001
yearmo salinity	3,837	2,479.3	0.64615	0.05	153.22	<.0001
yearmo dissolvedO2	3,837	2,480.6	0.64650	-0.01	150.81	<.0001
yearmo bayzone	3,831	2,276.8	0.59431		153.95	<.0001
yearmo bayzone col_gear	3,830	2,182.6	0.56987	3.78	120.52	<.0001
yearmo bayzone temperature	3,830	2,262.7	0.59077	0.55	152.63	<.0001
yearmo bayzone bvegCover	3,830	2,267.3	0.59199	0.36	128.14	<.0001
yearmo bayzone effort	3,830	2,272.1	0.59324	0.17	158.21	<.0001
yearmo bayzone salinity	3,830	2,275.6	0.59414	0.03	154.07	<.0001
yearmo bayzone dissolvedO2	3,830	2,275.9	0.59424	0.01	152.28	<.0001
yearmo bayzone totShoreCover	3,830	2,276.6	0.59440	-0.01	146.16	<.0001
yearmo bayzone col_gear	3,830	2,182.6	0.56987		120.52	<.0001
yearmo bayzone col_gear effort	3,829	2,170.7	0.56691	0.46	125.46	<.0001
yearmo bayzone col_gear temperature	3,829	2,170.9	0.56697	0.45	119.63	<.0001
yearmo bayzone col_gear dissolvedO2	3,829	2,178.7	0.56901	0.13	117.70	<.0001
yearmo bayzone col_gear salinity	3,829	2,179.6	0.56924	0.10	123.11	<.0001
yearmo bayzone col_gear totShoreCover	3,829	2,180.0	0.56934	0.08	122.64	<.0001
yearmo bayzone col_gear bvegCover	3,829	2,182.6	0.57002	-0.02	116.26	<.0001

Table 5.3.1.6.4. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for exploited-size blue crabs on the Atlantic coast of Florida in April-May and October-November during 1990-2005. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	434	1,034.9	2.38445	.	190.99	<.0001
yearmo bayzone	427	937.7	2.19593	7.91	181.94	<.0001
yearmo totShoreCover	433	1,004.3	2.31943	2.73	145.36	<.0001
yearmo effort	433	1,017.6	2.35016	1.44	203.97	<.0001
yearmo col_gear	433	1,020.3	2.35630	1.18	173.15	<.0001
yearmo temperature	433	1,027.8	2.37368	0.45	187.81	<.0001
yearmo bvegCover	433	1,033.0	2.38577	-0.06	189.28	<.0001
yearmo dissolvedO2	433	1,033.3	2.38634	-0.08	188.40	<.0001
yearmo salinity	433	1,034.2	2.38851	-0.17	183.63	<.0001
yearmo bayzone	427	937.7	2.19593		181.94	<.0001
yearmo bayzone totShoreCover	426	904.6	2.12345	3.04	171.30	<.0001
yearmo bayzone col_gear	426	922.3	2.16507	1.29	163.75	<.0001
yearmo bayzone effort	426	928.5	2.17966	0.68	190.53	<.0001
yearmo bayzone bvegCover	426	928.6	2.17980	0.68	171.38	<.0001
yearmo bayzone temperature	426	936.0	2.19712	-0.05	182.12	<.0001
yearmo bayzone salinity	426	937.3	2.20027	-0.18	178.55	<.0001
yearmo bayzone dissolvedO2	426	937.6	2.20089	-0.21	178.45	<.0001
yearmo bayzone totShoreCover	426	904.6	2.12345		171.30	<.0001
yearmo bayzone totShoreCover col_gear	425	891.2	2.09700	1.11	167.29	<.0001
yearmo bayzone totShoreCover effort	425	896.5	2.10947	0.59	175.88	<.0001
yearmo bayzone totShoreCover bvegCover	425	897.8	2.11248	0.46	172.49	<.0001
yearmo bayzone totShoreCover temperature	425	902.9	2.12445	-0.04	171.07	<.0001
yearmo bayzone totShoreCover dissolvedO2	425	903.4	2.12553	-0.09	166.82	<.0001
yearmo bayzone totShoreCover salinity	425	904.0	2.12704	-0.15	170.73	<.0001
yearmo bayzone totShoreCover col_gear	425	891.2	2.09700		167.29	<.0001
yearmo bayzone totShoreCover col_gear effort	424	868.1	2.04742	2.08	163.04	<.0001
yearmo bayzone totShoreCover col_gear temperature	424	888.2	2.09471	0.10	167.38	<.0001
yearmo bayzone totShoreCover col_gear bvegCover	424	888.5	2.09540	0.07	170.04	<.0001
yearmo bayzone totShoreCover col_gear dissolvedO2	424	890.3	2.09986	-0.12	164.03	<.0001
yearmo bayzone totShoreCover col_gear salinity	424	890.9	2.10123	-0.18	166.06	<.0001
yearmo bayzone totShoreCover col_gear effort	424	868.1	2.04742		163.04	<.0001
yearmo bayzone totShoreCover col_gear effort temperature	423	864.7	2.04421	0.13	163.01	<.0001
yearmo bayzone totShoreCover col_gear effort bvegCover	423	866.9	2.04938	-0.08	164.25	<.0001
yearmo bayzone totShoreCover col_gear effort dissolvedO2	423	867.7	2.05129	-0.16	160.28	<.0001
yearmo bayzone totShoreCover col_gear effort salinity	423	867.8	2.05155	-0.17	161.36	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
yearmo	3,838	2,733.4	0.71220	.	112.95	<.0001
yearmo col_gear	3,837	2,381.6	0.62070	12.85	94.19	<.0001
yearmo bayzone	3,831	2,571.9	0.67133	5.74	187.35	<.0001
yearmo bvegCover	3,837	2,593.5	0.67592	5.09	102.73	<.0001
yearmo effort	3,837	2,645.3	0.68941	3.20	136.75	<.0001
yearmo dissolvedO2	3,837	2,710.0	0.70629	0.83	115.19	<.0001
yearmo salinity	3,837	2,730.9	0.71173	0.07	112.55	<.0001
yearmo temperature	3,837	2,733.0	0.71227	-0.01	113.25	<.0001
yearmo totShoreCover	3,837	2,733.4	0.71238	-0.03	112.88	<.0001
yearmo col_gear	3,837	2,381.6	0.62070		94.19	<.0001
yearmo col_gear effort	3,836	2,225.0	0.58004	5.71	102.77	<.0001
yearmo col_gear bayzone	3,830	2,298.1	0.60003	2.90	104.65	<.0001
yearmo col_gear dissolvedO2	3,836	2,366.9	0.61702	0.52	95.06	<.0001
yearmo col_gear bvegCover	3,836	2,369.4	0.61768	0.42	96.15	<.0001
yearmo col_gear temperature	3,836	2,378.0	0.61991	0.11	94.03	<.0001
yearmo col_gear salinity	3,836	2,380.1	0.62045	0.03	93.06	<.0001
yearmo col_gear totShoreCover	3,836	2,381.5	0.62083	-0.02	94.30	<.0001
yearmo col_gear effort	3,836	2,225.0	0.58004		102.77	<.0001
yearmo col_gear effort bayzone	3,829	2,163.0	0.56489	2.13	123.87	<.0001
yearmo col_gear effort dissolvedO2	3,835	2,209.1	0.57604	0.56	103.44	<.0001
yearmo col_gear effort bvegCover	3,835	2,214.9	0.57754	0.35	103.94	<.0001
yearmo col_gear effort temperature	3,835	2,220.9	0.57911	0.13	102.43	<.0001
yearmo col_gear effort salinity	3,835	2,222.8	0.57962	0.06	102.68	<.0001
yearmo col_gear effort totShoreCover	3,835	2,225.0	0.58018	-0.02	101.50	<.0001
yearmo col_gear bayzone effort	3,829	2,163.0	0.56489		123.87	<.0001
yearmo col_gear bayzone effort dissolvedO2	3,828	2,143.1	0.55985	0.71	124.34	<.0001
yearmo col_gear bayzone effort temperature	3,828	2,158.4	0.56385	0.15	124.88	<.0001
yearmo col_gear bayzone effort bvegCover	3,828	2,158.8	0.56395	0.13	111.90	<.0001
yearmo col_gear bayzone effort totShoreCover	3,828	2,162.8	0.56499	-0.02	118.67	<.0001
yearmo col_gear bayzone effort salinity	3,828	2,162.9	0.56503	-0.02	123.80	<.0001

Table 5.3.1.6.5. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for recruit-size blue crabs on the gulf coast of Florida during the 1989-2005 calendar years. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	9,321	6,316.2	0.67763		216.83	<.0001
year bayzone	9,314	5,840.5	0.62707	7.46	195.90	<.0001
year col_gear	9,320	5,878.6	0.63075	6.92	144.68	<.0001
year bvegCover	9,320	6,097.1	0.65420	3.46	102.35	<.0001
year temperature	9,320	6,289.3	0.67481	0.42	196.07	<.0001
year totShoreCover	9,320	6,290.8	0.67498	0.39	111.58	<.0001
year salinity	9,320	6,309.7	0.67701	0.09	213.76	<.0001
year effort	9,320	6,314.1	0.67748	0.02	216.29	<.0001
year dissolvedO2	9,320	6,314.3	0.67750	0.02	217.18	<.0001
year bayzone	9,314	5,840.5	0.62707		195.90	<.0001
year bayzone col_gear	9,313	5,618.0	0.60324	3.52	122.93	<.0001
year bayzone temperature	9,313	5,830.4	0.62605	0.15	194.23	<.0001
year bayzone effort	9,313	5,833.2	0.62635	0.11	201.61	<.0001
year bayzone salinity	9,313	5,836.8	0.62674	0.05	195.86	<.0001
year bayzone bvegCover	9,313	5,837.4	0.62680	0.04	161.55	<.0001
year bayzone totShoreCover	9,313	5,837.9	0.62685	0.03	192.40	<.0001
year bayzone dissolvedO2	9,313	5,838.8	0.62695	0.02	194.64	<.0001
year bayzone col_gear	9,313	5,618.0	0.60324		122.93	<.0001
year bayzone col_gear effort	9,312	5,588.6	0.60015	0.46	129.08	<.0001
year bayzone col_gear totShoreCover	9,312	5,608.9	0.60233	0.13	132.02	<.0001
year bayzone col_gear temperature	9,312	5,609.6	0.60241	0.12	121.22	<.0001
year bayzone col_gear salinity	9,312	5,612.8	0.60275	0.07	123.93	<.0001
year bayzone col_gear dissolvedO2	9,312	5,613.0	0.60278	0.07	121.11	<.0001
year bayzone col_gear bvegCover	9,312	5,613.4	0.60281	0.06	125.90	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	31,455	20,402.8	0.64864		325.07	<.0001
year bayzone	31,439	19,982.2	0.63559	2.01	321.32	<.0001
year col_gear	31,454	20,018.9	0.63645	1.88	353.58	<.0001
year effort	31,454	20,248.2	0.64374	0.75	339.49	<.0001
year salinity	31,454	20,368.2	0.64756	0.17	298.34	<.0001
year bvegCover	31,454	20,385.1	0.64809	0.08	328.48	<.0001
year totShoreCover	31,454	20,395.8	0.64843	0.03	281.57	<.0001
year dissolvedO2	31,454	20,399.8	0.64856	0.01	322.74	<.0001
year temperature	31,454	20,402.8	0.64866	0.00	324.75	<.0001
year bayzone	31,439	19,982.2	0.63559		321.32	<.0001
year bayzone effort	31,438	19,666.2	0.62555	1.55	323.66	<.0001
year bayzone col_gear	31,438	19,703.9	0.62676	1.36	348.68	<.0001
year bayzone salinity	31,438	19,958.7	0.63486	0.11	342.30	<.0001
year bayzone totShoreCover	31,438	19,963.5	0.63501	0.09	277.37	<.0001
year bayzone temperature	31,438	19,981.3	0.63558	0.00	322.08	<.0001
year bayzone bvegCover	31,438	19,981.4	0.63558	0.00	320.49	<.0001
year bayzone dissolvedO2	31,438	19,981.5	0.63558	0.00	320.75	<.0001
year bayzone effort	31,438	19,666.2	0.62555		323.66	<.0001
year bayzone effort col_gear	31,437	19,396.2	0.61699	1.32	334.63	<.0001
year bayzone effort totShoreCover	31,437	19,631.6	0.62448	0.17	265.34	<.0001
year bayzone effort salinity	31,437	19,647.5	0.62498	0.09	341.14	<.0001
year bayzone effort bvegCover	31,437	19,663.9	0.62550	0.01	322.74	<.0001
year bayzone effort temperature	31,437	19,664.5	0.62552	0.00	324.89	<.0001
year bayzone effort dissolvedO2	31,437	19,666.0	0.62557	0.00	323.19	<.0001
year bayzone col_gear effort	31,437	19,396.2	0.61699		334.63	<.0001
year bayzone col_gear effort bvegCover	31,436	19,374.2	0.61631	0.11	333.15	<.0001
year bayzone col_gear effort salinity	31,436	19,392.9	0.61690	0.01	336.34	<.0001
year bayzone col_gear effort totShoreCover	31,436	19,393.5	0.61692	0.01	298.35	<.0001
year bayzone col_gear effort dissolvedO2	31,436	19,395.0	0.61697	0.00	335.43	<.0001
year bayzone col_gear effort temperature	31,436	19,395.6	0.61699	0.00	335.20	<.0001

Table 5.3.1.6.6. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for exploited-size blue crabs on the gulf coast of Florida during the 1989-2005 calendar years. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	3,002	6,478.2	2.15796		560.67	<.0001
year bayzone	2,986	6,257.5	2.09563	2.89	587.12	<.0001
year effort	3,001	6,357.3	2.11838	1.83	543.62	<.0001
year dissolvedO2	3,001	6,412.1	2.13666	0.99	541.92	<.0001
year salinity	3,001	6,416.2	2.13801	0.92	520.78	<.0001
year temperature	3,001	6,420.9	2.13957	0.85	504.01	<.0001
year col_gear	3,001	6,464.6	2.15416	0.18	569.81	<.0001
year bvegCover	3,001	6,472.8	2.15690	0.05	557.19	<.0001
year totShoreCover	3,001	6,477.8	2.15853	-0.03	483.95	<.0001
year bayzone	2,986	6,257.5	2.09563		587.12	<.0001
year bayzone effort	2,985	5,931.8	1.98719	5.02	590.01	<.0001
year bayzone dissolvedO2	2,985	6,183.5	2.07154	1.12	565.36	<.0001
year bayzone temperature	2,985	6,201.4	2.07753	0.84	532.58	<.0001
year bayzone bvegCover	2,985	6,228.4	2.08658	0.42	588.11	<.0001
year bayzone salinity	2,985	6,240.8	2.09072	0.23	537.73	<.0001
year bayzone col_gear	2,985	6,256.4	2.09596	-0.02	586.51	<.0001
year bayzone totShoreCover	2,985	6,257.5	2.09632	-0.03	519.28	<.0001
year bayzone effort	2,985	5,931.8	1.98719		590.01	<.0001
year bayzone effort dissolvedO2	2,984	5,860.5	1.96396	1.08	565.58	<.0001
year bayzone effort temperature	2,984	5,897.6	1.97639	0.50	544.36	<.0001
year bayzone effort col_gear	2,984	5,908.9	1.98019	0.32	590.77	<.0001
year bayzone effort salinity	2,984	5,915.8	1.98250	0.22	535.84	<.0001
year bayzone effort totShoreCover	2,984	5,918.8	1.98352	0.17	466.56	<.0001
year bayzone effort bvegCover	2,984	5,921.6	1.98445	0.13	591.20	<.0001
year bayzone effort dissolvedO2	2,984	5,860.5	1.96396		565.58	<.0001
year bayzone effort dissolvedO2 col_gear	2,983	5,838.9	1.95738	0.31	565.52	<.0001
year bayzone effort dissolvedO2 totShoreCover	2,983	5,845.1	1.95947	0.21	447.71	<.0001
year bayzone effort dissolvedO2 salinity	2,983	5,845.5	1.95962	0.20	515.80	<.0001
year bayzone effort dissolvedO2 bvegCover	2,983	5,845.8	1.95970	0.20	566.91	<.0001
year bayzone effort dissolvedO2 temperature	2,983	5,852.6	1.96199	0.09	542.77	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	31,455	19,496.6	0.61982		396.19	<.0001
year col_gear	31,454	18,588.7	0.59098	4.65	462.52	<.0001
year effort	31,454	18,682.0	0.59395	4.18	438.81	<.0001
year bayzone	31,439	19,020.1	0.60498	2.39	390.89	<.0001
year temperature	31,454	19,307.1	0.61382	0.97	382.88	<.0001
year dissolvedO2	31,454	19,349.8	0.61518	0.75	397.84	<.0001
year salinity	31,454	19,417.2	0.61732	0.40	316.89	<.0001
year bvegCover	31,454	19,452.8	0.61845	0.22	403.38	<.0001
year totShoreCover	31,454	19,487.9	0.61957	0.04	376.33	<.0001
year col_gear	31,454	18,588.7	0.59098		462.52	<.0001
year col_gear effort	31,453	17,425.9	0.55403	5.96	468.02	<.0001
year col_gear bayzone	31,438	18,308.1	0.58236	1.39	470.52	<.0001
year col_gear temperature	31,453	18,362.5	0.58381	1.16	447.81	<.0001
year col_gear dissolvedO2	31,453	18,493.4	0.58797	0.49	462.19	<.0001
year col_gear salinity	31,453	18,540.2	0.58946	0.25	391.3	<.0001
year col_gear totShoreCover	31,453	18,566.5	0.59029	0.11	484.36	<.0001
year col_gear bvegCover	31,453	18,580.4	0.59073	0.04	461.76	<.0001
year col_gear effort	31,453	17,425.9	0.55403		468.02	<.0001
year col_gear effort bayzone	31,437	16,636.5	0.52920	4.01	412.36	<.0001
year col_gear effort temperature	31,452	17,180.6	0.54625	1.26	440.13	<.0001
year col_gear effort salinity	31,452	17,221.2	0.54754	1.05	352.59	<.0001
year col_gear effort dissolvedO2	31,452	17,299.9	0.55004	0.64	457.62	<.0001
year col_gear effort totShoreCover	31,452	17,410.3	0.55355	0.08	482.01	<.0001
year col_gear effort bvegCover	31,452	17,425.5	0.55403	0.00	467.14	<.0001
year col_gear bayzone effort	31,437	16,636.5	0.52920		412.36	<.0001
year col_gear bayzone effort temperature	31,436	16,463.0	0.52370	0.89	399.16	<.0001
year col_gear bayzone effort dissolvedO2	31,436	16,574.5	0.52724	0.32	414.27	<.0001
year col_gear bayzone effort bvegCover	31,436	16,629.8	0.52901	0.03	409.05	<.0001
year col_gear bayzone effort totShoreCover	31,436	16,632.0	0.52907	0.02	392.48	<.0001
year col_gear bayzone effort salinity	31,436	16,636.0	0.52920	0.00	375.96	<.0001

Table 5.3.1.6.7. Statistics used in stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for recruit-size blue crabs on the Atlantic coast of Florida during the 1990-2005 calendar years. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	1,026	1,765.1	1.72041		127.43	<.0001
year bayzone	1,019	1,694.3	1.66270	3.35	111.70	<.0001
year col_gear	1,025	1,735.8	1.69346	1.57	140.99	<.0001
year salinity	1,025	1,746.1	1.70346	0.99	124.98	<.0001
year bvegCover	1,025	1,754.2	1.71136	0.53	135.24	<.0001
year effort	1,025	1,756.2	1.71340	0.41	120.75	<.0001
year totShoreCover	1,025	1,760.5	1.71758	0.16	129.30	<.0001
year temperature	1,025	1,761.6	1.71859	0.11	128.76	<.0001
year dissolvedO2	1,025	1,765.1	1.72209	-0.10	127.41	<.0001
year bayzone	1,019	1,694.3	1.66270		111.70	<.0001
year bayzone col_gear	1,018	1,671.6	1.64205	1.20	111.96	<.0001
year bayzone effort	1,018	1,682.8	1.65305	0.56	114.93	<.0001
year bayzone totShoreCover	1,018	1,691.9	1.66193	0.04	114.14	<.0001
year bayzone salinity	1,018	1,691.9	1.66197	0.04	113.19	<.0001
year bayzone bvegCover	1,018	1,692.7	1.66272	0.00	105.77	<.0001
year bayzone temperature	1,018	1,693.5	1.66356	-0.05	110.91	<.0001
year bayzone dissolvedO2	1,018	1,693.7	1.66378	-0.06	110.38	<.0001
year bayzone col_gear	1,018	1,671.6	1.64205		111.96	<.0001
year bayzone col_gear effort	1,017	1,649.8	1.62218	1.15	112.28	<.0001
year bayzone col_gear salinity	1,017	1,669.3	1.64143	0.04	113.09	<.0001
year bayzone col_gear totShoreCover	1,017	1,669.4	1.64146	0.03	114.08	<.0001
year bayzone col_gear dissolvedO2	1,017	1,670.1	1.64214	-0.01	109.97	<.0001
year bayzone col_gear temperature	1,017	1,671.2	1.64328	-0.07	111.55	<.0001
year bayzone col_gear bvegCover	1,017	1,671.5	1.64360	-0.09	111.41	<.0001
year bayzone col_gear effort	1,017	1,649.8	1.62218		112.28	<.0001
year bayzone col_gear effort totShoreCover	1,016	1,646.6	1.62069	0.09	115.32	<.0001
year bayzone col_gear effort salinity	1,016	1,648.2	1.62227	-0.01	113.32	<.0001
year bayzone col_gear effort dissolvedO2	1,016	1,648.7	1.62276	-0.03	110.33	<.0001
year bayzone col_gear effort bvegCover	1,016	1,649.3	1.62332	-0.07	111.87	<.0001
year bayzone col_gear effort temperature	1,016	1,649.7	1.62368	-0.09	111.93	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	9,321	6,316.2	0.67763		216.83	<.0001
year bayzone	9,314	5,840.5	0.62707	7.46	195.90	<.0001
year col_gear	9,320	5,878.6	0.63075	6.92	144.68	<.0001
year bvegCover	9,320	6,097.1	0.65420	3.46	102.35	<.0001
year temperature	9,320	6,289.3	0.67481	0.42	196.07	<.0001
year totShoreCover	9,320	6,290.8	0.67498	0.39	111.58	<.0001
year salinity	9,320	6,309.7	0.67701	0.09	213.76	<.0001
year effort	9,320	6,314.1	0.67748	0.02	216.29	<.0001
year dissolvedO2	9,320	6,314.3	0.67750	0.02	217.18	<.0001
year bayzone	9,314	5,840.5	0.62707		195.90	<.0001
year bayzone col_gear	9,313	5,618.0	0.60324	3.52	122.93	<.0001
year bayzone temperature	9,313	5,830.4	0.62605	0.15	194.23	<.0001
year bayzone effort	9,313	5,833.2	0.62635	0.11	201.61	<.0001
year bayzone salinity	9,313	5,836.8	0.62674	0.05	195.86	<.0001
year bayzone bvegCover	9,313	5,837.4	0.62680	0.04	161.55	<.0001
year bayzone totShoreCover	9,313	5,837.9	0.62685	0.03	192.40	<.0001
year bayzone dissolvedO2	9,313	5,838.8	0.62695	0.02	194.64	<.0001
year bayzone col_gear	9,313	5,618.0	0.60324		122.93	<.0001
year bayzone col_gear effort	9,312	5,588.6	0.60015	0.46	129.08	<.0001
year bayzone col_gear totShoreCover	9,312	5,608.9	0.60233	0.13	132.02	<.0001
year bayzone col_gear temperature	9,312	5,609.6	0.60241	0.12	121.22	<.0001
year bayzone col_gear salinity	9,312	5,612.8	0.60275	0.07	123.93	<.0001
year bayzone col_gear dissolvedO2	9,312	5,613.0	0.60278	0.07	121.11	<.0001
year bayzone col_gear bvegCover	9,312	5,613.4	0.60281	0.06	125.90	<.0001

Table 5.3.1.6.8. Statistics used in the stepwise construction of the delta Poisson model (see Section 5.1.4) for fishery-independent catch rates for exploited-size blue crabs on the Atlantic coast of Florida during the 1990-2005 calendar years. See Section 5.1.4 for more details and definition of variables.

Positive values only, Poisson link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	1,046	1,956.0	1.86997		179.92	<.0001
year bayzone	1,039	1,906.0	1.83444	1.90	131.42	<.0001
year totShoreCover	1,045	1,927.8	1.84477	1.35	120.32	<.0001
year effort	1,045	1,935.8	1.85240	0.94	194.71	<.0001
year col_gear	1,045	1,942.4	1.85874	0.60	162.14	<.0001
year dissolvedO2	1,045	1,945.2	1.86141	0.46	181.75	<.0001
year temperature	1,045	1,948.8	1.86484	0.27	180.93	<.0001
year salinity	1,045	1,952.0	1.86795	0.11	171.14	<.0001
year bvegCover	1,045	1,955.7	1.87146	-0.08	179.57	<.0001
year bayzone	1,039	1,906.0	1.83444		131.42	<.0001
year bayzone col_gear	1,038	1,878.4	1.80960	1.33	111.33	<.0001
year bayzone totShoreCover	1,038	1,881.2	1.81232	1.18	119.74	<.0001
year bayzone bvegCover	1,038	1,892.1	1.82287	0.62	120.89	<.0001
year bayzone dissolvedO2	1,038	1,894.6	1.82522	0.49	128.89	<.0001
year bayzone salinity	1,038	1,895.1	1.82571	0.47	127.29	<.0001
year bayzone effort	1,038	1,895.6	1.82618	0.44	141.82	<.0001
year bayzone temperature	1,038	1,902.0	1.83239	0.11	132.21	<.0001
year bayzone col_gear	1,038	1,878.4	1.80960		111.33	<.0001
year bayzone col_gear effort	1,037	1,823.1	1.75805	2.76	120.31	<.0001
year bayzone col_gear totShoreCover	1,037	1,855.3	1.78908	1.10	114.98	<.0001
year bayzone col_gear salinity	1,037	1,864.8	1.79831	0.60	105.32	<.0001
year bayzone col_gear dissolvedO2	1,037	1,866.6	1.80002	0.51	107.35	<.0001
year bayzone col_gear temperature	1,037	1,869.9	1.80316	0.34	109.93	<.0001
year bayzone col_gear bvegCover	1,037	1,873.7	1.80685	0.15	115.37	<.0001
year bayzone col_gear effort	1,037	1,823.1	1.75805		120.31	<.0001
year bayzone col_gear effort totShoreCover	1,036	1,800.9	1.73836	1.05	120.71	<.0001
year bayzone col_gear effort salinity	1,036	1,811.2	1.74827	0.52	113.73	<.0001
year bayzone col_gear effort dissolvedO2	1,036	1,812.0	1.74900	0.48	116.80	<.0001
year bayzone col_gear effort temperature	1,036	1,813.4	1.75039	0.41	118.89	<.0001
year bayzone col_gear effort bvegCover	1,036	1,819.7	1.75647	0.08	122.27	<.0001
year bayzone col_gear totShoreCover effort	1,036	1,800.9	1.73836		120.71	<.0001
year bayzone col_gear totShoreCover effort dissolvedO2	1,035	1,787.0	1.72657	0.63	115.77	<.0001
year bayzone col_gear totShoreCover effort temperature	1,035	1,788.3	1.72777	0.57	118.86	<.0001
year bayzone col_gear totShoreCover effort salinity	1,035	1,791.9	1.73127	0.38	113.03	<.0001
year bayzone col_gear totShoreCover effort bvegCover	1,035	1,798.1	1.73730	0.06	123.52	<.0001

Presence/Absence, Binomial link

FACTOR	DF	Deviance	Dev/DF	%Reduction	ChiSq	P(ChiSq)
year	9,321	6,431.0	0.68995		184.57	<.0001
year col_gear	9,320	5,760.6	0.61809	10.42	122.35	<.0001
year bvegCover	9,320	6,208.7	0.66617	3.45	160.83	<.0001
year bayzone	9,314	6,206.8	0.66640	3.41	305.91	<.0001
year effort	9,320	6,219.9	0.66737	3.27	238.49	<.0001
year dissolvedO2	9,320	6,330.5	0.67924	1.55	199.11	<.0001
year temperature	9,320	6,376.1	0.68413	0.84	194.14	<.0001
year salinity	9,320	6,416.8	0.68850	0.21	182.22	<.0001
year totShoreCover	9,320	6,429.7	0.68989	0.01	183.95	<.0001
year col_gear	9,320	5,760.6	0.61809		122.35	<.0001
year col_gear effort	9,319	5,301.9	0.56894	7.12	145.71	<.0001
year col_gear temperature	9,319	5,666.9	0.60810	1.45	127.41	<.0001
year col_gear dissolvedO2	9,319	5,674.7	0.60894	1.33	137.88	<.0001
year col_gear bayzone	9,313	5,675.6	0.60942	1.26	143.31	<.0001
year col_gear bvegCover	9,319	5,748.3	0.61683	0.18	125.84	<.0001
year col_gear salinity	9,319	5,752.2	0.61726	0.12	120.69	<.0001
year col_gear totShoreCover	9,319	5,759.7	0.61806	0.00	122.62	<.0001
year col_gear effort	9,319	5,301.9	0.56894		145.71	<.0001
year col_gear effort temperature	9,318	5,202.8	0.55836	1.53	150.26	<.0001
year col_gear effort dissolvedO2	9,318	5,210.2	0.55916	1.42	165.29	<.0001
year col_gear effort bayzone	9,312	5,242.3	0.56297	0.87	175.87	<.0001
year col_gear effort salinity	9,318	5,290.0	0.56772	0.18	145.93	<.0001
year col_gear effort bvegCover	9,318	5,290.1	0.56773	0.17	147.61	<.0001
year col_gear effort totShoreCover	9,318	5,301.7	0.56897	0.00	141.65	<.0001
year col_gear effort temperature	9,318	5,202.8	0.55836		150.26	<.0001
year col_gear effort temperature bayzone	9,311	5,142.5	0.55231	0.88	184.62	<.0001
year col_gear effort temperature dissolvedO2	9,317	5,184.3	0.55643	0.28	159.24	<.0001
year col_gear effort temperature bvegCover	9,317	5,185.3	0.55654	0.26	152.11	<.0001
year col_gear effort temperature salinity	9,317	5,191.4	0.55719	0.17	147.18	<.0001
year col_gear effort temperature totShoreCover	9,317	5,202.5	0.55839	0.00	148.37	<.0001

Table 5.3.4.1. Predicted median catch rates whose $\log_e$ values were used as indices of relative abundance in the various population dynamics models. Indices are for small recruit blue crabs, 40-79 mm CW, and exploited-size blue crabs,125 mm CW and larger. Indices pertain to seasonal time frames, April-May and October-November, and calendar year time frames.

Gulf coast

	April-May		October-November		Calendar
	Recruits	Exploited	Recruits	Exploited	Exploited
1989	0.712	0.276	0.072	0.023	0.136
1990	0.706	0.262	0.017	0.124	0.165
1991	0.289	0.284	0.292	0.028	0.103
1992	0.936	0.353	0.307	0.208	0.283
1993	0.380	0.125	0.203	0.166	0.180
1994	0.412	0.171	0.161	0.086	0.109
1995	0.527	0.434	0.179	0.129	0.248
1996	0.542	0.399	0.204	0.412	0.389
1997	0.275	0.158	0.316	0.103	0.152
1998	0.588	0.203	1.169	0.906	0.778
1999	0.533	0.378	0.137	0.131	0.288
2000	0.303	0.103	0.085	0.143	0.138
2001	0.438	0.087	0.108	0.109	0.102
2002	0.267	0.166	0.045	0.072	0.111
2003	0.349	0.150	0.151	0.228	0.177
2004	0.617	0.231	0.102	0.231	0.250
2005	0.340	0.226	0.218	0.233	0.258

Atlantic coast

	April-May		October-November		Calendar
	Recruits	Exploited	Recruits	Exploited	Exploited
1989					
1990	0.310	0.247	0.356	0.040	0.083
1991	0.295	0.233	1.383	0.449	0.284
1992	1.160	0.890	0.122	0.058	0.641
1993	0.662	0.242	0.209	0.112	0.155
1994	0.362	0.796	0.371	0.164	0.459
1995	1.078	0.724	0.180	0.147	0.245
1996	0.369	0.630	0.143	0.061	0.211
1997	0.345	0.214	0.068	0.085	0.165
1998	0.666	0.306	0.252	0.043	0.163
1999	0.180	0.012	0.206	0.034	0.053
2000	0.238	0.306	0.076	0.060	0.167
2001	0.089	0.158	0.041	0.095	0.178
2002	0.209	0.072	0.024	0.056	0.120
2003	0.050	0.036	0.079	0.090	0.089
2004	0.329	0.148	0.090	0.216	0.354
2005	0.133	0.221	0.068	0.337	0.346

Table 6.2.2.1. Values of instantaneous natural mortality (M) estimated within a Tampa Bay ECOPATH model, distributed across ages 0-3 using the Lorenzen ralationship of M and body weight (top table). These were further grouped into life stages then partitioned into the six-month seasons used in the catch-survey analysis model (bottom table).

	ECOPATH M	M_0	M_1	M_2	M_3	recruits	postrecruits
1989	1.67	2.42	1.58	1.36	1.31	1.96	1.34
1990	1.50	2.17	1.42	1.22	1.18	1.75	1.20
1991	1.34	1.94	1.27	1.09	1.05	1.57	1.07
1992	1.39	2.02	1.32	1.13	1.10	1.64	1.12
1993	1.33	1.92	1.26	1.08	1.04	1.56	1.06
1994	1.18	1.72	1.12	0.96	0.93	1.39	0.95
1995	1.34	1.94	1.27	1.09	1.05	1.57	1.07
1996	1.59	2.30	1.50	1.29	1.25	1.86	1.27
1997	1.16	1.69	1.10	0.95	0.91	1.36	0.93
1998	1.49	2.16	1.41	1.21	1.17	1.75	1.19
1999	1.58	2.30	1.50	1.29	1.25	1.86	1.27
2000	0.96	1.40	0.91	0.78	0.76	1.13	0.77
2001	1.24	1.79	1.17	1.01	0.97	1.45	0.99
2002	1.31	1.89	1.24	1.06	1.03	1.53	1.04
2003	1.47	2.14	1.40	1.20	1.16	1.73	1.18
2004	1.49	2.16	1.41	1.21	1.17	1.75	1.19
2005[a]		2.16	1.41	1.21	1.17	1.75	1.19

[a] assumed equal to 2004 value

	May-October		November-April	
	recruits	exploited size	recruits	exploited size
1989	0.98	0.67	0.91	0.62
1990	0.88	0.60	0.82	0.56
1991	0.78	0.54	0.81	0.55
1992	0.82	0.56	0.79	0.54
1993	0.78	0.53	0.72	0.49
1994	0.69	0.47	0.75	0.51
1995	0.78	0.53	0.88	0.60
1996	0.93	0.63	0.77	0.52
1997	0.68	0.47	0.81	0.55
1998	0.87	0.60	0.91	0.62
1999	0.93	0.63	0.69	0.47
2000	0.56	0.39	0.67	0.46
2001	0.72	0.49	0.75	0.51
2002	0.77	0.52	0.83	0.57
2003	0.86	0.59	0.87	0.59
2004	0.87	0.60	0.87	0.60
2005	0.87	0.60	0.87	0.60

Table 7.2.1.1 Calendar year instantaneous fishing mortality estimates for blue crabs on the gulf and Atlantic coasts of Florida during 1970-2005. Estimates were made using the catch-survey analysis (CSA), the non-equilibrium surplus production models (ASPIC), and stochastic stock reduction analysis (SRA).

	Gulf			Atlantic		
	CSA	ASPIC	SRA	CSA	ASPIC	SRA
1970		0.74	0.01		0.63	0.13
1971		0.67	0.04		0.91	0.15
1972		0.59	0.04		0.80	0.13
1973		0.49	0.06		0.49	0.14
1974		0.47	0.05		1.07	0.15
1975		0.57	0.10		0.75	0.18
1976		0.54	0.08		0.74	0.18
1977		0.77	0.11		0.61	0.14
1978		0.63	0.18		0.63	0.18
1979		0.60	0.29		0.51	0.15
1980		0.60	0.40		0.61	0.17
1981		0.89	0.36		0.40	0.18
1982		0.58	0.20		0.55	0.19
1983		0.56	0.26		0.75	0.22
1984		0.79	0.33		0.87	0.16
1985		0.90	0.44		0.49	0.15
1986		0.59	0.35		0.37	0.19
1987		0.80	0.31		0.86	0.24
1988		0.91	0.19		0.58	0.18
1989	0.52	0.84	0.25		0.51	0.15
1990	0.53	0.74	0.32	0.48	0.81	0.22
1991	0.32	0.50	0.27	0.29	0.56	0.24
1992	0.51	0.65	0.23	0.22	0.90	0.18
1993	0.48	0.64	0.20	0.26	0.56	0.11
1994	0.46	0.59	0.23	0.24	0.77	0.21
1995	0.38	0.55	0.32	0.16	0.47	0.12
1996	0.43	0.80	0.32	0.26	0.72	0.12
1997	0.42	0.62	0.43	0.40	0.84	0.11
1998	0.53	0.96	0.30	0.31	0.74	0.12
1999	0.27	1.15	0.33	0.72	0.81	0.12
2000	0.41	0.86	0.38	0.35	1.05	0.18
2001	0.35	0.56	0.49	0.23	0.66	0.14
2002	0.36	0.55	0.31	0.25	0.48	0.24
2003	0.45	0.61	0.36	0.28	0.31	0.35
2004	0.33	0.62	0.62	0.24	0.44	0.36
2005	0.30	0.49	0.69	0.23	0.40	0.21

Table 7.2.2.1 Abundance (in thousands) of exploitable blue crabs on May 1 each year from the catch-survey analysis (CSA); estimates of the average annual biomass (in thousands of pounds) of exploited-size blue crabs from the surplus production model (ASPIC); and the average vulnerable biomass (in thousands of pounds) predicted for the beginning of the year from the stochastic stock reduction analysis (SRA).

	Gulf			Atlantic		
	CSA (000's no.)	ASPIC (000's lbs)	SRA (000's lbs)	CSA (000's no.)	ASPIC (000's lbs)	SRA (000's lbs)
1970		20,090	36,378		12,390	20,639
1971		18,230	38,110		10,010	21,755
1972		18,090	39,265		7,908	21,197
1973		19,450	40,998		7,951	17,850
1974		21,570	32,914		7,004	19,523
1975		22,380	37,533		5,621	20,081
1976		22,400	36,956		5,425	18,966
1977		20,480	33,491		5,608	18,966
1978		18,570	30,026		6,073	19,523
1979		18,550	29,449		6,817	17,292
1980		18,760	30,026		7,529	18,408
1981		16,640	27,717		8,643	16,734
1982		15,450	26,562		9,824	15,619
1983		16,850	28,872		9,326	15,619
1984		16,320	24,252		7,793	16,734
1985		13,740	23,097		7,637	13,388
1986		13,160	20,788		9,369	14,503
1987		13,200	18,478		9,217	13,388
1988		11,480	17,323		8,393	12,830
1989	95,460	10,000	15,013		9,114	13,388
1990	88,093	9,643	16,168	65,528	8,714	8,367
1991	91,992	11,030	12,126	61,438	8,283	22,870
1992	113,324	12,730	23,097	150,764	7,592	35,700
1993	50,613	13,460	17,323	58,056	7,115	17,292
1994	61,965	14,490	12,126	119,270	7,103	31,795
1995	131,474	15,970	23,097	109,672	7,439	21,197
1996	129,216	15,610	31,181	111,537	7,839	17,850
1997	57,639	14,970	19,055	54,881	6,945	13,945
1998	78,017	13,420	54,278	67,639	6,209	11,714
1999	117,160	9,691	30,604	12,499	5,728	5,020
2000	40,912	7,654	15,013	66,111	4,649	12,830
2001	34,516	8,269	12,126	41,516	4,134	13,388
2002	57,330	10,190	12,126	25,721	4,894	10,598
2003	56,200	11,900	17,323	17,248	6,691	8,925
2004	79,420	13,150	23,675	50,277	8,752	25,102
2005	76,678	15,080	24,252	58,778	10,470	24,544

Table 8.4.1. Estimated values for stock biomass (million of pounds), the yield (millions of pounds), and instantaneous fishing mortality (F, yr^{-1}) under maximum sustainable yield levels and on average during the period 2003-2005. Results come from the non-equilibrium surplus production model, ASPIC. The average estimated number of traps pulled in the commercial fishery during 2003-2005 is also given.

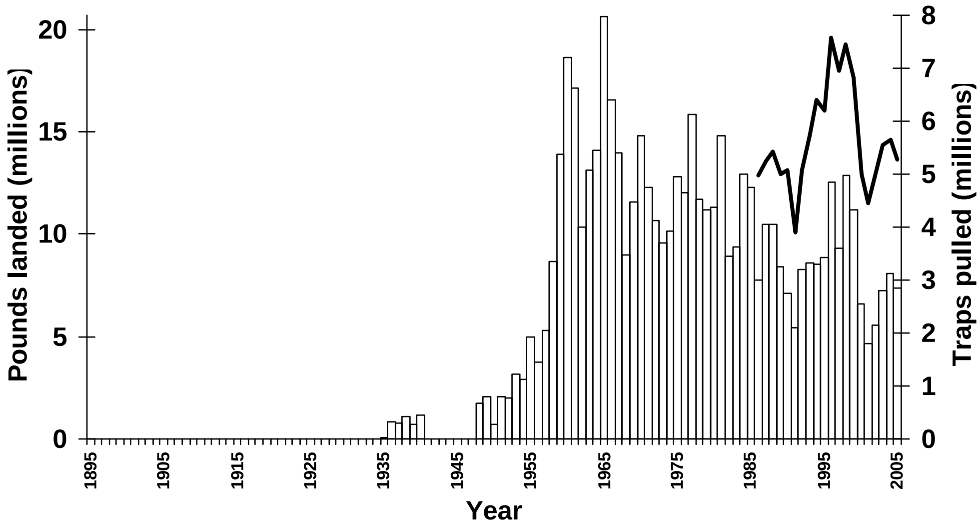
Gulf coast	at MSY	2003-2005
Biomass	28.78	13.38
Yield	13.07	7.56
F	0.45	0.57
Traps pulled		5.49

Atlantic coast		
Biomass	16.13	8.64
Yield	6.89	3.38
F	0.43	0.38
Traps pulled		2.20

13.0 Figures

Figure 3.1.1. Reported commercial landings (bars) of blue crabs, in pounds, and estimated numbers of traps pulled (line) on the gulf and Atlantic coast of Florida during 1897-2005. Commercial landings before 1986 came from the National Marine Fisheries Service and predecessor's General Canvass of wholesale seafood dealers. Since 1986 landings and effort data were reported (or derived from, i.e., traps pulled) the FWC-FWRI's Marine Resources Information System. There are low amounts of landings in reported in some early years that don't appear on this scale (see Table 5.1.2.1)

Gulf coast



Atlantic coast

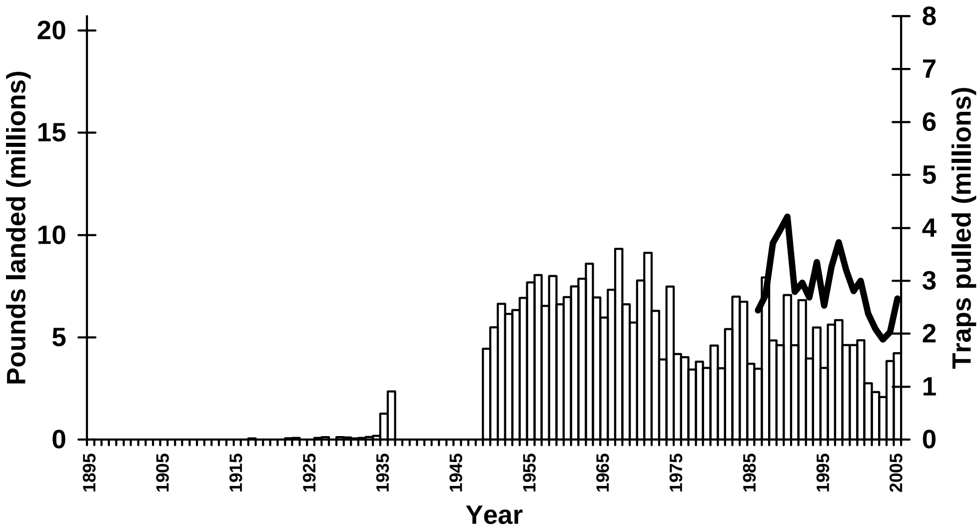


Figure 5.1.2.1. Reported and linearly interpolated commercial landings of blue crab over the historic (prior to 1950) and reported landings over the more recent (1950-2005) years on the gulf (thick line) and Atlantic (thin line) coasts of Florida. Low levels of landing were first recorded in 1908 on the gulf coast and in 1897 on the Atlantic coast (see Table 5.1.2.1).

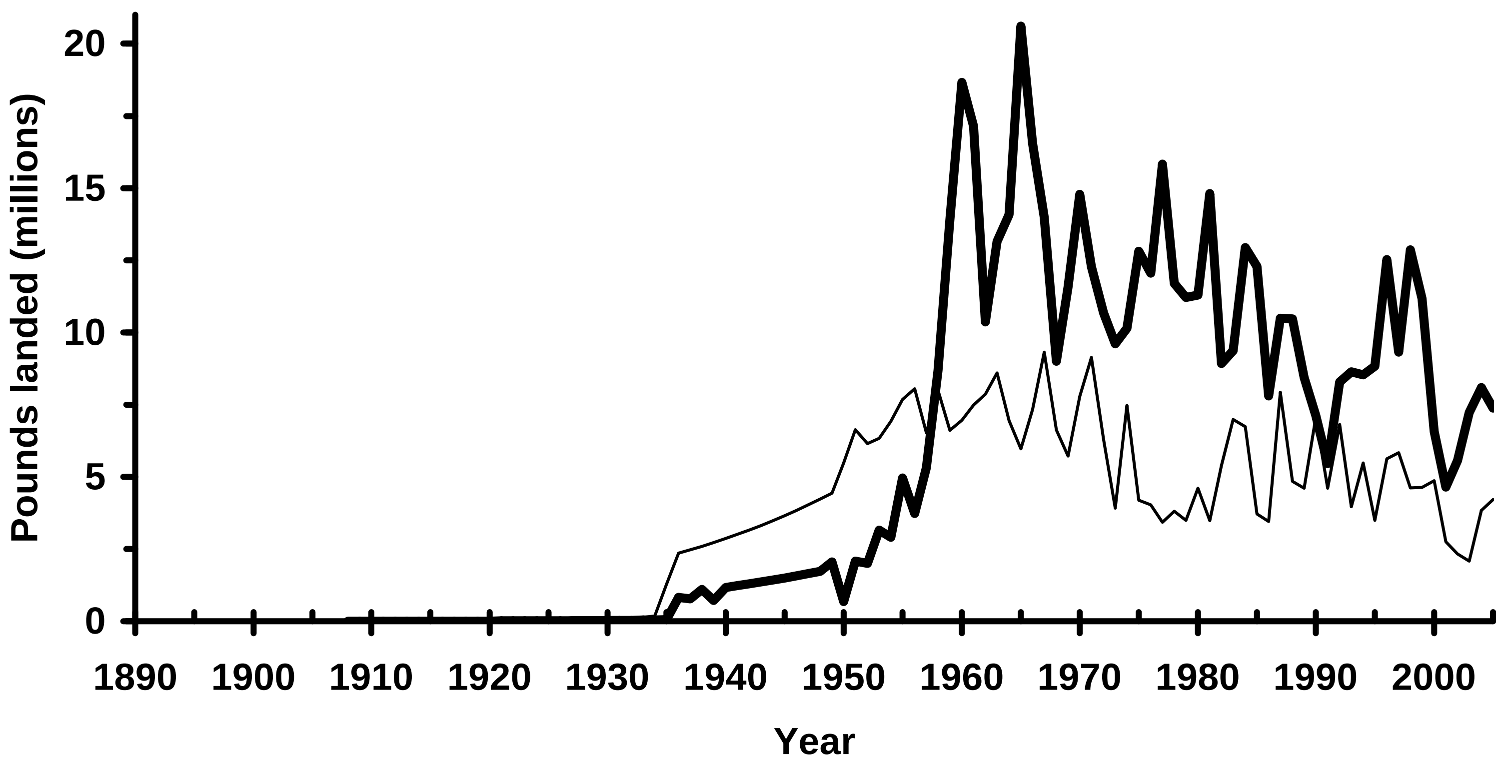


Figure 5.1.4.1. Annual commercial landings (pounds) of blue crab plotted against the number of reported fishing trips taken that year or the estimated number of traps-pulled that year on the gulf and Atlantic coast of Florida during the period 1986-2005.

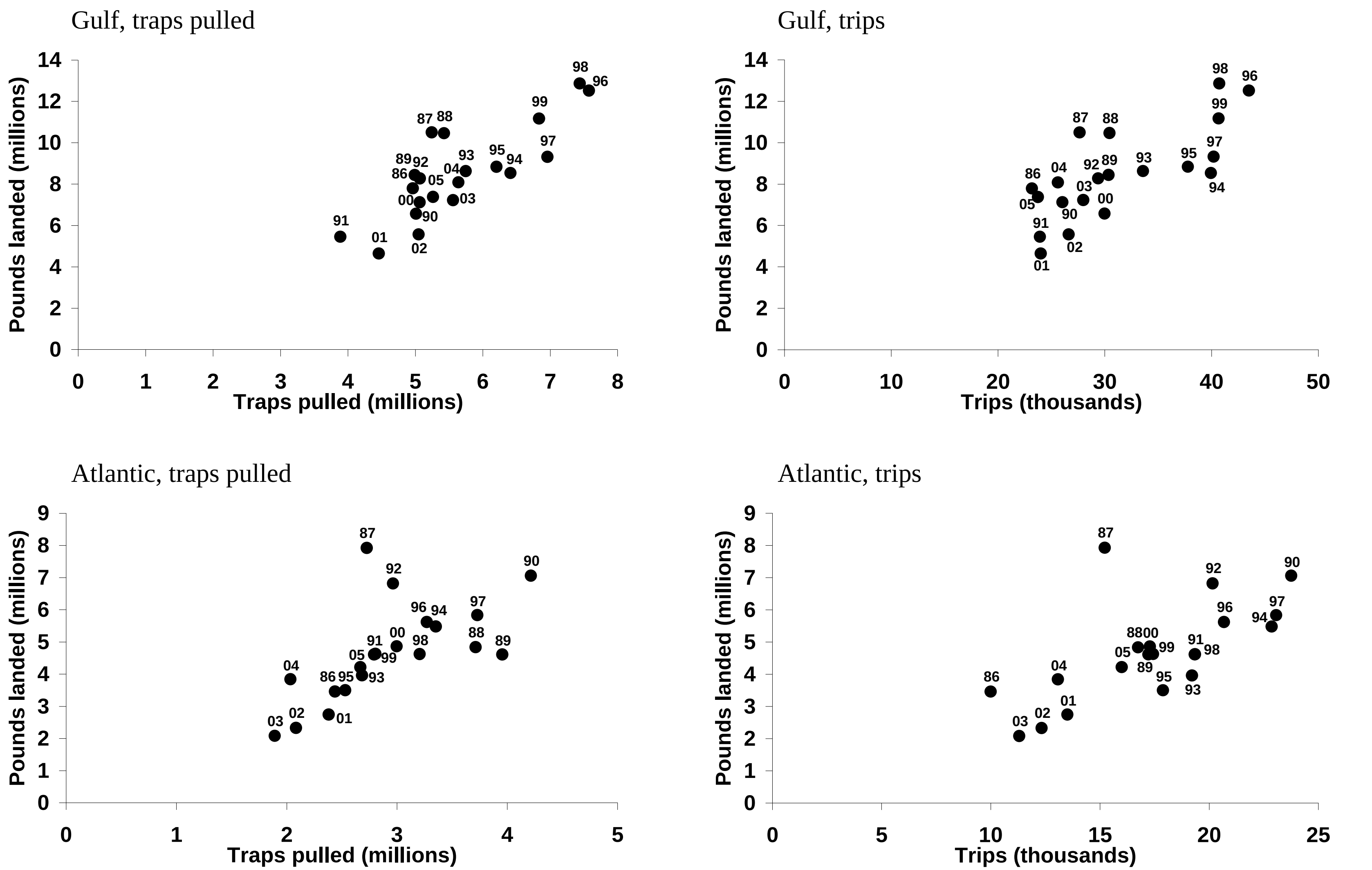


Figure 5.1.4.1. Standardized commercial landings per trip estimated for gulf coast commercial blue crab fishers and standardization diagnostics. Landings rate graphs show the annual sample size (in thousands), median, interquartile range, and 95% confidence bands. Standardized deviance residuals show the distribution of the observed data about the estimated mean (horizontal line at zero) against the predicted value and for each year. The QQ plot at bottom shows the fit of these residuals to a standard normal distribution [N(0,1)].

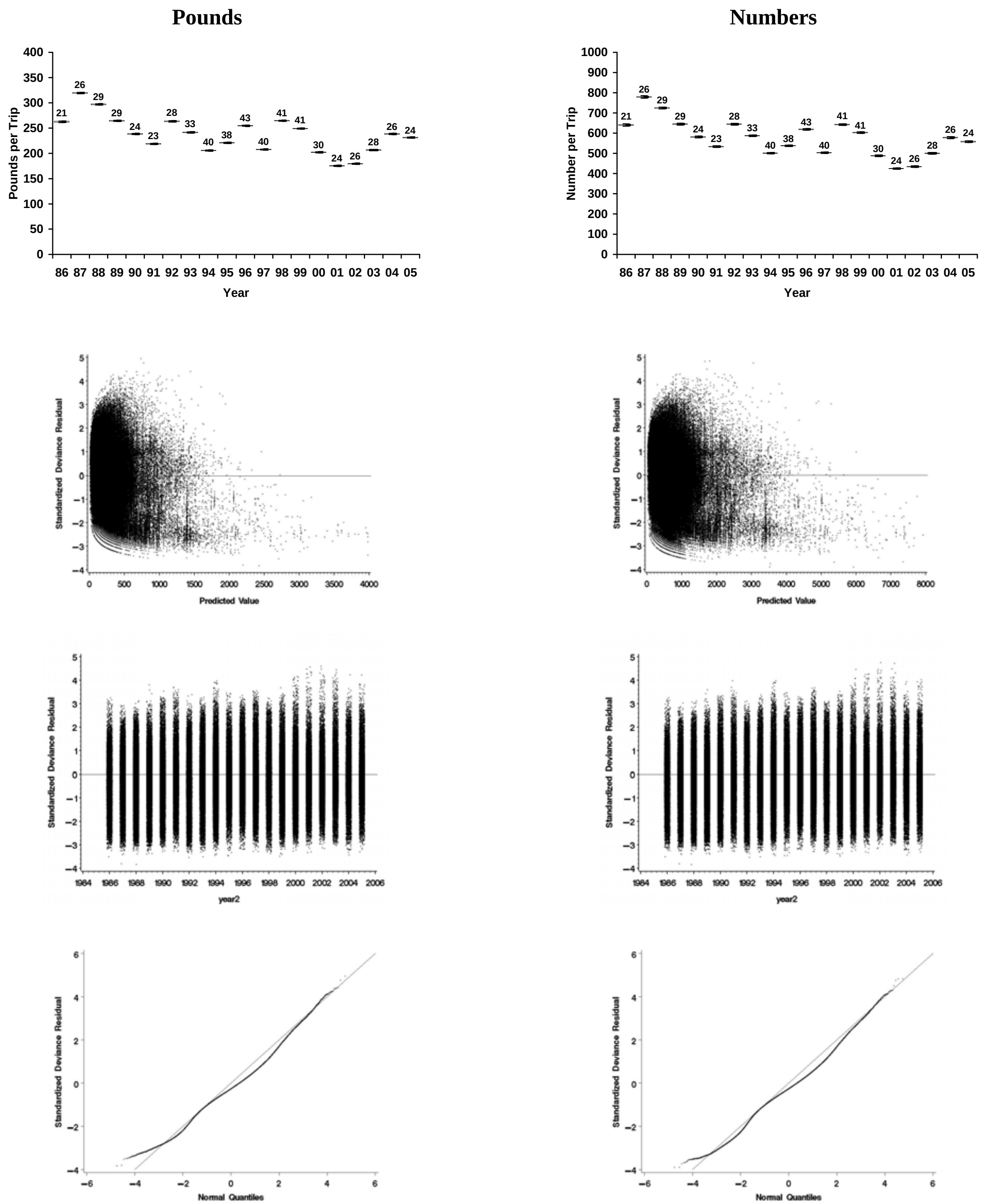


Figure 5.1.4.1. Standardized commercial landings per trip estimated for Atlantic coast commercial blue crab fishers and standardization diagnostics. Landings rate graphs show the annual sample size (in thousands), median, interquartile range, and 95% confidence band. Standardized deviance residuals show the distribution of the observed data about the estimated mean (horizontal line at zero) against the predicted value and for each year. The QQ plot at bottom shows the fit of these residuals to a standard normal distribution [N(0,1)].

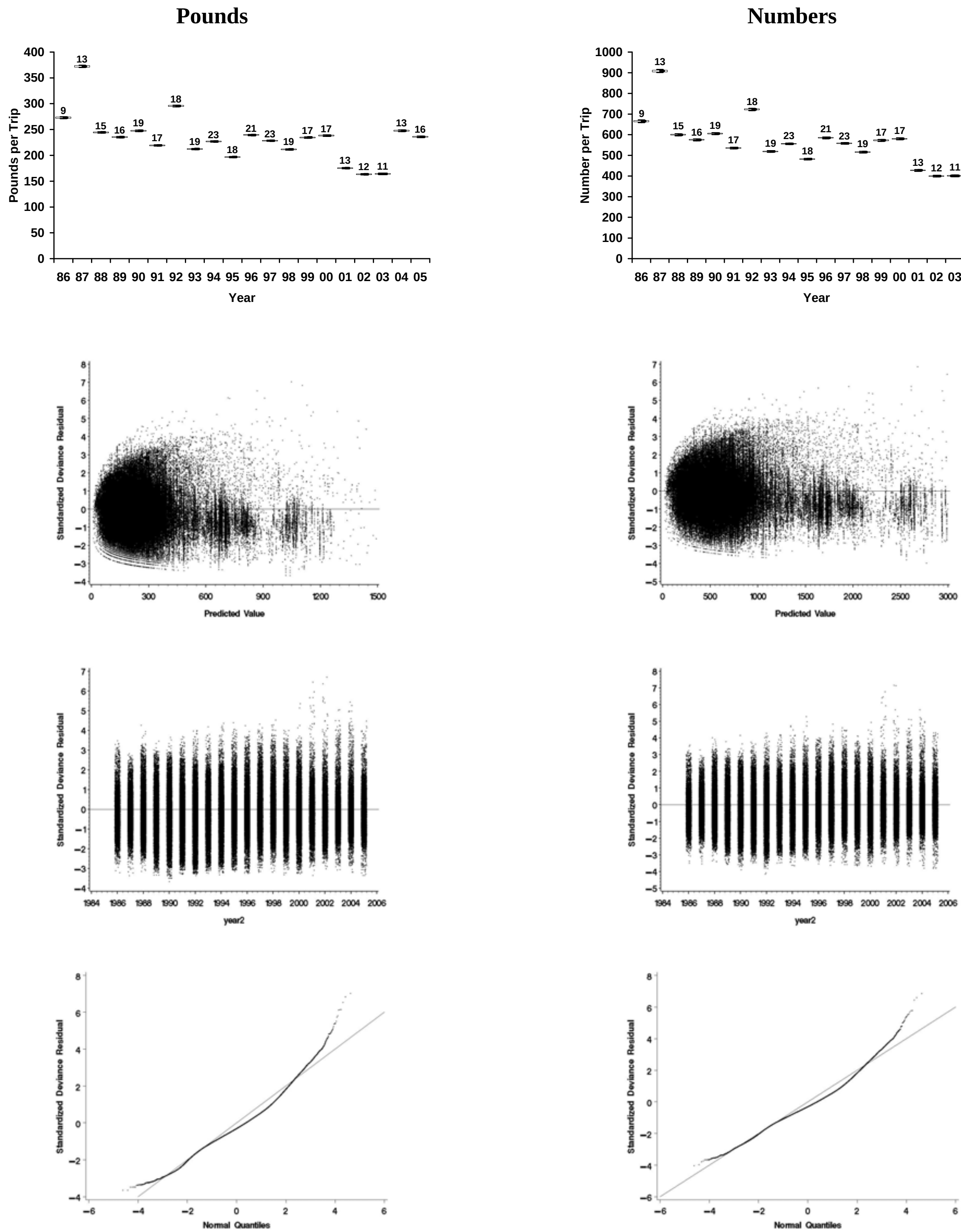
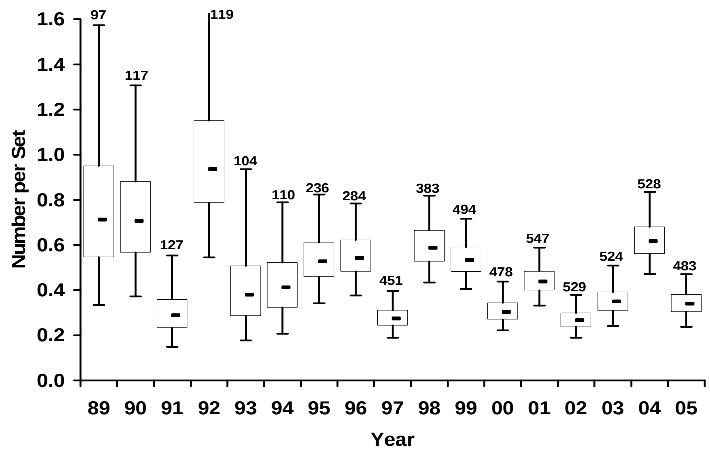
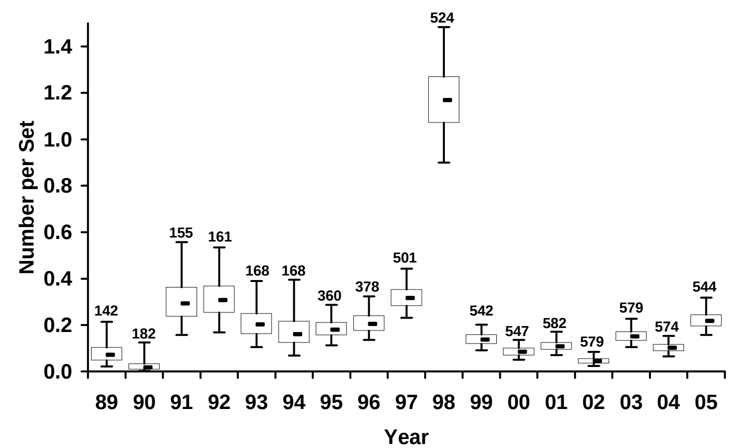


Figure 5.3.2.1. Standardized catch rate estimate distributions for the April-May and October November sub-cohorts of blue crabs captured during the fishery-independent monitoring survey on the gulf coast of Florida during 1989-2005. The distribution each year show the number of sets, the interquartile range (box) and 95 percent range (whiskers) distributed about the median estimate (horizontal dash). Where sample sizes lie next to whisker the upper whisker has been truncated.

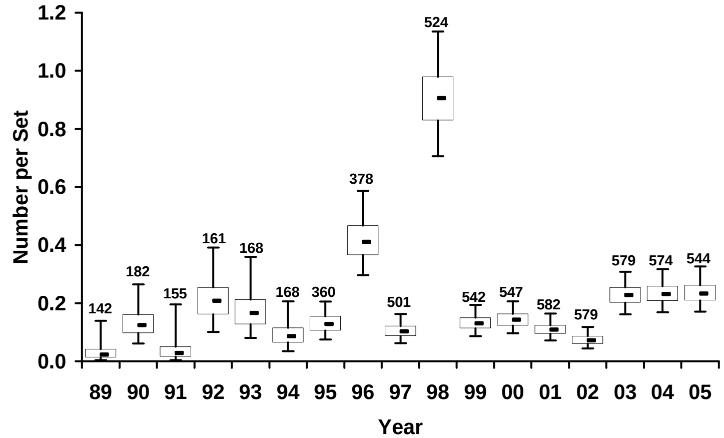
April – May, young of the year



October – November, young of the year



October – November, exploited size



April – May, exploited size

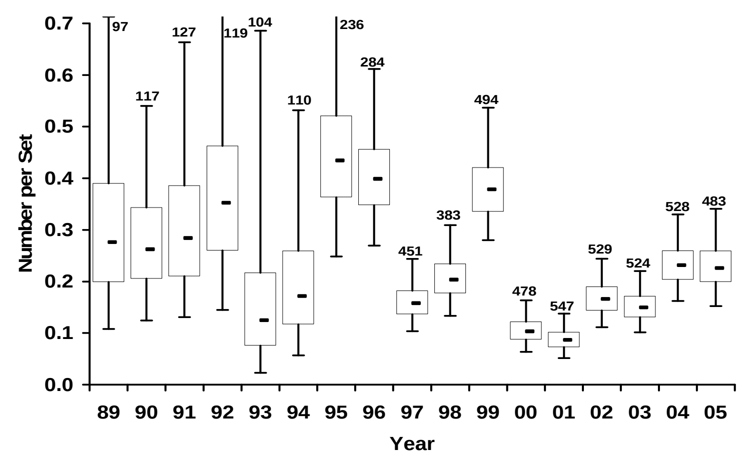
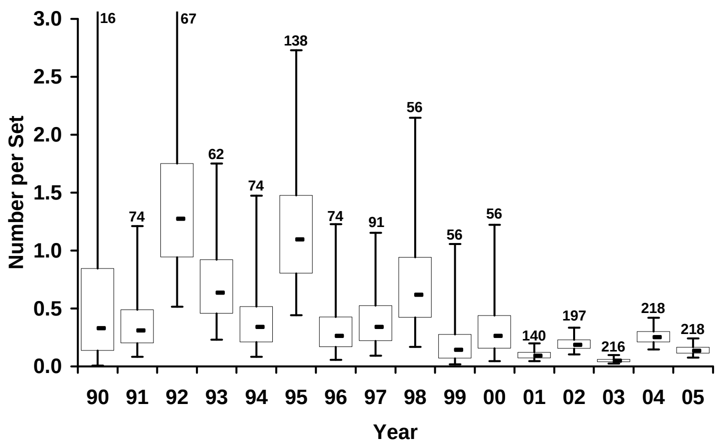
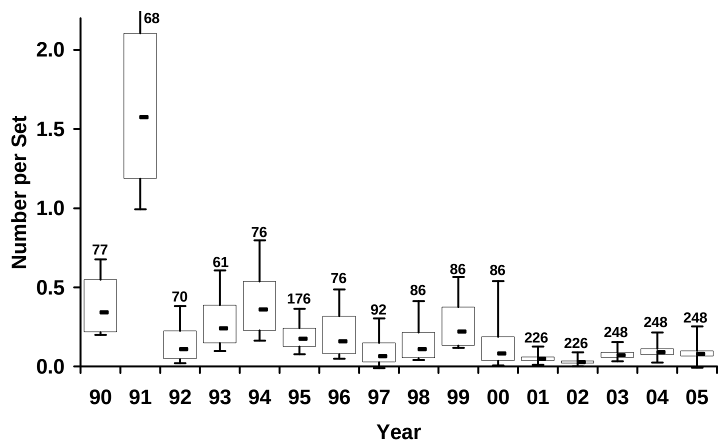


Figure 5.3.2.2. Standardized catch rate estimate distributions for the April-May and October November sub-cohorts of blue crabs captured during the fishery-independent monitoring survey on the Atlantic coast of Florida during 1990-2005. The distribution each year show the number of sets, the interquartile range (box) and 95 percent range (whiskers) distributed about the median estimate (horizontal dash). Where sample sizes lie next to whisker the upper whisker has been truncated.

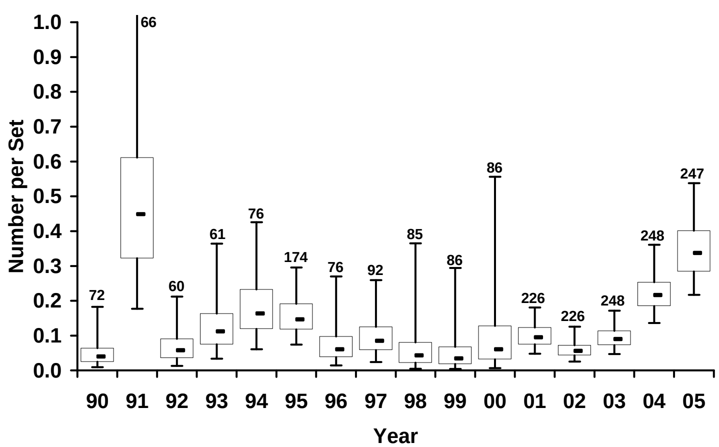
April – May, young of the year



October – November, young of the year



October – November, exploited size



April – May, exploited size

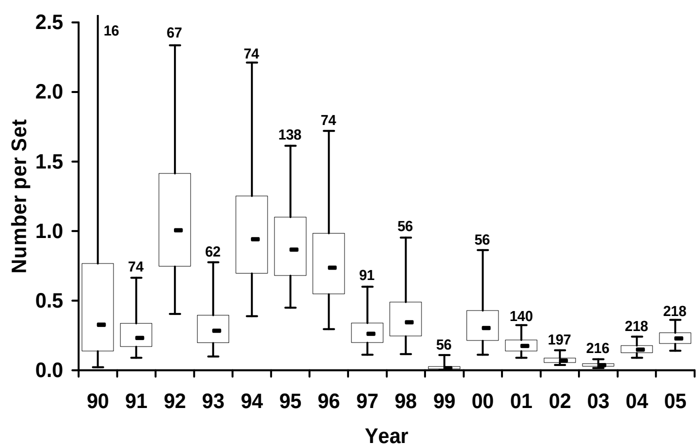
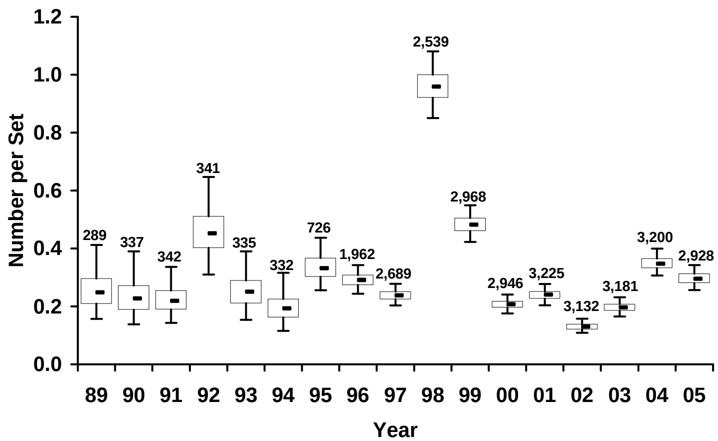
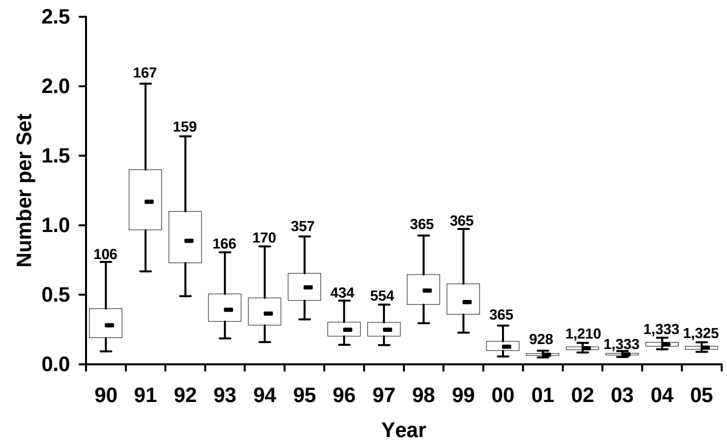


Figure 5.3.2.3. Standardized catch rate estimate distributions for the calendar year abundances of blue crabs captured during the fishery-independent monitoring survey on the Atlantic coast of Florida during 1990-2005. The distribution each year show the number of sets, the interquartile range (box) and 95 percent range (whiskers) distributed about the median estimate (horizontal dash).

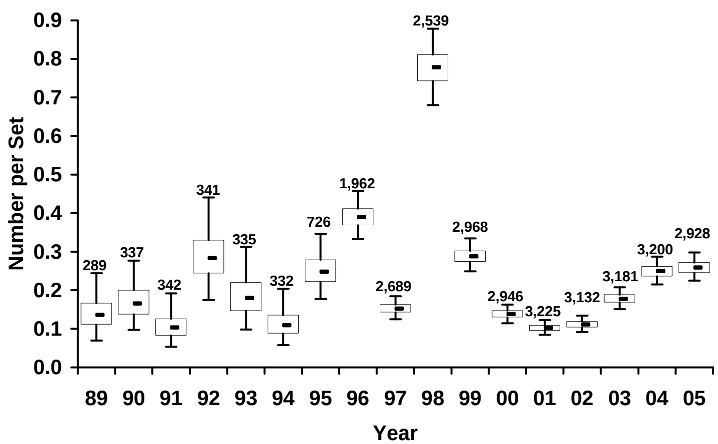
Gulf, young of the year



Atlantic, young of the year



Gulf, exploited size



Atlantic, exploited size

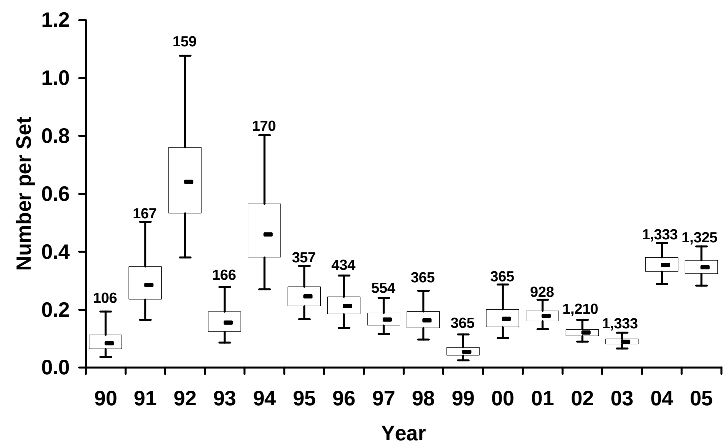
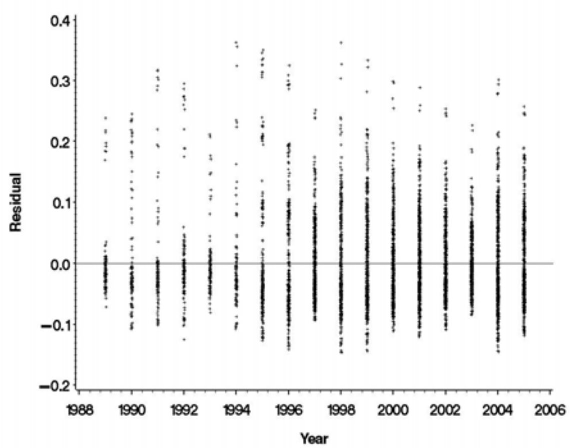


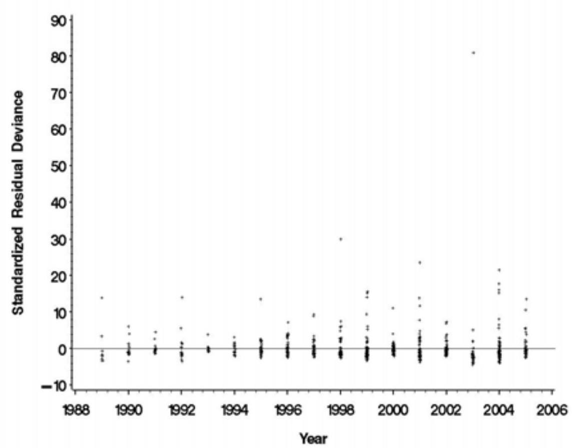
Figure 5.4.1. Diagnostics for the generalized linear modeling of gulf coast fishery-independent survey catch rates for blue crab during 1989-2005, showing April-May pre-recruits and subsequent October-November exploited-size blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.1 and 5.3.1.6.2.

April – May, young of the year

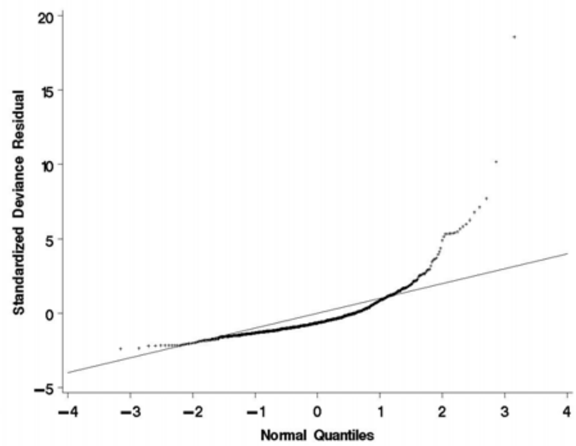
Raw residuals from binomial



Standardized Residuals from Poisson

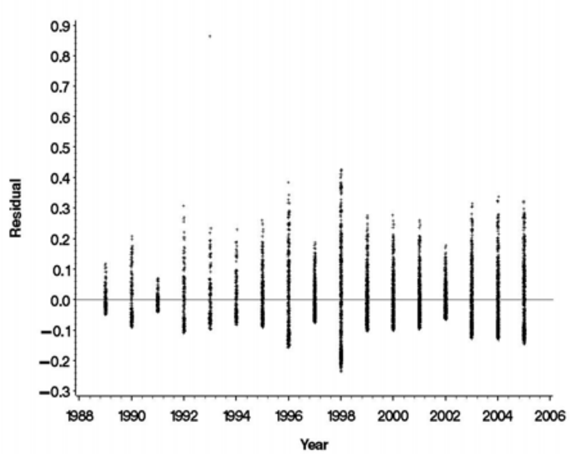


Quantile-Quantile fit to Poisson

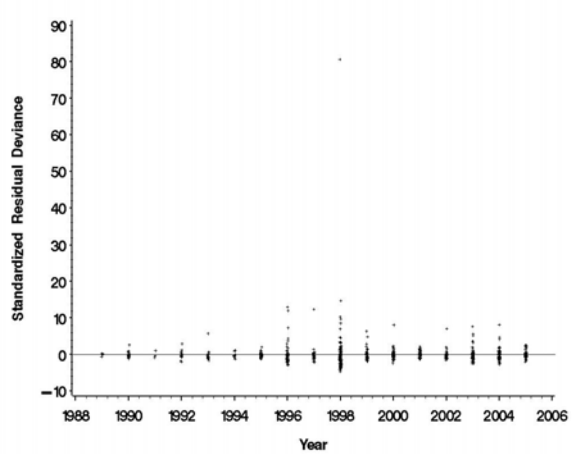


October – November, exploited phase

Raw residuals from binomial



Standardized Residuals from Poisson



Quantile-Quantile fit to Poisson

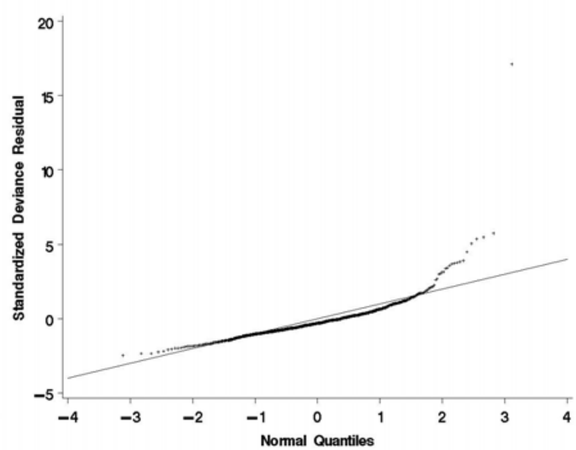
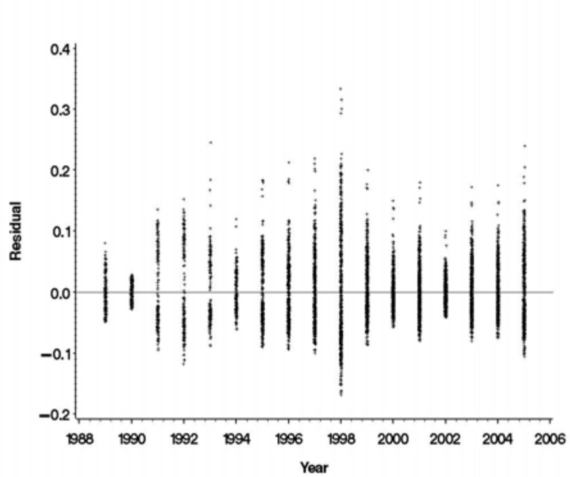


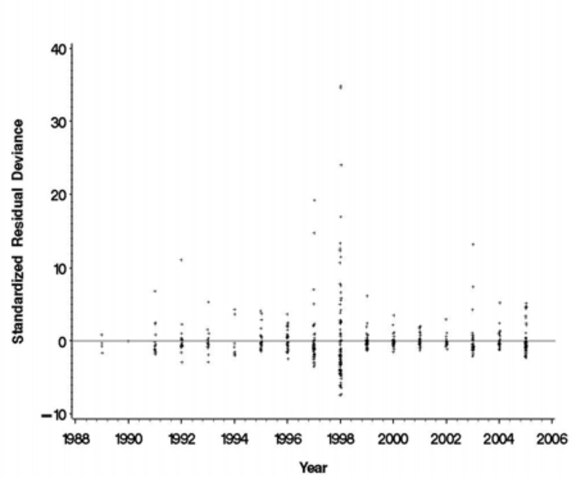
Figure 5.4.2. Diagnostics for the generalized linear modeling of gulf coast fishery-independent survey catch rates for blue crab during 1989-2005, showing October-November pre-recruits and subsequent April-November exploited-size blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.1 and 5.3.1.6.2.

October – November, young of the year

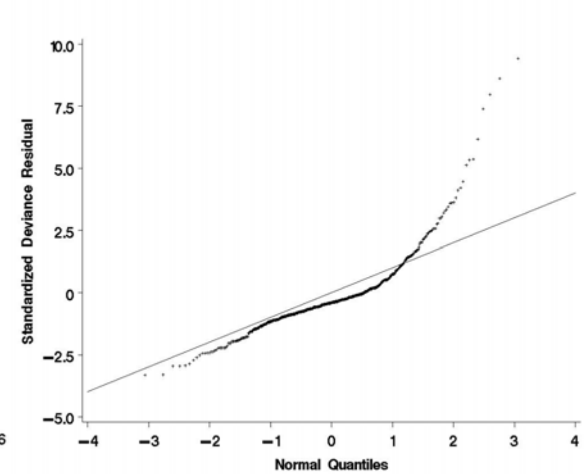
Raw residuals from binomial



Standardized Residuals from Poisson

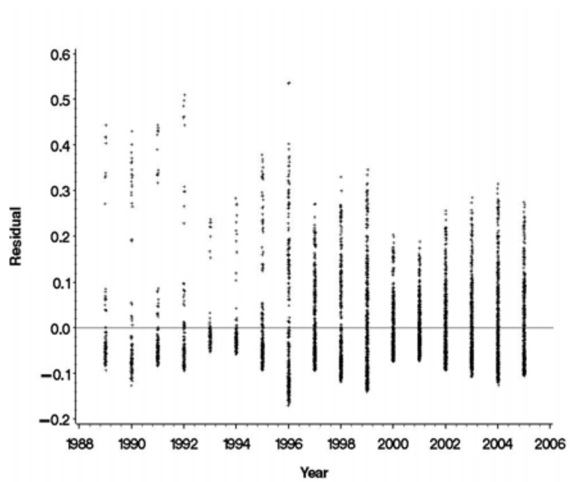


Quantile-Quantile fit to Poisson

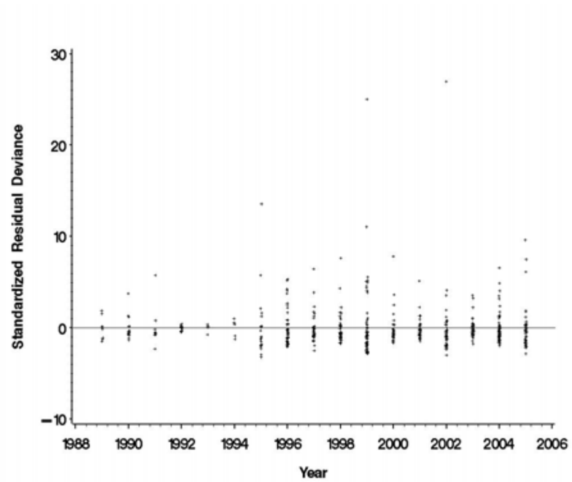


April – May, exploited phase

Raw residuals from binomial



Standardized Residuals from Poisson



Quantile-Quantile fit to Poisson

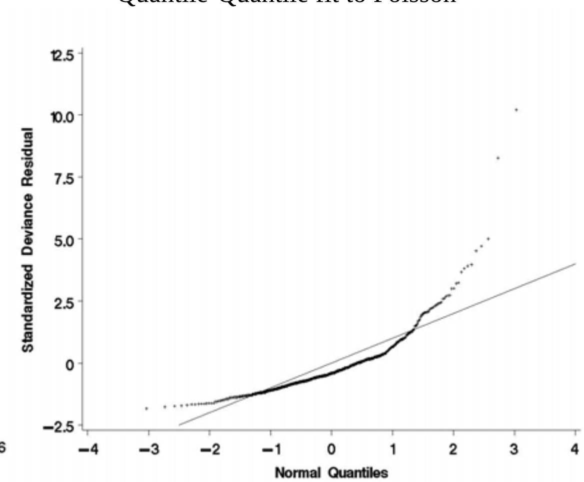
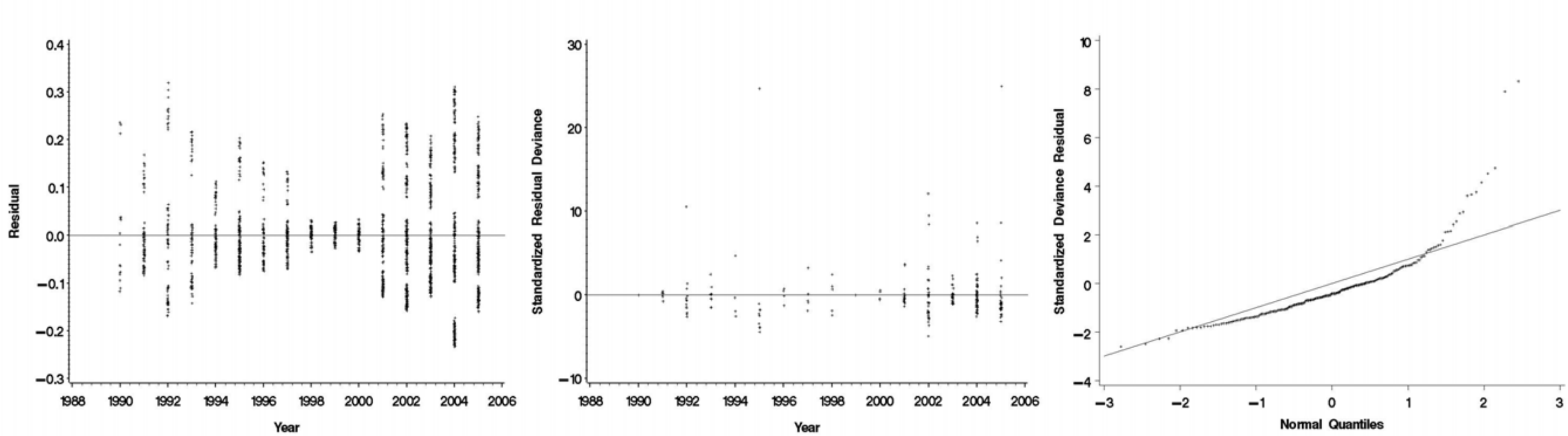


Figure 5.4.3. Diagnostics for the generalized linear modeling of Atlantic coast fishery-independent survey catch rates for blue crab during 1990-2005, showing April-May pre-recruits and subsequent October-November exploited-size blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.3 and 5.3.1.6.4.

April – May, young of the year

Raw residuals from binomial | Standardized Residuals from Poisson | Quantile-Quantile fit to Poisson



October – November, exploited phase

Raw residuals from binomial | Standardized Residuals from Poisson | Quantile-Quantile fit to Poisson

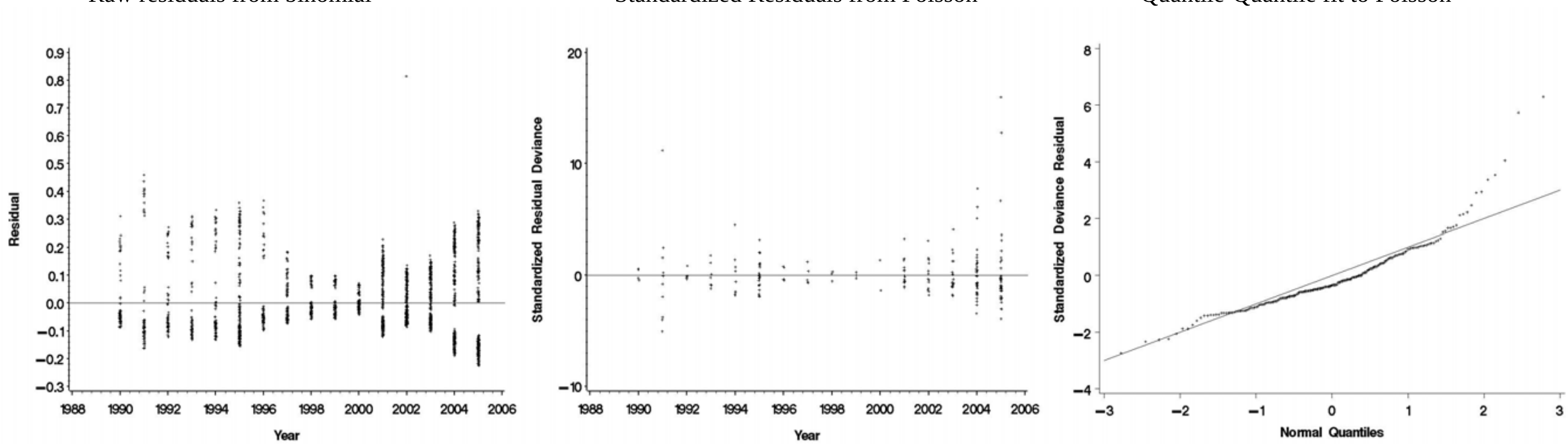
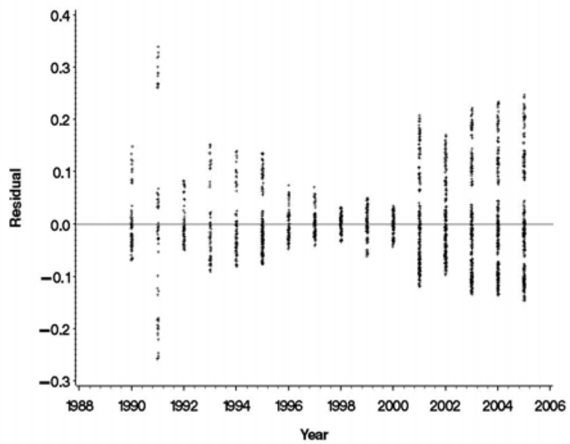


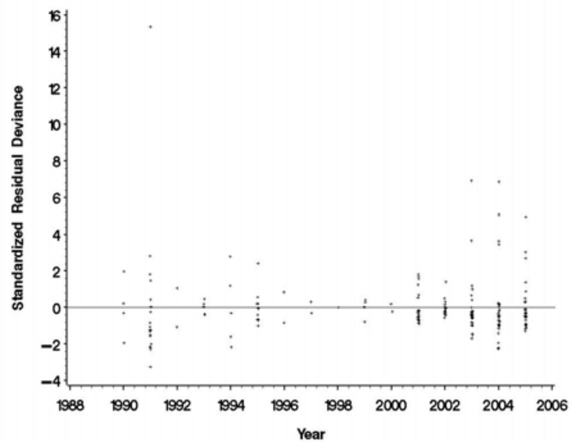
Figure 5.4.4. Diagnostics for the generalized linear modeling of Atlantic coast fishery-independent survey catch rates for blue crab during 1990-2005, showing October-November pre-recruits and subsequent April-November exploited-sized blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.3 and 5.3.1.6.4

October – November, young of the year

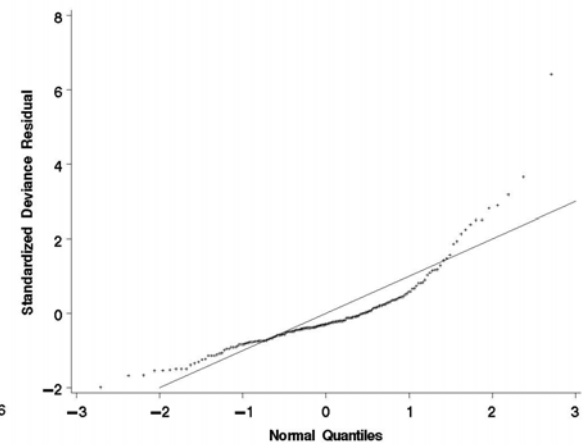
Raw residuals from binomial



Standardized Residuals from Poisson

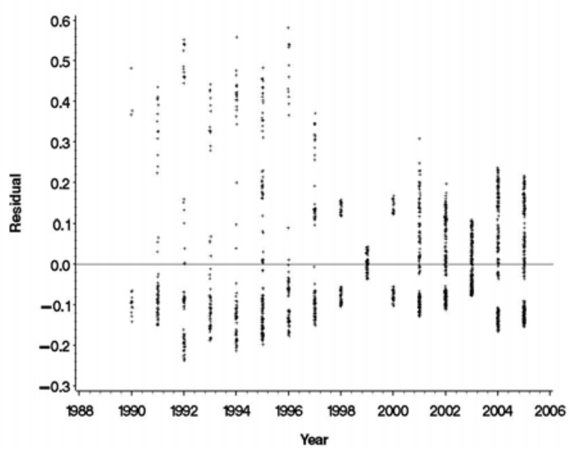


Quantile-Quantile fit to Poisson

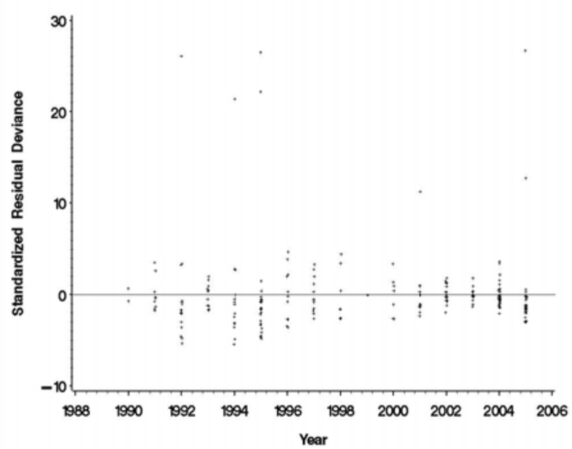


April – May, exploited phase

Raw residuals from binomial



Standardized Residuals from Poisson



Quantile-Quantile fit to Poisson

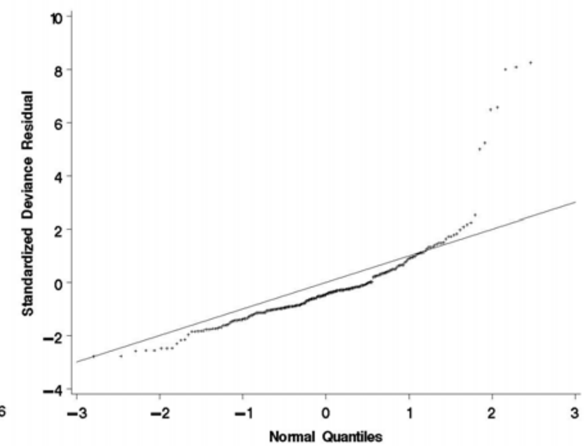
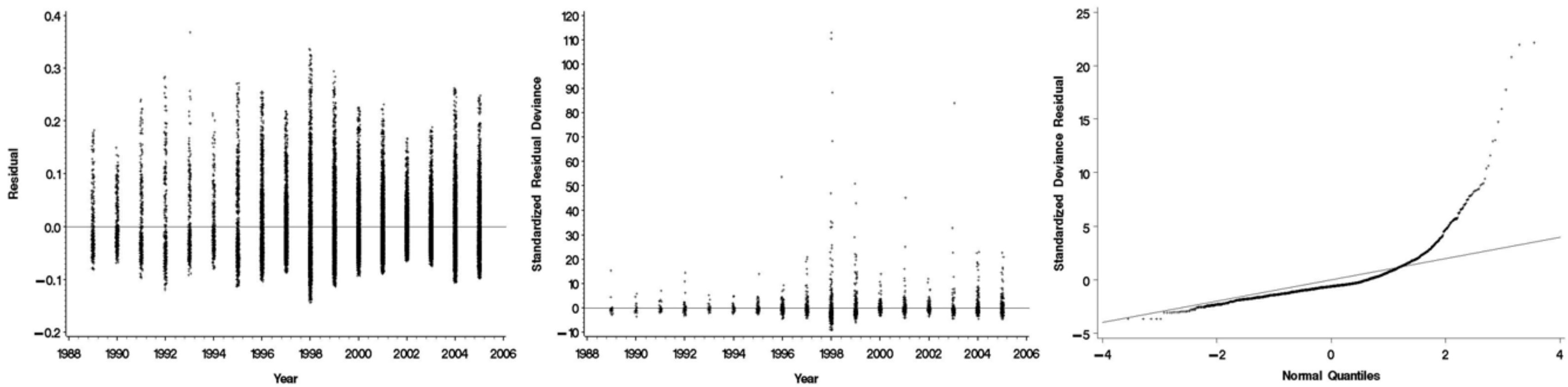


Figure 5.4.5. Diagnostics for the generalized linear modeling of gulf coast fishery-independent survey catch rates for blue crab during 1989-2005, showing calendar year pre-recruits and subsequent exploited-size blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.5 and 5.3.1.6.6.

Young of the year

Raw residuals from binomial | Standardized Residuals from Poisson | Quantile-Quantile fit to Poisson



Exploited size

Raw residuals from binomial | Standardized Residuals from Poisson | Quantile-Quantile fit to Poisson

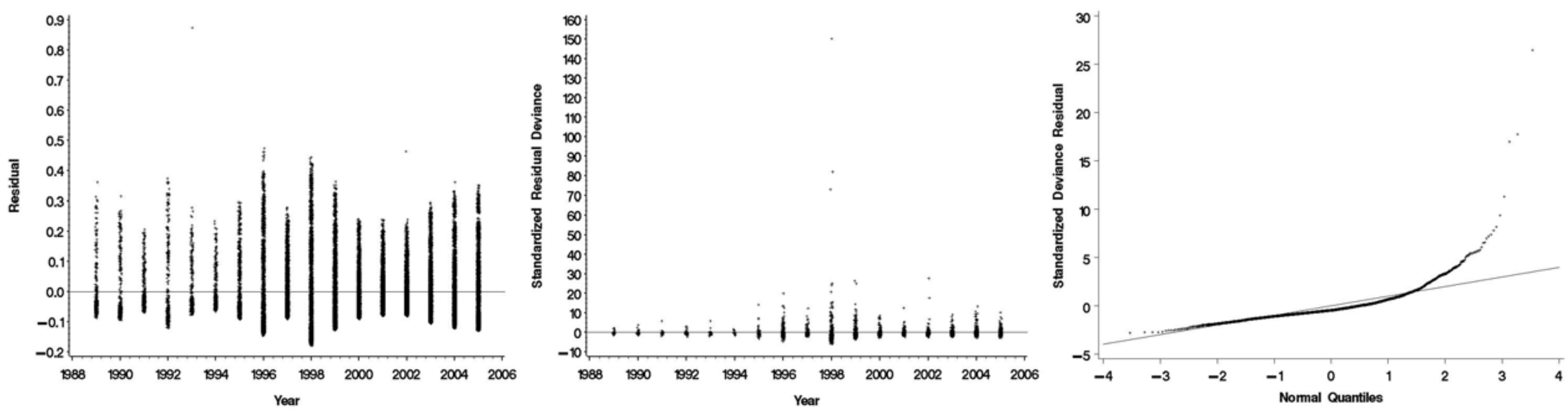
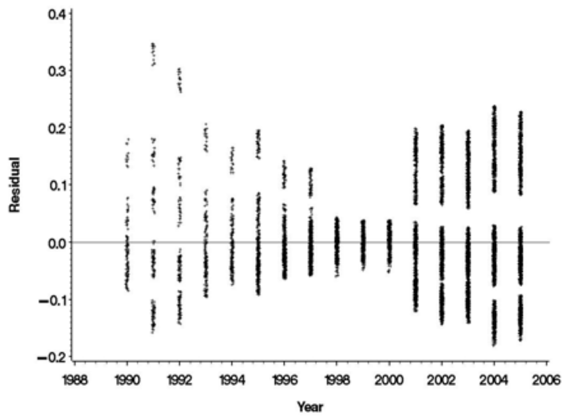


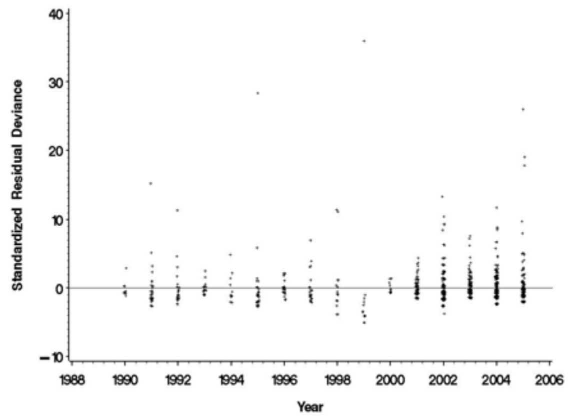
Figure 5.4.6. Diagnostics for the generalized linear modeling of Atlantic coast fishery-independent survey catch rates for blue crab during 1990-2005, showing calendar year pre-recruits and subsequent exploited-size blue crabs. Each model was fit using a Poisson delta approach that combined modeling of presence-absence under a binomial distribution and positive catches under a Poisson distribution. More information on the modeling process is given in the text under Section 5.3.1.6 and final models are shown in Tables 5.3.1.6.7 and 5.3.1.6.8.

Young of the year

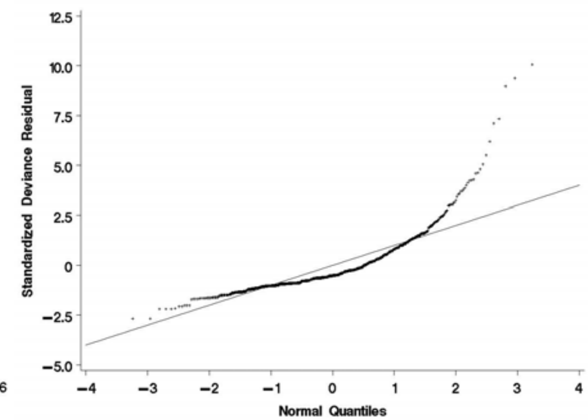
Raw residuals from binomial



Standardized Residuals from Poisson

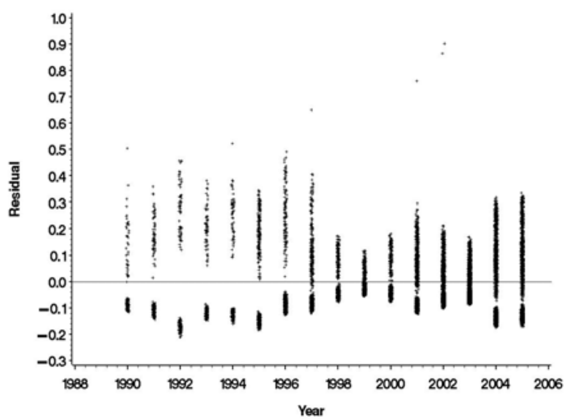


Quantile-Quantile fit to Poisson

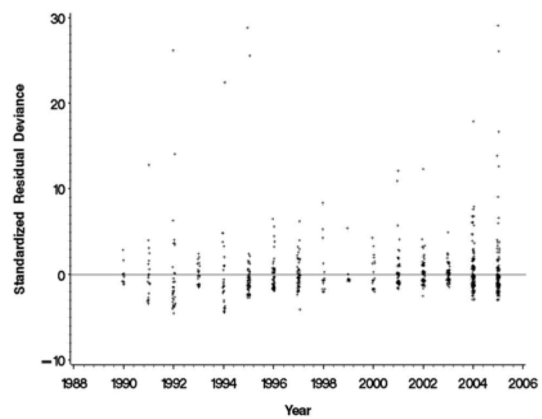


Exploited size

Raw residuals from binomial



Standardized Residuals from Poisson



Quantile-Quantile fit to Poisson

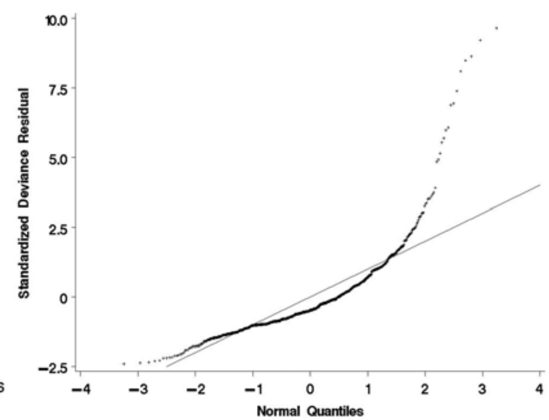


Figure 6.2.2.1. Estimated continuous-growth von Bertalanffy model developed for blue crabs showing the estimated mean size (carapace width) at age (dashed lines in top graph and solid line in middle graph)). Overlayed on the top growth curve is the assumed sizes of mature female blue crabs (open cirvles in top graph). The modeled sigmoidal vulnerability schedule across age is also shown in this graph. The stochastic stock reduction analysis required an estimate of the coefficient of variation for the mean sizes at age and the approximate 95% (± 2 standard deviations) confidence bounds are shown in the middle graph for the chosen CV of 0.15. Finally, the assumed distribution of the instantaneous natural mortality coefficient for exploited-sized blue crabs is shown at the bottom.

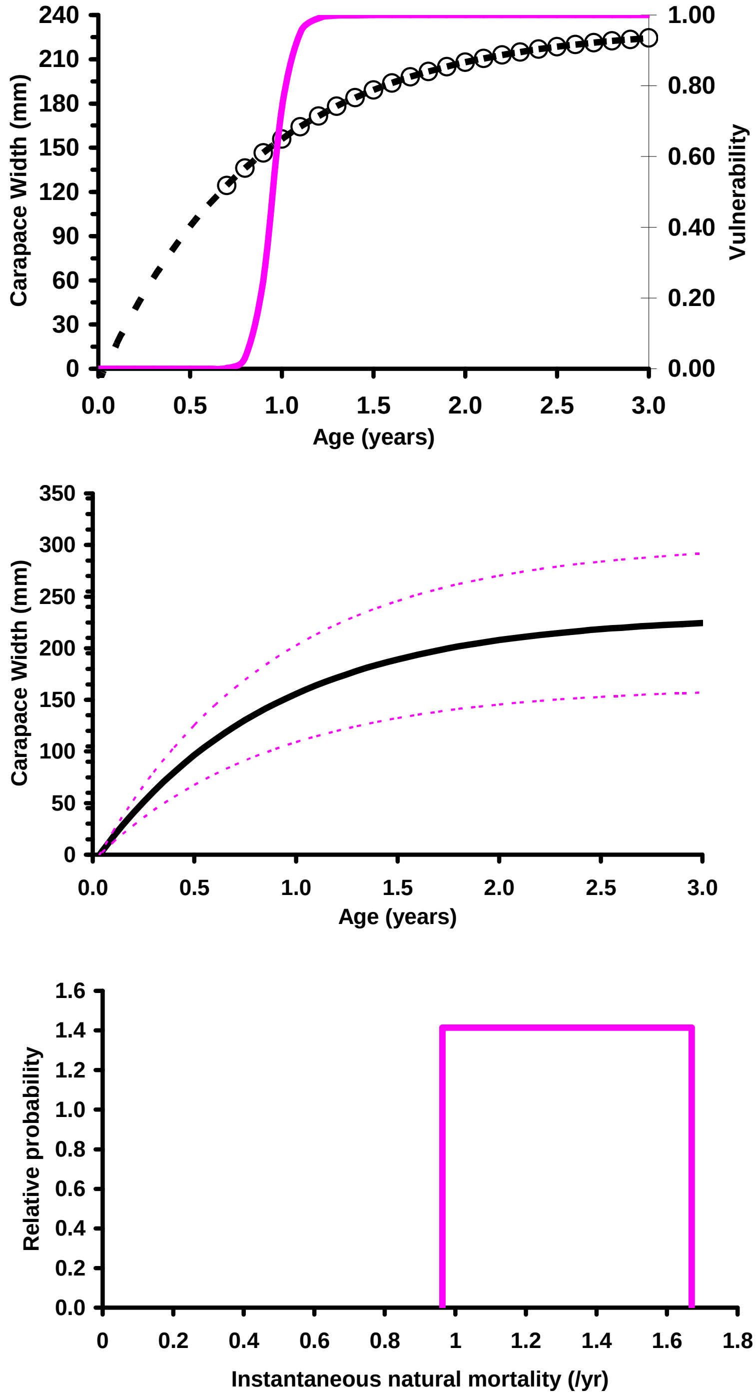
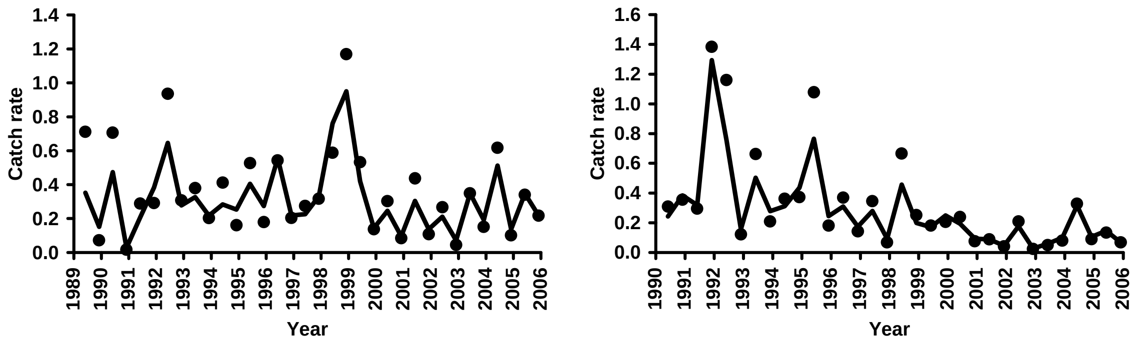


Figure 7.1.1. Fits, residuals and quantile-quantile plots for the blue crab recruit relative abundance data used in the CSA model on the gulf and Atlantic coasts. Observed vs. predicted plots are in the arithmetic scale whereas the residuals and qq-plots use residuals of the $\log_e$ values standardized to the standard deviation of the $\log_e$ residual data.

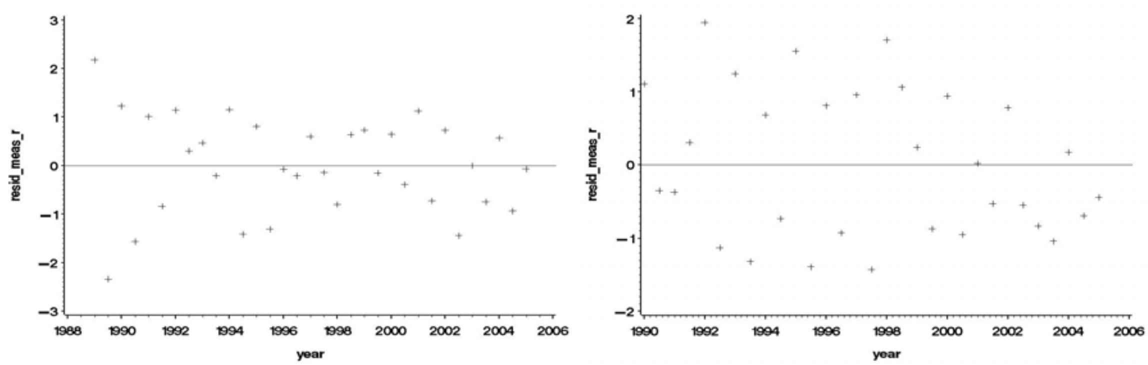
Gulf coast

Atlantic coast

Observed (dots) vs. predicted (lines)



Residuals



quantile-quantile plots

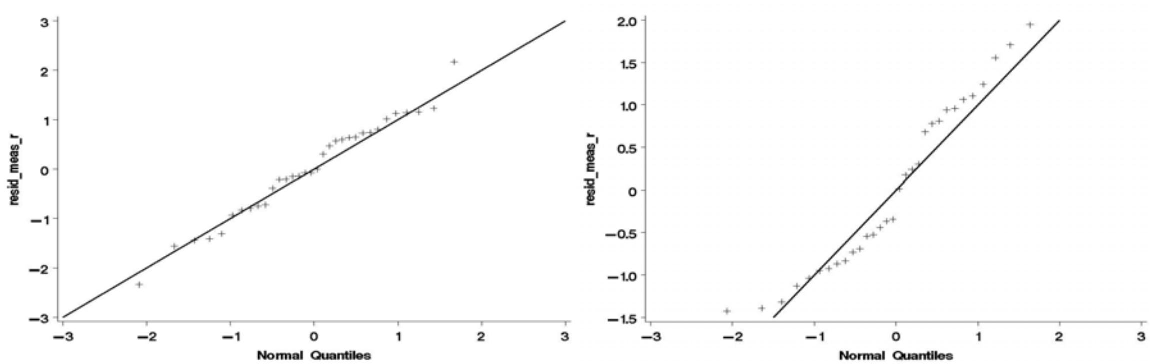
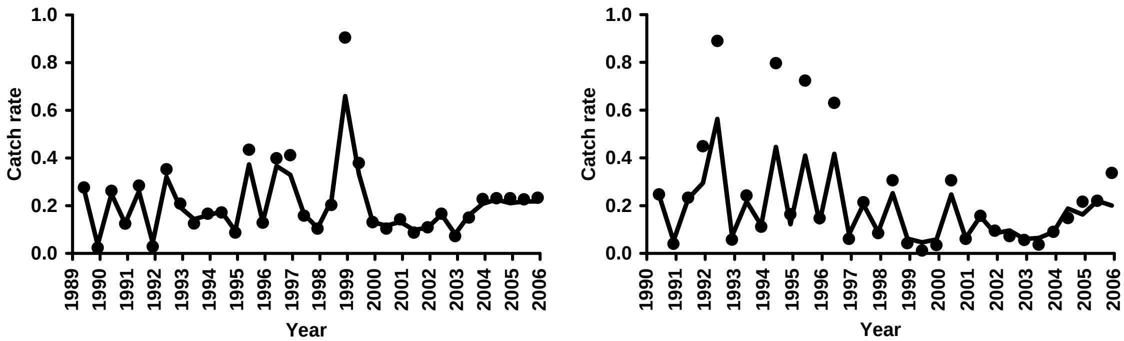


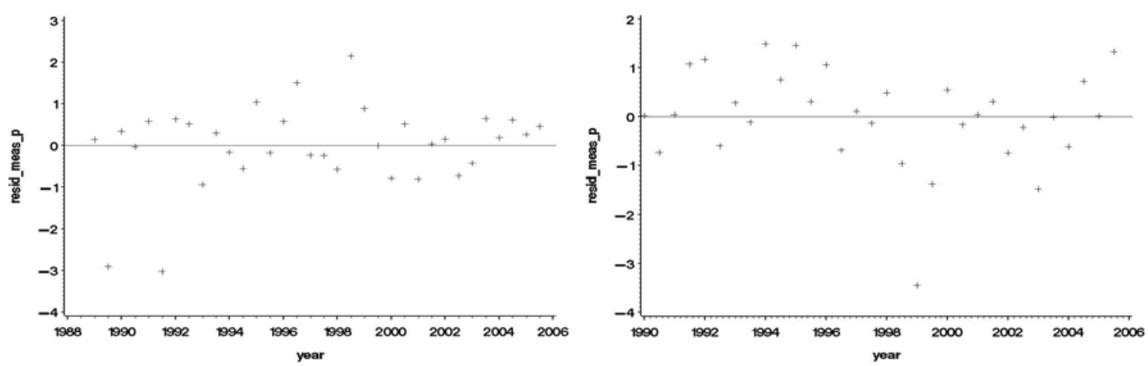
Figure 7.1.2. Fits, residuals and quantile-quantile plots for the observed exploited-size blue crab relative abundance data used in the CSA model on the gulf and Atlantic coasts. Observed vs. predicted plots are in the arithmetic scale whereas the residuals and qq-plots use residuals of the $\log_e$ values standardized to the standard deviation of the $\log_e$ residual data.

Gulf coast | Atlantic coast

Observed (dots) vs. predicted (lines)d



Residuals



quantile-quantile plots

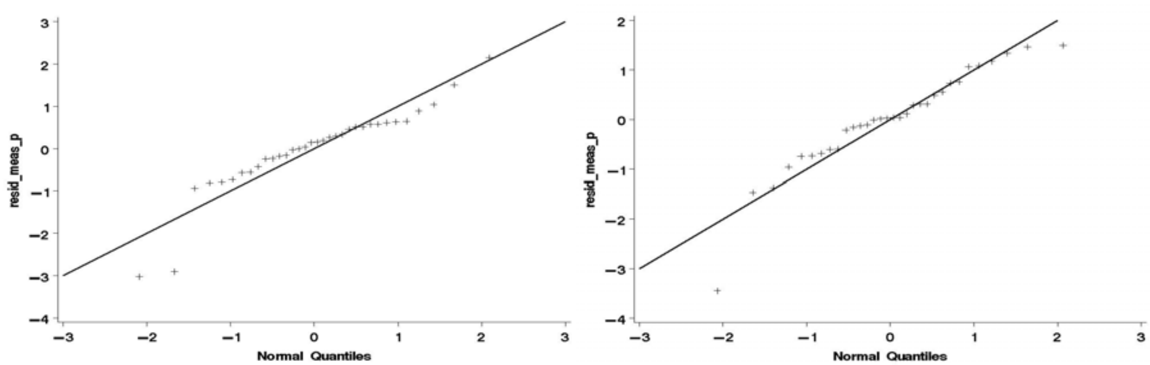
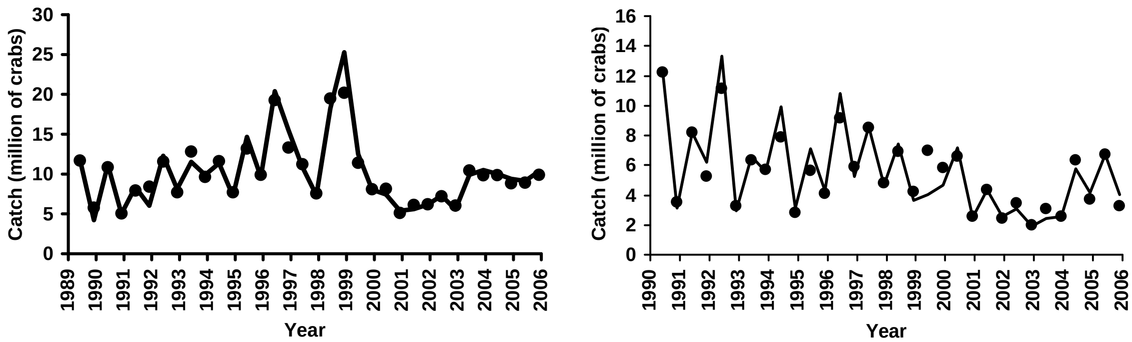


Figure 7.1.3. Fits, residuals and quantile-quantile plots for the blue crab catch data included in the CSA model on the gulf and Atlantic coasts. Observed vs. predicted plots are in the arithmetic scale whereas the residuals and qq-plot use residuals of the $\log_e$ values standardized to the standard deviation of the $\log_e$ residual data.

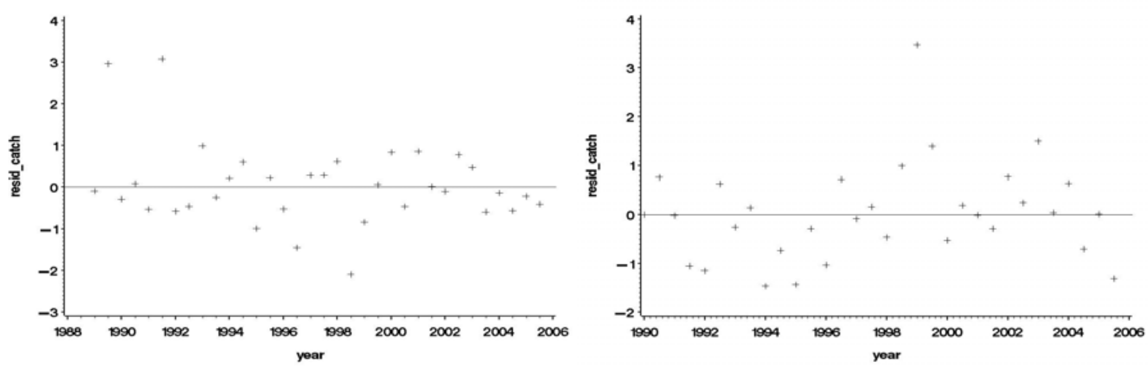
Gulf coast

Atlantic coast

Observed (dots) vs. predicted (lines)



Residuals



quantile-quantile plots

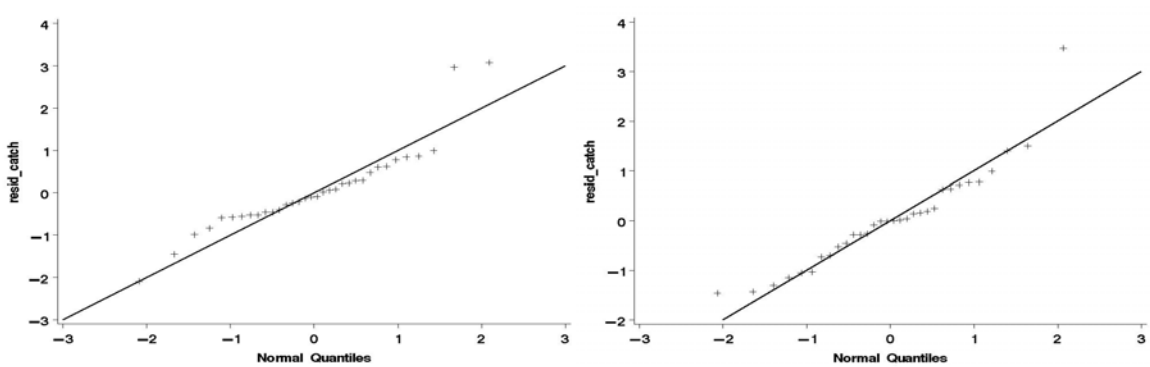
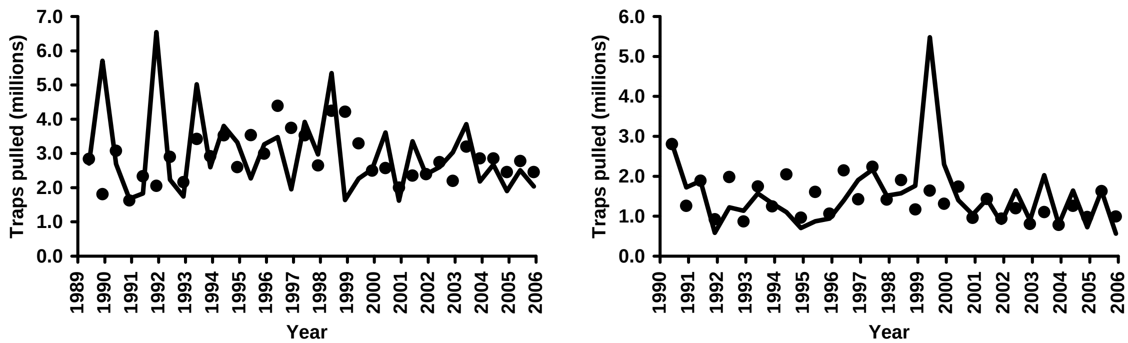


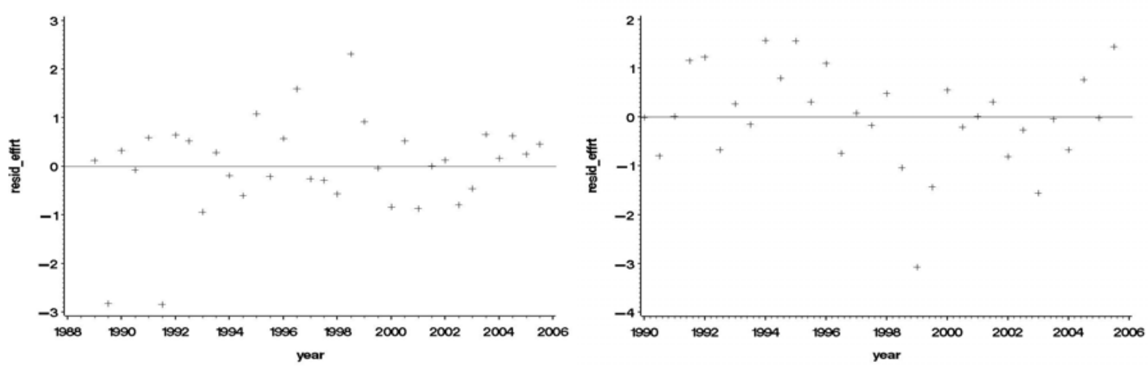
Figure 7.1.4. Fits, residuals and quantile-quantile plots for the blue crab fishing effort (traps pulled) data included in the CSA model on the gulf and Atlantic coasts. Observed vs. predicted plots are in the arithmetic scale whereas the residuals and qq-plot use residuals of the $\log_e$ values standardized to the standard deviation of the $\log_e$ residual data.

Gulf coast | Atlantic coast

Observed (dots) vs. predicted (lines)



Residuals



quantile-quantile plots

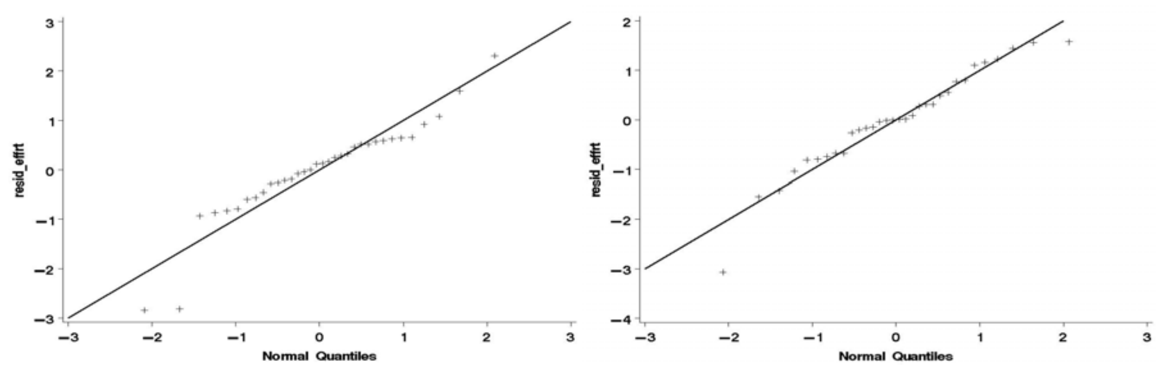
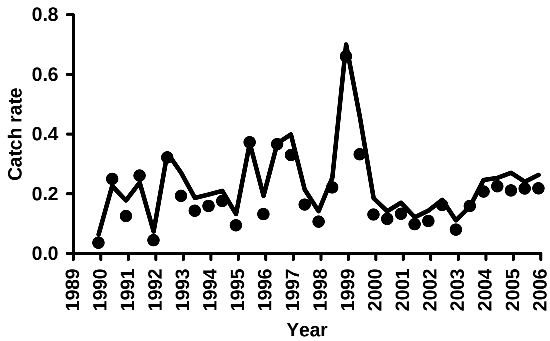
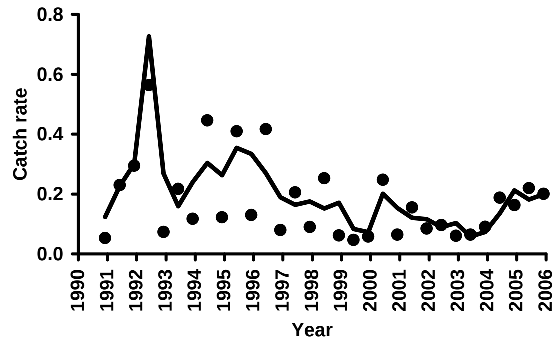


Figure 7.1.5. Fits, residuals and quantile-quantile plots for the process error (predicted exploited-size relative abundance) included in the CSA model on the gulf and Atlantic coasts. Observed vs. predicted plots are in the arithmetic scale whereas the residuals and qq-plot use residuals of the $\log_e$ values standardized to the standard deviation of the $\log_e$ residual data.

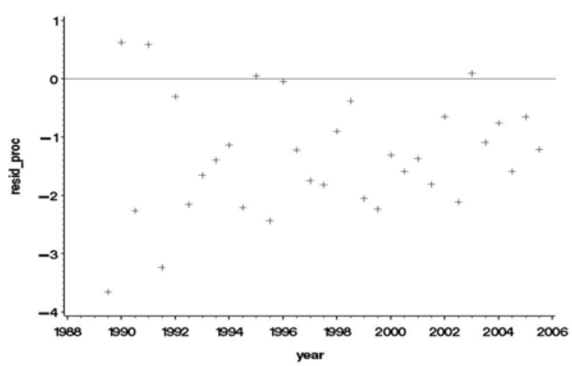
Gulf coast | Atlantic coast

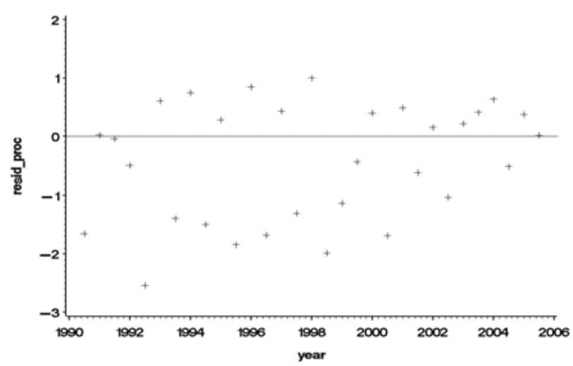
Observed (dots) vs. predicted (lines)



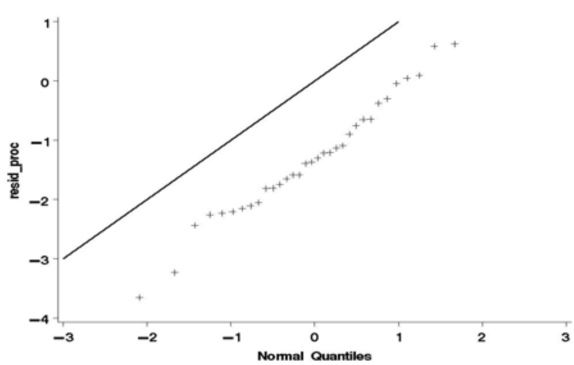


Residuals





quantile-quantile plots



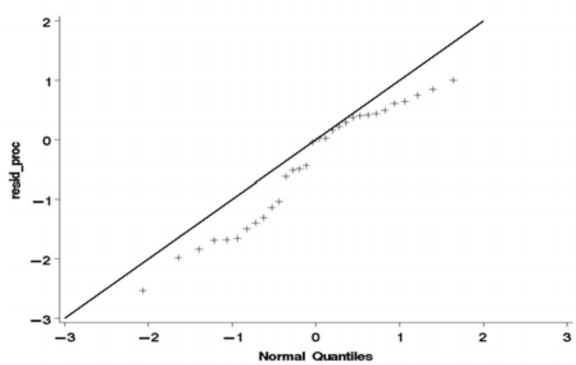
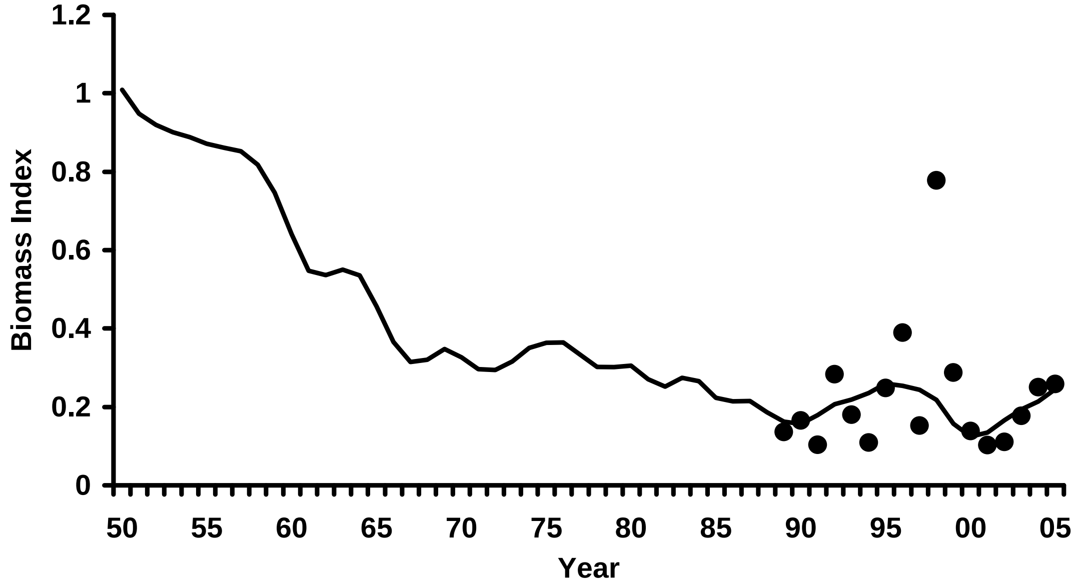


Figure 7.1.6. Observed calendar-year indices of abundance of exploited-size blue crabs on the gulf (1989-2005) and Atlantic (1990-2005) coasts of Florida and model-predicted (lines) estimates of relative biomass from the ASPIC biomass dynamic model during the period 1950-2005.

Gulf coast



Atlantic coast

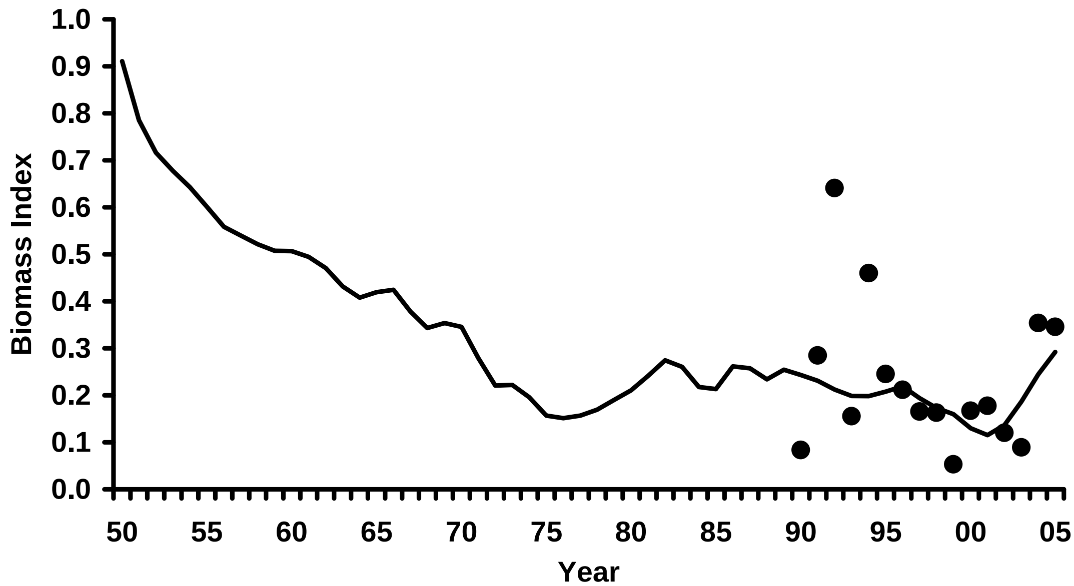


Figure 7.1.7. Color contour plots from the stochastic stock reduction analysis describing the probability of vulnerable biomass levels for the blue crab stocks on the gulf and Atlantic coasts of Florida during 1908-2005 and 1897-2005, respectively. The black filled circles represent the biomasses implied by the fishery-independent survey indices for calendar-year abundance of exploited-size blue crabs. The vertical line shows the position of the 2005 data point. The contour gradient from low probability to high runs the spectrum from blue to red in color or from dark to light in black and white.

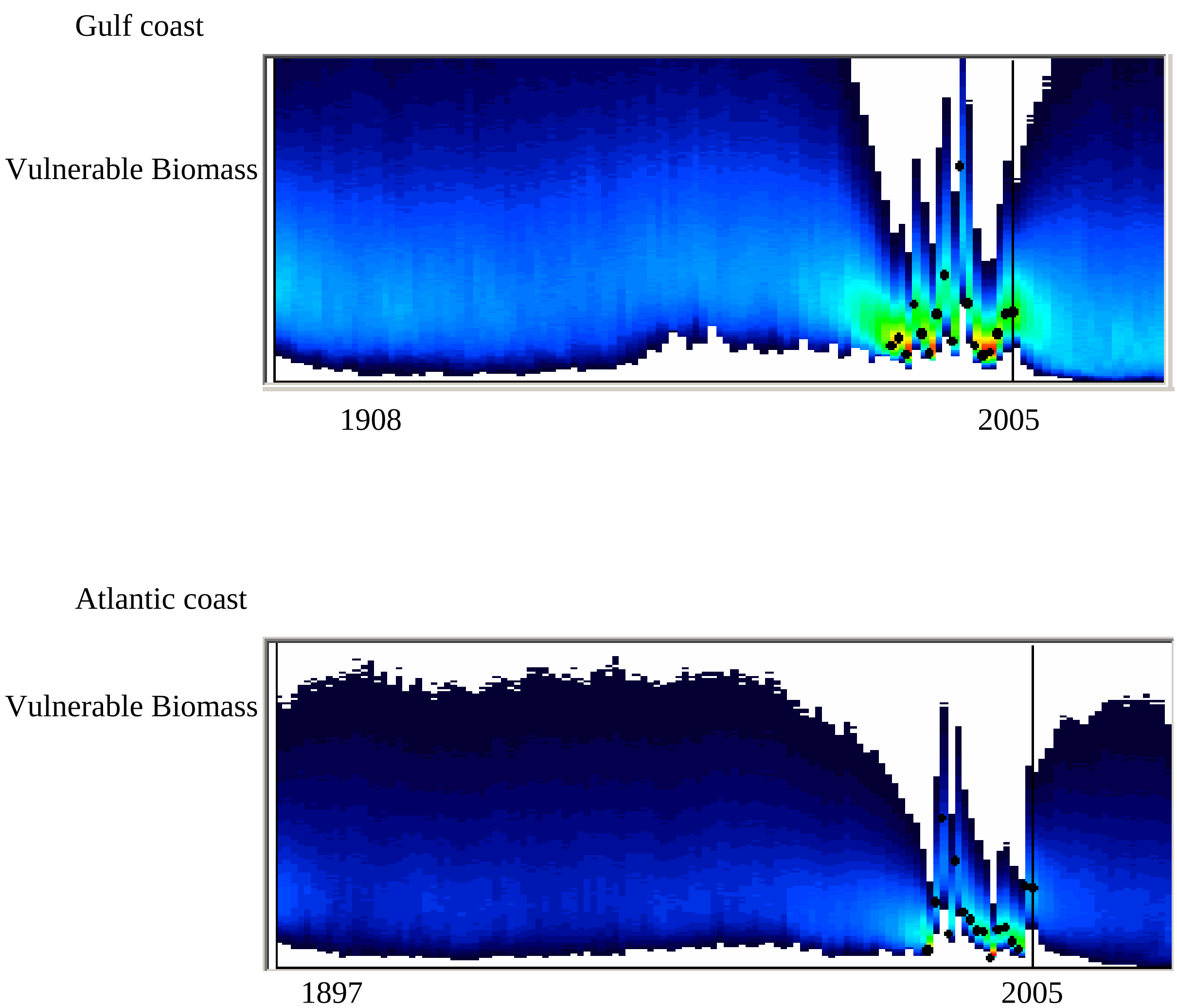
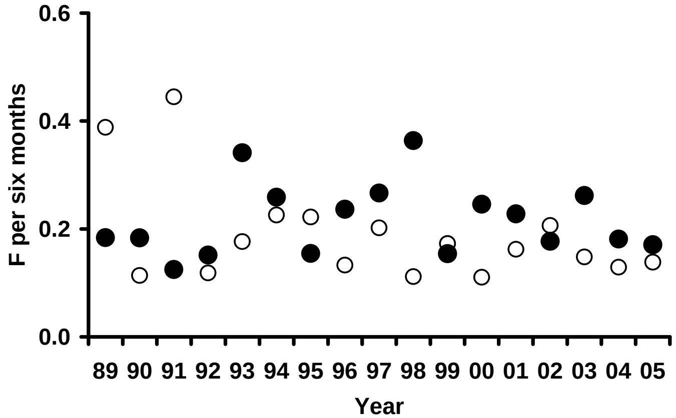
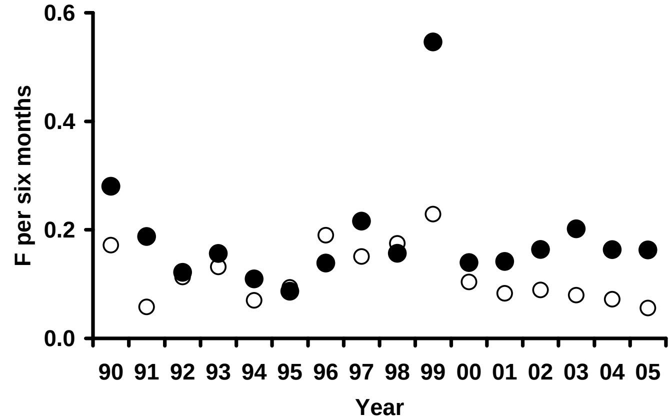


Figure 7.2.1.1. Instantaneous fishing mortality estimates for fully-recruited (exploited-size) blue crab on the gulf and Atlantic coasts of Florida during 1989-2005. The top row of graphs show six-month seasonal estimates of F from the catch-survey analysis (CSA, filled circle is May-October and open circle is November-April)). The bottom row shows calendar year estimates of F for the CSA (filled circle), the non-equilibrium surplus production models (ASPIC, 'X'), and the stochastic stock reduction analysis (SRA, open triangle, values off the scale were 1990 – F=2.66 and 1999 - F=1.98).

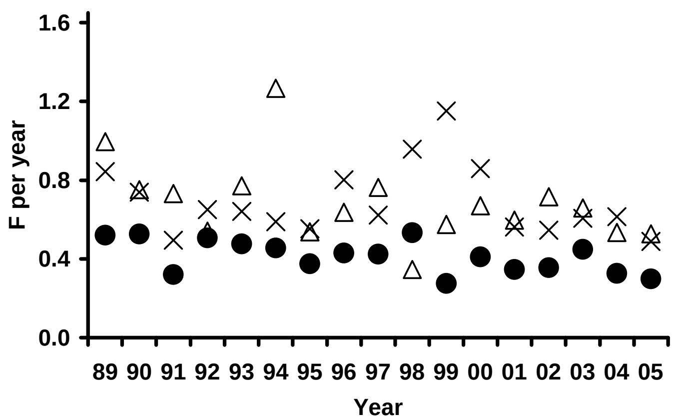
Gulf coast, CSA spring and fall cohorts



Atlantic coast, CSA spring and fall cohorts



Gulf coast, calendar – CSA, ASPIC, SRA



Atlantic coast, calendar – CSA, ASPIC, SRA

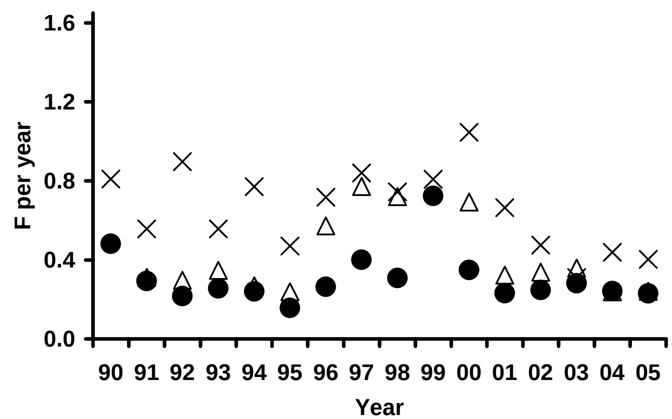
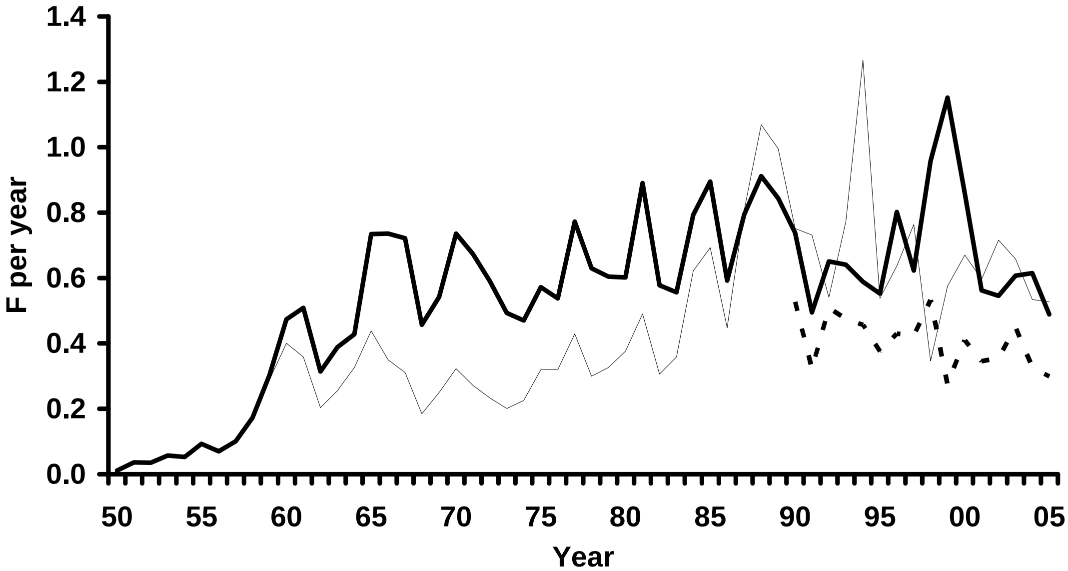


Figure 7.2.1.2. Estimates of instantaneous fishing mortality (F) on blue crabs on the gulf and Atlantic coasts of Florida during 1950-2005. Estimates from the non-equilibrium surplus production modeling run are indicated as the heavy solid line. The stochastic stock reduction analysis estimates of F are indicated as the thin solid line, except for the extreme values indicated by the labeled F values in 1990 and 1999. The catch-survey analysis estimates run from 1989-2005 on the gulf coast and 1990-2005 on the Atlantic coast and are indicated as a dashed line.

Gulf coast



Atlantic coast

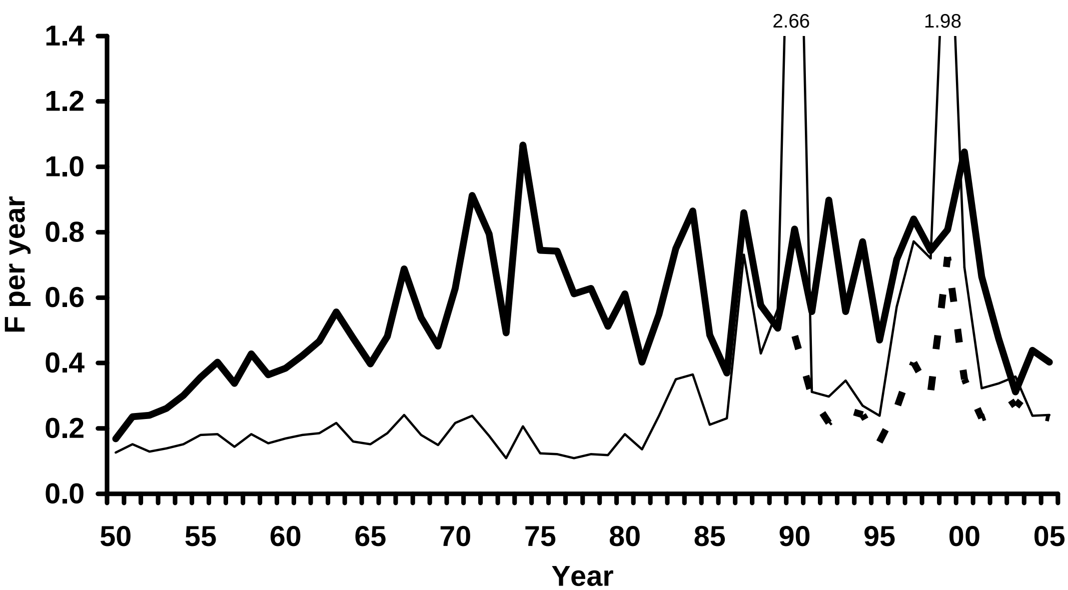
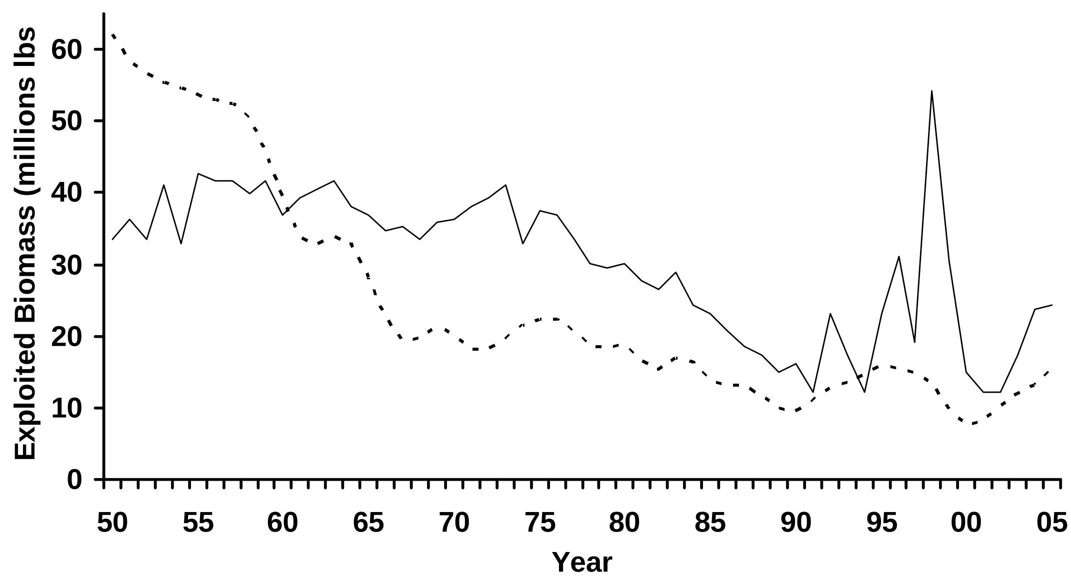


Figure 7.2.2.1. Estimates of average exploitable biomass of blue crabs on the gulf and Atlantic coasts of Florida during 1950-2005. Estimates from the non-equilibrium surplus production modeling run (ASPIC) are indicated as the dashed line and from the stock reduction analysis as a thin solid line.

Gulf coast



Atlantic coast

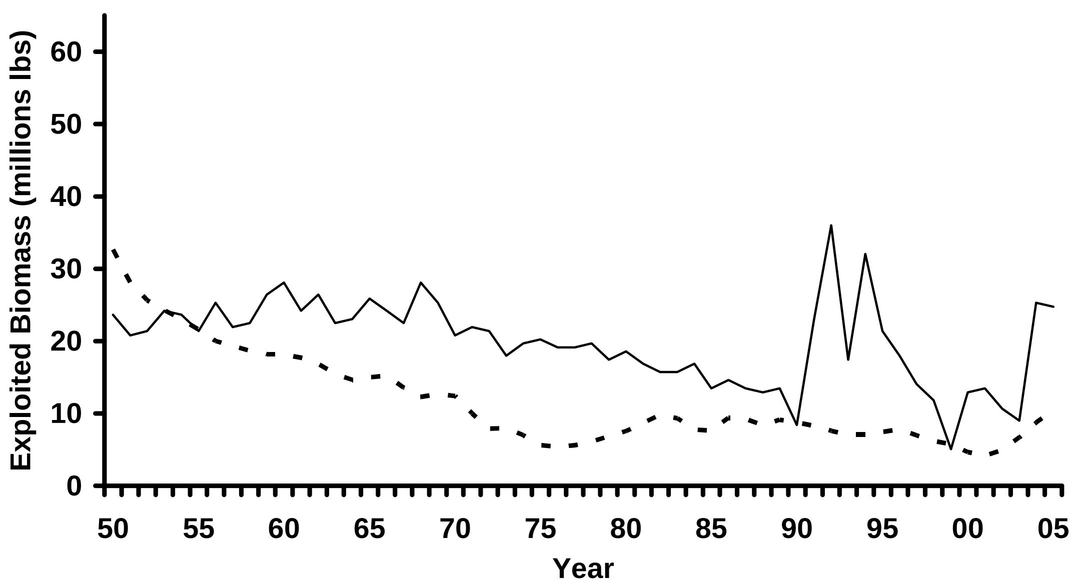
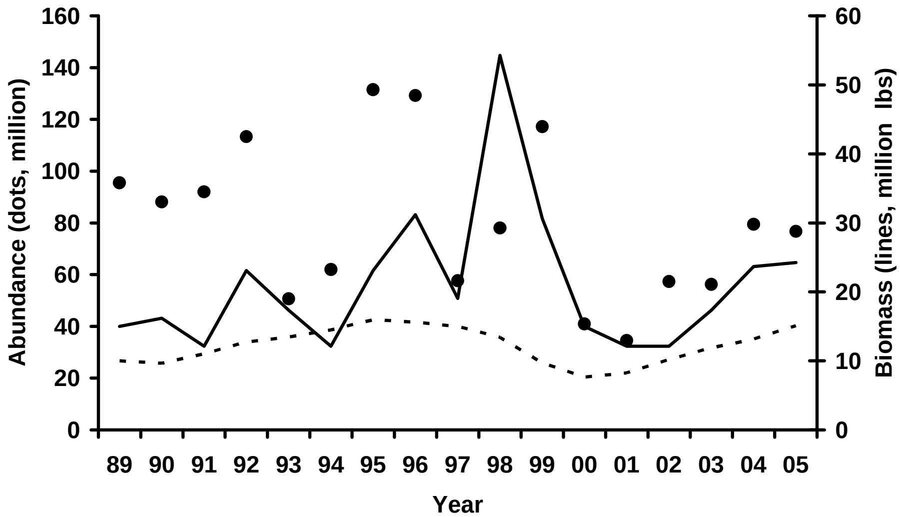


Figure 7.2.2.2. Abundance estimates for exploited blue crabs using the catch-survey (solid circles) analysis for the gulf coast during 1989-2005 and for the Atlantic coast during 1990-2005. Estimates of exploited stock biomass of blue crabs over the same time frames made using the non-equilibrium surplus production model (dashed line – ASPIC) and using the stochastic stock reduction analyses (solid line) are also shown.

Gulf coast



Atlantic coast

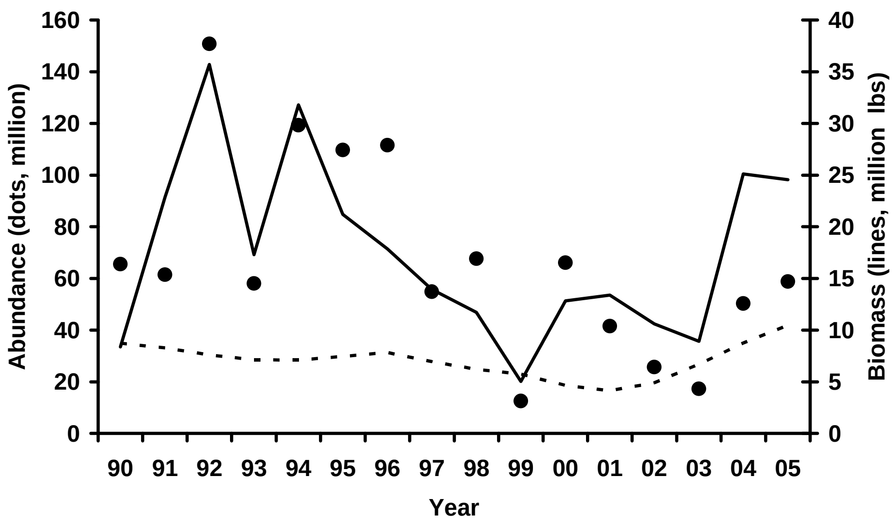
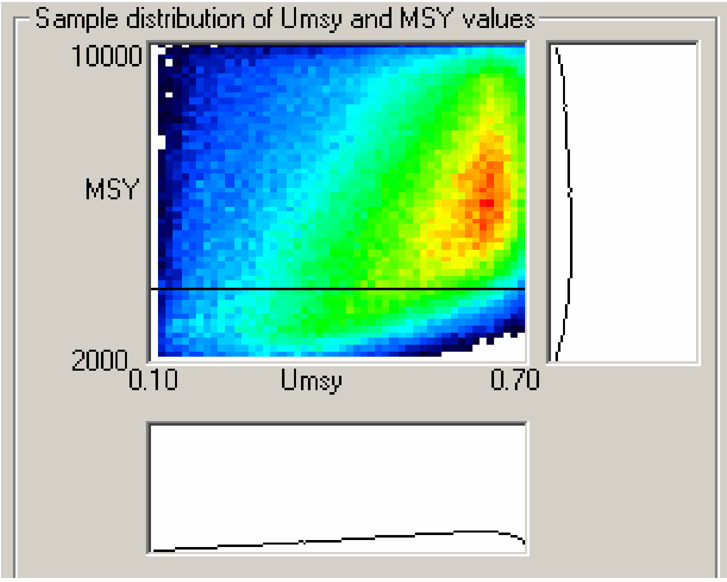


Figure 7.2.2.3. Sample distributions of the exploitation rate at maximum sustainable yield (U_{msy}) and the maximum sustainable yield (MSY, in metric tons) on the gulf and Atlantic coast as generated from 1,000,000 MCMC during the stochastic stock reduction analysis. The low to high surface contours run spectrally from blue to red, in color, and from dark to light (sort of) in black-and-white. The distribution of the values for each parameter are given along each axis and indicate the level of uncertainty in the analysis. Recent (1990-2005) mean catch shown as the solid horizontal line indicates that there is a high probability that recent mean catches have been below MSY.

Gulf coast



Atlantic coast

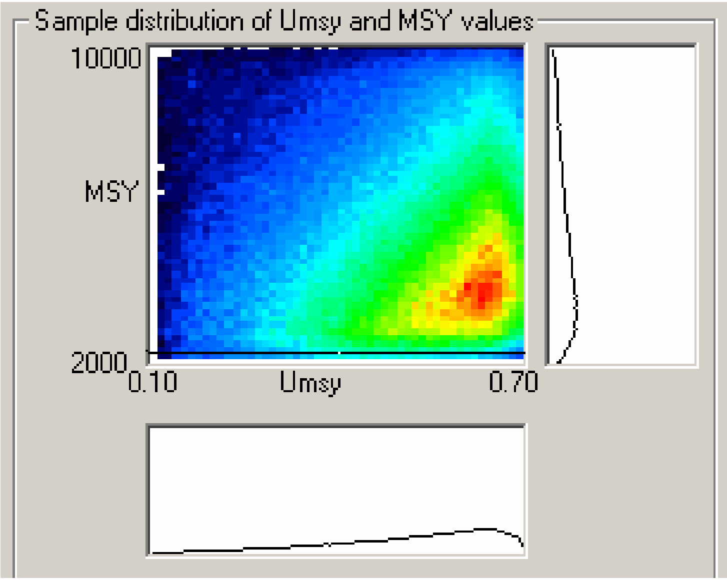
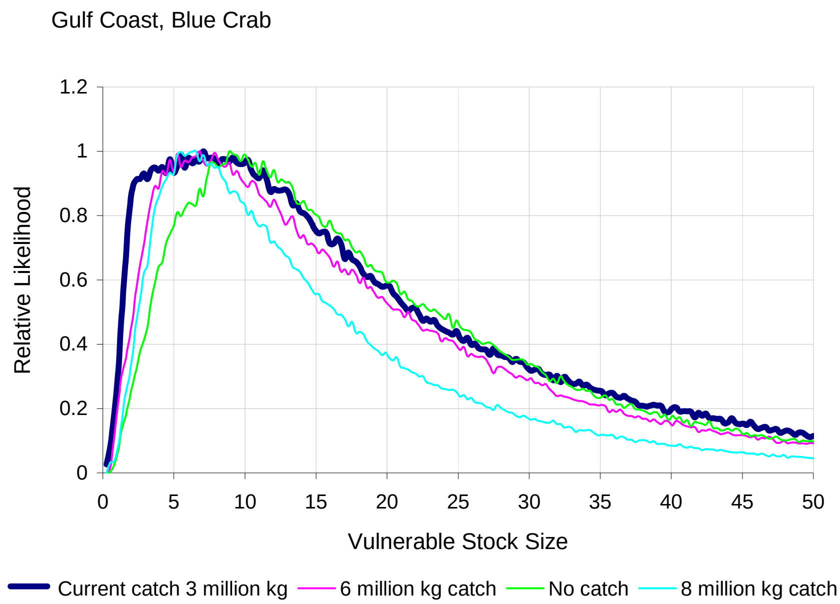


Figure 7.3.1. Relative likelihood estimates of future (year 2015) vulnerable stock biomass of blue crabs on the gulf and Atlantic coast of Florida. These were projected by the stochastic stock reduction analysis for differing levels of future catch, as projected to remain at these catch levels during 2006 through 2015.



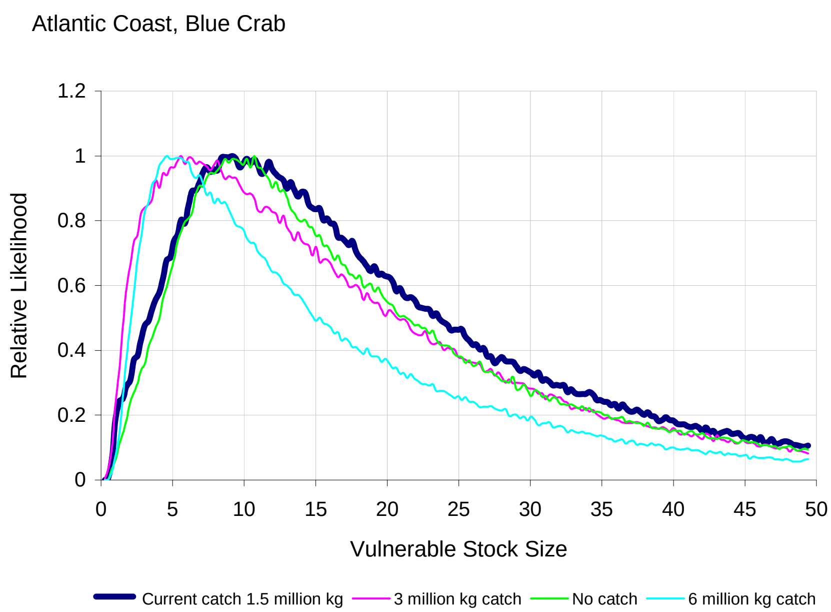
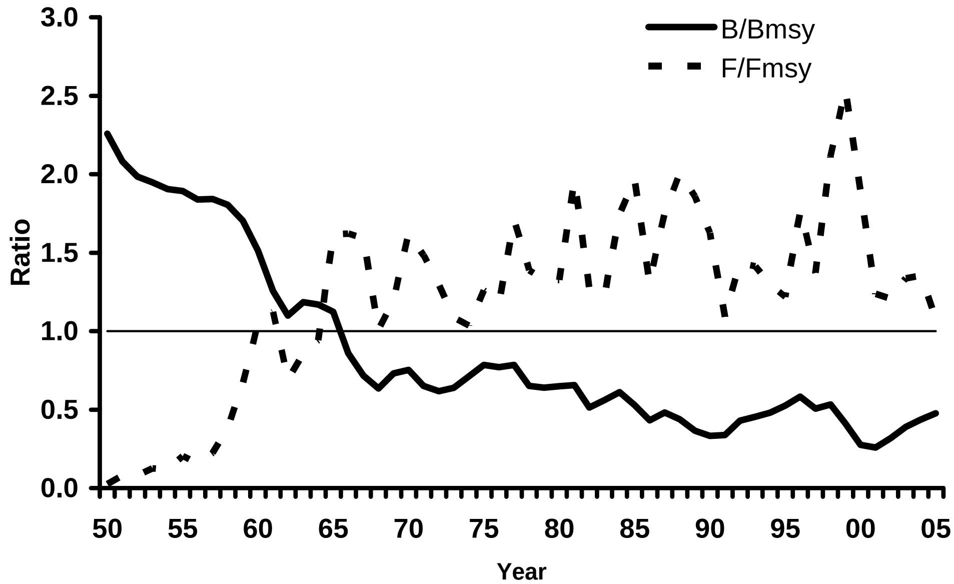


Figure 8.4.1. Ratios of average exploitable biomass each year during 1950-2005 to the average exploitable biomass associated with maximum sustainable yield (B/B_{MSY}) and the ratio of the instantaneous fihsing mortality rate each year to the instantaneous fishing mortality rate associated with maximum sustainable yield (F/F_{MSY}).

Gulf coast



Atlantic coast