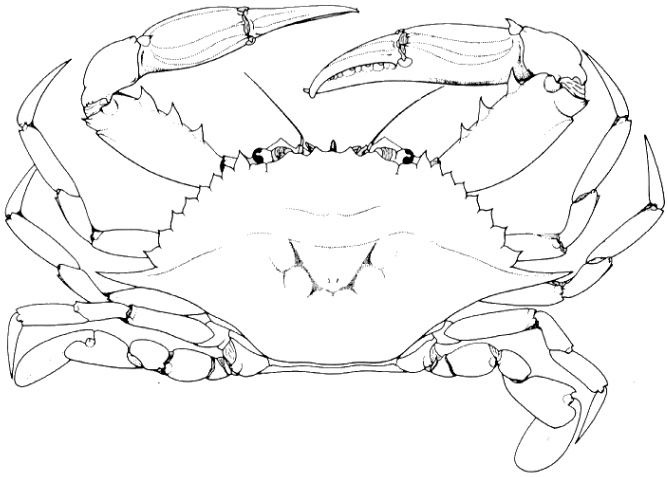
A stock assessment for blue crab, *Callinectes sapidus*, in Florida waters through 2011



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Executive Summary

This third quantitative assessment of blue crabs in Florida consists of two detailed population assessments for blue crabs inhabiting either the Gulf or Atlantic coast of Florida. Updated information is also provided on aspects of blue crab life history.

During the 1930's and 1940's, statewide blue crab landings ranged between 4.5 and 7.0 million pounds. The Gulf coast represented approximately 1.0 million pounds of the harvest for the period. The landings remained relatively constant through the 1950's and 1960's on the Atlantic coast, whereas Gulf coastal landings increased over the same period, reaching 15 million pounds by mid-1960. Since 1965, commercial landings of blue crab on both coasts have declined. The lowest landings were reported for the Gulf coast in 2008 and the Atlantic coast in 2009. Through 2011, landings and commercial catch rates for both coasts have marginally increased since the lowest years experienced, but overall the declining trend remains. In 2011, landings were about 6.8 million pounds for the Gulf coast and 3.7 million pounds for the Atlantic coast.

Fishery-independent indices of abundance (IOA) were variable when the surveys were initiated (1989 or 1996) and showed a depression in abundance during both the early and late 2000's. The IOA trends on both coasts mirror the commercial catch rate trends and the trends in commercial effort. The abundance indices have increased in 2011 on the Atlantic, but experienced a drop in the Gulf during 2011.

All three assessment models indicate that fishing mortality rates have trended downwards on both coasts since the mid- to late 1990's, which follows the general trend in the number of traps fished over this time period. The analyses differ based on the time span over which the models were run. The historical models that use longer time periods show two peaks in fishing effort: (1) a mid-60's peak from the rapid increase in fishing effort prior to 1960 , followed by a decline through the 1980's; (2) a secondary, albeit smaller peak in effort in the mid- to late 1990's, after which landings steadily declined through present. Although fishing rates have declined since the late 1990's, all three models find that the abundance of crabs has not increased markedly with this decrease in effort, but has remained relatively stable marked with large fluctuations in their abundance.

Although there were differences in the predicted stock status among the three analyses, the general conclusions suggest that neither coast is currently overfished nor undergoing overfishing. The primary assessment model, a two-stage catch-survey analysis, found that neither coast is currently overfished nor undergoing overfishing, with an estimated MSY of 31.9 and 12.0 million crabs for the Gulf and Atlantic coasts, respectively. The stochastic stock reduction analysis (SSRA) came to the same conclusions regarding stock status, with an estimated MSY of 35.3 and 23.2 million crabs for the Gulf and Atlantic, respectively. The surplus production model found a similar result for the stock status on the Gulf coast (not overfished nor overfishing), but found that the Atlantic coast was overfished and undergoing overfishing, with estimated MSY of 15.4 and 22.1 million crabs for the Gulf and Atlantic, respectively. These conclusions regarding stock status are similar to those from the corresponding models in the previous assessment (through 2005). While differences exist among the analyses in this current assessment, a common feature from these analyses is that blue crabs are highly resilient, and in particular, freshwater inflow can have a strong influence on their dynamics, leading to large fluctuations in year-to-year abundance.

There are troubling gaps in our knowledge about blue crabs that could bias these analyses. The ages of blue crabs are not known, making inferences regarding mortality rates difficult. Some information suggests that commercial discard mortality could be high, and that the recreational catch could be significant. No estimates currently exist for recreational harvest, making the conclusions of this assessment suspect if these landings are, as suspected, substantial. In addition, underreporting from landings, which may be substantial, could also bias the conclusions from this assessment.

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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). Much of the background literature is reprinted from the review in Murphy et al. (2007) and updated with new information as appropriate.

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. The Gulf population includes 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, where 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 enacted 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. A moratorium was placed on the issuance of new blue crab endorsements beginning in June 1998. The Blue Crab Effort Management Plan (BCEMP) was implemented in 2007 to address the problems of seasonal crowding of traps in confined waterways, lost traps, bycatch, overcapitalization, latent endorsements and conflicts between hard shell blue crab fishermen and soft shell blue crab fishermen. On July 1, 2008 the BCEMP separated the blue crab endorsements by product type: hard shell (VH), soft shell (VS), non-transferable (VN) and incidental catch (VI) along with issuing tags for each trap fished based on where and how the blue crab trap was fished (inshore, offshore, soft shell and hard shell). The high number of trap tags (822,750) ordered in 2008 represents year 1 of BCEMP when there was no charge for trap fees and fishers ordered the maximum allowable number of their allotment of traps, the majority of which were not fished. Fees for trap tags were implemented in 2009 and the number more accurately reflects traps (290,599) that are potentially used by the fishery. The BCEMP is structured so fishermen must annually re-qualify with landings in order to renew their endorsements. Non-renewals may appeal if there were extenuating circumstances that prevented them from renewing on time or attaining the minimum volume of landings for requalification. Otherwise, those non-renewal endorsements were lost, permanently decreasing the number of endorsements in the fishery. The BCEMP has resulted in a reduction in endorsements from 2,283 in 2007 to 950 in 2011.

1.3 Assessment History

Two previous assessments for blue crabs in Florida were conducted in 2001 and 2007 (Murphy et al. 2001, Murphy et al. 2007). Findings from the 2001 assessment were highly dependent on the apparent maximum age achieved by unexploited blue crabs and the natural mortality rate implied from the associated 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). When they explored 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 blue crab populations in each Gulf coast state (Gillory *et al.* 1999). They found 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 in the blue crab fishery throughout the Gulf States.

The 2007 assessment results indicate that fishing mortality rates have trended downward, and each of the three models used indicated a rebound in abundance in the later years of their assessment. Results on the status of the fishery were different depending on the model used, but generally showed that the stocks were not being overfished, and blue crabs appear to be highly resilient to 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.

2.0 Life History

2.1 Age

Crustaceans 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 as seen in finfish, 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 around 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 been used to estimate 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.* (2004) 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. Researchers in Florida spent four years in an effort to apply the extraction techniques developed by Ju et al. (1999, 2001) and Puckett et al. (2008) to aging blue crabs in the Florida fishery (Crowley 2012). Crowley (2012) investigated the robustness of the extraction technique for lipofuscin age determination in Florida blue crabs using two known age cohorts. Cohorts were from different sources, one wild (n=105) and one from the Blue Crab Aquaculture program at the University of Southern Mississippi's Gulf Coast Research Laboratory (USM/GCRL) (n= 80). Each cohort was cultured under different conditions and a known age curve was developed for each population to determine the reliability of the extraction technique for ageing blue crabs before its application in the Florida blue crab fishery. Results of the Florida study did not support the conclusions of Ju et al. (1999, 2001) and Puckett et al. (2008) that linked accumulation of extractable lipofuscin with chronological age in blue crab (Crowley 2012). In contrast to those authors, the Florida study found negative correlations with age in the pond ($y= - 0.05x + 0.43$, $p<0.001$, $R2 = 0.13$) and tanks ($y= - 0.012x + -0.919$, $p<0.07$, $R2 = 0.002$). The lipofuscin indices generated by the extraction method were not correlated with age and precluded the development of a calibration curve and age determination of blue crabs in the Florida fishery. Use of lipofuscin methodology has been found to be unsuccessful in aging garden lizards, *Calotes versicolor* (Manibabu and Patnaik 1997, Majhi and Patnaik 2000) and

Sheehy (2008) noted that the accuracy of the extraction methodology may not be sufficiently vetted for use in ageing.

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 Growth

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 crab absorbs water to expand and the exoskeleton hardens, allowing for growth. Environmental conditions such as temperature (Leffler 1972), salinity (Tagatz 1965, 1968a), 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, although additional experimentation would be required to support this theory. Molting and pre-molt mature female in the post terminal molt state have been observed in other studies (Abbe 1974; Olmi 1984; Steele and Bert 1994; 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 13 mm carapace width (CW), to one to two months for a 100 mm CW 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%. Tagatz (1968a) 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 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). Up to 18 months is necessary for maturation in Chesapeake Bay (Van Engel 1958), while blue crabs in the Gulf of Mexico may reach maturity within a year (Perry 1975, Tatum 1980). Florida pond studies of Crowley (2012) found the first mature female raised from a wild cohort in a ¼ acre pond at approximately 7.7 months of age and the last immature female was captured in the pond at approximately 10.3 months of age.

Growth data exist for Gulf of Mexico blue crabs from length-frequency distributions and more recently from aquaculture studies conducted in Florida and Mississippi. Perry (1975) estimated seasonal (July through January) growth by tracing modal progressions in monthly width-frequency distributions for crabs in Mississippi Sound. The estimated growth rate of 24-25 mm/month is somewhat higher than rates found for other Gulf estuaries. Adkins (1972a) found growth in Louisiana waters to be about 14 mm/month for young crabs with slightly higher rates (15-20 mm/month) as crabs exceeded 85 mm in carapace width. Darnell's (1959) growth estimate of 16.7 mm/month for crabs in Lake Pontchartrain falls within the average reported by Adkins. More (1969) noted a growth rate of 15.3-18.5 mm/month in Texas. Plotting the progression of modal groups from February through August, Hammerschmidt (1982) reported higher growth rates for crabs in Texas (21.4 and 25.2 mm/month for seine and trawl samples, respectively) and attributed these rates to the use of seasonal rather than yearly data. Tatum (1980) also found seasonal changes in the rate of growth of young blue crabs in Mobile Bay, Alabama. He observed monthly rates of 19, 10, and 5 mm for crabs recruited in April, August, and December, respectively. Pond studies in Florida (Crowley 2012) found growth rates of males and females from 15 mm to a legal size of 127 mm to be approximately 12.4 and 12.7 mm/month, respectively. Mississippi aquaculture research has estimated crab growth from studies in tanks and ponds (Perry unpublished data). During the early grow-out period (megalopae to beginning crab stages) in recirculating tanks, crabs had a growth rate of 16.5 mm/month. In pond studies (early juvenile crabs to adults), crab growth was 20.2 mm/month.

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

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

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

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

Due to the strong temperature dependence on growth in blue crabs, von Bertalanffy growth parameter estimates from individual studies would only be appropriate for individuals spawned during similar months; for example, those spawning in spring could have markedly different growth parameter estimates than those spawned in the fall. To distill a single set of growth parameter estimates for Florida crabs, the climatological average of temperatures was calculated from the fisheries independent monitoring data, and this temperature time series was input into the molt-process model to simulate size-at-age data for individuals spawning throughout the entire spawning season. The spawning season was based on the proportion of ovigerous females sampled in fisheries independent sampling from the GulfThe proportion data were used to assign the spawning date using an empirical distribution for the simulated crabs in the model. A von Bertalanffy model was then fit to these simulated size-at-age data to obtain a single growth model estimate:

$$CW_t = 166.05\ (1\text{-}e^{-2.1582(t\text{-}01740)})$$

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, Murphy et al. (2007) present separate relationships from fisheries independent and fisheries dependent analyses, and conclude that the equations are applicable for the entire state due to lack of strong interaction differences among regions in the states. For this assessment, we have combined the various Florida data sources (independent and dependent data; n=11,425 total, n=6,959 males, n=4,041 females) into a single set of relationships for use in the assessment models. Carapace widths ranged 56-235 mm for females and 53-227 mm for males. Crab weights (W) ranged 15-780 g for females and 15-670 g for males.

Both Sexes:	$W = 0.00856 * CW^{1.994}$
Males:	$W = 0.00214 * CW^{2.289}$
Females:	$W = 0.00786 * CW^{1.981}$

In the Chesapeake Bay, a relationship of carapace width (mm) to weight (g) 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: $W = 0.003487 * CW^{2.1165}$
Male: $W = 0.000221 * CW^{2.7208}$

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: $W = 0.000287 * CW^{2.6395}$
Male: $W = 0.000181 * CW^{2.7748}$

Guillory and Hein (1997a) developed a relationship for blue crabs from the Terrebonne Basin, Louisiana. Blue crab weight (grams) at CW for both sexes combined was determined as:

Both Sexes: $W = 0.000826 * CW^{2.446}$

Relationships from Mississippi fishery-independent monitoring and fishery-dependent were developed for the 2011 Gulf of Mexico blue crab assessment (GDAR 2013). The composite weight-length relationship (both sexes, fisheries independent, FID, and dependent data, FDD) and category-specific relationships were estimated as follows:

Both Sexes (FID, FDD): $W = 0.000888 * CW^{2.429}$
Males (FDD): $W = 0.00141 * CW^{2.373}$
Females (FDD): $W = 0.00264 * CW^{2.199}$
Males (FID): $W = 0.000185 * CW^{2.751}$
Females (FDD): $W = 0.000337 * CW^{2.613}$

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. 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 adult 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 as they approach maturity.

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. The 2011 Gulf of Mexico blue crab assessment (GDAR 2013) models an eastern (FL) and western (AL through TX) break in the distribution, based on genetic information (below) and larval dispersal studies (Johnson et al. 2009 and 2013).

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 population 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 and northwest 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 Natural Mortality

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 and colleagues (referenced in Murphy et al. 2007) 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. Murphy et al. (2007) used these ecosystem model estimates of M on a 6-month time step as inputs into the base assessment model for the previous assessment.

For this assessment, we followed the Hewitt and Hoenig (2005) rule of thumb estimate of constant natural mortality ($M=3/t_{max}$, where t_{max} is maximum age of 3.0) in combination with the Lorenzen (2006) approach to scale to an age-specific mortality rate. Following SEDAR 12, the mortality estimate is rescaled where the average mortality rate over ages vulnerable to the fishery is equivalent to the constant rate over ages as:

$$M_a = M\frac{nL(a)}{\sum_{a_c}^{a_{max}} L(a)}$$

where M is a constant natural mortality rate over exploitable ages a, a_{max} is the oldest age-class, a_c is the first fully exploited age-class, and n is the number of exploitable ages. The Lorenzen curve as a function of age is calculated from:

$$L(a) = W_a^{-.288}$$

where -0.288 is the allometric exponent estimated for natural ecosystems (Lorenzen 1996). To obtain the predicted weight-at-age for the Lorenzen calculations, the median size-at-age was obtained from simulated data using the individual-based molt-process (see description above), and these size-at-age data were applied to the weight-at-length relationship to obtain the weight-at-age. This approach produces the estimates of M of 1.28 and 0.87 yr^{-1} for juveniles and adults, respectively, for the Gulf coast, and 1.29 and 0.86 yr^{-1} for juveniles and adults, respectively, for the Atlantic coast.

2.7 Total Mortality

Independent estimates of total adult mortality (Z) can be computed using a linearalized catch curve analysis (eq. 4.4.5.3 in Sparre and Venema 1998) on fisheries independent monitoring size frequency data of fully-selected adults. For this, an average estimate across years, reflective of the typical total mortality crabs experienced, was obtained by applying the catch curve analysis to the total crabs caught in each 10mm size bin from all years combined. This analysis utilized the von Bertalanffy growth parameters and weight-at-size parameters discussed above. This approach produces estimates of Z of 3.10 and 2.46 86 yr^{-1} for the Gulf and Atlantic coasts, respectively.

3.0 Fishery Description

3.1 Brief Overview of Fisheries

The commercial fishery for blue crabs is conducted almost exclusively using traps. Information on the recreational fishery is lacking but various small traps, dip nets, and lines are used to catch blue crabs. Commercial landings peaked in the mid 1960's, and have shown a general decreasing trend since then. 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. Hard shell crabs represent the major component of landings (>99% average across years by weight; Tables 3.1.1, 3.1.2; Figures 3.1.1, 3.1.2).

The Florida blue crab fishery is highly mobile. Many fishermen with blue crab endorsements fish for blue crabs in both the Gulf of Mexico and Atlantic Ocean. The separation of the licenses based on the coast fished is not achievable using licenses. The licensing data presented here illustrate the overall changes within the Florida fishery. In 1995, there was a significant increase in the number of blue crab endorsements sold in Florida (Table 3.1.3). During this period a statewide ban on net fishing was implemented and many commercial finfish fishermen entered the blue crab fishery. The statewide number of endorsements increased from 4,933 in 1994 to 6,082 in 1995. After the increase in 1995 a steady decrease in endorsements has followed. In 2011, the total number of endorsements (VH,VS,VN and VI) for blue crab fishing (950) were a fraction (15.6%) of the endorsements issued in 1995. The decrease in endorsements over the period was steady and was enhanced by the Blue Crab Effort Management Plan (BCEMP) in 2007. The BCEMP was enacted to address the problems of seasonal crowding of traps in confined waterways, lost traps, bycatch, overcapitalization, latent endorsements and conflicts between hard shell blue crab fishermen and soft shell blue crab fishermen.

On July 1, 2008 the BCEMP separated the blue crab endorsements by product type: hard shell (VH), soft shell (VS), non-transferable (VN) and incidental catch (VI) along with issuing tags for each trap fished based on where and how the blue crab trap was fished (inshore, offshore, soft shell and hard shell). The high number of traps for 2008 (822,750) represents when there was no charge for trap fees (year 1 of BCEMP) and the fishers ordered the maximum allowable number of their allotment of traps, the majority of which were not fished. Fees for trap tags were implemented in 2009 and the number more accurately reflects traps (213,555) that are potentially used by the fishery (Table 3.1.3). The BCEMP is structured so fishermen must annually re-qualify with landings in order to renew their endorsements. Non-renewals may appeal if there were extenuating circumstances that prevented them from renewing on time or attaining the minimum volume of landings for requalification. Otherwise, those non-renewal endorsements were lost, permanently decreasing the number of endorsements in the fishery.

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.

A more recent survey was conducted of the commercial blue crab fishery in Florida (Gandy 2012), which differed in the questions from the previous mail survey. The new survey included questions on the locations typically fished, distance traveled, expenses, satisfaction with the fishery, response to potential changes in regulations, effects of the effort management plans, and current perception of the fishery. Overall, job satisfaction among blue crab fishermen in Florida is high, although regional differences exist. The career length of fishermen in the Florida blue crab fishery is spread over a wide range (1 to 40+ years), and represents both part time and full time employment for responding fishermen. Statewide responses to distances fished indicated that the majority of respondents fish less than 50 miles from their home base, mostly in the region they reside in. All regions followed the statewide trend where the majority of the catch is sold, mostly to wholesalers, within the state. This is in line with the survey's focus on harvesters. It is interesting to note that very few respondents are vertically integrated to function as wholesalers exporting product out of state. Fuel and new gear were typically the top two ranked fishing expenses for respondents in all regions, although other factors played a role in some regions. Over the past five years, the landings of respondents have either been stable or decreased. Regionally, the majority of respondents in the northeast, central east, central, panhandle and southeast indicated their landings have significantly decreased over the period. The majority of respondents in the central west, northwest and southwest indicated their landings have remained stable over the past five years. Weather was the primary factor affecting respondent's landings. After the implementation of the effort management plan, in 2007, the majority of respondents in all regions indicated they have not noticed any changes in the fishery. The majority of respondents would not support potential fisheries management

tools: increases in the minimum sizes of male or female blue crabs; summer closures on female blue crabs; blue crab refuge/no take areas.

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 post settlement and reproduction phases (Guillory *et al.* 2001a). Though post settlement blue crabs are most abundant in estuaries, they can be found in freshwater and the 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, post settlement 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 metamorphose 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 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) 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 (Moody 2001; Guillory *et al.* 2001). 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 the complexity of seagrass habitat influences juvenile blue crab survival by influencing the vulnerability to intraspecific predation affecting 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). Tagging studies by 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). Recent analysis of isotope and trace metal concentrations may point to breeding grounds extending further into the middle of the bay than was previously thought (Gandy, personal communication). 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 survival, 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 successful methodologies have been developed to rear blue crab larvae, Megalopae and juveniles (Crab 1 stage) using readily available cultures of several micro algal species, Rotifer cultures, *Artemia sp.* nauplii and artificial diets (Zmora *et al.* 2005). 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 1950-2011. 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 1986-2011. Trip tickets included edited batches 1 – 1,175 pulled on 2/5/2013, with minor gaps remaining in both the 2011 and 2012 batches. 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 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, 2001, 2002, 2006, 2007, 2009, and 2010 on the gulf coast and during 1997, 1998, 2000, 2001, 2003, and 2005-2011 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. FWC-FWRI Crustacean Fisheries have recently conducted a disease survey with commercial fisherman during the months of 2-4, 8, and 9 in 2011 at five regions throughout Florida.

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

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.

The biostatistics data for landed commercial blue crabs is available periodically from 1997-2011 on the Gulf and Atlantic coast. Figures 5.1.1.2.1 and 5.1.1.2.1 show the relative sampling intensity aggregated among all the various sampling programs, demonstrating the substantial lack of information for many month and year combinations. 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).

5.1.1.3 Biases

The landings collected by the NMFS program were 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 (Murphy et al. 2007) 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 misreporting by the official landings system is randomly distributed over the years. Another possible bias is the selectivity of the dealers, where many wholesale dealers will only accept catch that is of a certain standard. Any small sized crabs generally < 150 mm or recently molted (low weight) will not be accepted. This is particularly true for years when demand is down and they will only accept high quality crabs which they can sell (C. Crowley pers. comm.). 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 unknown bias, particularly given the sporadic nature with entire years of sampling missing for both coasts. The biostatistics sampling that occurred statewide during 1997-2011 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 by FWC-FWRI Crustacean Fisheries Research staff 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. The FWC-FWRI Crustacean Fisheries disease survey, conducted during the months of 2-4, 8, and 9 in 2011 sampled crabs for size, weight, and sex at five regions throughout Florida.

5.1.1.5 Age and Size Composition

No aging methods were applied to commercial blue crabs. Figures 5.1.1.5.1 and 5.1.1.5.2 shows the size frequency distributions of crabs landed for both coasts. The smallest average size of crabs landed was during the late spring and early summer months, coinciding with maturation and recruitment of crabs to the fishery. This period also coincides with the peak monthly landings overall, suggesting a large portion of crabs landed may be newly recruited individuals (Figures 5.1.1.5.3, 5.1.1.5.4).

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, following Murphy et al. (2007). 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 0.4276 pounds per crab. This is the statewide average of aggregated data from the 2002-2004 biostatistical survey, the TIP program, and the 2011 disease sampling from commercial crabbers. The number of traps pulled was estimated based on matching missing or inaccurate trip ticket records with complete and seemingly valid trip ticket records that shared some trait with the bad records. The valid 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 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 valid 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 9.2) 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), 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 from a Monte Carlo simulation (5000 Student's *t* distributed realizations) that computed 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 Commercial Landings

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. 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. 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 and Atlantic coasts have varied widely but with a consistent declining trend. The lowest landings reported on each coast since 1950 occurred in 2008 (Gulf) and 2009 (Atlantic), with an increase in 2010 and 2011 on both coasts (Tables 3.1.1, 3.1.2; Figures 3.1.1, 3.1.2).

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) when 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, cited in Murphy et al. 2007). 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 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 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 of blue crabs were 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 their minima in 2008. 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. As with the Gulf coast, the lowest landings and effort occurred during the same year in 2009 (Tables 3.1.1, 3.1.2; Figures 5.1.4.1, 5.1.4.2).

The trends in standardized landings (CPUE) rate median values were generally downward for both coasts, although year-to-year variability was high (Figures 5.1.4.1, 5.1.4.2). More noticeable is the general decline in lowest values observed with time (2008 and 2009 for Gulf and Atlantic, respectively). In the most recent year (2011), the standardized CPUE has increased substantially on the Gulf coast. In the standardization process, the number of traps pulled per trip was the only significant factor in the stepwise procedure, while year was not significant in either coast (Tables 5.1.4.1 and 5.1.4.2). The diagnostic residual plots are shown in Figures 5.1.4.3 and 5.1.4.4 for both coasts. While these diagnostics suggest some violations of the assumptions used in the standardization, the overall trends in the median values are likely more robust to these departures than measures of the precision of the expected values.

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 ('juveniles') and exploited-size blue crabs ('adults') 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). Juveniles were considered those individuals <=80 mm carapace width (CW) sampled from October through March during the winter peak in recruitment. Adults were any crabs >=127 mm (harvestable size), sampled from April through September, coinciding with the peak in adult abundances.

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. The sampling effort for the three main gears used in this assessment is presented in Tables 5.3.1.2.1 and 5.3.1.2.2. The annual number of sets made statewide each year also increased markedly during 1996 when the program switched from seasonal to monthly, and due to the addition of the large haul seines in 1996 and 1997 for the Gulf and Atlantic coasts, respectively.

5.3.1.3 Biases

The fishery-independent stratified random survey is designed to sample finfish randomly within strata. However, these gear or methods are not targeted specifically for blue crabs at any life stage or habitat and may be subject to gear selectivity bias. 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 and some lumping among habitat categories and gear type recorded for each sample. Although trawl and large seine gears were both used for adult indices of abundance, leading to an unbalanced design (i.e., trawls began in 1989 and 1990, while large seines began in 1996 and 1997 for Gulf and Atlantic coasts, respectively), differences in the mean standardized indices were minimal compared to using just the large seine versus both gears combined. Therefore, the decision was made to use both gears for the entire time frame, while accounting for differences in gears in the standardization framework, in order to obtain a longer time series for the assessment model. 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 (Murphy et al. 2007).

The migratory characteristics of mature 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. However, the extent of the migration relative to the proportion of the entire population that indeed migrates is not well known.

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 Age and Size Composition

No direct aging method has been applied to Florida fisheries independent blue crabs. Size-frequency distributions for different size bins, gear types, and month of sampling are presented in Figures Figure 5.3.1.5.1-5.3.1.5.4. Generally, juvenile crabs (<80mm) were caught in the highest frequency during the winter months (November through March), while adult crabs (>125mm) were caught in the greatest frequency during the summer months (April through October).

5.3.1.6 Development of Estimates

Standardized catch rates, known as indices of abundance (IOAs), were developed for juveniles and adults. Estimates were made for each year using October through March for juveniles, and April through September for adults, corresponding to their peaks in abundance. For standardization, a Generalized Linear Model (GENMOD) was used that combined the analysis of the binomial information on presence/absence with the lognormally-distributed positive catch data (a delta model, Lo *et al.* 1987). We assumed that there were no substantial significant interaction terms with year in this model and consider only the main effects (names in parentheses correspond to those in the standardization statistics, see next section): year (year), month (month), area (bayzone), vegetative shore cover (shore), sampling gear category (gr), surface water temperature (temperature), bottom vegetation cover (bveg), bottom type (bot), salinity (salinity), and depth (depth). 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, was necessary for including each additional term in the model. If year was not chosen in the standardization procedure, it was manually inserted at the end of the search criteria. 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 (year) provided indices of abundance for juvenile and adult crabs.

5.3.2 Catch Rates (Numbers)

The Gulf coast standardized catch rates have been relatively stable from 1989-2011 without any observable long-term trend, but marked with significantly large fluctuations from year to year (Table 5.3.2.1, Figure 5.3.2.1). Years with high juveniles abundances often correspond to years with high adult abundances. Similar to the juvenile catch rates, the adult catch rates have shown substantial year-to-year variability, often peaking on similar years with the juvenile rates (1998, 2005, 2010) and experiencing similar lows (2001, 2002, 2008). The adult catch rates are suggestive of a general decline in abundance over the full time frame, although this decline is minor if present. Multiple covariates had a significant effect in the standardization procedure for the Gulf coast. For juveniles, year, gear, bayzone, and bottom

type were important predictors for positive catches, while year, gear, and bayzone were important for presence/absence. For adults, year, gear, and salinity were important for positive catches, while year, gear, and bayzone were important for presence/absence (Tables 5.3.2.2-5.3.2.5). The residual plots are shown in Figures 5.3.2.2 and 5.2.2.3.

The Atlantic coast rates generally had higher variability than the Gulf, partly due to the lower sampling intensity on the Atlantic coast (Table 5.3.2.6, Figure 5.3.2.4). Both juveniles and adults have been relatively stable for the entire time frame, although juveniles were slightly higher in abundance in the early years (1996-2000) than subsequent years, despite the difference between these periods being minimal and marked with high variability for the initial period. Like the Gulf coast, juveniles and adult catch rates corresponded to each other during some years, for example, both experiencing lows in 2002 and 2009. For adults, gear and shoreline were important for positive catches, while year and bayzone were important for presence/absence (Tables 5.3.2.7-5.3.2.10). The residual plots are shown in Figures 5.3.2.5 and 5.2.2.6.

5.3.3 Length/Weight/Catch-at-Age

No aging methodology has been applied to the fisheries independent survey data.

5.3.4 Abundance Indices

The year-specific medians predicted for the fishery-independent survey catch rates 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. However, doing so would lead to the same relative pattern of abundance as using the indices based on numbers of crabs.

5.3.4 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 lognormal and the presence/absence would be distributed as a binomial process. The combination of these models into a delta lognormal 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 5.3.2.2 and 5.3.2.3 for the Gulf coast, and Figures 5.3.2.5 and 5.3.2.6 for the Atlantic coast.

5.5 Environmental Data Sources

Due to the relationship between blue crabs and freshwater inflow, data were collected on both precipitation and streamflow along the Gulf and Atlantic coasts. Precipitation data were obtained from the National Climatic Data Center (http://www.ncdc.noaa.gov/) on a monthly basis from 1950-2012 (Table 5.5.1). Streamflow data were obtained from USGS gauges (http://waterdata.usgs.gov/nwis/). To select appropriate streamflow gauges, GIS analyses were used to select all gauges within each hydrologic sub-basin unit (http://water.usgs.gov/GIS/huc.html). Within each sub-basin, the gauges were then sorted to select a single gauge from each sub-basin with the highest average flow for the longest period of time spanning 1980-present (Table 5.5.1, Figure 5.5.1). Gauges were restricted to a single gauge within each sub-basin and scaled to the mean yearly anomaly in order to evenly distribute the signal along the coastal distribution. These data were used in the base assessment model to explore links between crab dynamics and freshwater inflow.

The precipitation and streamflow data corresponded well to each other, and the streamflow anomalies were similar between the Gulf and Atlantic coasts, as would be partly expected given the similar climatic conditions (Figure 5.5.2). For both coasts, the juvenile and adult abundances were related to the freshwater inflow, where abundances typically increased in the year following higher than average rainfall (Figures 5.5.3, 5.5.4).

6.0 Methods

6.1 Models

Three separate models were utilized in this assessment, following the models used in the previous assessment: a catch-survey analysis, also known as a modified Delury model (Collie and Sissenwine 1983); a non-equilibrium biomass dynamics model, also known as a surplus production model (ASPIC, Prager 1994); and stochastic stock reduction analysis (SSRA, Walters *et al.* 2006). The catch-survey analysis used here is a two-stage model (juveniles and adults) adapted from the 2011 Chesapeake blue crab assessment and developed for the 2011 Gulf of Mexico blue crab assessment (GDAR 2013). The two-stage model was selected as the base model due to the preference for this modeling approach from recent blue crab assessments (e.g., Chesapeake, Louisiana, Delaware), while ASPIC and SSRA were used as supporting models.

The two-stage model was a forward-projecting model, similar to a statistical catch-at-age but with only two age classes represented: juveniles (age-0) and adults (age-1+). This model was adapted from the 2011 Chesapeake blue crab assessment model, hereafter termed "Chesapeake model", using the ADMB code available online (http://hjort.cbl.umces.edu/crabs/Assessment.html). The Chesapeake model is similar to a catch-survey analysis (CSA), but is not conditioned on catch (i.e., assuming no error in catch statistics), as it typically done in these models. Instead, the expected catch is predicted from estimated fishing mortality rates in the model, and compared to observed catches, while accounting for an input level of error in landings data. In addition, this model utilizes a built-in stock recruitment relationship, providing for MSY-based reference points. A full description and source code of the two-stage model can be found in the GOM blue crab assessment report (GDAR 2013).

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 landings and indices of abundance, and can additionally include other inputs such as fishing effort and exploitation rate estimates.

Stochastic stock reduction analysis is a population model that allows investigation of how a known series of catches could be removed from a stock while allowing it to persist through time and at abundance levels that reflect those for which we have estimates for in recent years. SSRA is essentially an exploratory analysis that provides credible stock recruit dynamics given observed catches and indices of abundance. The formulation used in this assessment was an age-structured population model with a Beverton-Holt stock-recruitment function, 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 set of possible historical stock trajectories are derived using Markov Chain Monte Carlo simulation.

6.2 Model Calibration

The catch-survey analyses were calibrated against absolute observations of commercial landings and fishing effort. These data scaled the final outputs of abundance and fishing mortality to represent an absolute scale. Due to difficulties in scaling the absolute estimate of fishing mortality from just the landings and effort data, an independent estimate of total mortality, Z, was input into the model to calibrate the fishing rates. The non-equilibrium surplus production model (Northeast Fisheries Science Center NOAA Fisheries Toolbox, ASPIC, v.5.34) was calibrated with 1950-2011 commercial landings and the 1986-2011 standardized commercial catch rates. The stochastic stock reduction analysis was calibrated against the commercial landings of blue crabs reported since the beginning of the fishery and against the indices of abundance from the fishery-independent survey data for adult blue crabs.

6.2.1 Tuning Indices

The input data used to derive indices of the relative changes in abundance (IOAs) of blue crabs over time came from fishery-independent surveys (See Section 5.3 above). For tuning, the mean-scaled values of the standardized catch rates were assumed to be linearly related to the abundance of blue crabs. The IOAs were used as tuning indices in both the two-stage model (separate juvenile and adult IOAs) and the surplus production model (adult IOAs).

6.2.2 Input Parameters and Specifications

The two-stage model uses annual time steps for the years, modeling the years beginning with the earliest index of abundance for each stock (1989 and 1996 for Gulf and Atlantic coasts, respectively), through 2011. Due to the fast growth rates of blue crabs in Florida (e.g., 7-9 months to reach a legal size of 127 mm), the model time step was begun on July 1st, corresponding to the middle of the spawning season. Early difficulties with fitting the model using a calendar year time frame resulting in the adjustment of the model time step to begin at the time of spawning. This allowed us to model the juvenile stage as starting at the time of entry into the population through their first reproductive period (12 mo of age). Attempting to start the model on the calendar year would potentially negate the usefulness of a two-stage model under this fast growth, since a calendar year time frame would simulate juveniles as those individuals from 6mo-18 mo of age, with spawning occurring during the middle of the juvenile stage. If the primary component of landings are juvenile crabs entering the fishery in their first year (i.e., 12mo at age, representing an annual crop), then the majority of the dynamics would occur in only the juvenile stage, with few individuals remaining to model in the adult stage.

A summary of the model equations and code can be found in the GDAR (2013). The major parameterization and characteristics were as follows:

- Natural mortality: The stage-specific natural mortality rate was assumed constant. A Lorenzen curve was scaled such that the total natural mortality rate was based on a maximum life-span of 3 years. Due to a strong relationship between natural mortality and freshwater inflow as determined by initial runs of the model, the natural mortality was modeled as a function of streamflow in the base model run. This choice of the base model for this Florida-specific assessment differs from that in GDAR (2013), where the environmental influence was modeled as sensitivity in the GDAR assessment. This was done to conform to the full Gulf stock, where freshwater inflow effects were not evident for the western stock.
- Stock dynamics: The standard Baranov catch equation was applied. This assumes exponential decay in population size because of fishing and natural mortality processes.

- Sex Ratio/Maturity/Fecundity: The ratio of males to females was assumed to be 1:1, and only influenced the parameter estimates for the stock-recruitment relationship, reflecting spawning by only females. The maturity was fixed with 100% of juveniles being mature by 12mo of age when spawning occurs at the end of the model time step (i.e., all surviving juveniles spawn at the end of the time step). Fecundity was fixed for both juvenile and adult spawners.
- Recruitment: Recruitment to age-0 was estimated in the assessment model for each year with a set of annual deviation parameters centered on the bias-corrected average recruitment in a Ricker stock recruitment curve, estimated in log-space.
- Biological benchmarks: Maximum sustainable yield (MSY) benchmarks are presented in this assessment to correspond with those reference points estimated in the supporting models (ASPIC, SSRA). A default control rule was used from federal guidelines to assign the overfishing and overfished limits. Once these limits were established, overfishing was defined as F/F_{limit} greater than one, where the geometric mean of the estimated F rate in 2009 and 2010 was used as the current F estimate (note: the 2011 terminal year F was not used, as there were no 2012 survey data on which to tune the terminal year F estimate in the model). Overfished was defined as N/N_{limit} less than one (N is the adult abundance), where the geometric mean of the estimated N in 2009-2011 was used as the current N estimate.
- Fishing: The commercial trap fishery was the only fishery explicitly modeled. Recreational fishing pressure, currently unmonitored, was set at 5 % of the commercial catch per year. Fishing mortality rates were estimated for each year. Juveniles were assumed to have a vulnerability to the fishery of 30%, representing the proportion of the year at which they are vulnerable to fishing (reaching a legal size of 127 mm by 7-9 mo). This vulnerability was set based on simulation runs from an individual-based molt-process model, adapted from Bunnell and Miller (2005) and fit to pond growth data from Florida and Mississippi, which suggest growth to legal size within 7-9 mo, dependent on temperature. This parameter was also included in sensitivity runs to assess the model's response to varying degrees of vulnerability of juveniles to the fishery.
- Fitting criterion: The fitting criterion was a total likelihood approach in which total catch and the patterns of the abundance indices for both juveniles and adults were fit based on a log-normal error distribution. A 5 % CV was assumed for total catch measurement error, and year-specific estimates of measurement error were used for the indices of abundance. In addition to the primary data sources, a prior on the average Z estimate was included in the model fit in order to anchor the initial abundance and recruitment estimates in the model (see Model testing below).
- Model testing: To test the ability of the model to fit the data, a simulation was constructed with different levels of process error (recruitment deviations, F and M deviations and trends, landings deviations and trends, environmental deviations and trends) and measurement error (juvenile and adult abundances). Simulations were done using the same basic population dynamics model as in the assessment model, and found to recover the parameters estimated from the assessment model under limited variability scenarios (e.g., 1-5 % CVs). The parameter estimates because more variable, relative to the known values, as the simulation variability increased (e.g., up to 10-50 % CVs for different processes). Under all simulation variability scenarios however, the median parameter estimates were centered on their known simulated values, indicating that the model performs well. The model produces unbiased estimates only when an absolute measurement of F or abundance is included as a prior in the

model, in order to anchor the estimates in place. This combination of testing and verification procedures suggests that the assessment model has been implemented correctly and provides an accurate assessment of blue crab dynamics, conditional on the quality and error in the data.

It is important to note that although this assessment was run concurrently with the Gulf-wide assessment and using the same two-stage model as in the GDAR Assessment Report, the estimates in this report differ from those in the Gulf-wide assessment (where the eastern stock represents the Florida Gulf coast). This is due to a different model configuration as the base model in this assessment versus in the Gulf-wide assessment. The specific configuration differences include: (1) using the Florida Trip Ticket landings data directly in this assessment, versus using the consensus to use the official NOAA landings in the GDAR assessment; (2) using the Trip Ticket effort data in this report, versus the consensus to avoid its use in the GDAR assessment due to potential bias in states with limited trip ticket data; and (3) using environmental influences on mortality in the base model configuration in this report, versus using the environmental influence as a sensitivity run in the GDAR 1 assessment model.

For the surplus production model, we used the National Marine Fisheries Service Fisheries NOAA Fisheries Toolbox implementation of the non-equilibrium surplus production model ASPIC (version 5.34) to derive comparable population dynamics parameters for the Gulf and Atlantic coasts from 1950-2011. 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. For these analyses, the iterative reweighting mode was used in conjunction with the generalized production model where the exponent was estimated directly. Default starting values for parameters were generated using the built-in facilities.

The stochastic stock reduction analysis (SSRA) was run for each coast of Florida for the period 1908 through 2011. 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). The life-history parameter inputs used in SRA were derived from the von Bertalanffy model fit to the molt-process growth model and the weight-length relationships (section 2.2). A coefficient of variation for the sizes predicted by the growth equation was set at 0.3 due to the high variability in size at age. Maturity of blue crabs was assumed to occur in a knife-edge fashion at a predicted size of 125 mm carapace width. The vulnerability of blue crabs to capture and take was input for juveniles at 0.3 following the base two-stage model, while vulnerability of older ages was input as 1.0. The instantaneous natural mortality coefficient was modeled as a uniform distribution with the Lorenzen option, bounded from 0.8 to 1.2 following the base model criteria. The initial 2011 exploitation rate was set to 0.3 with a standard deviation of 0.05, based on the estimated rates from the two-stage model given the absence of any independent information.

6.3 Sensitivity Analyses

A total of 16 sensitivity runs were completed with the two-stage model. These sensitivity runs are represented by those involving input data and those involving changes to the

model configuration. Formal sensitivity analyses were not performed for either ASPIC or SSRA as these were considered complimentary supporting models. As such, all sensitivity analyses presented below refer specifically to the base model.

6.3.1 Sensitivity to Input Data

Several sensitivity runs were conducted to examine various effects to changes in the input data. The following is a list of these sensitivity runs. The sensitivities are run for both the Gulf and Atlantic stocks, using the notation 'bc-xx-glf' or 'bc-xx-atl'.

Run Number	Sensitivity Examined
bc-00	None (base model)
bc-01	Juvenile fishing selectivity set to 0.2
bc-02	Juvenile fishing selectivity set to 0.4
bc-03	Juvenile fishing selectivity set to 0.6
bc-04	Natural mortality as Lorenzen curve with maximum age of 2yr
bc-05	Natural mortality as constant with maximum age of 3yr
bc-06	Average Z estimate from catch-curve analysis times 0.7 (30% less)
bc-07	Average Z estimate from catch-curve analysis times 1.3 (30% greater)
bc-08	Maximum F and M set to 3.0 in the model (versus default of 4.0)
bc-09	Maximum F and M set to 5.0 in the model
bc-10	No streamflow influence on natural mortality
bc-11	Precipitation influence on natural mortality
bc-12	Precipitation influence on stock recruitment process (lagged one year)
bc-13	USGS stream flow influence on stock recruitment process (lagged one year)

The vulnerability of juveniles to fishing, also referred to as partial recruitment in similar models, is difficult to ascertain for blue crabs given their high variability in growth rates, temperature-dependent growth, and seasonal fishing effort. We used a value of 0.3 in the base model, given that crabs typically reach legal size within 7-9 mo post spawn in the Gulf, and would therefore be susceptible to fishing for 3-5 months of their first year. This derivation assumes that fishing pressure is evenly spread throughout the year. To explore the sensitivity of the estimates to this parameter choice, we included sensitivities using 0.2, 0.4, and 0.6. Although higher values are not biologically feasible if fishing pressure is evenly distributed throughout the year, these values could be obtained if effort is higher during the time frame when juveniles become legal size (e.g., late spring/early summer).

Given uncertainty in mortality estimates, we explored various options as sensitivities. First, we modeled natural mortality using a Lorenzen curve with a 2yr maximum age, where this maximum age may be more typical of females in the Gulf since they can reach their terminal molt within 1yr. Constant natural mortality across stages using the 3yr maximum age (M=1.0 for juveniles and adults) was also assessed. We also looked at the sensitivity to our average Z estimate from the length-based catch curve analyses on the fisheries independent data. For these, we increased and decreased the estimate by 30% as two separate sensitivity runs. Related to the Z estimate, which was necessary to anchor the absolute F estimates in the model, we also adjusted our estimates of the maximum F and M allowed. This would not be expected to have a large sensitivity, given that the average Z estimate should be driving the absolute estimates, but

it was explored anyways to check for any possible interactions. Finally, to assess the importance of freshwater inflow on mortality, the model was run without the relationship between mortality and streamflow, and alternatively as a function of the precipitation data.

The influence of precipitation and streamflow was also assessed on the stock-recruitment process as added sensitivities. Exploratory analyses with the model found that lack of contrast in the data leads to difficulties in independently estimating a freshwater effect on both recruitment and mortality simultaneously. Therefore, the recruitment effect was modeled as a separate set of sensitivities from the mortality effect.

6.3.2 Sensitivity to Model Configuration

Several sensitivity runs were conducted to examine various effects to changes in the model configuration. The following is a list of these sensitivity runs:

Run Number	Sensitivity Examined
bc-14	Use of Beverton-Holt stock recruit relationship
bc-15	No stock-recruit relationship (steepness=.99 for B-H)
bc-16	No effort time series

Although a Ricker stock-recruitment relationship has often been used for blue crab assessments (Chesapeake, Delaware), we explored the use of a Beverton-Holt relationship. Lack of a stock-recruitment relationship was also assessed by forcing the model to a steepness value of 0.99 (using a Beverton-Holt relationship). Finally, due to potential biases in effort data (e.g., improper recording on trip tickets), the model was run without using an effort time series.

6.4 Retrospective Analyses

Retrospective analyses were completed by running the model in a series of runs sequentially omitting years 2011 to 2007, as indicated below:

Run Number	Sensitivity Examined
bc-17	Retrospective analysis with modeling ending in 2010
bc-18	Retrospective analysis with modeling ending in 2009
bc-19	Retrospective analysis with modeling ending in 2008
bc-20	Retrospective analysis with modeling ending in 2007
bc-21	Retrospective analysis with modeling ending in 2006

6.5 Reference Point Estimation – Parameterization, Uncertainty, and Sensitivity Analysis

Following GDAR (2013), this assessment presents maximum sustainable yield (MSY) based benchmarks using a Ricker stock recruitment model with a bias correction. This approach was chosen because it conforms to the federal fisheries guidelines, was successfully implemented for the 2011 Chesapeake Bay blue crab assessment, and corresponds to those reference points provided by the supporting assessment models (ASPIC, SSRA), making direct comparisons possible. The quantities FMSY, uMSY, NMSY, and MSY were estimated by the

method of Shepherd (1982). MSY based benchmarks are commonly used in the federal management system and maximize equilibrium landings.

7.0 Outputs/Results

7.1 Goodness of Fit of Model Used

For the Gulf coast, the model fit the landings data well without any clear patterning in the standardized residuals (Figure 7.1.1). Although residual patterns were similarly not evident in either the juvenile or adult IOA fits, the model did a relatively poor job at capturing the large fluctuations in abundance, particularly the joint peaks in abundance of both juveniles and adults that occurred on some years (1998, 2003, 2006, 2010; Figure 7.1.1). This was likely due to lack of a mechanism in the model configuration that would allow for juveniles and adults to increase or decrease rapidly in abundance during the same year, given an expected cyclical lag in abundance between juveniles and adults. While the influence of freshwater inflow on mortality significantly improved the model fit, and generally corresponded with these peaks, other processes may be occurring that additionally regulate the magnitude of these fluctuations. Other relationships with freshwater inflow, such as nonlinear dynamics or interaction effects with predator abundances, may be useful to better fit these peaks in abundance.

While the Atlantic coast model did a better job than the Gulf coast at fitting the magnitude of the peaks in abundance, it did a poorer job at fitting the juvenile data, as can be seen by the strong patterning in the residuals (Figure 7.1.2). In these data, the model underestimated the juvenile abundance in the initial years (prior to 2000), but overestimated the abundance through to 2011. This resulted because recruits are a function of adults the year before, and adults did not experience the general declining trend that juveniles have experienced, particularly the large drop from 1997 through present. This is suggestive of other processes leading to declines in juvenile crabs on the Atlantic coast, as could happen due to declining recruitment habitat over time. A similar trend was found for blue crabs in the western stock of the Gulf from the GDAR 1 assessment, where juveniles appear to declining at a faster rate than adults. Identification of the mechanisms that could lead to such a trend is important to help understand regulation of these systems and the management approaches to deal with these issues.

The ASPIC surplus production model for the Gulf and Atlantic stocks provided a relatively good average fit to the standardized commercial catch rates and fishery-independent survey indices used as indicators of trends in biomass (Figures 7.1.3, 7.1.4). However, the underlying population dynamics model was unable to capture the year-to-year variability seen in the fishery-independent indices, leading to a relatively smooth transition from year-to-year.

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 for both coasts by this exploratory process (Figures 7.1.5, 7.1.6), when comparing the median of the biomass time series to the indices.

7.2 Parameter Estimates and Uncertainty Estimates

7.2.1 Abundance and Exploitation Estimates

The two-stage model parameters and their corresponding precision estimates (ADMB delta-method estimate of standard deviations, and MCMC confidence intervals) are presented in Tables 7.2.1.1 and 7.2.1.2 for the two coasts. Derived parameters (juvenile/adult abundances,

full F) and precision estimates (delta-method SDs, MCMC confidence interval) are presented in Tables 7.2.1.3 and 7.2.1.4, and Figures 7.2.1.1 and 7.2.1.2. Overall, landings in the Gulf increased substantially from 1989 to a peak of 39 million crabs in 1998, but then dropped rapidly in 2000 to an average landings of around 10-15 million crabs (Figure 7.2.1.3). This increase in landings was marked by a higher estimated proportion of juveniles caught (i.e., those individuals in late spring / early summer before their first spawning event). Fishing mortality followed a similar trend to overall landings (Figure 7.2.1.1), with an increase through to 1998, but a steady decline since then. The trend in abundances for both juveniles and adults on the Gulf coast have remained relatively stable since the start of the model time span, with an average of around 10 million adults at the start of the spawning season, and 75 million juveniles at the start of the season. The adult trend suggests a slight decreasing trend in abundance, marked by large year-to-year fluctuations, and this is additionally supported by the landings standardized catch rates (Figure 5.1.5.1). The lack of increase in abundances of juveniles and adults as fishing pressures and landings have decreased suggests forces other than fishing pressure may be currently limiting the recovery of these populations. Additional drivers (e.g., habitat degradation, drought) could be driving this lack of recovery during the last decade as fishing rates have decreased. An alternative hypothesis to fishery-driven abundances is that the yearly fishing effort is governed by environmentally-driven abundances, and therefore blue crabs would not be expected to increase with decreasing landings or effort. Instead, effort may track abundance as fishermen respond to environmentally-driven populations, where the declining nature of effort and landings is a combination of effort-reduction plans and large scale environmental degradation.

The estimated abundances for the Gulf coast from the surplus production model, ASPIC, suggest a steadily declining population since the start of the model period (1950), from the peak of landings in 1960 at nearly 50 million crabs to present (Figure 7.2.1.4). This coincides with a low estimated fishing rate (< 0.1), suggesting that the model is slowly depleting a large initial estimated biomass in order to fit the indices of abundance towards the end of the model time frame. This scenario is unlikely, given the low estimated fishing rates that do not correspond to other estimates, and does a poor job at fitting the year-to-year variability in abundances. A similar pattern was shown with the ASPIC model in Murphy et al. (2007), but with higher F estimates providing for more year-to-year variability, although still markedly lower than those estimated in the two-stage model in this assessment.

The SSRA model predicts generally minor fluctuations in a declining abundance trend through to 1980 (Figure 7.2.1.5), after which large fluctuations begin as a result of increasing effort (Figure 7.2.1.6) and initiation of the indices time series that have high year-to-year variability. The initiation of the variable indices led to large recruitment anomalies as estimated in the model, compared to the early model years when the indices data were not available. Along with the large fluctuations due to the fit to the indices, the SSRA model also estimated a large increase in abundances in the late 1980's when landings plummeted, before increasing during the mid- to late 1990's, after which they began declining again.

Landings on the Atlantic coast have undergone a steady decline since the start of the two-stage model time step (1996), from approximately 15 million crabs in 1996 to an average of 8 million crabs from 2003-2011 (Figure 7.2.1.4). Similar to the Gulf coast, the Atlantic coast adult and juvenile abundances, along with fishing effort, have remained at a similar level throughout the model time span (1996-2011; Figure 7.2.1.2). The trends suggest that the abundances and effort decreased slightly for the first half of this period (1996-2002/2003), after

which abundances increased through 2005, and then experienced another decline, while effort remained relatively constant throughout the later half of the time period (2003-2011). The standardized catch per unit effort data from the landings (Figure 5.1.5.2) shows a more consistent decline in abundance over this period, but generally these data are considered less reliable than the fisheries independent catch rates, due to the potential bias in effort reporting.

The estimated abundances from the surplus production model on the Atlantic coast were more variable than on the Gulf coast, but still relatively smooth compared to the other models (Figure 7.2.1.8). Similar to the Gulf coast, the surplus production model for the Atlantic estimated an initially high biomass at the beginning of the time frame (1950) with a steadily declining biomass until the end of the model, following the general trend in landings.

The trend from the Atlantic coast surplus production model was similar to that estimated by SSRA, but where SSRA was marked with a highly variable abundance towards the end of the model time frame due to initiation of the variable indices, which led to high estimates of recruitment anomalies during this period (Figure 7.2.1.9). The Atlantic coast did not experience the large increase in landings and effort in the mid- to late 1990's as experienced on the Gulf coast (Figure 7.2.1.10), where effort has been relatively stable since the late 1970's.

The two-stage model internally fit a stock-recruitment relationship for both coasts, with a higher steepness in the Gulf versus Atlantic coasts (Tables 7.2.1.1, 7.2.1.2; Figures 7.2.1.11, 7.2.1.12). No large-scale patterns were evident in the residuals, although the residuals do exhibit some serial autocorrelation during certain periods (e.g., 1998-2002, 2002-2005 for Gulf coast), that could correspond to periods of similar environmental conditions (e.g., multi-year drought periods).

7.2.2 Precision and Uncertainty of Parameter Estimates

Precision and uncertainty in the two-stage model were examined through both the sensitivity runs and through the MCMC analyses. While the model estimates were more uncertain for the Atlantic coast compared to the Gulf coast (Figures 7.2.1.1, 7.2.1.2), the median estimates from the uncertainty analyses differed little from the base model estimate. The MCMC analyses were run using the built-in ADMB features, for a total of 2,000,000 iterations with a thinning rate of 1000 iterations. Over this iteration time, the parameter estimates and subsequent reference points were relatively stable for both stocks (MCMC trace plots, Figures 7.2.2.1-7.2.2.4). The exception was with the Atlantic coast, where the initial abundance estimate at the start of the model experienced a primary and secondary stable region at roughly 10 and 0.1 million crabs, respectively (Figure 7.2.2.3). The secondary region with a low estimated initial abundance coincided with an increase in the estimated initial recruitment levels, but generally had no effect on other parameters or reference point estimates (Figures 7.2.2.3, 7.2.2.4).

The SSRA was run for a total of 1,000,000 iterations within the acceptance range, leading to a total of approximately 2 million iterations for both coasts, with a thinning rate of 1000 iterations. Similar to the MCMC analysis from the two-stage model, the parameter estimates across this iteration period were relatively stable when viewing the trace plots (Figures 7.2.2.5, 7.2.2.6).

7.3 Projection Estimates

No projections were attempted within any of the models, but are possible for each. Exploratory analyses with projections of the two-stage model show that blue crabs are highly resilient, and can quickly recover under ideal conditions. However, their resiliency is highly dependent on environmental conditions, which are generally not projectable into the future.

7.4 Sensitivity Analysis

All sensitivity results are presented in Tables 7.4.1 and 7.4.2 for the Gulf and Atlantic coasts, respectively. Overall, both coasts were relatively insensitive to changes in the input data and model configuration, although notable exceptions occurred, particularly with respect to the environmental influences and fit to the data (negative log-likelihood values). Despite some of these sensitivities, the estimates of MSY and stock status were relatively stable across all sensitivities, with the exception of the precipitation influence on natural mortality (bc-11-glf), where the estimated FMSY decreased and NMSY increased substantially, and led to the stock being estimated as in an overfished state in the Gulf.

7.5 Retrospective Analyses

No major patterns or biases were evident in the retrospective analysis for either abundances or fishing rates in either stock, nor in the reference points or stock status in either stock (Tables 7.4.1, 7.4.2; Figures 7.5.1, 7.5.2).

7.6 Selectivity

No selectivity estimates were made in any of the models, while the two-stage model and SSRA used input values of selectivity of 0.3 for recruits and 1.0 for adults, based on growth dynamics of crabs reaching an exploitable size within 7-9 months.

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). Following the 2011 Chesapeake blue crab assessment and the GDAR 1 blue crab assessment, we present MSY-based reference points for both targets and limits. Estimates of MSY-based reference points were made available in this assessment due to the newly-developed two-stage model's internal structure, which was not available from the CSA model used in Murphy et al (2007). As such, it was possible to compare the two-stage model directly to ASPIC and SSRA, both of which present MSY-based reference points.

For short-lived species that experience large swings in abundance, the overfished status relative to abundance can be computed as follows (Restrepo et al. 1998):

$$N_{limit} = cN_{MSY}$$
$$c = \max(1 - M, 0.5)$$

This formulation allows for the overfished limit being inversely proportional to the natural mortality rate. A default control rule (Restrepo et al. 1998) to scale the limit of overfishing to this overfished limit is as follows:

$$F_{limit} = \frac{F_{MSY}N}{cN_{MSY}} \; for\ all\ N \ \leq N_{limit}$$
$$F_{limit} = F_{MSY}\ for\ all\ N > N_{limit}$$

Similarly, N_{MSY} can be replaced with B_{MSY} for biomass-based models. Using these limits, overfishing is defined as $F/F_{limit} < 1.0$ and overfished is defined as $N/N_{limit} < 1.0$ in the current year(s). For the two-stage model, the F and N in the current years were computed as geometric means over the final 3 years.

8.2 Results

The reference point estimates from the two-stage model, both the base model estimate and the quartiles with 95% confidence intervals from the uncertainty analysis, are presented in Tables 8.2.1 and 8.2.2 for the Gulf and Atlantic coasts, respectively. The estimated MSY was 30.8 million individuals for the Gulf coast, and 12.3 million individuals for the Atlantic coast. The uncertainty analyses from the MCMC analysis found that these estimates were relatively stable and within roughly 1 million pounds of the base model estimate. When compared to the landings time series (Figures 7.2.1.3, 7.2.1.7), both coasts have experienced catches at less than the estimated MSY for the majority of the time series. These estimated values for MSY from ASPIC did not correspond well with the MSY estimates from the two-stage model for either coast (15.4 and 22.1 million crabs for the Gulf and Atlantic, respectively). SSRA performed slightly better or the Gulf coast relative to the two-stage model (35.3 million crabs), but similar was a poor match to the Atlantic coast relative to the two-stage model (23.2 million crabs).

Both coasts were found to be neither overfished nor undergoing overfishing in the two-stage model (Tables 8.2.1, 8.2.2; Figures 8.2.1-8.2.4). Phase plots are presented in Figures 8.2.1 and 8.2.2 showing the year-specific estimates of F and N (not geometric means) relative to FMSY and NMSY, where the dotted line corresponds to the overfishing and overfished limits. From the phase plots, the Gulf coast was only in an overfished/overfishing state for one year out of the model run (1996), while the Atlantic coast was neither overfished nor overfishing in any of the years.

The surplus production model found a similar result to the two-stage model for the stock status on the Gulf coast (not overfished nor overfishing; Figure 8.2.5), but found that the Atlantic coast was overfished and undergoing overfishing (Figure 8.2.6). The stochastic stock reduction analysis (SSRA) came to the same conclusions regarding stock status compared to the two-stage model, where both coasts were neither overfished nor undergoing overfishing (Figures 8.2.7, 8.2.8). While differences exist among the analyses in this current assessment, a common feature from these analyses is that blue crabs are highly resilient. In particular, the two-stage model demonstrates that freshwater inflow can have a strong influence on their dynamics, leading to large fluctuations in year-to-year abundance.

It is important to note that because blue crabs are influenced by the environment, calculation of overfished and overfishing status in particular years can be biased, if the system is not at equilibrium or average conditions. Therefore, judging the status of the stock with

reference only to fishing may not be appropriate for this species. For example, an extended drought or high predation period during the end of the time series could bias estimates of MSY and subsequent reference points, since the system during the terminal years would not be at "average" conditions. Taking the geometric mean of the last few years attempts to account for this issue, but only works if the variability among years are not serially autocorrelated during these latter years (i.e., a span of years where environmental influences are similar).

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 suggests that it is not being overfished in recent years. Although fishing mortality rates have generally been declining since the mid-1990's, the adult abundances have remained relatively stable with strong year-to-year fluctuations. These fluctuations from low to high abundance generally coincide with dry and wet years, respectively.

9.2 Research Recommendations

It is critical to future assessments that monitoring 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.

Of particular use would be development of a consistent and long-term biostatistical sampling program for commercial landings. Currently, only scattered data are available through TIP as blue crab are not a priority species, and from independent research projects (e.g., the FWRI disease study). Data from biostatistical sampling (e.g., sex and size information) will provide for implementing new length-based assessment models, often used in data-rich crustacean species.

A critical need is the development of a blue crab specific fishery-independent monitoring program focused on collecting information on spawning stock, future recruitment, sex ratios of the crabs, detailed catch per trap information and population health assessment.

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. Gulf stock total landings from NMFS per crab category (hard and soft-shell), and the corresponding landings, trips, and traps pulled from the FL MRIS trip ticket dataset.

Year	Hard Lbs	Soft Lbs	Total Lbs	Total Lbs (FL)	Trips (FL)	Traps (FL)
1950	684100	300	684400			
1951	2076600	3400	2080000			
1952	1984200	14600	1998800			
1953	3153400	2900	3156300			
1954	2902900	400	2903300			
1955	4954100	800	4954900			
1956	3728100	1400	3729500			
1957	5301600	10000	5311600			
1958	8693400	800	8694200			
1959	13895400	3200	13898600			
1960	18648300	4200	18652500			
1961	17129500	5100	17134600			
1962	10356300	200	10356500			
1963	13148400	4000	13152400			
1964	14068500	13000	14081500			
1965	20597500	11700	20609200			
1966	16547200	800	16548000			
1967	13975800	6800	13982600			
1968	9008100	0	9008100			
1969	11583800	400	11584200			
1970	14786300	300	14786600			
1971	12278700	0	12278700			
1972	10673200	100	10673300			
1973	9598500	0	9598500			
1974	10133700	100	10133800			
1975	12806500	1600	12808100			
1976	12048500	0	12048500			
1977	15832200	0	15832200			
1978	11678677	22236	11700913			
1979	11198262	9328	11207590			
1980	11275741	16866	11292607			
1981	14787653	22631	14810284			
1982	8870850	53452	8924302			
1983	9337318	35831	9373149			
1984	12912367	27563	12939930			
1985	12273006	17073	12290079			
1986	7644267	9407	7653674	7792426	23172	4953520
1987	10412930	11718	10424648	10498404	27654	5236177
1988	10385527	17257	10402784	10462466	30435	5422988
1989	8158507	38876	8197383	8438583	30365	5018056
1990	6878103	36775	6914878	7107902	25996	5056906
1991	5212938	22029	5234967	5456284	23922	3854758
1992	7618951	34681	7653632	8279883	29373	5034135
1993	8501970	21412	8523382	8638649	33619	5716788
1994	8406570	57364	8463934	8552332	40013	6371380
1995	8724825	56008	8780833	8849470	37873	6188208
1996	12414241	60673	12474914	12524026	43536	7571289
1997	9254589	66587	9321176	9330034	40262	6931567
1998	12771080	91701	12862781	12880644	40841	7442459
1999	11046665	122802	11169467	11187745	40786	6824154
2000	6412794	159850	6572644	6588100	30100	4981852
2001	4547898	98762	4646660	4654594	24070	4401740
2002	5489433	77585	5567018	5571260	26650	5010556
2003	7140725	84648	7225373	7218472	27958	5516763
2004	8007719	75445	8083164	8171465	25892	5692018
2005	7312485	57518	7370003	7401564	23798	5206611
2006	8564662	45488	8610150	8615894	23530	5107056
2007	6074386	35439	6109825	6115092	20593	4333320
2008	2627342	35754	2663096	2663869	14540	2899435
2009	3313987	50227	3364214	3365110	16062	3051610
2010	5709557	49111	5758668	5758393	21234	3949870
2011	6795718	37488	6833206	6856585	21605	3924216

Table 3.1.2. Atlantic stock total landings from NMFS per crab category (hard and soft-shell), and the corresponding landings, trips, and traps pulled from the FL MRIS trip ticket dataset.

Year	Hard Lbs	Soft Lbs	Total Lbs	Total Lbs (FL)	Trips (FL)	Traps (FL)
1950	5482400	0	5482400			
1951	6638000	0	6638000			
1952	6149200	1400	6150600			
1953	6326700	500	6327200			
1954	6927300	0	6927300			
1955	7682900	0	7682900			
1956	8049200	1500	8050700			
1957	6532700	0	6532700			
1958	7996500	0	7996500			
1959	6612600	0	6612600			
1960	6962100	300	6962400			
1961	7485600	400	7486000			
1962	7868600	200	7868800			
1963	8595200	200	8595400			
1964	6950800	2100	6952900			
1965	5963200	1000	5964200			
1966	7323000	200	7323200			
1967	9320000	600	9320600			
1968	6615300	300	6615600			
1969	5724100	100	5724200			
1970	7778500	200	7778700			
1971	9132200	0	9132200			
1972	6287500	0	6287500			
1973	3913700	0	3913700			
1974	7471700	100	7471800			
1975	4185400	400	4185800			
1976	4024000	200	4024200			
1977	3424400	200	3424600			
1978	3809500	1423	3810923			
1979	3493231	0	3493231			
1980	4602149	0	4602149			
1981	3483817	0	3483817			
1982	5393364	115	5393479			
1983	6990630	0	6990630			
1984	6736811	915	6737726			
1985	3709606	2678	3712284			
1986	3005159	374	3005533	3458670	2572904	9998
1987	7914500	2810	7917310	7924606	2796085	15217
1988	4775477	23952	4799429	4836404	3826702	16741
1989	4553920	34317	4588237	4610533	4081073	17221
1990	6968386	47387	7015773	7074624	4377816	23793
1991	4490650	58426	4549076	4611657	2789073	19350
1992	6116634	38229	6154863	6821237	2970526	20160
1993	3924317	37414	3961731	3954614	2679304	19173
1994	5333025	61376	5394401	5461366	3337518	22783
1995	3407238	49251	3456489	3481645	2516810	17811
1996	5538556	45516	5584072	5617247	3265257	20646
1997	5636640	59931	5696571	5826657	3723927	23005
1998	4490117	42476	4532593	4603148	3179371	19244
1999	4387190	27853	4415043	4607576	2778008	17320
2000	4700807	47610	4748417	4844801	2966920	17161
2001	2647036	25115	2672151	2737310	2359228	13440
2002	2206193	27244	2233437	2322293	2072756	12302
2003	1958424	29323	1987747	2079616	1877463	11267
2004	3510479	25179	3535658	3813027	2003508	12992
2005	4009703	35735	4045438	4204157	2641288	15938
2006	3103692	26139	3129831	3274545	2462376	14954
2007	4042856	19827	4062683	4258214	3010789	16296
2008	3315751	25769	3341520	3521219	2811827	15356
2009	1619431	20478	1639909	1700695	1816325	11382
2010	2527453	25054	2552507	2728497	2123896	13374
2011	3193288	32421	3225709	3663516	2453778	14603

Table 3.1.3. Licensing data for all of Florida. Due to the mobility of the blue crab fishery between both coasts, it is not possible to separate licensing data from the Gulf and Atlantic coasts.

		Sub-divisions of Endorsements					Sub-divisions of Trap Tags			
Year	Blue Crab Endorsements	VH	VS	VN	VI	Total Traps	Inshore Trap Tags	Offshore Trap Tags	Soft Shell Trap Tags	Non-Transferable Trap Tags
2011	950	700	87	47	116	251,950	193,150	36,650	16,750	5,400
2010	1,035	727	95	103	110	257,050	192,850	38,550	17,700	7,950
2009 ***	1,021	768	112	141		290,599	213,550	50,100	17,749	9,200
2008 **	1,190	832	157	182	19	822,750	450,000	299,600	54,950	18,200
2007	2,283									
2006	2,579									
2005	2,798									
2004	2,931									
2003	3,222									
2002	3,435									
2001	4,376									
2000	4,784									
1999	5,297									
1998	5,920									
1997	5,737									
1996	5,519									
1995 *	6,082									
1994	4,933									
1993	4,491									
1992	4,491									
1991	4,558									

***Net Ban**
**** Effort Management Plan**
***** Trap Tag Fee**

Table 5.1.4.1. Statistics used in the stepwise construction of the standardization model for commercial landings rates for blue crab on the Gulf coast during 1986-2011. Variables include year, ln(traps pulled), county, area fished (fishloc), and month. DF is degrees of freedom.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	430078	484938.80	1.13			
ltraps_pulled	430077	474286.40	1.10	2.20	124974.02	<.0001
county	430073	483001.90	1.12	0.40	21069.91	<.0001
year	430052	483123.10	1.12	0.37	20104.82	<.0001
month	430067	484525.00	1.13	0.08	4476.19	<.0001
fishloc	430076	484819.60	1.13	0.02	1289.73	<.0001
ltraps_pulled	430077	474286.40	1.10			
ltraps_pulled year	430051	472891.30	1.10	0.28	18616.29	<.0001
ltraps_pulled county	430072	473934.80	1.10	0.07	5178.54	<.0001
ltraps_pulled month	430066	474048.80	1.10	0.05	3084.26	<.0001
ltraps_pulled fishloc	430075	474141.50	1.10	0.03	2109.88	<.0001

Table 5.1.4.2. Statistics used in the stepwise construction of the standardization model for commercial landings rates for blue crab on the Atlantic coast during 1986-2011. Variables include year, ln(traps pulled), county, area fished (fishloc), and month. DF is degrees of freedom.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	746595	848222.10	1.14			
ltraps_pulled	746594	824395.00	1.10	2.81	270002.61	<.0001
county	746579	837201.00	1.12	1.30	118067.74	<.0001
year	746569	845515.60	1.13	0.32	28329.68	<.0001
fishloc	746593	846738.10	1.13	0.18	15458.07	<.0001
month	746584	847772.20	1.14	0.05	4617.30	<.0001
ltraps_pulled	746594	824395.00	1.10			
ltraps_pulled county	746578	820209.20	1.10	0.49	57222.15	<.0001
ltraps_pulled year	746568	822482.30	1.10	0.22	24923.50	<.0001
ltraps_pulled fishloc	746592	823500.40	1.10	0.11	11518.16	<.0001
ltraps_pulled month	746583	824015.00	1.10	0.04	4878.77	<.0001

Table 5.3.1.2.1. Gulf coast fisheries independent monitoring sampling for the three gears used in the index of abundance calculations. The 21.3-m seines were used for juveniles, while the 183-m seines and 6.1m otter trawls were combined for adults. Note: these data include all samples recorded.

	21.3-m Seines			183-m Seines			6.1-m Otter Trawls		
Year	Total Trips	Positive Trips	Total Crabs	Total Trips	Positive Trips	Total Crabs	Total Trips	Positive Trips	Total Crabs
1989	186	48	237	NA	NA	NA	161	73	688
1990	218	47	256	NA	NA	NA	190	88	437
1991	241	65	335	NA	NA	NA	193	65	260
1992	249	90	408	NA	NA	NA	184	104	431
1993	245	67	226	NA	NA	NA	182	80	452
1994	262	52	210	NA	NA	NA	192	68	397
1995	592	164	575	NA	NA	NA	460	146	738
1996	1542	414	1488	312	121	769	732	354	1836
1997	1680	388	2143	836	179	672	830	290	1231
1998	1332	502	3508	1077	432	3978	313	226	2135
1999	1404	505	3039	1414	419	2266	372	197	1694
2000	1446	430	2039	1442	281	915	414	185	747
2001	1769	500	2336	1402	245	776	669	262	1166
2002	1776	356	1161	1342	259	805	684	230	1058
2003	1852	550	2480	1344	326	939	720	271	1133
2004	2304	763	3420	1354	488	1782	899	473	2685
2005	2412	648	2224	923	293	1100	1260	598	2999
2006	2411	707	3463	924	386	2255	1260	754	4704
2007	2411	658	3948	924	292	1169	1260	648	3759
2008	2171	418	1652	924	184	387	1164	371	1442
2009	2172	377	1799	887	187	478	1163	266	975
2010	2040	536	2576	852	307	1452	1098	434	2120
2011	2039	648	3538	852	272	1394	1104	446	3055

Table 5.3.1.2.2. Atlantic coast fisheries independent monitoring sampling for the three gears used in the index of abundance calculations. The 21.3-m seines were used for juveniles, while the 183-m seines and 6.1m otter trawls were combined for adults. Note: these data include all samples recorded.

	21.3-m Seines			183-m Seines			6.1-m Otter Trawls		
Year	Total Trips	Positive Trips	Total Crabs	Total Trips	Positive Trips	Total Crabs	Total Trips	Positive Trips	Total Crabs
1990	85	6	27	NA	NA	NA	55	13	43
1991	122	20	140	NA	NA	NA	82	37	254
1992	125	18	59	NA	NA	NA	77	46	375
1993	124	15	49	NA	NA	NA	80	30	108
1994	127	7	17	NA	NA	NA	75	37	305
1995	241	17	33	NA	NA	NA	196	92	499
1996	422	18	62	NA	NA	NA	150	72	267
1997	431	21	40	372	91	239	143	63	380
1998	379	75	315	434	128	582	NA	NA	NA
1999	380	40	119	420	89	292	NA	NA	NA
2000	380	40	135	420	117	401	NA	NA	NA
2001	705	124	689	548	113	388	266	114	501
2002	839	116	497	614	129	391	383	155	597
2003	839	198	600	613	135	406	485	201	738
2004	912	252	806	614	208	730	491	280	1281
2005	1038	277	889	610	209	792	596	387	1561
2006	1123	322	1381	611	173	699	684	415	2168
2007	1173	315	1413	614	195	747	684	419	2606
2008	1172	254	855	592	150	499	684	365	1669
2009	1172	212	613	564	107	309	684	234	779
2010	1172	280	1036	564	122	399	683	288	1218
2011	1091	270	1299	564	140	411	684	388	1919

Table 5.3.2.1. Gulf stock indices of abundance (IOAs). For the recruits, the IOA was limited to 21.3m seines. For adults, IOAs were calculated separately for both gears, and using both gears combined. Although the combined IOA had an unbalanced design with years, the results were near identical to an IOA where the years were restricted to all full years (1996-2011); therefore, the full time series was used to fit the base model to maximize the length of the time series.

	Juveniles		Adults					
	21.3m Seine		183m Seine		6.1m Otter Trawl		Both Gears	
Year	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV
1989	1.00	36.66	NA	NA	2.20	38.86	2.80	37.44
1990	0.28	44.07	NA	NA	0.84	39.49	1.09	40.08
1991	1.14	28.83	NA	NA	0.58	41.64	0.79	40.65
1992	0.93	29.76	NA	NA	1.84	34.16	2.13	33.99
1993	0.79	27.79	NA	NA	0.49	44.67	0.64	44.52
1994	0.64	24.27	NA	NA	0.74	49.71	0.99	50.85
1995	0.83	13.04	NA	NA	0.43	34.60	0.60	33.49
1996	0.71	11.52	1.75	20.81	1.64	21.07	1.45	14.49
1997	0.97	11.95	0.57	20.32	0.41	31.05	0.46	16.69
1998	2.01	10.93	2.04	11.93	3.64	53.87	1.92	11.62
1999	1.30	11.38	0.84	12.82	0.88	71.74	0.79	12.20
2000	1.08	10.80	0.44	16.20	0.17	163.63	0.41	15.76
2001	0.77	11.29	0.29	18.58	0.35	50.47	0.28	17.13
2002	0.64	11.36	0.44	15.66	0.36	82.93	0.39	15.20
2003	1.78	9.16	0.82	13.12	0.32	89.46	0.67	12.76
2004	1.11	9.32	1.11	11.73	1.77	23.05	1.14	10.34
2005	0.85	9.36	1.22	13.74	0.88	17.34	1.02	10.67
2006	1.60	9.17	2.38	12.47	2.65	13.01	2.30	9.45
2007	0.83	10.13	0.77	16.00	0.95	16.39	0.74	11.50
2008	0.57	10.67	0.22	25.84	0.22	35.68	0.19	20.75
2009	0.73	10.62	0.43	18.79	0.06	67.72	0.24	17.80
2010	1.67	9.82	1.59	13.52	0.92	19.26	1.17	11.01
2011	0.77	14.92	1.08	14.52	0.66	19.51	0.78	11.83

Table 5.3.2.2. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for juveniles (positives, lognormal link) on the Gulf coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	5058	6731.300	1.331			
bayzone	5035	5350.700	1.063	20.147	1161.253	<0.0001
gr	5055	5401.940	1.069	19.701	1113.032	<0.0001
salinity	5046	5934.300	1.176	11.631	624.813	<0.0001
bot	5029	6272.860	1.247	6.273	311.326	<0.0001
year	5035	6394.620	1.270	4.568	259.589	<0.0001
bveg	5057	6457.180	1.277	4.053	210.336	<0.0001
shore	3458	4503.540	1.302	2.139	212.786	<0.0001
depth	5054	6677.270	1.321	0.724	39.405	<0.0001
temperature	5052	6674.980	1.321	0.719	40.689	<0.0001
month	5053	6693.530	1.325	0.463	28.472	<0.0001
bayzone	5035	5350.700	1.063			
bayzone gr	5032	5095.960	1.013	3.756	246.770	<0.0001
bayzone year	5012	5179.590	1.033	2.199	164.422	<0.0001
bayzone bot	5006	5241.420	1.047	1.178	68.888	<0.0001
bayzone salinity	5023	5317.010	1.059	0.313	18.155	<0.0001
bayzone month	5030	5329.400	1.060	0.239	20.173	0.0012
bayzone depth	5031	5346.070	1.063	0.006	3.823	0.0506
bayzone bveg	5034	5350.690	1.063	-0.016	0.002	0.9628
bayzone temperature	5029	5345.890	1.063	-0.023	2.022	0.1550
bayzone shore	3435	3892.740	1.133	-5.302	17.643	<0.0001
bayzone gr	5032	5095.960	1.013			
bayzone gr year	5009	4947.610	0.988	1.876	149.460	<0.0001
bayzone gr bot	5003	5001.700	1.000	0.975	56.357	<0.0001
bayzone gr month	5027	5076.280	1.010	0.219	19.581	0.0015
bayzone gr salinity	5020	5073.480	1.011	0.155	9.534	0.0020
bayzone gr depth	5028	5084.400	1.011	0.112	10.877	0.0010
bayzone gr bveg	5031	5095.940	1.013	-0.015	0.018	0.8946
bayzone gr temperature	5026	5092.810	1.013	-0.044	0.770	0.3802
bayzone gr shore	3432	3708.880	1.081	-5.107	3.814	0.0508
bayzone gr year	5009	4947.610	0.988			
bayzone gr year bot	4980	4851.620	0.974	1.016	58.882	<0.0001
bayzone gr year salinity	4997	4919.230	0.984	0.249	18.158	<0.0001
bayzone gr year month	5004	4929.990	0.985	0.191	18.055	0.0029
bayzone gr year depth	5005	4934.050	0.986	0.144	13.102	0.0003
bayzone gr year bveg	5008	4947.570	0.988	-0.014	0.042	0.8369
bayzone gr year temperature	5003	4944.160	0.988	-0.037	0.789	0.3743
bayzone gr year shore	3409	3614.710	1.060	-5.455	5.184	0.0228
bayzone gr year bot	4980	4851.620	0.974			
bayzone gr year bot month	4975	4833.690	0.972	0.197	18.635	0.0022
bayzone gr year bot salinity	4968	4828.050	0.972	0.180	13.523	0.0002
bayzone gr year bot depth	4976	4836.590	0.972	0.168	15.005	0.0001
bayzone gr year bot bveg	4979	4851.620	0.974	-0.015	0.001	0.9733
bayzone gr year bot temperature	4974	4847.590	0.975	-0.027	1.632	0.2014
bayzone gr year bot shore	3380	3511.480	1.039	-4.860	0.000	0.9927

Table 5.3.2.3. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for juveniles (presence/absence, binomial link) on the Gulf coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	16371	20245.640	1.237			
bayzone	16348	18972.530	1.161	6.156	1273.114	<0.0001
salinity	16340	19536.820	1.196	3.318	668.937	<0.0001
bot	16334	19581.650	1.199	3.061	592.227	<0.0001
gr	16368	19623.730	1.199	3.054	621.911	<0.0001
year	16348	19896.990	1.217	1.584	348.650	<0.0001
bveg	16370	20038.730	1.224	1.016	206.915	<0.0001
month	16366	20107.460	1.229	0.652	138.177	<0.0001
temperature	16357	20103.280	1.229	0.618	124.701	<0.0001
depth	16364	20163.800	1.232	0.362	72.575	<0.0001
shore	9890	12298.910	1.244	-0.557	507.445	<0.0001
bayzone	16348	18972.530	1.161			
bayzone year	16325	18576.560	1.138	1.829	395.969	<0.0001
bayzone gr	16345	18611.700	1.139	1.768	360.826	<0.0001
bayzone depth	16341	18719.190	1.146	1.213	242.294	<0.0001
bayzone bot	16311	18717.040	1.148	1.054	209.784	<0.0001
bayzone month	16343	18843.700	1.153	0.609	128.830	<0.0001
bayzone salinity	16317	18844.120	1.155	0.458	84.718	<0.0001
bayzone temperature	16334	18928.840	1.159	0.136	23.613	<0.0001
bayzone bveg	16347	18966.990	1.160	0.022	5.539	0.0186
bayzone shore	9867	11764.260	1.192	-2.567	87.945	<0.0001
bayzone year	16325	18576.560	1.138			
bayzone year gr	16322	18198.450	1.115	1.856	378.110	<0.0001
bayzone year depth	16318	18335.220	1.124	1.156	231.432	<0.0001
bayzone year bot	16288	18335.700	1.126	0.987	194.147	<0.0001
bayzone year month	16320	18455.680	1.131	0.571	120.881	<0.0001
bayzone year salinity	16294	18457.490	1.133	0.416	77.621	<0.0001
bayzone year temperature	16311	18521.470	1.136	0.194	35.404	<0.0001
bayzone year bveg	16324	18570.920	1.138	0.022	5.635	0.0176
bayzone year shore	9844	11576.750	1.176	-3.081	90.508	<0.0001
bayzone year gr	16322	18198.450	1.115			
bayzone year gr depth	16315	18014.740	1.104	0.872	170.773	<0.0001
bayzone year gr bot	16285	18017.800	1.106	0.692	135.280	<0.0001
bayzone year gr month	16317	18069.170	1.107	0.613	129.281	<0.0001
bayzone year gr salinity	16291	18077.510	1.110	0.429	76.713	<0.0001
bayzone year gr temperature	16308	18133.670	1.112	0.244	42.702	<0.0001
bayzone year gr bveg	16321	18198.070	1.115	-0.004	0.374	0.5407
bayzone year gr shore	9841	11395.310	1.158	-3.475	33.933	<0.0001

Table 5.3.2.4. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for adults (positives, lognormal link) on the Gulf coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	2164	1564.450	0.723			
gr	2162	1157.450	0.535	25.947	652.344	<0.0001
depth	2157	1283.310	0.595	17.704	401.044	<0.0001
year	2142	1406.060	0.656	9.201	231.094	<0.0001
bveg	2163	1482.840	0.686	5.173	115.986	<0.0001
bayzone	2150	1512.000	0.703	2.723	73.831	<0.0001
bot	2155	1533.730	0.712	1.554	33.854	<0.0001
temperature	2156	1539.830	0.714	1.208	4.565	0.0326
salinity	2153	1539.530	0.715	1.090	0.577	0.4473
month	2159	1557.190	0.721	0.233	10.063	0.0735
shore	1365	986.440	0.723	0.038	65.667	<0.0001
gr	2162	1157.450	0.535			
gr year	2140	1097.480	0.513	3.115	115.191	<0.0001
gr salinity	2151	1133.270	0.527	1.176	10.052	0.0015
gr temperature	2154	1136.950	0.528	1.042	11.008	0.0009
gr bayzone	2148	1134.350	0.528	1.005	43.649	<0.0001
gr depth	2155	1141.220	0.530	0.801	4.242	0.0394
gr month	2157	1150.040	0.533	0.304	13.913	0.0162
gr bot	2153	1148.220	0.533	0.284	12.581	0.0004
gr bveg	2161	1157.060	0.535	-0.010	0.722	0.3955
gr shore	1363	768.060	0.564	-3.893	1.728	0.1887
gr year	2140	1097.480	0.513			
gr year salinity	2129	1073.510	0.504	1.190	9.667	0.0019
gr year bayzone	2126	1074.640	0.505	1.019	45.525	<0.0001
gr year depth	2133	1081.820	0.507	0.783	4.550	0.0329
gr year temperature	2132	1082.110	0.508	0.731	3.184	0.0744
gr year bot	2131	1088.070	0.511	0.311	14.688	0.0001
gr year bveg	2139	1096.130	0.512	0.054	2.652	0.1034
gr year month	2135	1094.780	0.513	0.008	5.324	0.3777
gr year shore	1341	717.860	0.535	-3.109	1.539	0.2148
gr year salinity	2129	1073.510	0.504			
gr year salinity bayzone	2115	1054.090	0.498	0.809	39.347	0.0003
gr year salinity bot	2120	1065.930	0.503	0.199	11.024	0.0009
gr year salinity depth	2128	1070.540	0.503	0.161	5.986	0.0144
gr year salinity temperature	2127	1071.340	0.504	0.076	3.529	0.0603
gr year salinity month	2124	1070.960	0.504	0.002	5.136	0.3995
gr year salinity bveg	2128	1073.000	0.504	0.000	1.023	0.3117
gr year salinity shore	1331	701.980	0.527	-3.205	0.838	0.3598

Table 5.3.2.5. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for adults (presence/absence, binomial link) on the Gulf coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	12918	11679.610	0.904			
year	12896	10955.020	0.849	6.044	724.596	<0.0001
bayzone	12904	11452.650	0.888	1.837	226.961	<0.0001
gr	12916	11532.050	0.893	1.248	147.561	<0.0001
salinity	12883	11577.540	0.899	0.605	57.528	<0.0001
depth	12900	11618.630	0.901	0.383	35.508	<0.0001
temperature	12898	11638.480	0.902	0.198	11.715	0.0006
month	12913	11656.720	0.903	0.157	22.891	0.0004
bveg	12916	11660.990	0.903	0.144	18.254	<0.0001
shore	8119	7338.960	0.904	0.023	22.354	<0.0001
bot	12854	11629.470	0.905	-0.066	1.387	0.2389
year	12896	10955.020	0.849			
year bayzone	12882	10745.970	0.834	1.693	209.052	<0.0001
year gr	12894	10823.970	0.839	1.110	131.046	<0.0001
year depth	12878	10882.080	0.845	0.495	52.039	<0.0001
year salinity	12861	10883.730	0.846	0.357	31.227	<0.0001
year month	12891	10927.880	0.848	0.196	27.137	<0.0001
year temperature	12876	10919.740	0.848	0.157	11.758	0.0006
year bveg	12894	10939.330	0.848	0.120	15.548	<0.0001
year bot	12832	10904.500	0.850	-0.033	1.741	0.1870
year shore	8097	6906.760	0.853	-0.389	24.483	<0.0001
year bayzone	12882	10745.970	0.834			
year bayzone gr	12880	10616.430	0.824	1.098	129.531	<0.0001
year bayzone depth	12864	10682.310	0.830	0.418	45.678	<0.0001
year bayzone bveg	12880	10714.250	0.832	0.258	31.579	<0.0001
year bayzone month	12877	10717.620	0.832	0.208	28.345	<0.0001
year bayzone temperature	12862	10709.280	0.833	0.172	16.317	<0.0001
year bayzone salinity	12847	10705.680	0.833	0.095	6.479	0.0109
year bayzone bot	12818	10699.240	0.835	-0.057	0.063	0.8022
year bayzone shore	8083	6750.230	0.835	-0.103	42.848	<0.0001
year bayzone gr	12880	10616.430	0.824			
year bayzone gr month	12875	10588.540	0.822	0.204	27.894	<0.0001
year bayzone gr temperature	12860	10584.360	0.823	0.134	11.791	0.0006
year bayzone gr depth	12862	10594.000	0.824	0.065	4.694	0.0303
year bayzone gr salinity	12845	10582.130	0.824	0.047	0.535	0.4647
year bayzone gr bveg	12878	10616.340	0.824	-0.013	0.001	0.9773
year bayzone gr bot	12816	10569.920	0.825	-0.054	0.252	0.6158
year bayzone gr shore	8081	6669.780	0.825	-0.123	2.824	0.0929

Table 5.3.2.6. Atlanic stock indices of abundance (IOAs). For the recruits, the IOA was limited to 21.3m seines. For adults, IOAs were calculated separately for 183m seines and 183m seines + 6.1m otter trawls. Note: both the combined gears and the 6.1m otter trawl from 1990-2011 failed to converge, and as such only the time period from 1997-2011 is presented.

	Recruit		Adult			
	21.3m Seine		183m Seine		Both Gears	
Year	CPUE	CV	CPUE	CV	CPUE	CV
1996	1.70	85.98	NA	NA	NA	NA
1997	3.01	34.90	0.72	28.84	1.05	20.46
1998	1.12	35.63	1.62	19.06	1.61	18.74
1999	1.41	37.33	0.51	26.55	0.54	26.36
2000	1.20	33.49	1.40	19.95	1.43	19.56
2001	0.44	20.56	0.48	22.48	0.60	15.48
2002	0.22	22.52	0.46	20.79	0.41	16.42
2003	1.24	16.52	0.57	20.16	0.36	16.65
2004	0.55	16.82	1.27	15.37	1.36	11.28
2005	0.79	14.80	1.97	14.90	1.43	11.27
2006	0.84	13.94	1.45	16.02	1.42	11.29
2007	0.76	13.79	1.16	16.25	1.25	11.72
2008	0.42	17.10	0.84	18.39	1.05	12.08
2009	0.35	16.82	0.60	21.00	0.65	13.81
2010	0.96	14.39	0.92	18.89	0.80	13.36
2011	1.01	21.32	1.04	17.57	1.03	12.49

Table 5.3.2.7. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for juveniles (positives, lognormal link) on the Atlantic coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	1232	1300.310	1.055			
bayzone	1222	1006.530	0.824	21.960	315.766	<0.0001
gr	1229	1105.590	0.900	14.767	200.013	<0.0001
bveg	1231	1172.120	0.952	9.785	127.970	<0.0001
year	1216	1226.150	1.008	4.463	72.407	<0.0001
bot	1231	1249.820	1.015	3.804	48.826	<0.0001
shore	1010	1042.820	1.032	2.174	40.790	<0.0001
month	1227	1294.520	1.055	0.039	5.499	0.3580
salinity	1229	1297.720	1.056	-0.045	2.080	0.1493
depth	1229	1299.470	1.057	-0.179	0.424	0.5150
temperature	1229	1299.820	1.058	-0.206	0.092	0.7616
bayzone	1222	1006.530	0.824			
bayzone year	1206	950.630	0.788	3.356	70.451	<0.0001
bayzone bot	1221	974.670	0.798	2.408	39.656	<0.0001
bayzone depth	1219	985.240	0.808	1.463	26.029	<0.0001
bayzone bveg	1221	1006.310	0.824	-0.048	0.259	0.6111
bayzone temperature	1219	1005.100	0.825	-0.081	1.454	0.2279
bayzone gr	1220	1006.080	0.825	-0.093	0.544	0.7620
bayzone salinity	1219	1005.550	0.825	-0.117	0.901	0.3425
bayzone month	1217	1005.050	0.826	-0.206	1.812	0.8745
bayzone shore	1000	887.070	0.887	-6.007	0.473	0.4917
bayzone year	1206	950.630	0.788			
bayzone year bot	1205	924.120	0.767	2.022	34.867	<0.0001
bayzone year depth	1203	929.700	0.773	1.462	26.897	<0.0001
bayzone year bveg	1205	950.190	0.789	-0.028	0.565	0.4521
bayzone year gr	1204	949.630	0.789	-0.046	1.294	0.5236
bayzone year temperature	1203	949.680	0.789	-0.112	0.715	0.3979
bayzone year salinity	1203	950.180	0.790	-0.151	0.065	0.7987
bayzone year month	1201	948.710	0.790	-0.159	2.494	0.7774
bayzone year shore	984	828.850	0.842	-5.124	0.676	0.4108
bayzone year bot	1205	924.120	0.767			
bayzone year bot depth	1202	901.480	0.750	1.603	29.840	<0.0001
bayzone year bot gr	1203	922.860	0.767	-0.022	1.682	0.4313
bayzone year bot bveg	1204	924.100	0.768	-0.059	0.024	0.8770
bayzone year bot temperature	1202	923.130	0.768	-0.103	0.622	0.4305
bayzone year bot salinity	1202	923.420	0.768	-0.126	0.242	0.6226
bayzone year bot month	1200	922.400	0.769	-0.167	2.299	0.8063
bayzone year bot shore	983	804.630	0.819	-4.893	0.401	0.5264
bayzone year bot depth	1202	901.480	0.750			
bayzone year bot depth temperature	1201	900.170	0.750	0.044	1.788	0.1812
bayzone year bot depth bveg	1201	901.290	0.750	-0.044	0.264	0.6072
bayzone year bot depth salinity	1201	901.390	0.751	-0.052	0.126	0.7228
bayzone year bot depth gr	1200	900.660	0.751	-0.054	1.116	0.5724
bayzone year bot depth month	1197	899.510	0.751	-0.141	2.692	0.7474
bayzone year bot depth shore	981	785.900	0.801	-4.845	0.273	0.6015

Table 5.3.2.8. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for juveniles (presence/absence, binomial link) on the Atlantic coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	6014	6102.090	1.015			
bayzone	6004	5371.640	0.895	11.824	730.452	<0.0001
gr	6011	5777.840	0.961	5.267	324.253	<0.0001
bveg	6013	5899.850	0.981	3.298	202.238	<0.0001
bot	6012	5912.150	0.983	3.081	189.483	<0.0001
year	5998	5955.950	0.993	2.135	146.139	<0.0001
shore	4736	4785.380	1.010	0.416	129.606	<0.0001
temperature	6011	6094.250	1.014	0.079	1.496	0.2212
salinity	6011	6094.840	1.014	0.069	0.905	0.3414
month	6009	6093.630	1.014	0.056	8.460	0.1327
depth	6011	6095.730	1.014	0.054	0.017	0.8955
bayzone	6004	5371.640	0.895			
bayzone year	5988	5237.500	0.875	1.972	134.140	<0.0001
bayzone depth	6001	5280.530	0.880	1.452	85.427	<0.0001
bayzone bot	6002	5324.710	0.887	0.741	46.894	<0.0001
bayzone gr	6002	5360.090	0.893	0.160	11.553	0.0031
bayzone month	5999	5362.000	0.894	0.085	9.637	0.0862
bayzone salinity	6001	5365.000	0.894	0.065	0.961	0.3271
bayzone temperature	6001	5365.250	0.894	0.061	0.708	0.4000
bayzone bveg	6003	5369.170	0.894	0.026	2.466	0.1163
bayzone shore	4726	4283.690	0.906	-1.156	3.564	0.0590
bayzone year	5988	5237.500	0.875			
bayzone year depth	5985	5142.800	0.859	1.516	89.687	<0.0001
bayzone year bot	5986	5187.050	0.867	0.802	50.426	<0.0001
bayzone year gr	5986	5225.250	0.873	0.173	12.252	0.0022
bayzone year month	5983	5227.860	0.874	0.087	9.640	0.0861
bayzone year temperature	5985	5232.340	0.874	0.042	0.148	0.7007
bayzone year salinity	5985	5232.480	0.874	0.039	0.005	0.9419
bayzone year bveg	5987	5235.800	0.875	0.014	1.701	0.1921
bayzone year shore	4710	4154.230	0.882	-0.723	3.567	0.0589
bayzone year depth	5985	5142.800	0.859			
bayzone year depth bot	5983	5082.050	0.849	0.972	60.729	<0.0001
bayzone year depth gr	5983	5136.210	0.858	0.080	6.585	0.0372
bayzone year depth month	5980	5137.310	0.859	0.020	5.487	0.3594
bayzone year depth temperature	5984	5140.820	0.859	0.018	1.978	0.1596
bayzone year depth bveg	5984	5142.420	0.859	-0.008	0.375	0.5405
bayzone year depth salinity	5984	5142.690	0.859	-0.012	0.105	0.7463
bayzone year depth shore	4708	4058.220	0.862	-0.266	4.790	0.0286

Table 5.3.2.9. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for adults (positives, lognormal link) on the Atlantic coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	1600	2098.560	1.312			
gr	1599	799.120	0.500	61.897	1545.752	<0.0001
depth	1597	1525.850	0.955	27.154	508.004	<0.0001
bayzone	1590	1678.640	1.056	19.507	357.455	<0.0001
bot	1599	1719.040	1.075	18.034	319.376	<0.0001
bveg	1599	1737.400	1.087	17.158	302.369	<0.0001
year	1586	1918.800	1.210	7.759	143.371	<0.0001
salinity	1594	2064.520	1.295	1.252	21.863	<0.0001
temperature	1596	2081.680	1.304	0.556	10.914	0.0010
shore	1258	1642.240	1.305	0.470	7.348	0.0067
month	1595	2088.850	1.310	0.151	7.426	0.1908
gr	1599	799.120	0.500			
gr shore	1257	615.910	0.490	0.746	2.289	0.1303
gr year	1585	778.530	0.491	0.654	41.795	0.0001
gr bayzone	1589	783.020	0.493	0.533	32.590	0.0003
gr salinity	1593	790.680	0.496	0.261	4.010	0.0452
gr bveg	1598	795.660	0.498	0.142	6.965	0.0083
gr month	1594	793.810	0.498	0.134	10.674	0.0582
gr bot	1598	799.020	0.500	-0.019	0.217	0.6412
gr temperature	1595	797.960	0.500	-0.040	1.080	0.2987
gr depth	1596	798.520	0.500	-0.043	0.002	0.9630

Table 5.3.2.10. Statistics used in the stepwise construction of the standardization model for fisheries independent landings data for adults (presence/absence, binomial link) on the Atlantic coast.

Factor	DF	deviance	dev/DF	%Reduction	ChiSq	P(ChiSq)
	6707	7372.660	1.099			
bayzone	6697	7066.880	1.055	4.004	305.775	<0.0001
year	6693	7164.950	1.071	2.614	207.713	<0.0001
bot	6700	7254.400	1.083	1.501	114.984	<0.0001
bveg	6706	7285.450	1.086	1.168	87.214	<0.0001
gr	6706	7310.570	1.090	0.827	62.087	<0.0001
month	6702	7338.350	1.095	0.391	34.310	<0.0001
depth	6696	7337.030	1.096	0.320	25.540	<0.0001
salinity	6689	7335.370	1.097	0.238	16.413	<0.0001
temperature	6695	7352.420	1.098	0.096	7.281	0.0070
shore	5210	5755.480	1.105	-0.496	9.916	0.0016
bayzone	6697	7066.880	1.055			
bayzone year	6683	6856.390	1.026	2.664	210.499	<0.0001
bayzone bot	6690	7022.350	1.050	0.505	40.457	<0.0001
bayzone month	6692	7032.670	1.051	0.393	34.217	<0.0001
bayzone temperature	6685	7036.930	1.053	0.235	16.783	<0.0001
bayzone salinity	6679	7037.960	1.054	0.135	8.600	0.0034
bayzone gr	6696	7064.100	1.055	0.024	2.788	0.0950
bayzone depth	6686	7054.100	1.055	0.016	2.162	0.1415
bayzone bveg	6696	7066.660	1.055	-0.011	0.221	0.6381
bayzone shore	5200	5528.070	1.063	-0.715	0.742	0.3889
bayzone year	6683	6856.390	1.026			
bayzone year bot	6676	6806.350	1.020	0.584	46.289	<0.0001
bayzone year month	6678	6819.300	1.021	0.435	37.083	<0.0001
bayzone year temperature	6671	6818.090	1.022	0.354	25.793	<0.0001
bayzone year salinity	6665	6831.080	1.025	0.093	5.980	0.0145
bayzone year depth	6672	6843.330	1.026	0.024	2.391	0.1220
bayzone year gr	6682	6853.990	1.026	0.019	2.399	0.1214
bayzone year bveg	6682	6855.520	1.026	-0.002	0.870	0.3510
bayzone year shore	5186	5353.650	1.032	-0.581	0.325	0.5687

Table 5.5.1. Scaled environmental anomalies relative to the mean for coast-specific streamflow and state-wide precipitation.

Year	Gulf Streamflow	Atlantic Streamflow	Florida Precipitation
1980	-0.1188	-1.1440	-0.6628
1981	-1.3939	-1.5607	-1.4328
1982	0.2952	0.5595	1.1402
1983	1.5825	2.0926	1.6749
1984	0.4123	1.1449	-0.6570
1985	-0.4421	0.0066	-0.1456
1986	-0.2201	-0.2766	-0.0497
1987	0.7806	-0.2735	0.0012
1988	0.0507	-0.4871	-0.0671
1989	-0.1138	-1.3360	-0.6308
1990	-0.7591	-1.4273	-1.6275
1991	0.7456	0.6214	1.4148
1992	0.0709	-0.1178	0.4879
1993	-0.0942	-0.0744	-0.5175
1994	1.3011	1.2408	1.7533
1995	1.1351	1.4324	0.9775
1996	0.0447	0.5172	0.1450
1997	0.5258	0.6078	1.1475
1998	1.9786	1.5618	0.4952
1999	-0.8773	-0.0517	-0.5248
2000	-1.7860	-1.0764	-1.6812
2001	-0.9448	-0.3015	-0.0250
2002	-0.5821	0.1205	0.6913
2003	1.6394	0.1040	0.9267
2004	0.6286	0.2865	0.6521
2005	1.3119	1.9936	1.1649
2006	-1.1810	-0.9055	-1.7582
2007	-1.6482	-1.4030	-1.3834
2008	-0.8477	-0.4591	0.0520
2009	-0.0012	0.1406	0.1755
2010	0.0130	-0.3002	-0.8052
2011	-1.5056	-1.2352	-0.9316

Table 7.2.1.1. Gulf stock parameter estimates from the base run. Abundance estimates are in millions of individuals. The first two columns are from the ADMB base model fit and delta-method calculation of error, while the last two columns are from the MCMC runs. Note: because effort was fixed at 1.0 for the base model run, the initial q estimate is equivalent to the initial F estimate.

Parameter	Base Estimate	SD	MCMC Median	MCMC 95% CI
InitialN	16.00	2.81	15.94	11.02-21.22
InitialR	27.28	6.94	27.70	16.06-41.57
InitialF	1.66	0.14	1.64	1.39-1.94
S0	13.41	3.42	13.20	9.21-20.55
h	0.99	0.22	1.01	0.75-1.62

Table 7.2.1.2. Atlantic stock parameter estimates from the base run. Abundance estimates are in millions of individuals. The first two columns are from the ADMB base model fit and delta-method calculation of error, while the last two columns are from the MCMC runs. Note: because effort was fixed at 1.0 for the base model run, the initial q estimate is equivalent to the initial F estimate.

Parameter	Base Estimate	SD	MCMC Median	MCMC 95% CI
InitialN	11.51	4.78	8.10	0.04-16.66
InitialR	39.08	8.36	42.65	27.81-64.16
InitialF	1.20	0.22	1.31	0.99-1.74
S0	7.96	2.83	7.71	5.07-13.1
h	0.73	0.30	0.74	0.51-1.35

Table 7.2.1.3. Gulf stock estimated abundances (millions of individuals) at the start of the model year for juveniles and adults, and the estimate full F for the base model run, along with the MCMC median and 95% confidence intervals.

	Juvenile Abundance			Adult Abundance			Fishing Rate (F)		
Year	Base Estimate	MCMC Median	MCMC 95% CI	Best Estimate	MCMC Median	MCMC 95% CI	Best Estimate	MCMC Median	MCMC 95% CI
1989	27.28	27.70	16-42	16.00	15.94	11-21	1.48	1.46	1.24-1.73
1990	49.52	49.69	38-64	8.23	8.42	6-12	1.53	1.51	1.21-1.91
1991	65.09	65.64	53-81	7.65	7.74	5-11	1.42	1.41	1.13-1.75
1992	34.70	35.08	26-46	13.53	13.71	10-18	1.72	1.69	1.34-2.16
1993	71.06	71.66	56-90	10.38	10.51	7-15	2.02	2.00	1.58-2.52
1994	36.13	36.33	29-44	6.85	6.99	5-10	2.16	2.14	1.72-2.65
1995	44.90	44.98	37-54	11.40	11.50	8-15	2.03	2.00	1.62-2.49
1996	57.76	57.86	50-67	13.84	14.01	11-18	2.97	2.94	2.4-3.56
1997	41.41	41.76	36-48	5.07	5.13	4-7	1.99	1.98	1.63-2.38
1998	89.92	90.25	79-104	16.76	16.90	13-21	2.66	2.64	2.14-3.2
1999	86.51	86.53	71-105	9.68	9.82	7-13	1.65	1.64	1.32-2.01
2000	99.77	99.70	79-127	5.66	5.75	4-7	1.33	1.31	1.06-1.61
2001	61.16	61.32	51-74	3.87	3.93	3-5	1.62	1.61	1.32-1.95
2002	32.67	32.99	29-38	4.84	4.92	4-6	1.99	1.96	1.61-2.39
2003	51.60	52.08	45-60	7.35	7.47	6-9	1.94	1.91	1.57-2.33
2004	35.60	35.89	31-42	14.00	14.24	11-18	1.58	1.56	1.25-1.94
2005	53.95	54.07	47-63	13.94	14.05	11-18	1.26	1.25	1.01-1.53
2006	130.56	130.14	106-160	16.12	16.15	13-20	1.26	1.25	1.03-1.52
2007	68.67	68.44	55-86	7.62	7.75	6-10	1.06	1.05	0.86-1.29
2008	36.23	36.32	30-44	3.89	3.93	3-5	1.21	1.20	0.97-1.47
2009	35.08	35.25	30-42	4.74	4.80	4-6	1.16	1.14	0.94-1.4
2010	114.80	115.08	95-140	11.89	11.97	10-15	1.26	1.24	1.04-1.49
2011	114.85	114.18	90-146	8.81	8.94	7-11	1.02	1.01	0.84-1.21

Table 7.2.1.4. Atlantic stock estimated abundances (millions of individuals) at the start of the model year for juveniles and adults, and the estimate full F for the base model run, along with the MCMC median and 95% confidence intervals.

	Juvenile Abundance			Adult Abundance			Fishing Rate (F)		
Year	Base Estimate	MCMC Median	MCMC 95% CI	Best Estimate	MCMC Median	MCMC 95% CI	Best Estimate	MCMC Median	MCMC 95% CI
1996	39.30	42.65	28-64	11.37	8.10	0-17	1.54	1.67	1.25-2.21
1997	42.71	39.15	28-56	7.56	7.58	5-11	1.31	1.41	1.02-1.96
1998	31.70	30.05	22-40	10.99	9.82	7-14	1.22	1.32	0.96-1.85
1999	53.73	50.40	39-66	6.44	5.89	4-9	1.29	1.41	1.02-1.97
2000	35.04	32.34	23-44	11.05	9.93	7-15	1.15	1.23	0.92-1.63
2001	20.18	19.55	15-25	6.27	5.65	4-8	1.07	1.16	0.86-1.6
2002	13.33	12.98	10-17	5.06	4.64	3-7	1.07	1.17	0.84-1.62
2003	49.22	46.31	36-60	3.92	3.53	2-5	0.76	0.82	0.61-1.09
2004	30.47	30.10	24-37	10.81	9.92	7-14	1.01	1.09	0.81-1.48
2005	30.64	29.69	23-39	9.34	8.53	6-12	0.89	0.97	0.71-1.35
2006	42.62	39.73	30-52	10.01	9.00	6-13	1.02	1.09	0.82-1.44
2007	42.03	39.44	30-51	8.27	7.56	5-11	1.35	1.44	1.11-1.86
2008	18.83	18.11	14-23	7.20	6.57	5-9	0.87	0.96	0.7-1.33
2009	20.95	20.22	16-26	5.59	5.07	3-7	0.87	0.95	0.7-1.32
2010	42.86	39.95	30-53	5.95	5.43	4-8	0.98	1.05	0.79-1.4
2011	43.46	40.83	31-53	8.21	7.47	5-11	1.13	1.21	0.91-1.61

Table 7.4.1. Gulf stock sensitivity runs and retrospective analyses. F/FLim and N/NLim refer to the current status of the stock for each run, where red values for F/FLim (>1) represent current overfishing and red values for N/NLim (<1) represent overfished.

Run #	Run	negLL	MSY	FMSY	NMSY	F/FLim	N/NLim
bc-00-glf	**Base Model**	56.78	30.79	2.72	8.96	0.44	1.77
bc-01-glf	s=0.2	61.18	32.57	3.59	10.64	0.38	1.86
bc-02-glf	s=0.4	57.26	29.48	2.22	7.94	0.50	1.67
bc-03-glf	s=0.6	63.36	27.99	1.67	6.72	0.57	1.53
bc-04-glf	M={1.78, 1.22}	56.89	31.52	2.47	8.02	0.40	1.95
bc-05-glf	M={1, 1}	57.69	31.98	2.80	10.37	0.42	1.76
bc-06-glf	Average Z*0.7	56.37	35.17	2.17	13.67	0.34	2.01
bc-07-glf	Average Z*1.3	63.35	28.86	3.13	6.91	0.53	1.57
bc-08-glf	Max F/M=3	59.71	30.19	2.77	8.57	0.45	1.76
bc-09-glf	Max F/M=5	55.25	31.43	2.65	9.47	0.43	1.79
bc-10-glf	No Environment	141.74	21.82	2.93	5.74	0.57	2.22
bc-11-glf	Precipitation on M	119.51	29.35	1.44	18.42	0.97	0.90
bc-12-glf	Precipitation on R	139.37	21.40	2.76	6.10	0.60	2.08
bc-13-glf	Streamflow on R	138.34	25.48	4.13	3.98	0.40	3.19
bc-14-glf	Beverton -Holt	56.71	28.92	2.70	8.50	0.45	1.87
bc-15-glf	h=0.99	57.82	***NA***	***NA***	***NA***	***NA***	***NA***
bc-16-glf	No Effort	51.35	36.31	3.19	8.47	0.36	1.73
bc-17-glf	Retro 2010	60.98	28.77	2.51	9.31	0.44	1.39
bc-18-glf	Retro 2009	55.15	28.34	2.59	8.80	0.43	1.20
bc-19-glf	Retro 2008	53.48	29.67	2.89	7.95	0.41	1.95
bc-20-glf	Retro 2007	50.67	28.92	2.89	7.75	0.46	2.93
bc-21-glf	Retro 2006	51.91	27.77	2.72	8.08	0.56	3.29

Table 7.4.2. Atlantic stock sensitivity runs and retrospective analyses. F/FLim and N/NLim refer to the current status of the stock for each run, where red values for F/FLim (>1) represent current overfishing and red values for N/NLim (<1) represent overfished.

Run #	Run	negLL	MSY	FMSY	NMSY	F/FLim	N/NLim
bc-00-atl	**Base Model**	-0.40	12.31	1.86	5.73	0.50	2.28
bc-01-atl	s=0.2	-1.37	13.24	2.78	5.73	0.40	2.48
bc-02-atl	s=0.4	1.04	11.51	1.51	5.21	0.59	2.10
bc-03-atl	s=0.6	3.22	10.78	1.22	4.16	0.71	1.82
bc-04-atl	M={1.78, 1.22}	2.24	14.46	1.79	5.54	0.39	2.62
bc-05-atl	M={1, 1}	-0.76	12.51	1.94	6.35	0.47	2.32
bc-06-atl	Average Z*0.7	0.20	14.44	1.58	8.12	0.36	2.69
bc-07-atl	Average Z*1.3	0.73	11.19	2.36	3.90	0.62	1.99
bc-08-atl	Max F/M=3	0.00	11.99	2.04	5.00	0.51	2.26
bc-09-atl	Max F/M=5	-0.40	12.31	1.86	5.73	0.50	2.28
bc-10-atl	No Environment	5.97	11.16	2.39	3.82	0.56	2.20
bc-11-atl	Precipitation on M	-0.35	11.77	2.04	4.91	0.50	2.46
bc-12-atl	Precipitation on R	5.78	10.94	2.15	4.28	0.63	1.97
bc-13-atl	Streamflow on R	5.92	11.22	2.42	3.78	0.56	2.22
bc-14-atl	Beverton -Holt	-0.51	13.65	3.05	3.37	0.30	3.87
bc-15-atl	h=0.99	-0.44	***NA***	***NA***	***NA***	***NA***	***NA***
bc-16-atl	No Effort	0.04	13.91	2.04	5.80	0.44	2.45
bc-17-atl	Retro 2010	2.68	11.67	1.89	5.33	0.49	2.18
bc-18-atl	Retro 2009	8.05	11.09	1.70	5.74	0.70	2.24
bc-19-atl	Retro 2008	9.22	11.80	2.03	4.95	0.62	3.05
bc-20-atl	Retro 2007	14.17	13.56	2.43	4.55	0.47	3.35
bc-21-atl	Retro 2006	7.70	12.25	2.20	4.66	0.53	3.62

Table 8.2.1. Gulf stock reference points estimates for the base model and MCMC runs. Numbers (e.g., MSY, NMSY) are in millions of individuals.

	Base Model	MCMC Quantiles				
Reference Point	**Estimate**	**2.50%**	**25%**	**50%**	**75%**	**97.50%**
MSY	30.79	28.69	30.67	31.89	33.44	39.22
FMSY	2.72	1.93	2.41	2.77	3.23	4.35
NMSY	8.96	5.45	7.40	8.79	10.68	14.77
uMSY	0.60	0.54	0.58	0.60	0.62	0.65
FLimit	2.72	1.92	2.41	2.77	3.23	4.35
NLimit	4.48	2.72	3.70	4.40	5.34	7.38
F/FMSY	0.44	0.27	0.37	0.43	0.50	0.62
N/NMSY	0.88	0.56	0.75	0.91	1.07	1.45
U/UMSY	0.53	0.46	0.51	0.53	0.56	0.61
F/FLimit	0.44	0.27	0.37	0.43	0.50	0.62
N/NLimit	1.77	1.11	1.51	1.82	2.14	2.90
SPRCurrent	0.59	0.54	0.57	0.59	0.61	0.64

Table 8.2.2. Atlantic stock reference points estimates for the base model and MCMC runs. Numbers (e.g., MSY, NMSY) are in millions of individuals.

	Base Model	MCMC Quantiles				
Reference Point	**Estimate**	**2.50%**	**25%**	**50%**	**75%**	**97.50%**
MSY	12.31	10.64	11.39	11.97	13.51	17.99
FMSY	1.86	1.04	1.44	1.86	2.45	3.69
NMSY	5.73	3.15	4.40	5.50	7.09	10.40
uMSY	0.54	0.41	0.48	0.54	0.58	0.63
FLimit	1.86	1.04	1.44	1.86	2.45	3.69
NLimit	2.87	1.57	2.20	2.75	3.54	5.20
F/FMSY	0.50	0.28	0.41	0.54	0.70	0.92
N/NMSY	1.14	0.60	0.85	1.07	1.31	1.71
U/UMSY	0.67	0.56	0.65	0.72	0.80	0.92
F/FLimit	0.50	0.28	0.41	0.54	0.70	0.92
N/NLimit	2.28	1.20	1.70	2.15	2.61	3.42
SPRCurrent	0.65	0.49	0.58	0.62	0.64	0.69

Figures

Figure 3.1.1. Total landings of crabs along the Florida Gulf coast.

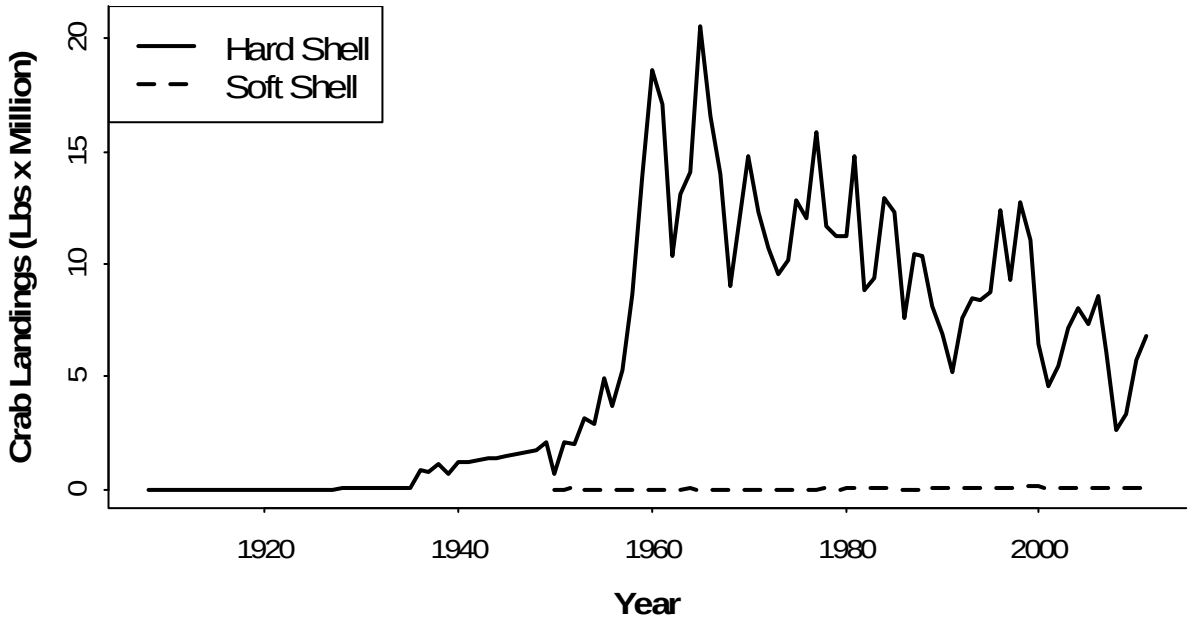


Figure 3.1.2. Total landings of crabs along the Florida Atlantic coast.

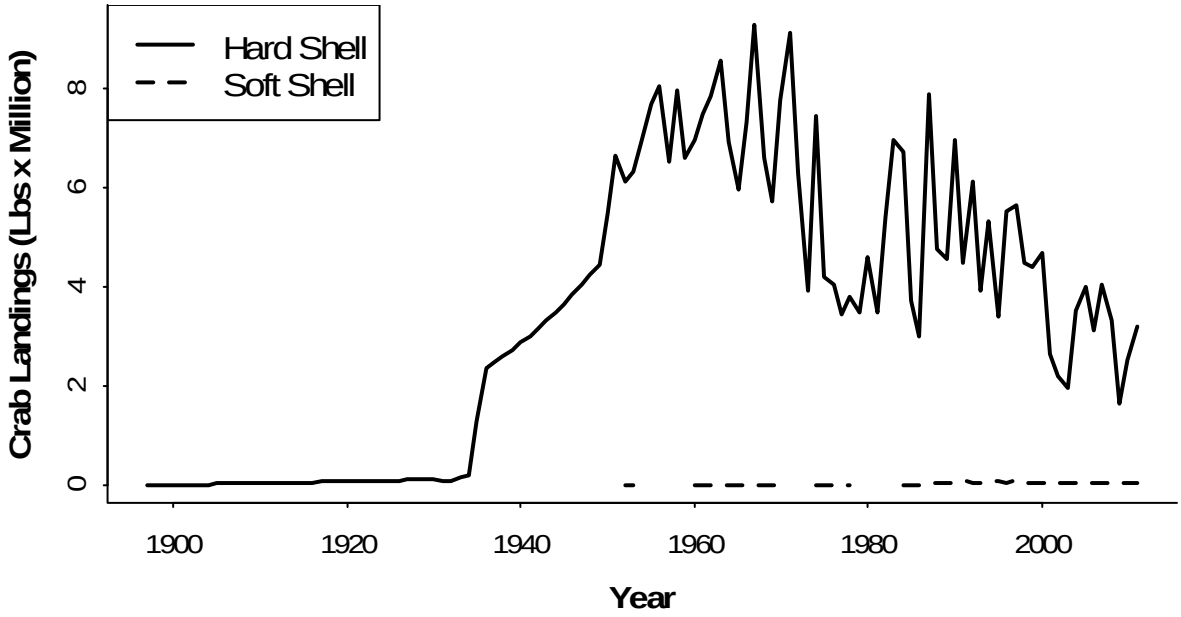


Figure 5.1.1.2.1. Relative number of crabs sampled by size class, month, and year for the combined biostatistical sampling along the Florida Gulf coast.

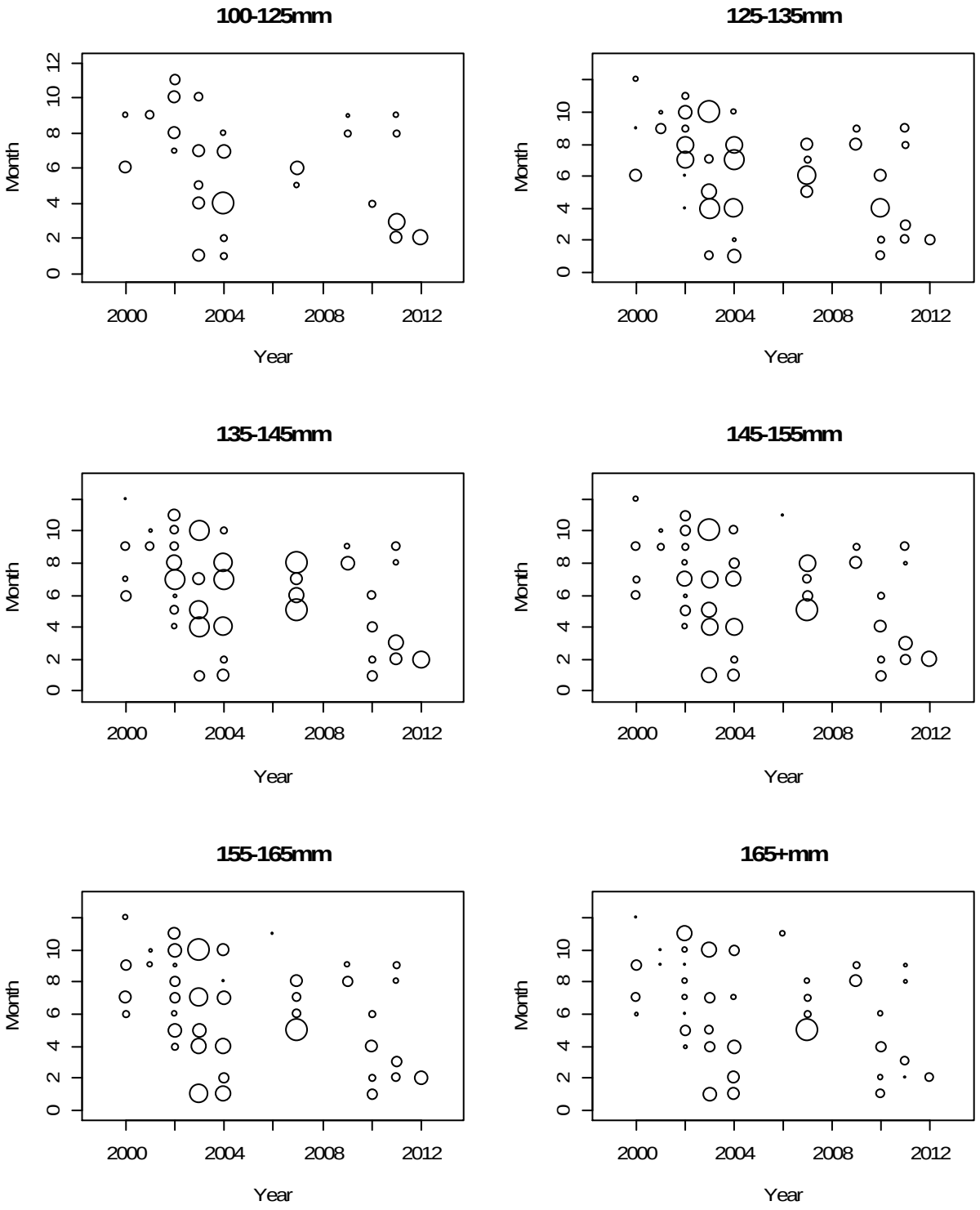


Figure 5.1.1.2.1. Number of crabs sampled by size, month, and year for the combined biostatistical sampling along the Florida Atlantic coast.

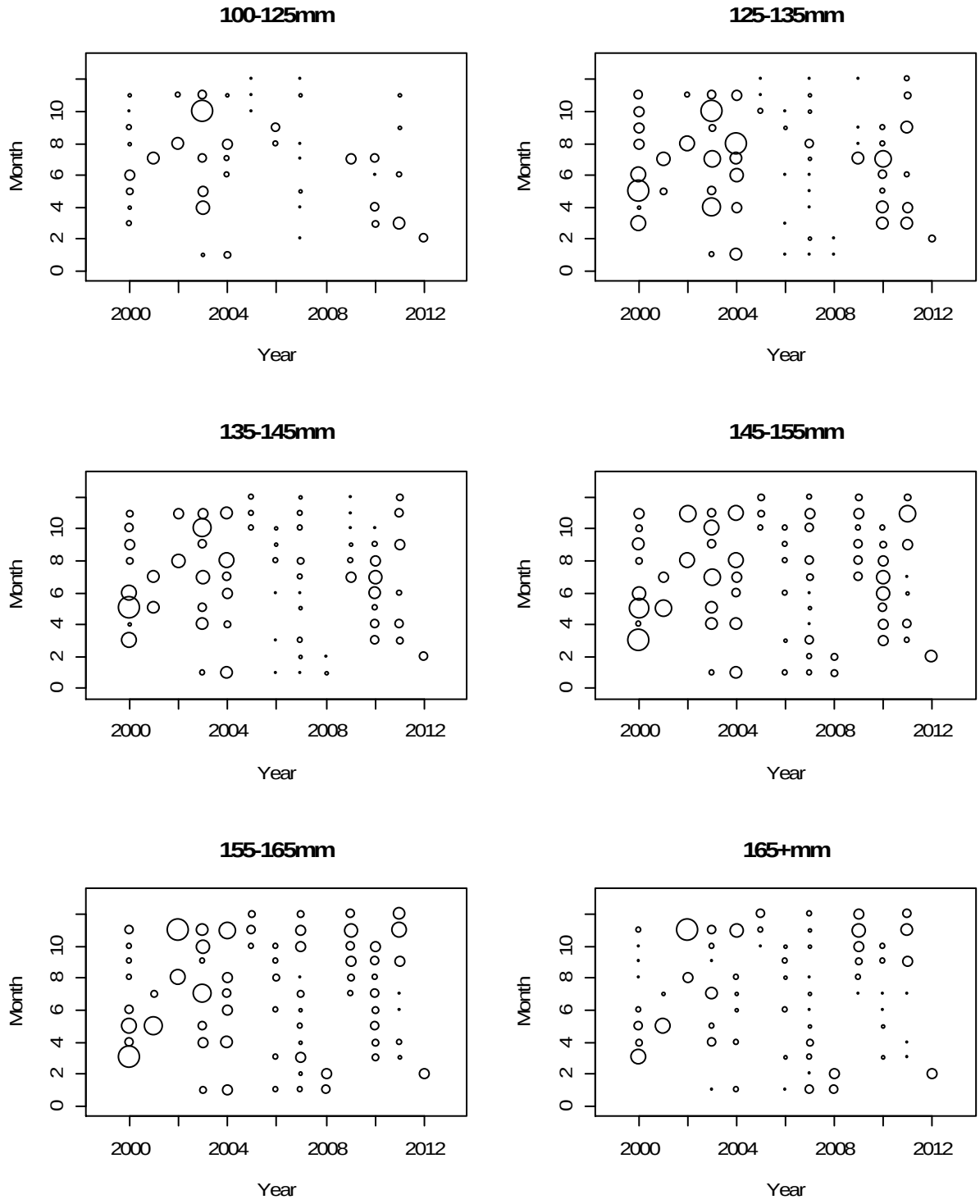


Figure 5.1.1.5.1. Size distribution of crabs landed along the Florida Gulf coast per year from the combined biostatistical sampling programs.

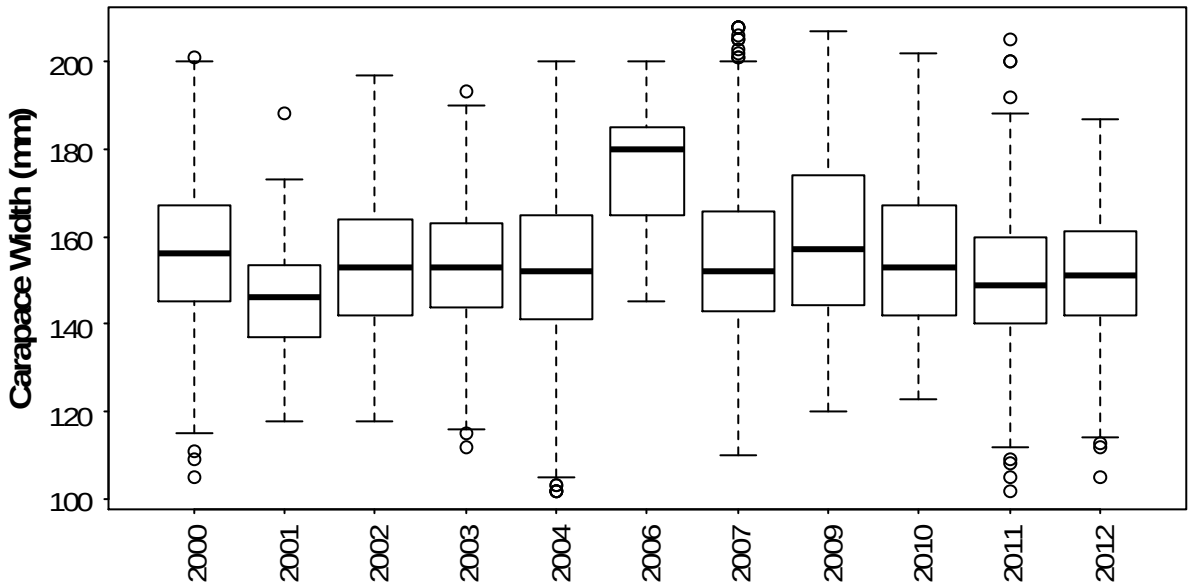


Figure 5.1.1.5.2. Size distribution of crabs landed along the Florida Atlantic coast per year from the combined biostatistical sampling programs.

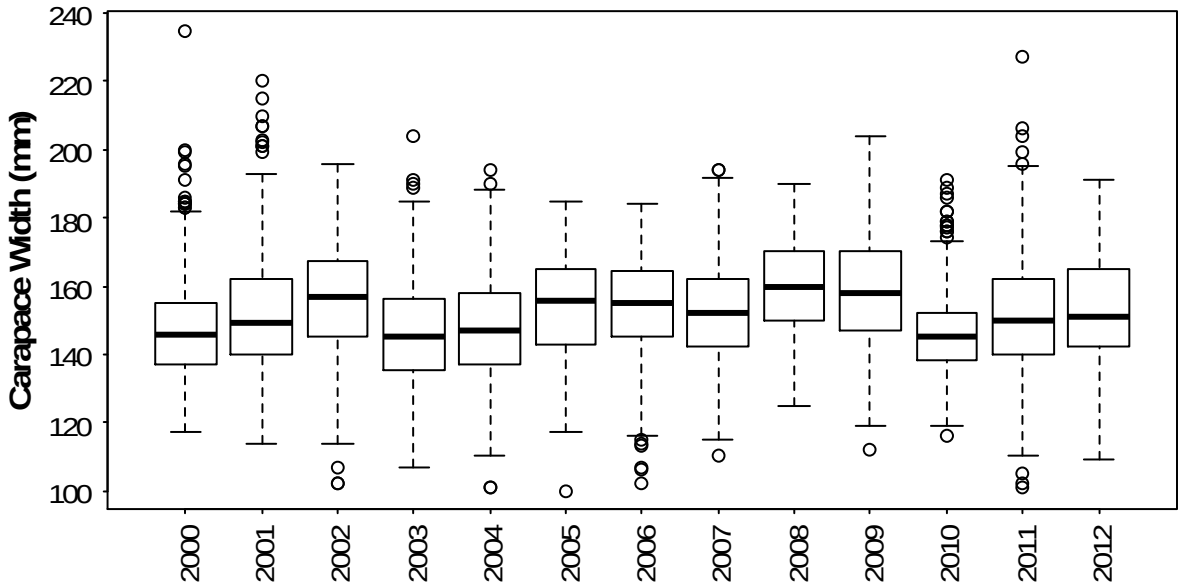


Figure 5.1.1.5.3. Mean size of crabs caught per month along the Florida Gulf and Atlantic Coasts.

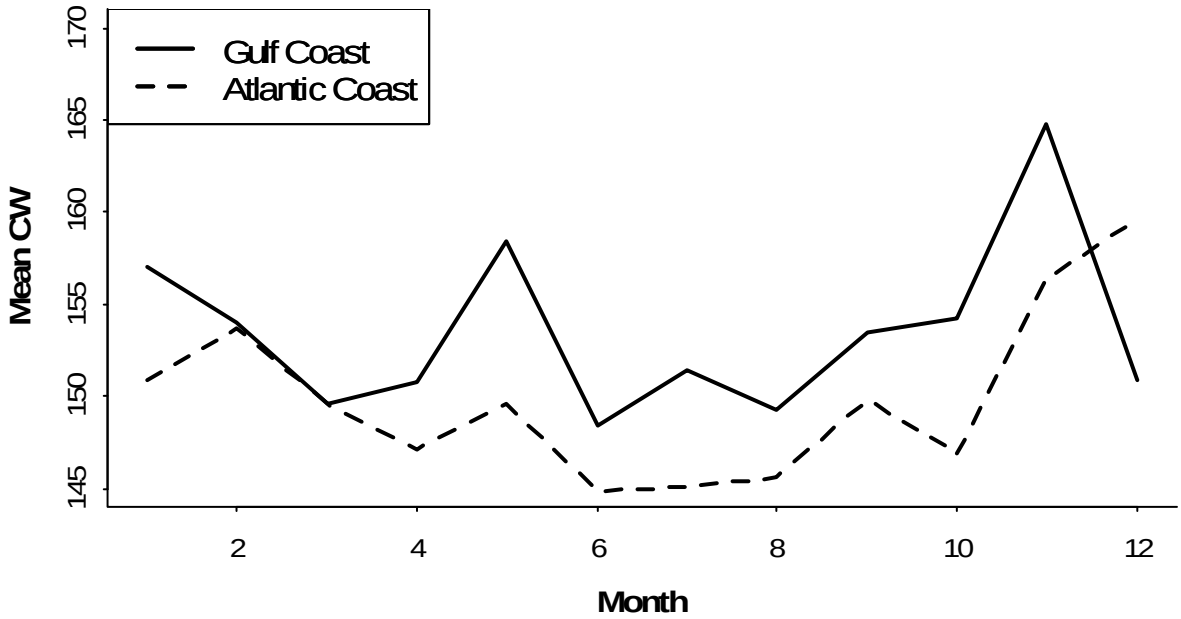


Figure 5.1.1.5.4. Mean number of crabs caught per month along the Florida Gulf Coast.

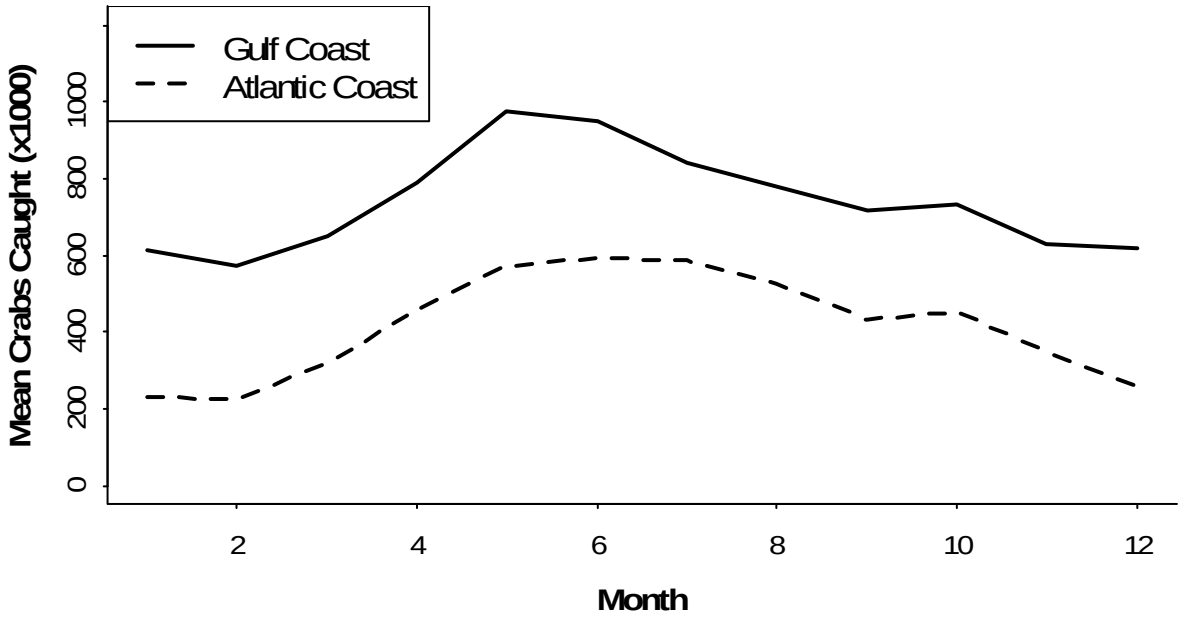


Figure 5.1.4.1. Landings, effort, and standardized CPUE for the Gulf coast.

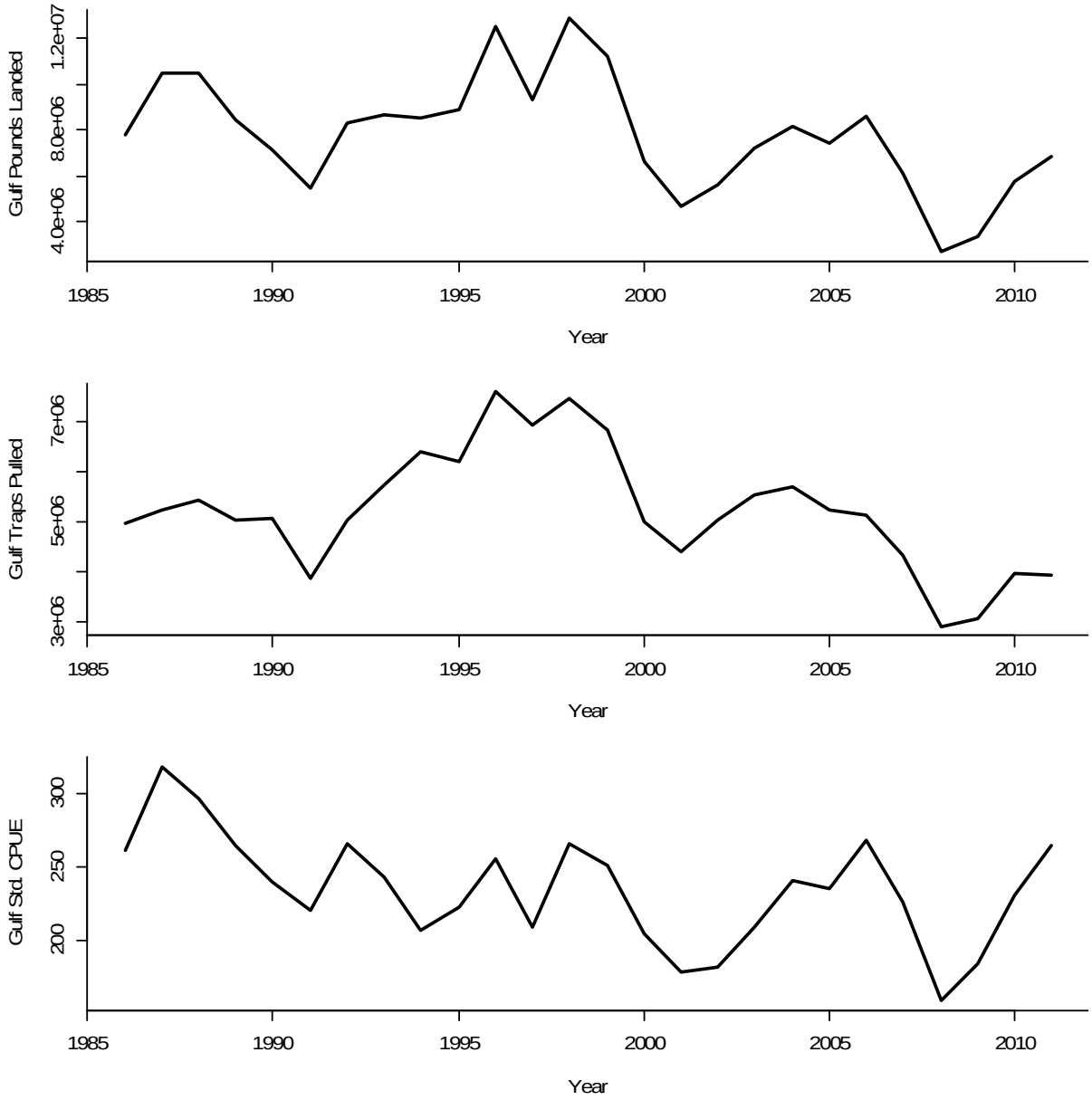


Figure 5.1.4.2. Landings, effort, and standardized CPUE for the Atlantic coast.

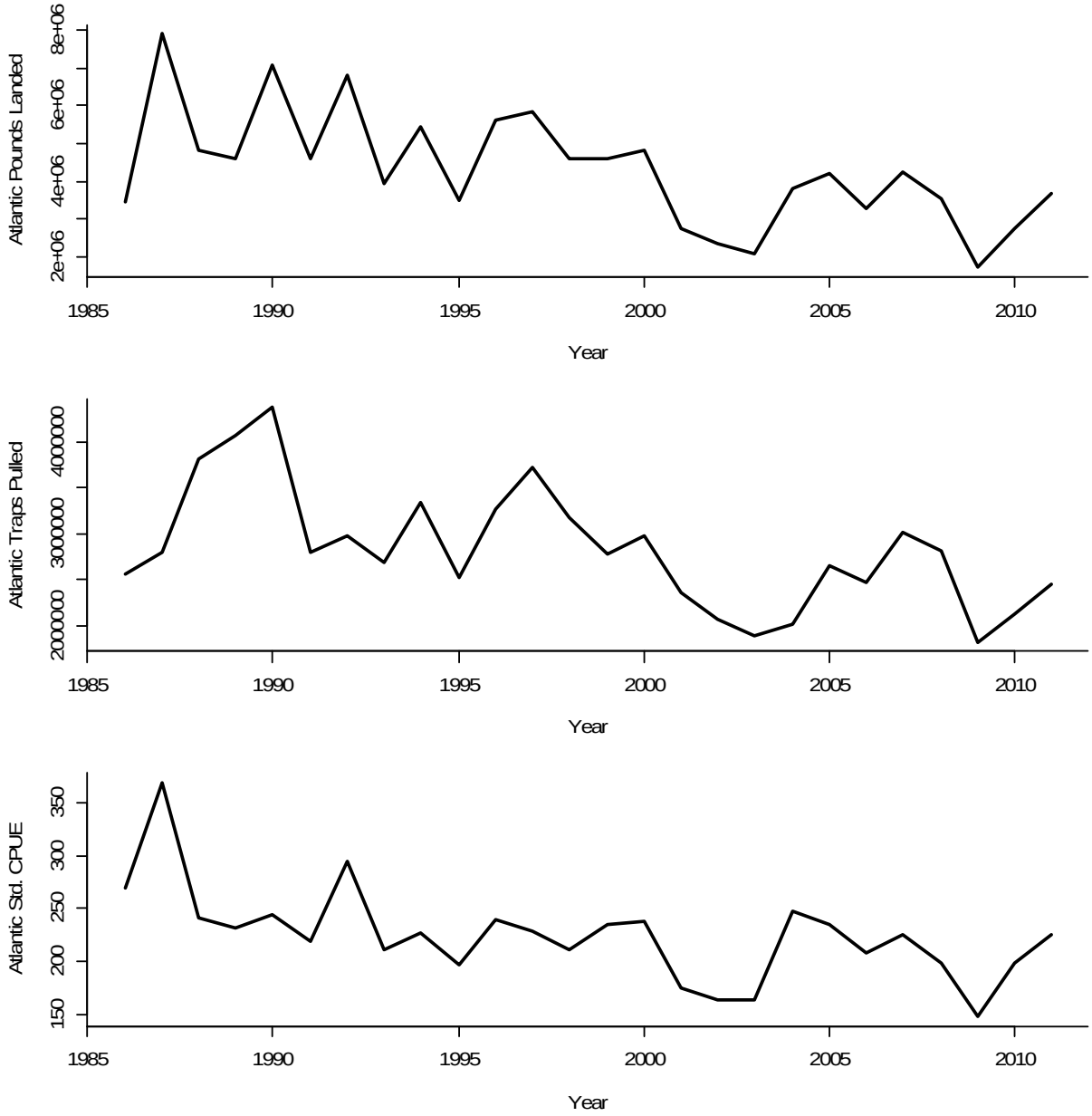


Figure 5.1.4.3. Residuals by year from the CPUE standardization procedure for the Gulf coast.

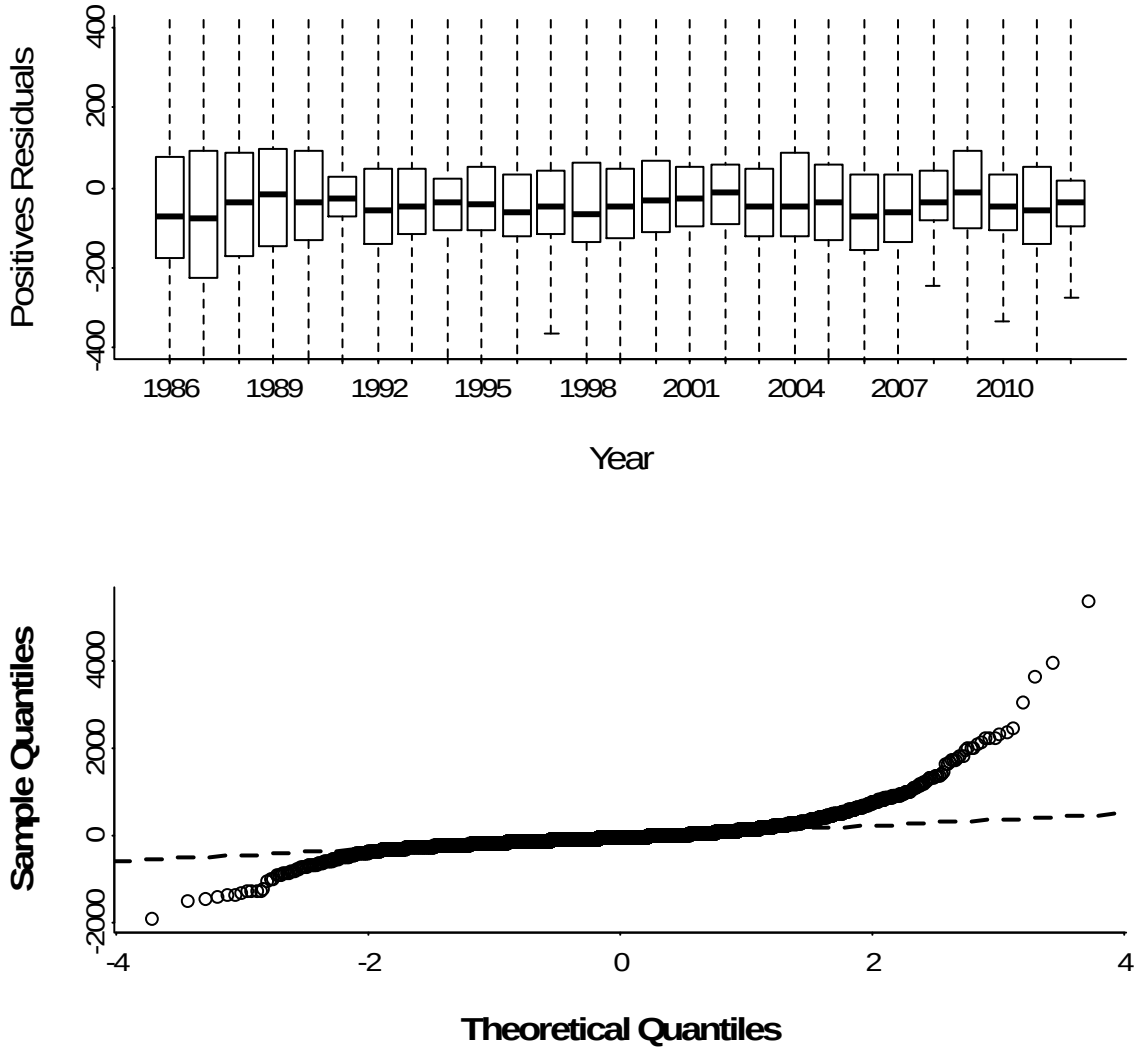


Figure 5.1.4.4. Residuals by year from the CPUE standardization procedure for the Atlantic coast.

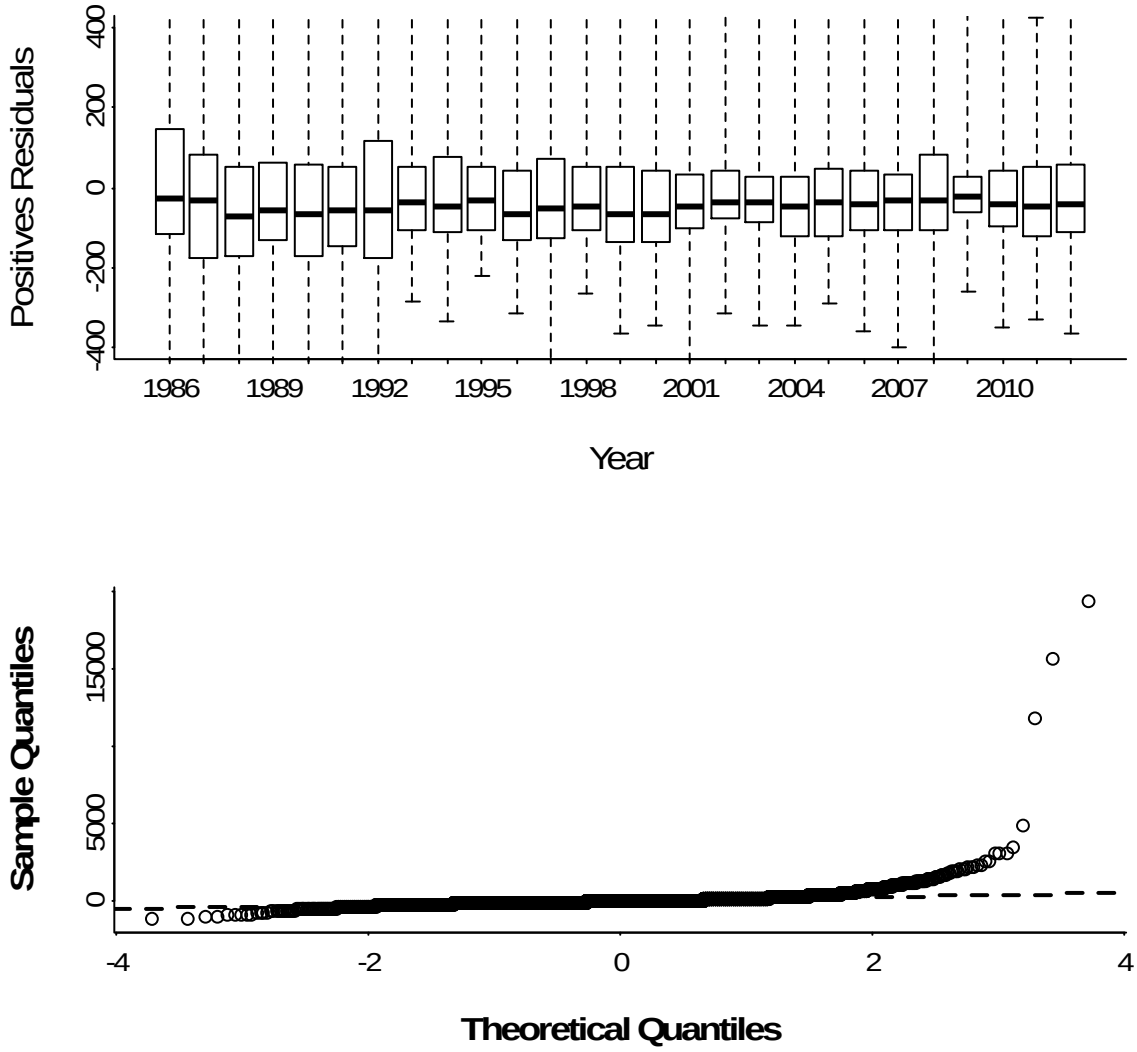


Figure 5.3.1.5.1. Size frequency distributions of crabs caught by month and year for the Gulf Coast, summed across gears (21.3-m seines, 183-m seines, and 6.1m otter trawls).

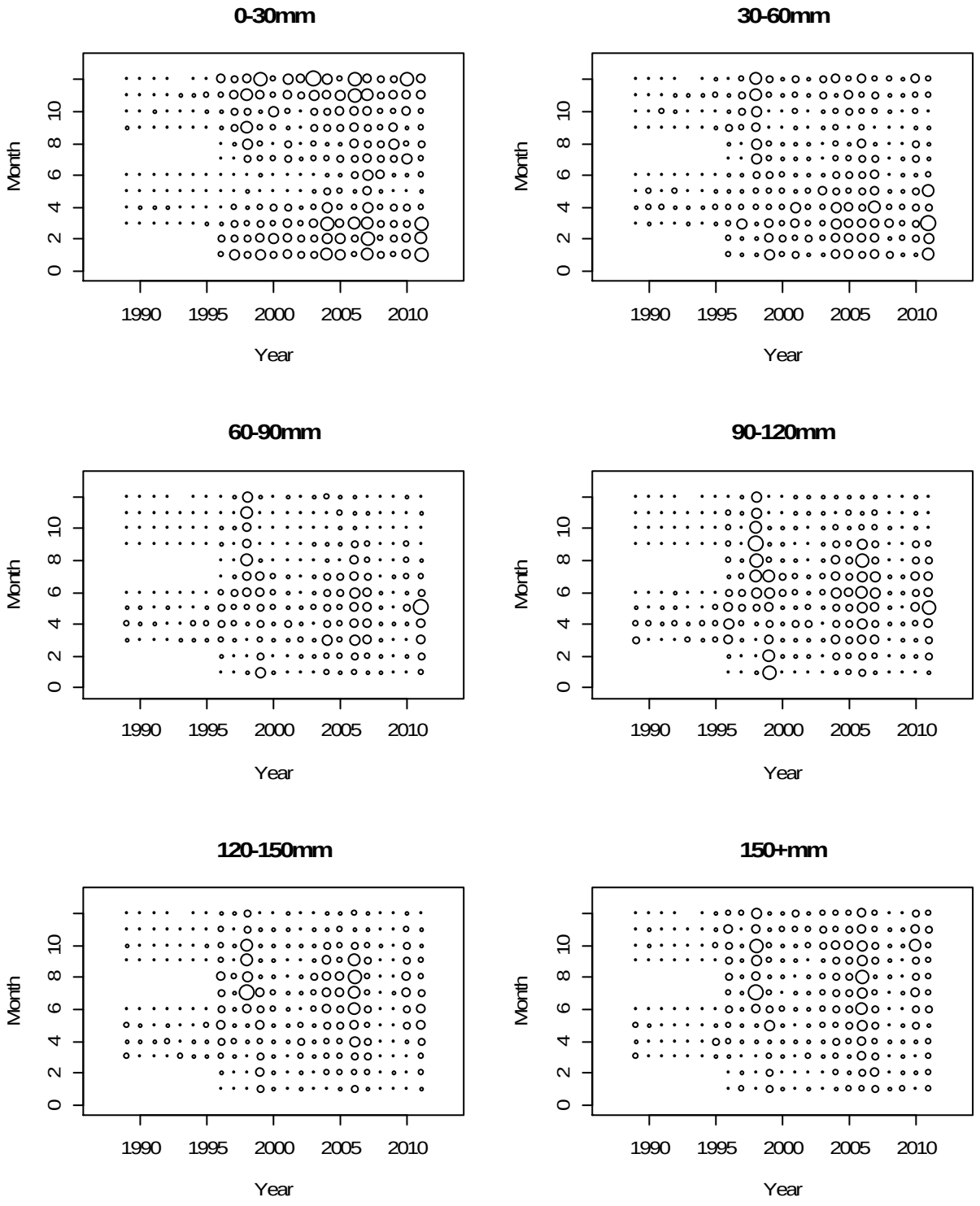


Figure 5.3.1.5.2. Size frequency distributions of crabs caught by gear across all years for the Gulf Coast, summed across gears (21.3-m seines, 183-m seines, and 6.1m otter trawls).

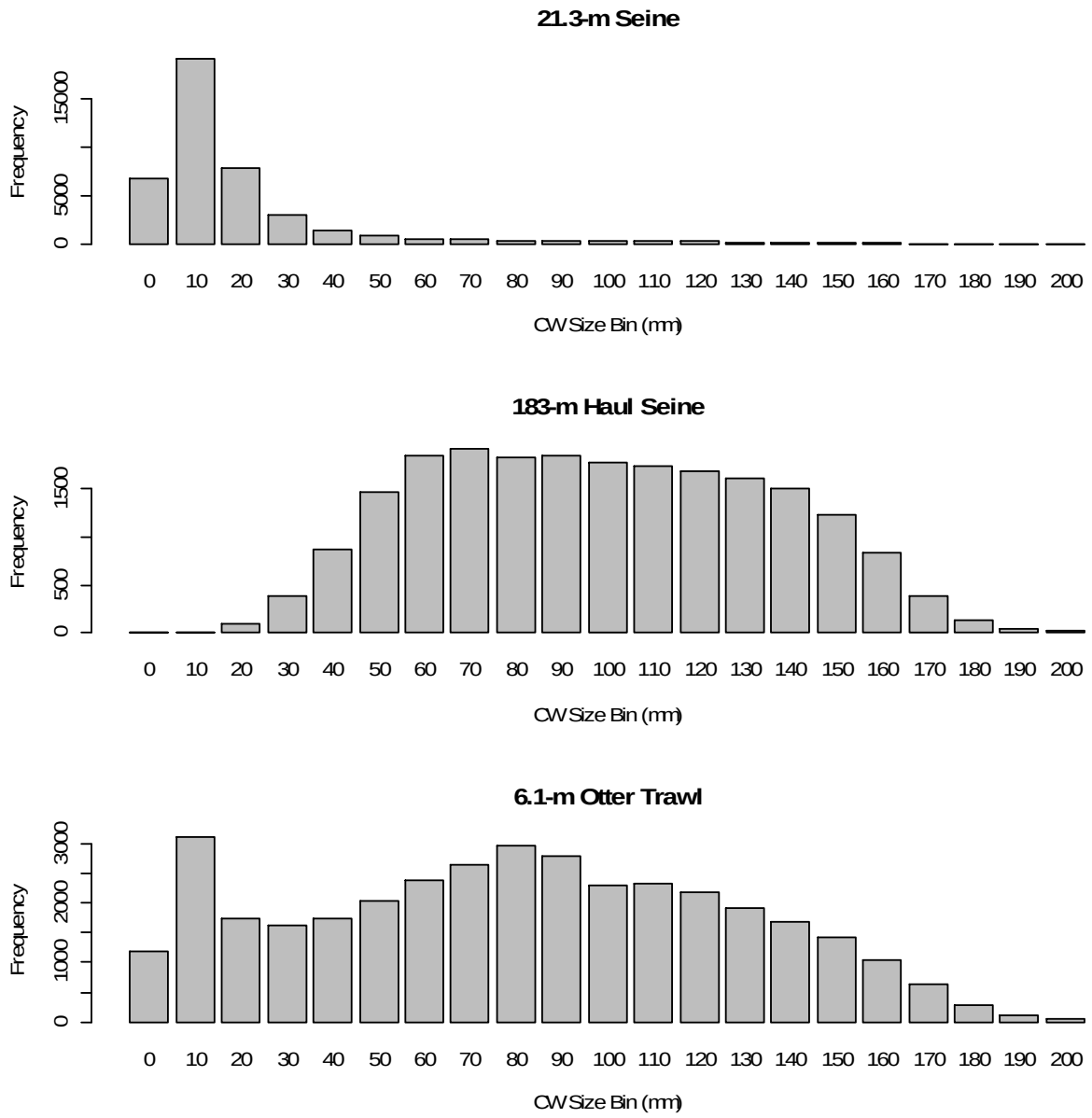


Figure 5.3.1.5.3. Size frequency distributions of crabs caught by month and year for the Atlantic Coast, summed across gears (21.3-m seines, 183-m seines, and 6.1m otter trawls).

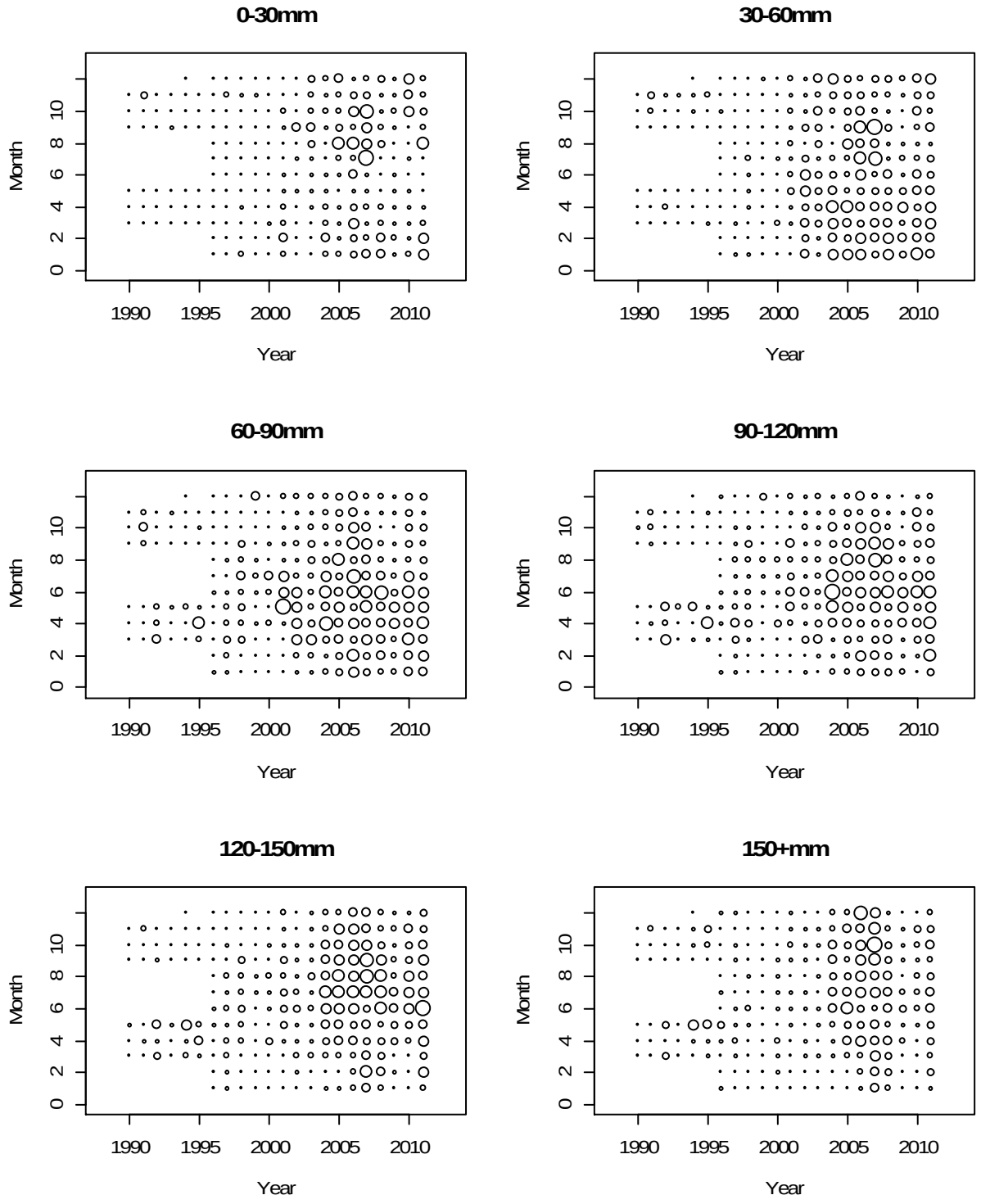


Figure 5.3.1.5.4. Atlantic stock size frequency distributions of crabs caught by gear across all years for the Atlantic Coast, summed across gears (21.3-m seines, 183-m seines, and 6.1m otter trawls).

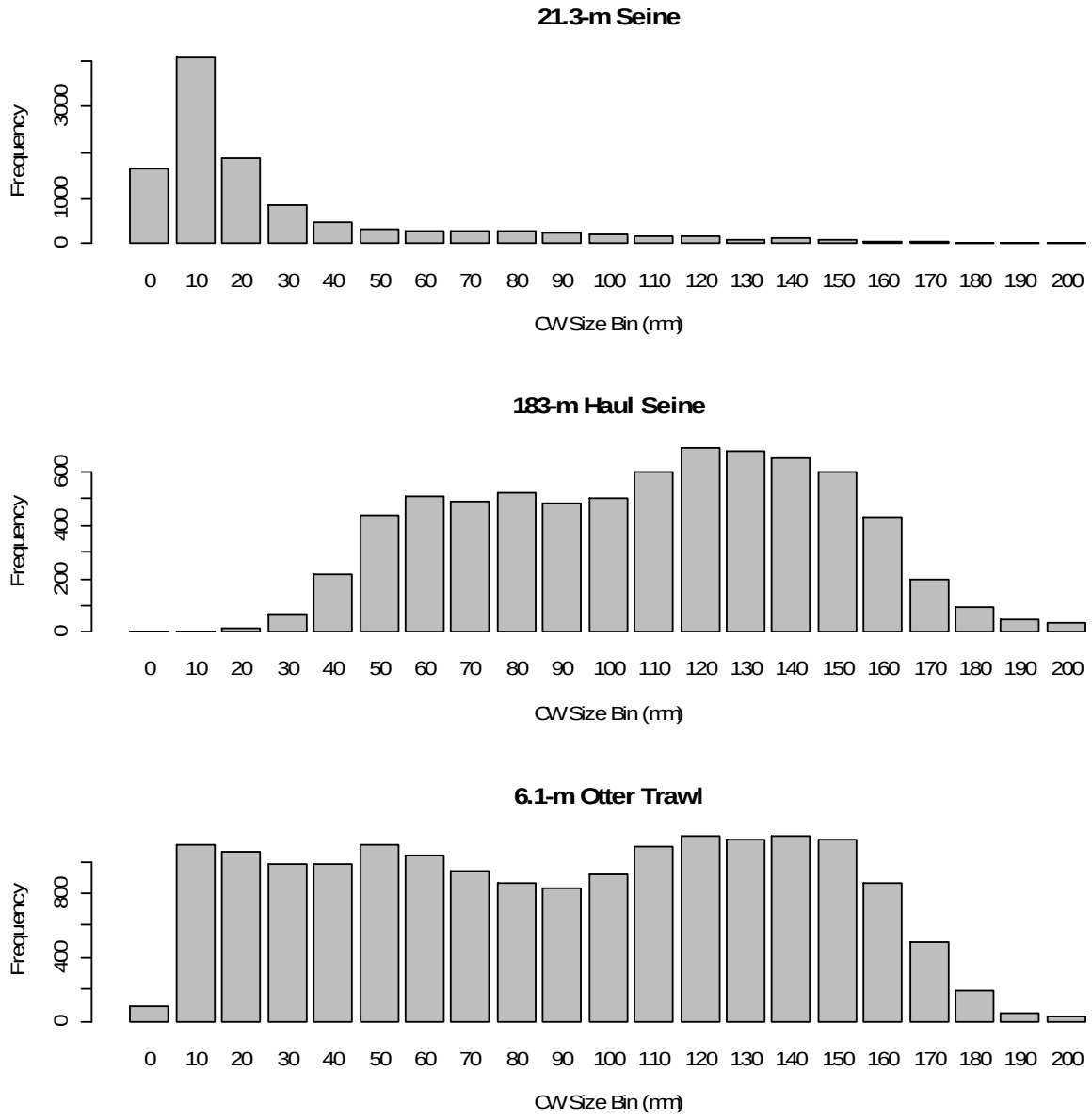


Figure 5.3.2.1. Gulf stock indices of abundance for recruits and adults. Solid line represents the mean (un-scaled), while the shaded region represents the 95% confidence interval.

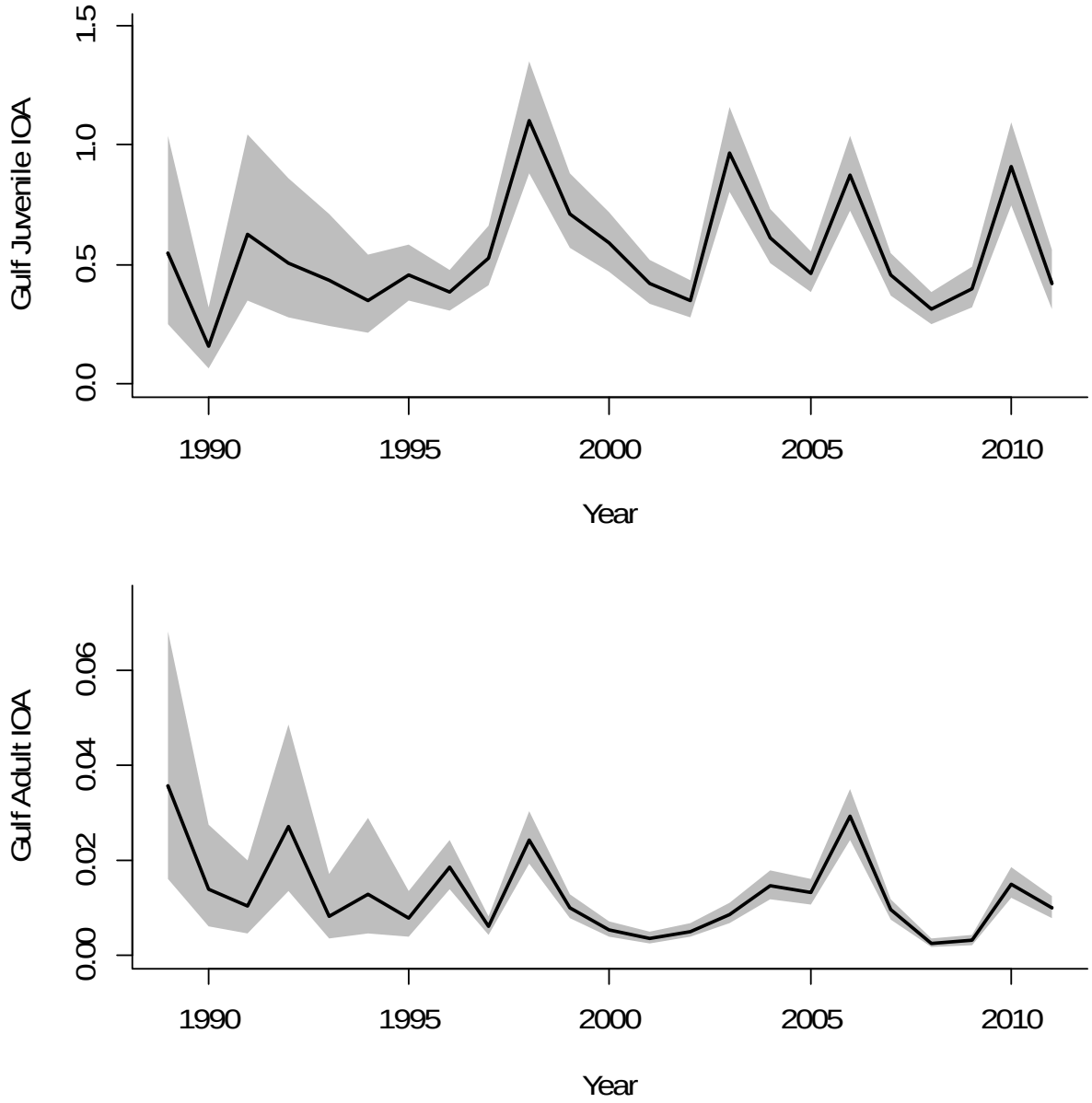


Figure 5.3.2.2. Diagnostics plots for the Gulf stock juvenile IOA.

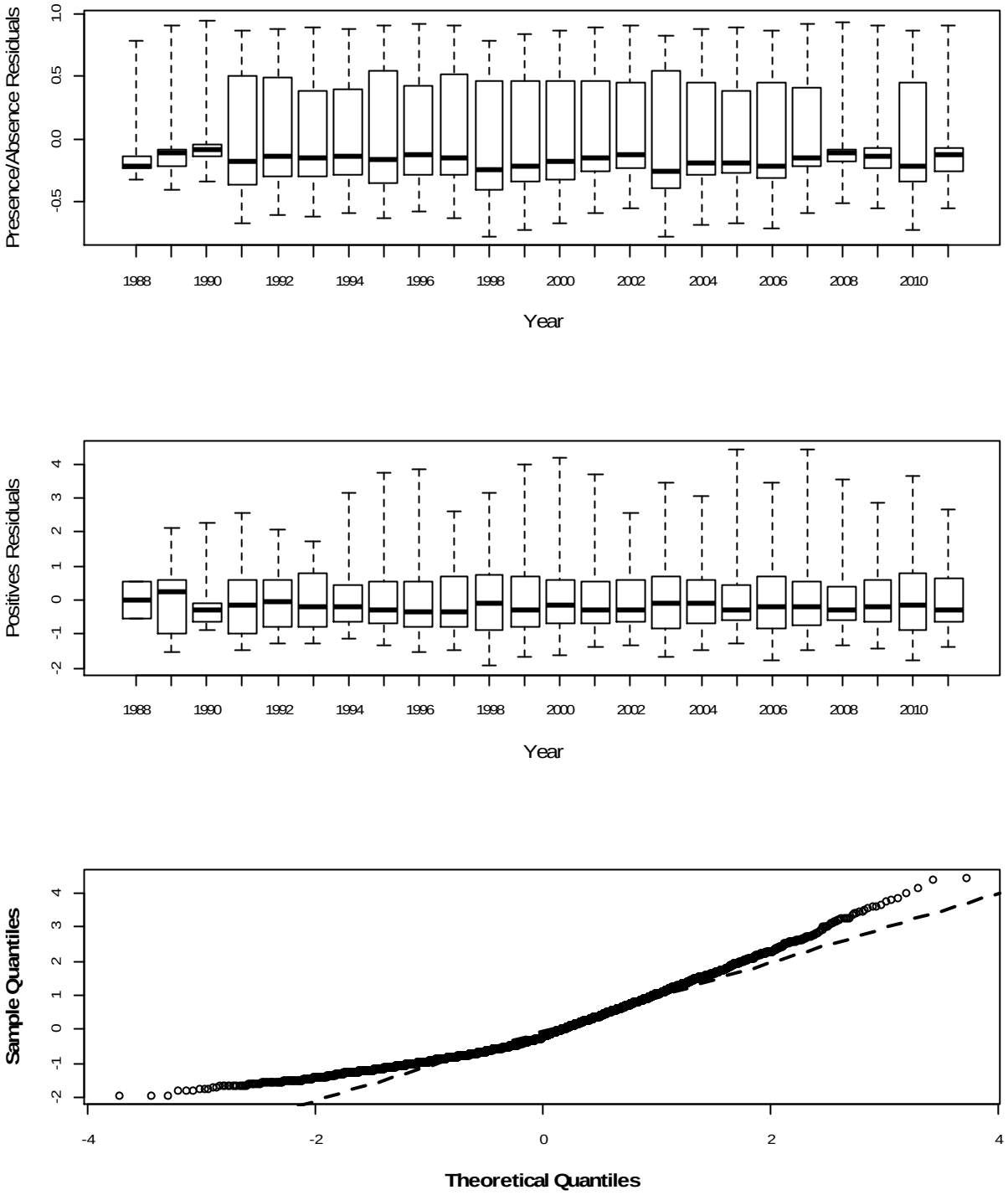


Fig. 5.3.2.3. Diagnostics plots for the Gulf stock adult IOA.

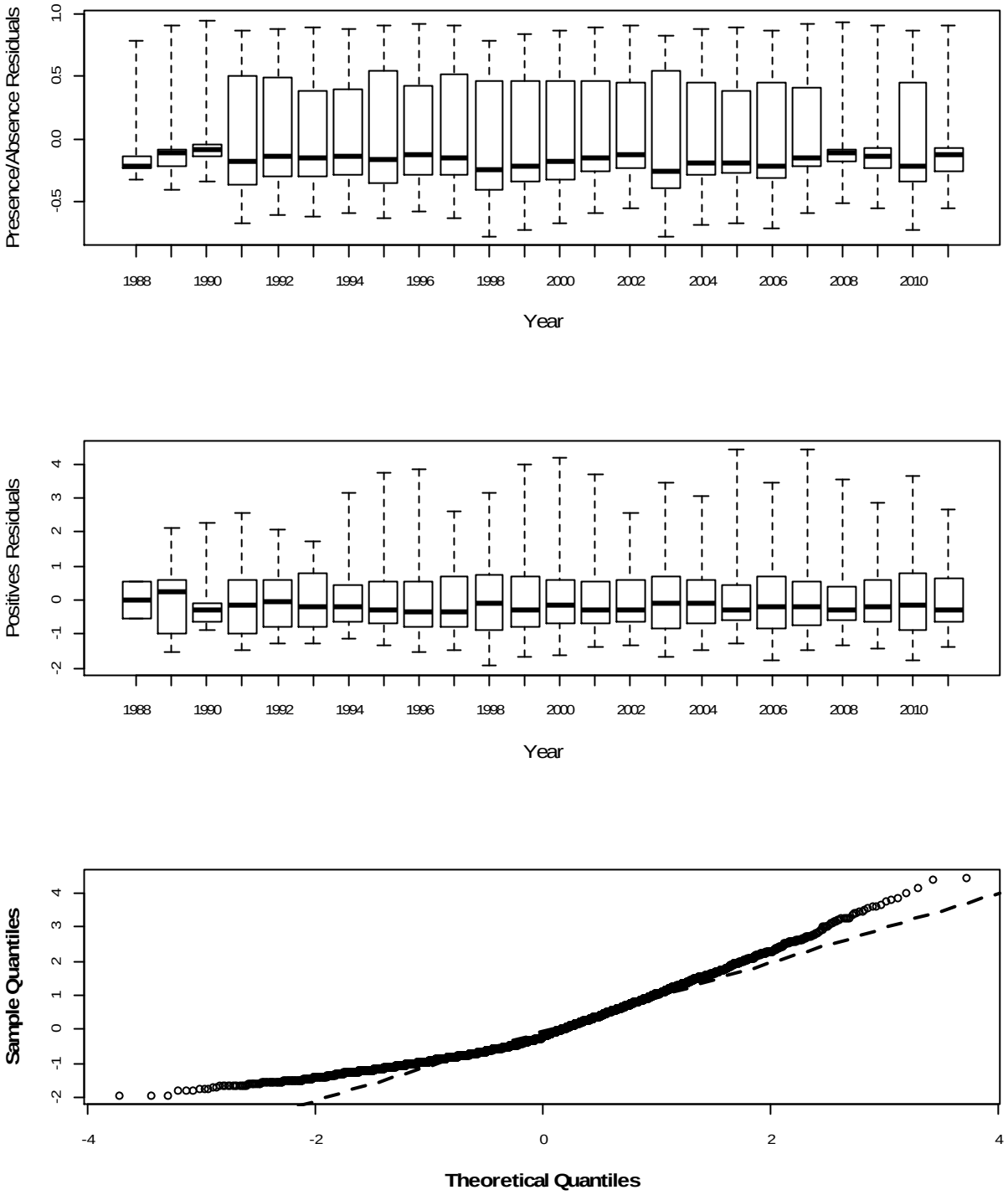


Figure 5.3.2.4. Atlantic stock indices of abundance for juveniles and adults. Solid line represents the mean (un-scaled), while the shaded region represents the 95% confidence interval.

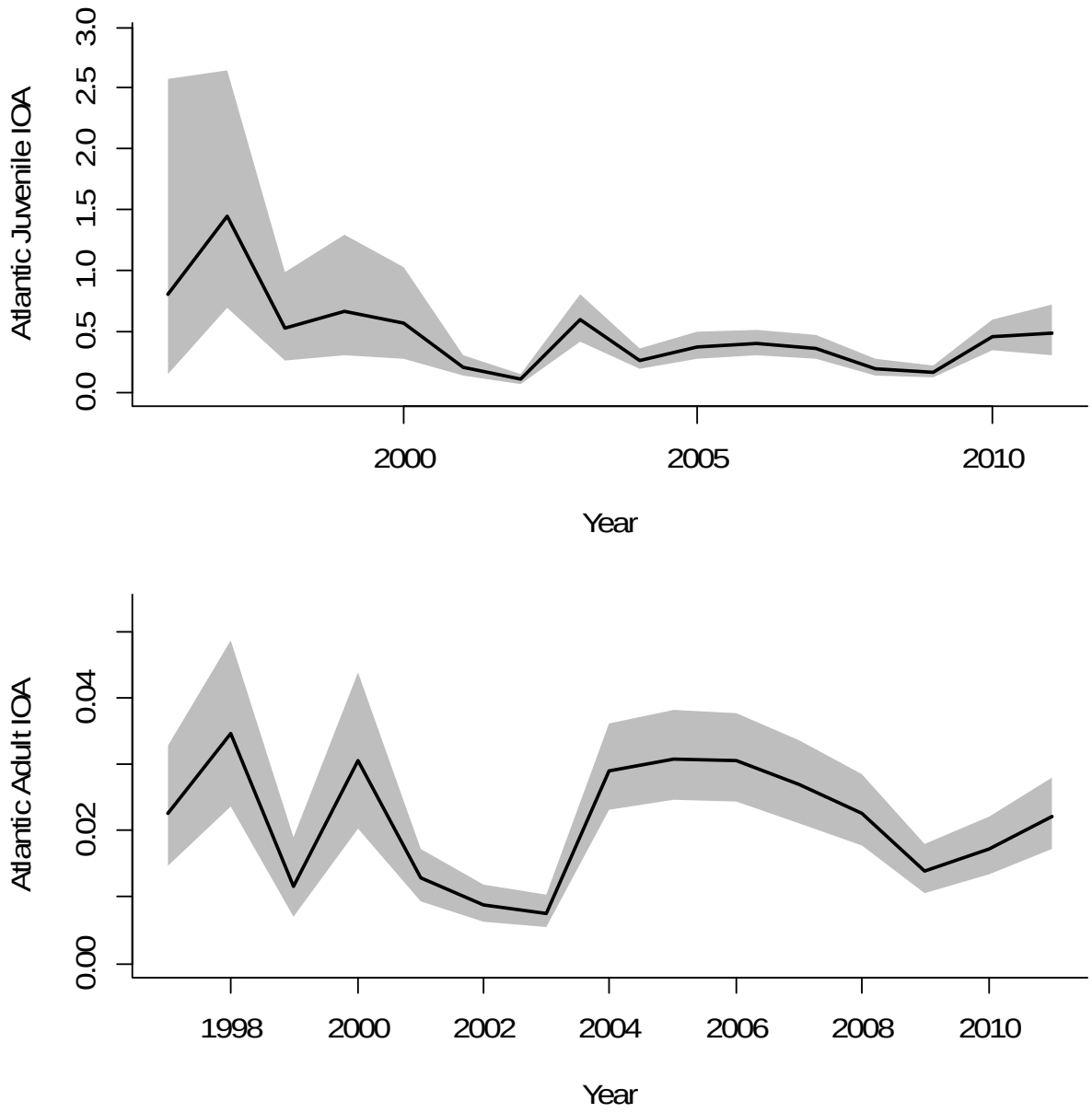


Figure 5.3.2.5. Diagnostics plots for the Atlantic stock juvenile IOA.

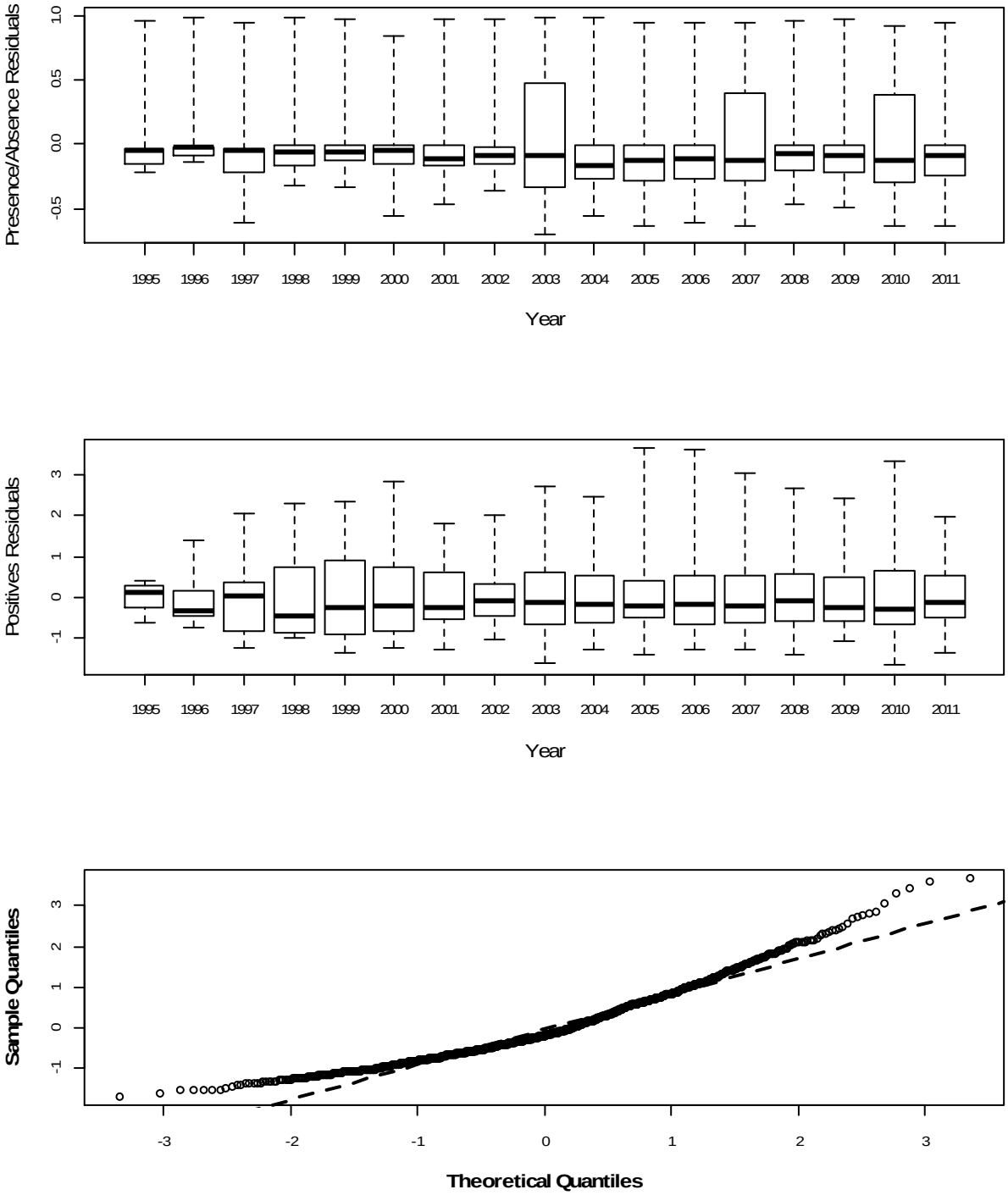


Figure 5.3.2.6. Diagnostics plots for the Atlantic stock adult IOA.

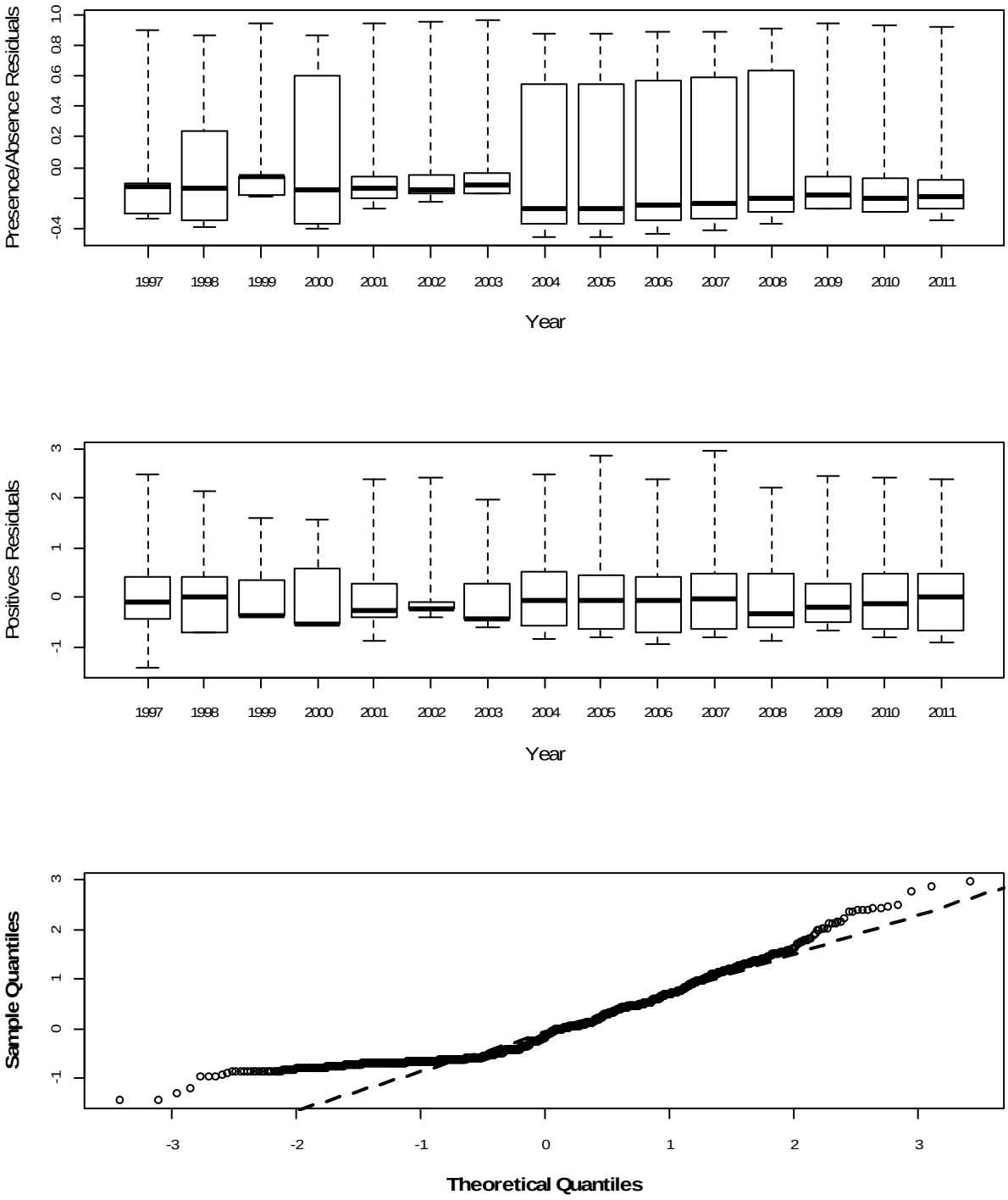


Fig. 5.5.1. USGS gauges used to extract streamflow data. For each hydrologic sub-basin (green and pink polygons for the Atlantic and Gulf coasts, respectively), a single gauge was selected that had the highest average flow and the longest period of data collection from 1980-2011 (starred gauges). The exception is the large sub-basin in the southeast, where three gauges were selected that were dispersed throughout the sub-basin.

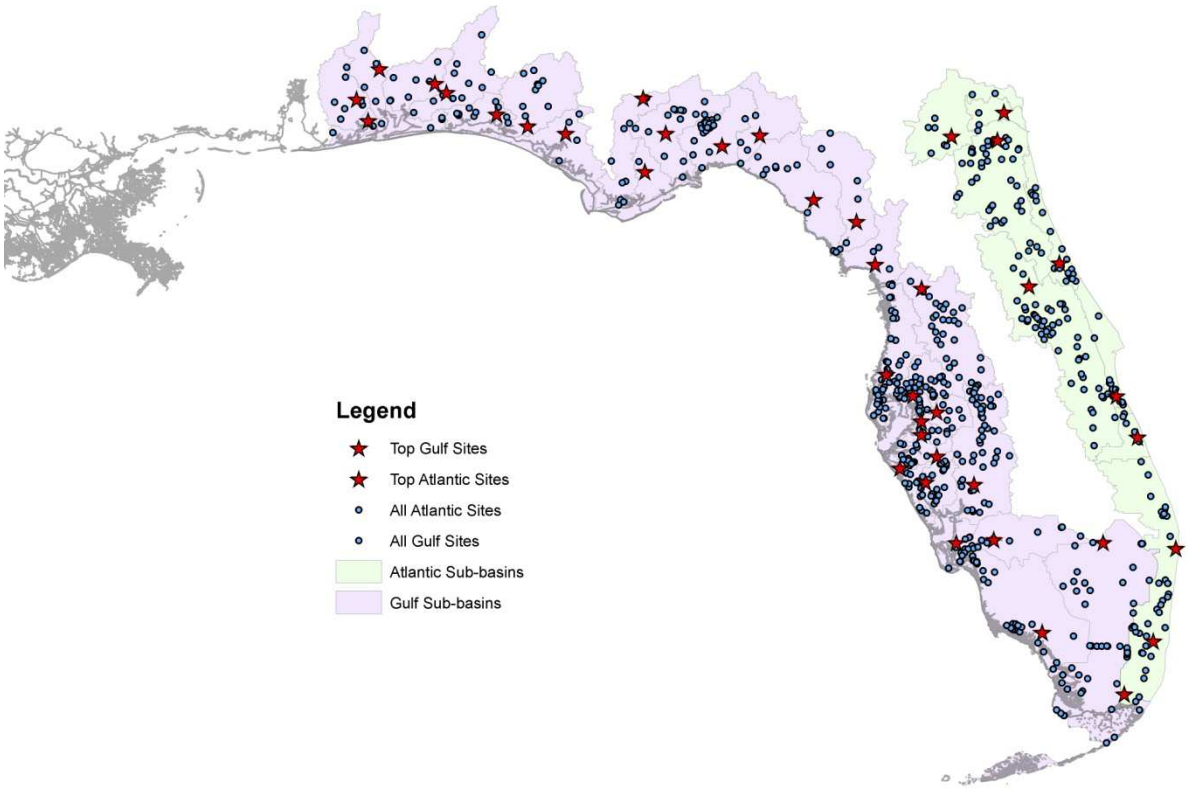


Figure 5.5.2. Environmental time series for both rainfall and USGS stream flow gauges.

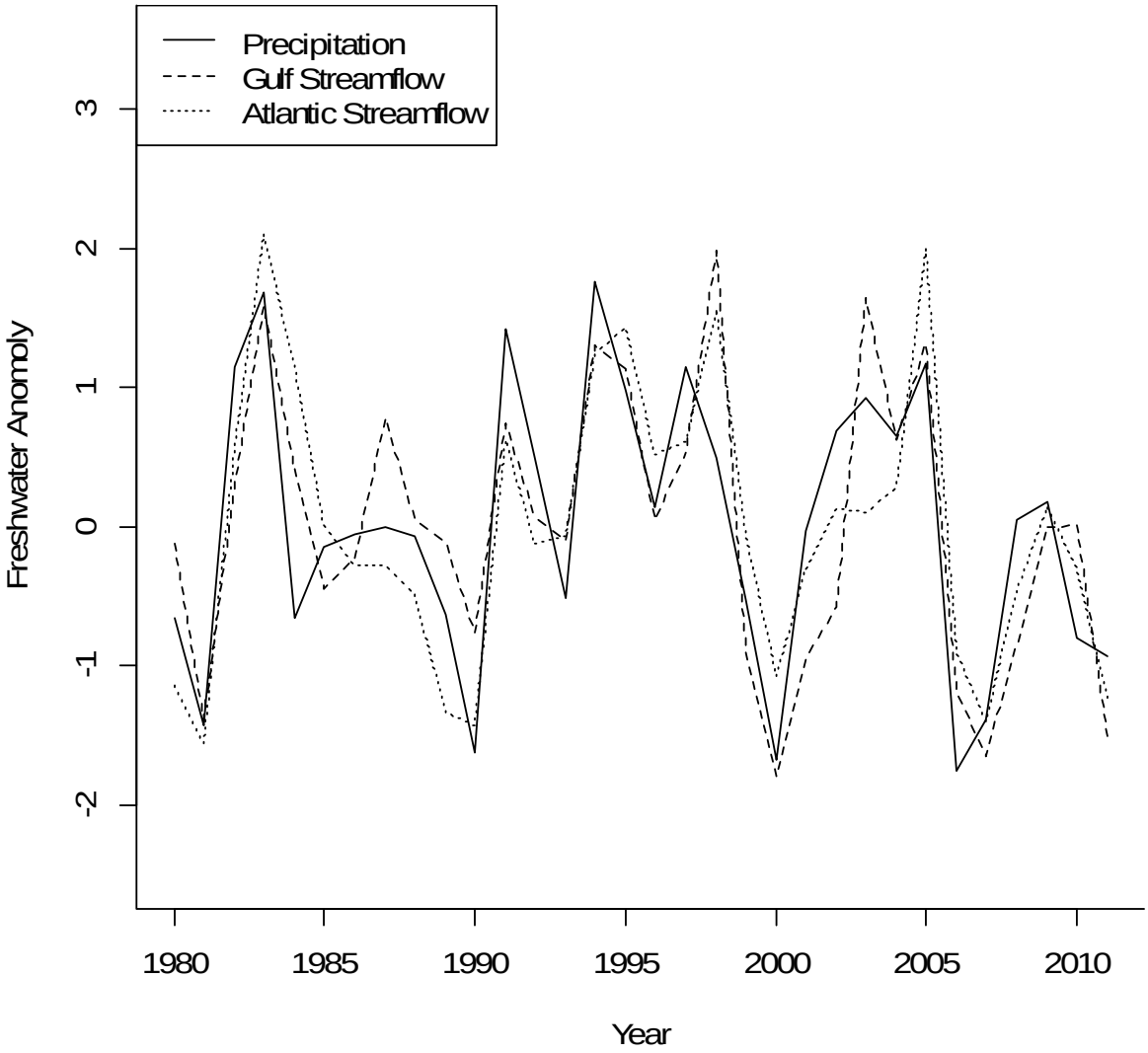
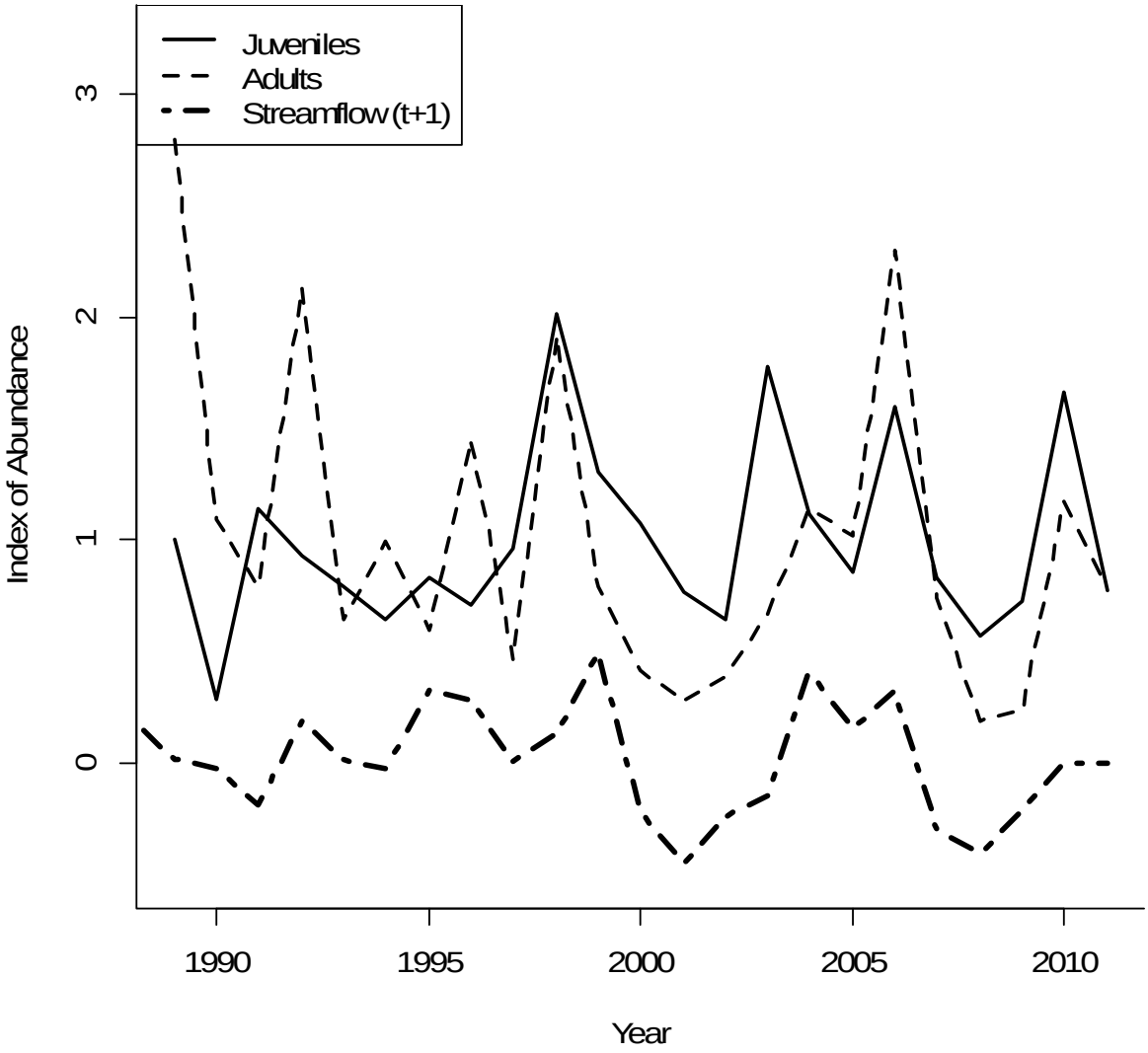


Figure 5.5.3. Gulf stock IOAs superimposed with the streamflow index, where the streamflow index is lagged one year (t+1) to demonstrate the relationship between the IOAs and freshwater input from the previous year.



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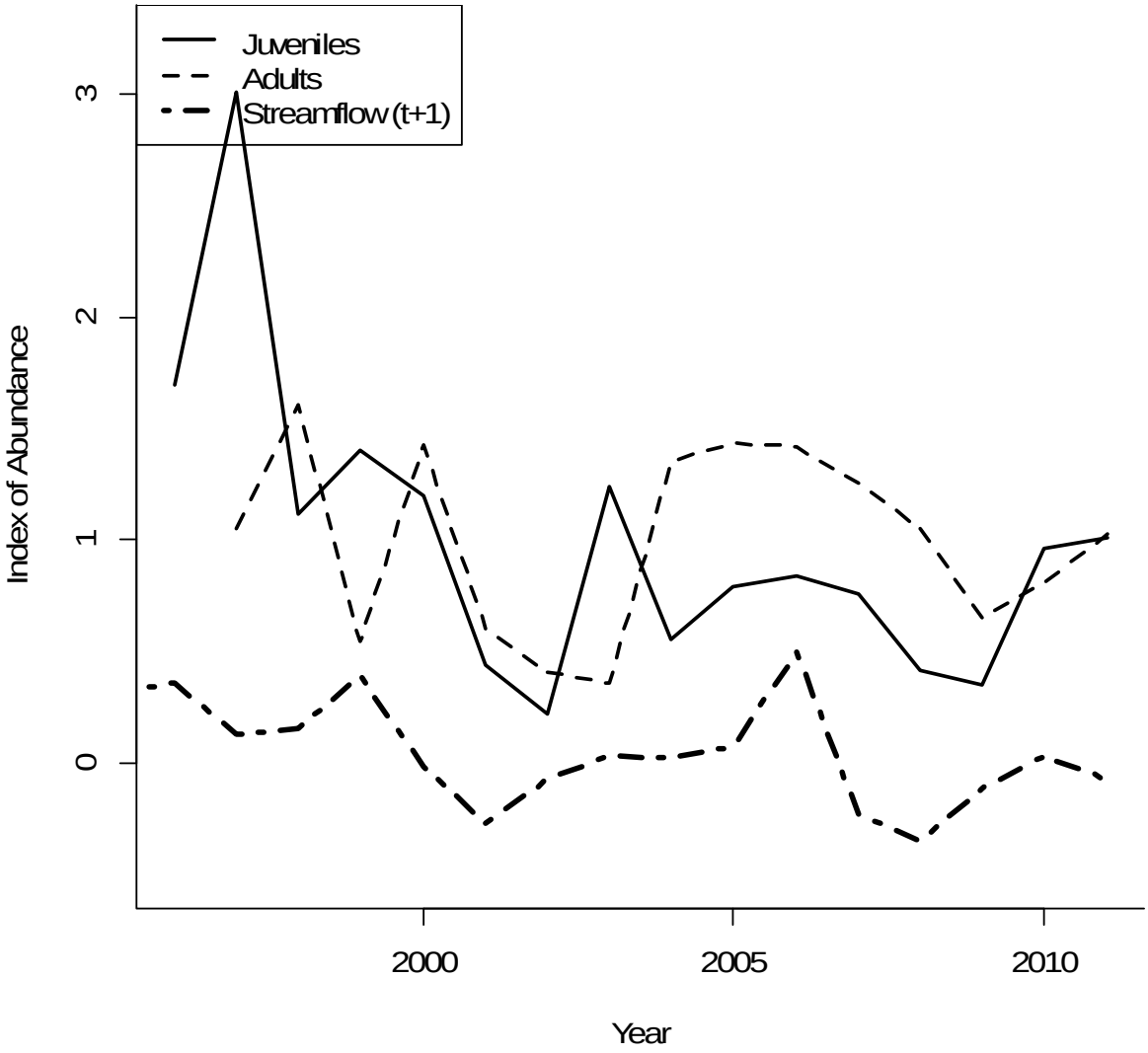

Figure 7.1.1. Gulf coast observed (points) and estimated (line) landings and abundances for the base run (left panes), with model residuals (right panes) from the two-stage model.

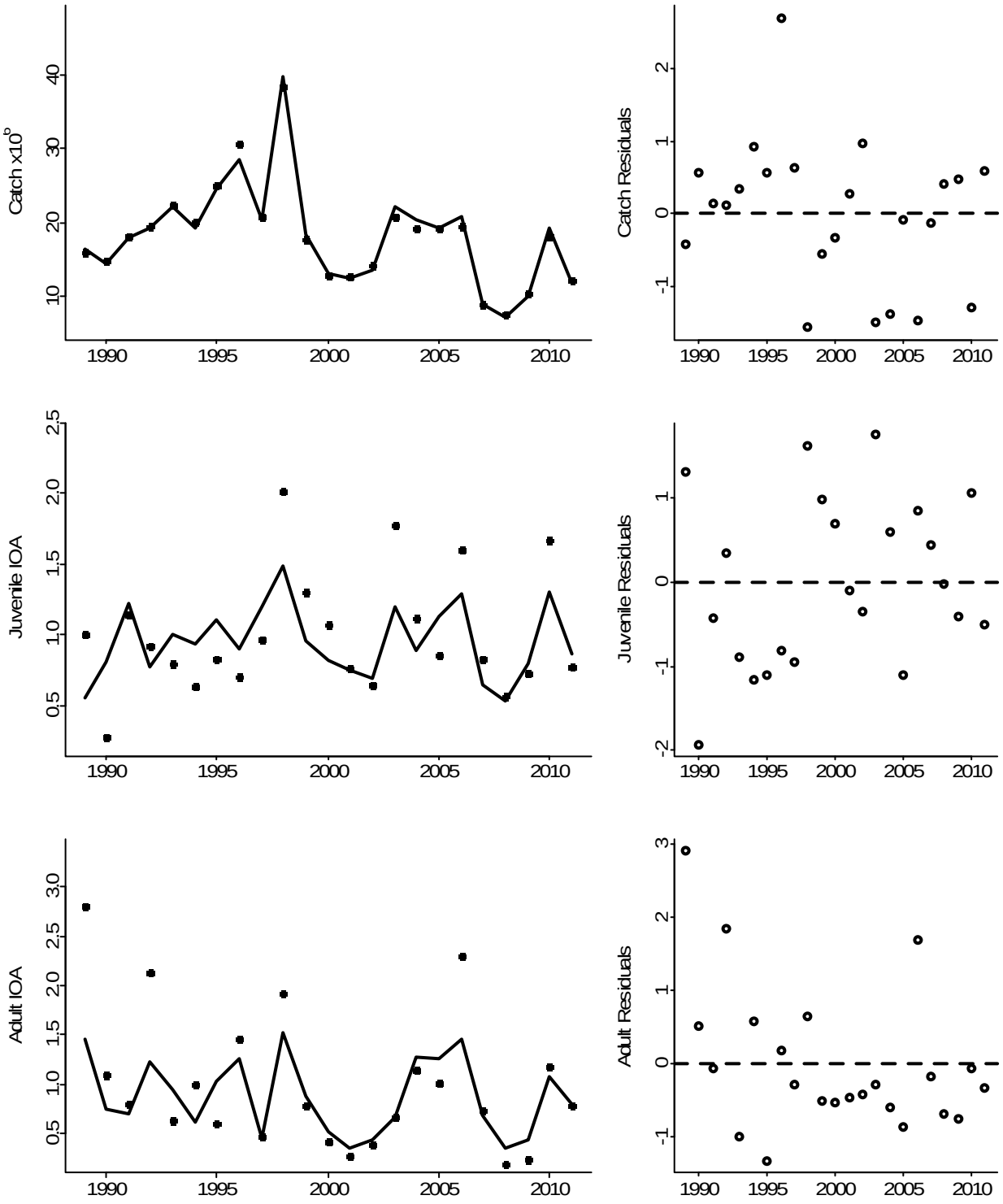

Figure 7.1.2. Atlantic coast observed (points) and estimated (line) landings and abundances for the base run (left panes), with model residuals (right panes) from the two-stage model.

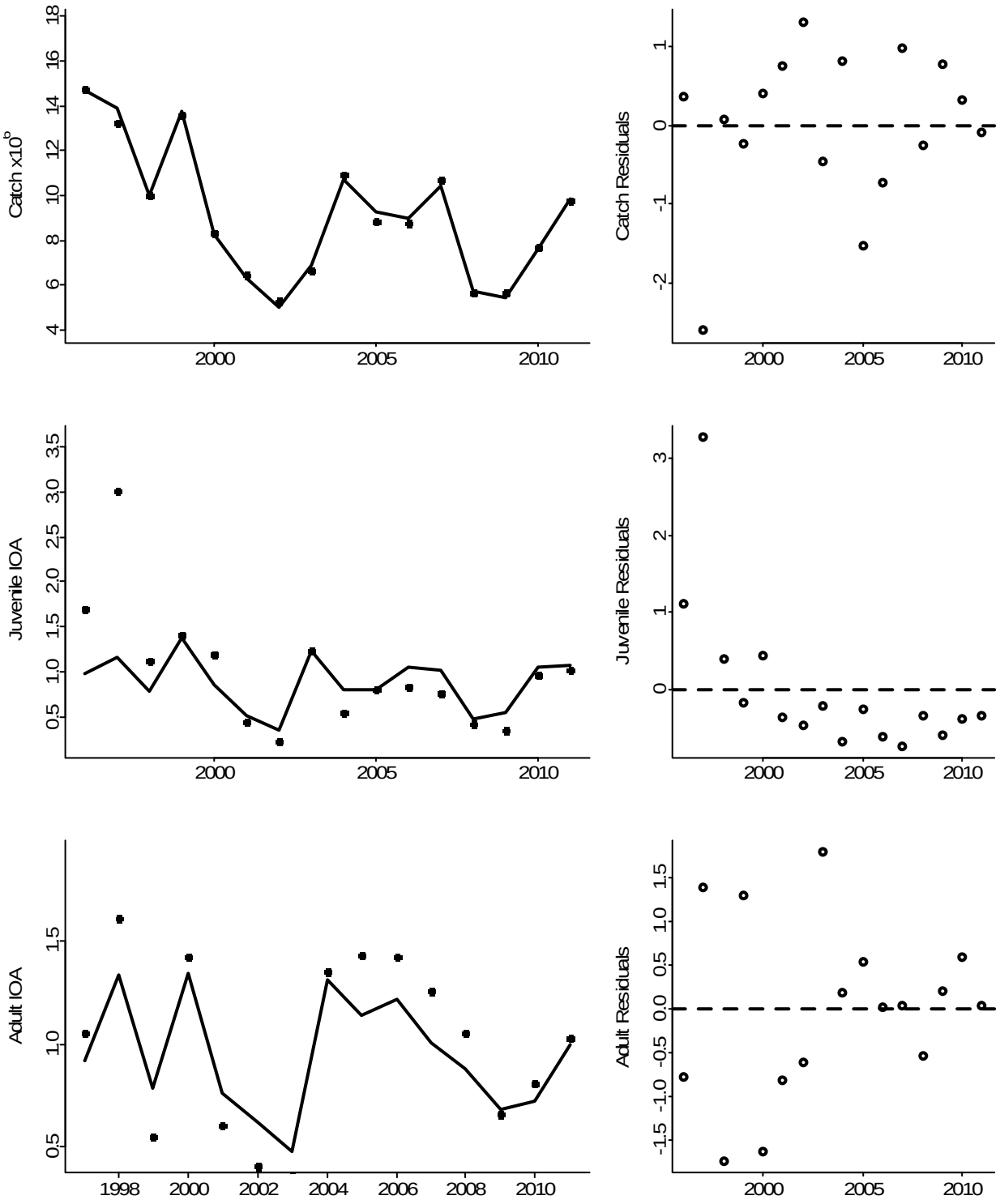

Figure 7.1.3. Gulf coast ASPIC model fit to the commercial CPUE data (top pane) and the FIM IOA (bottom pane), where points with dotted lines are the observed data, and the solid line is the model estimate.

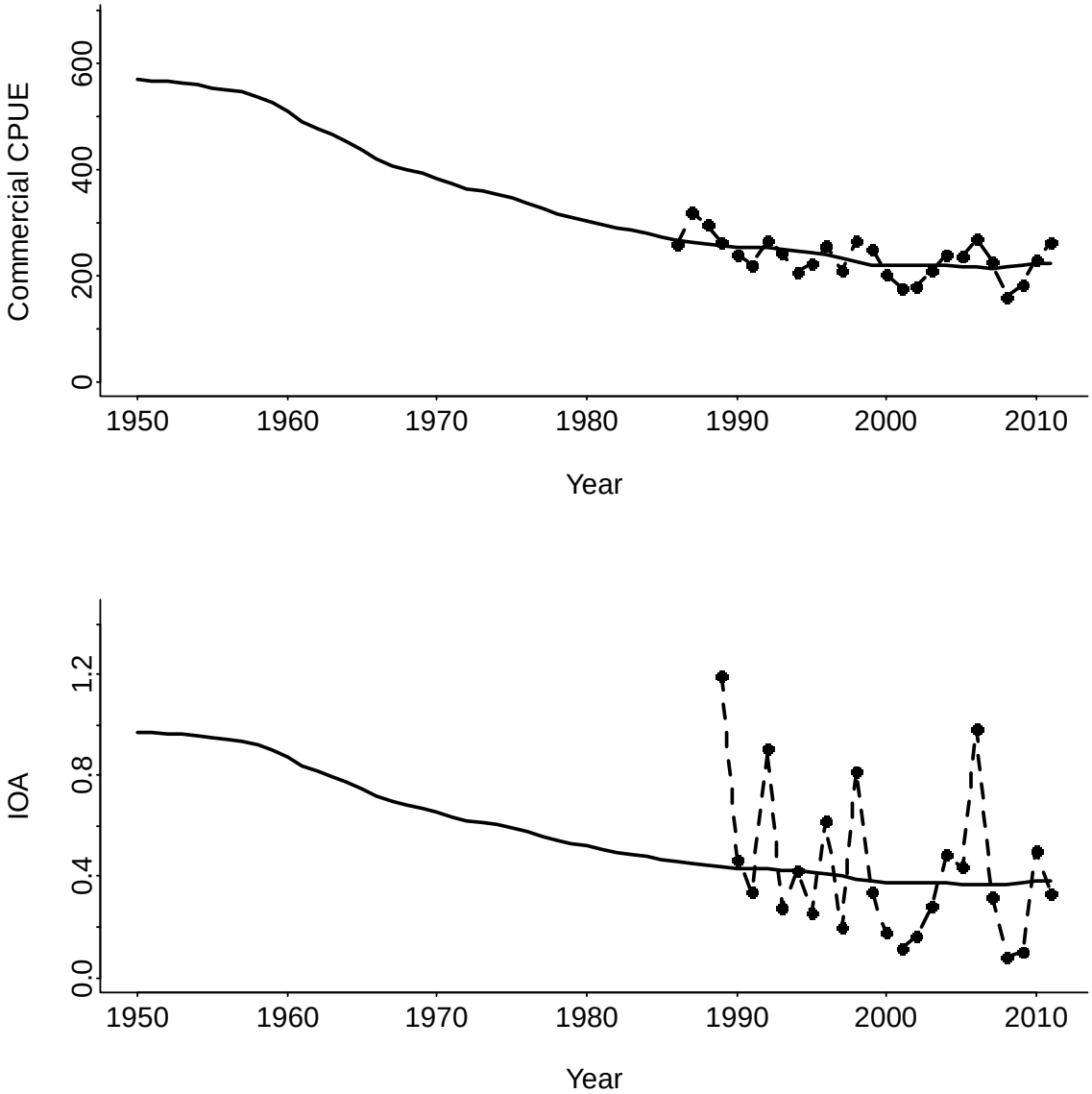

Figure 7.1.4. Atlantic coast ASPIC model fit to the commercial CPUE data (top pane) and the FIM IOA (bottom pane), where points with dotted lines are the observed data, and the solid line is the model estimate.

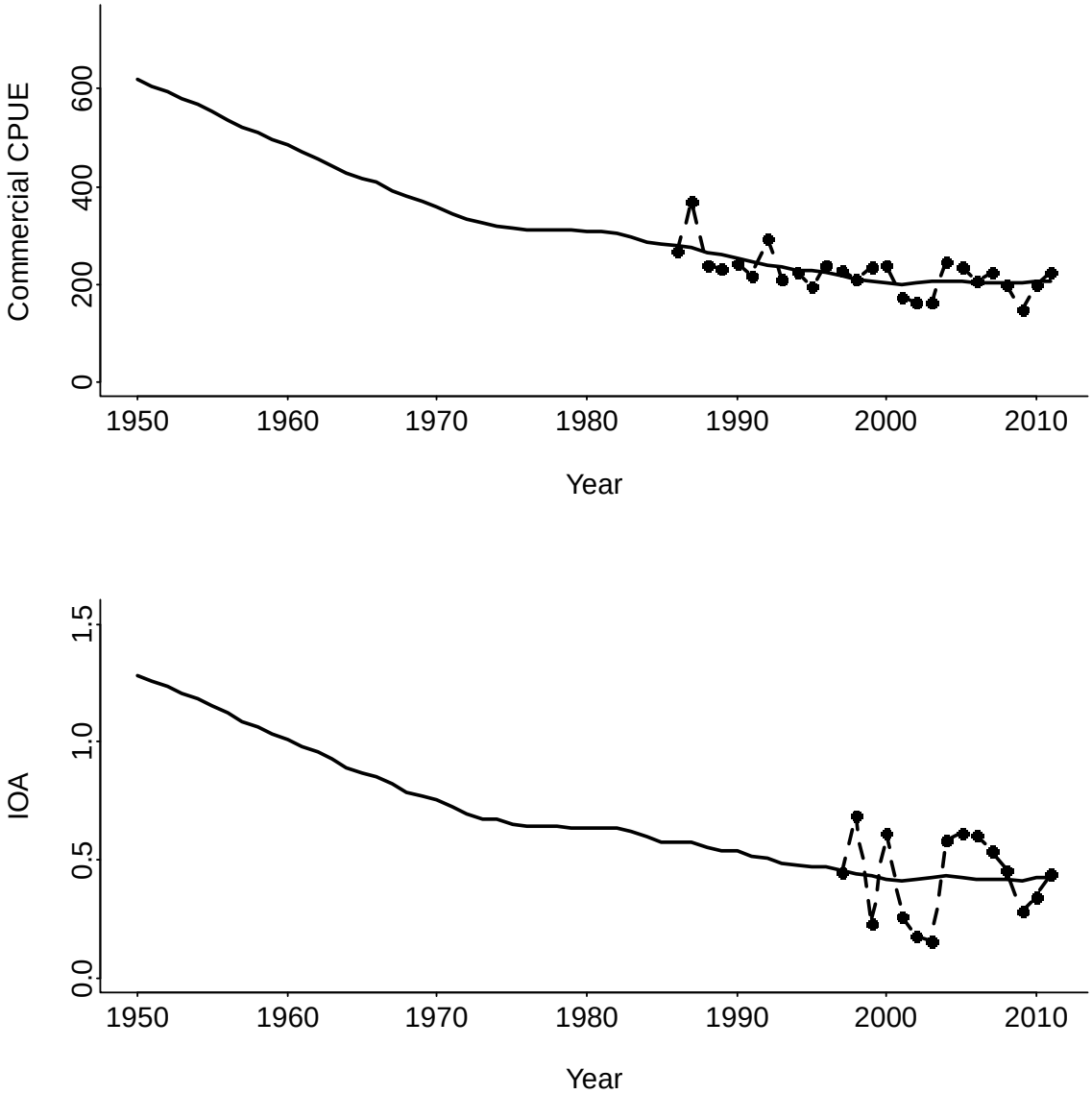

Figure 7.1.5. Gulf coast SSRA model fit to the FIM index of abundance, where points with dotted lines are the observed data, and the solid line is the model estimate.

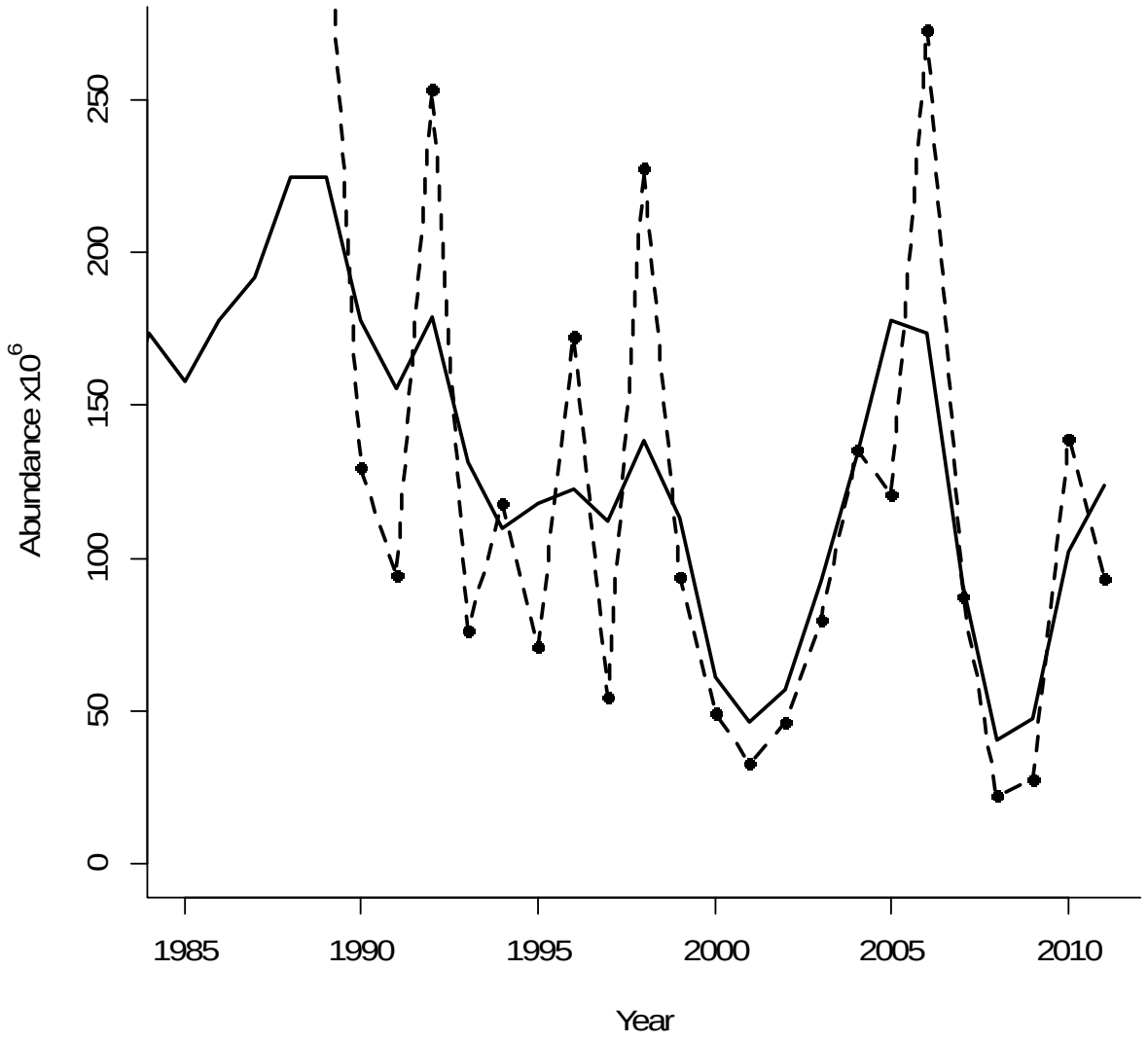

Figure 7.1.6. Atlantic coast SSRA model fit to the FIM index of abundance, where points with dotted lines are the observed data, and the solid line is the model estimate.

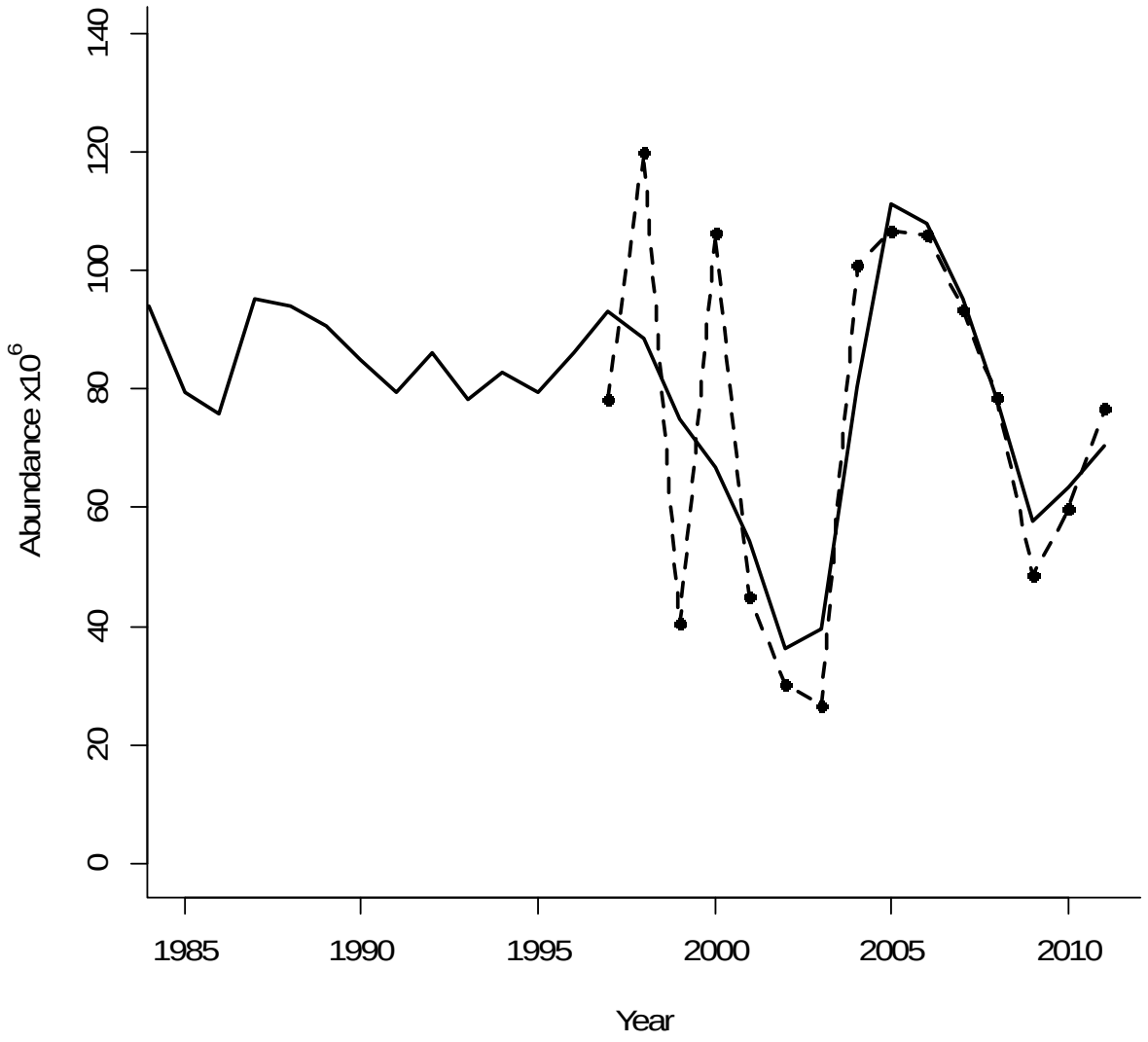

Figure 7.2.1.1. Gulf stock predicted abundance of juveniles and adults at the start of the year (top two panes) and the F rate (bottom pane) from the base model run best fit (solid line) and the MCMC median estimate (dotted line). 95% confidence intervals are presented from the MCMC runs.

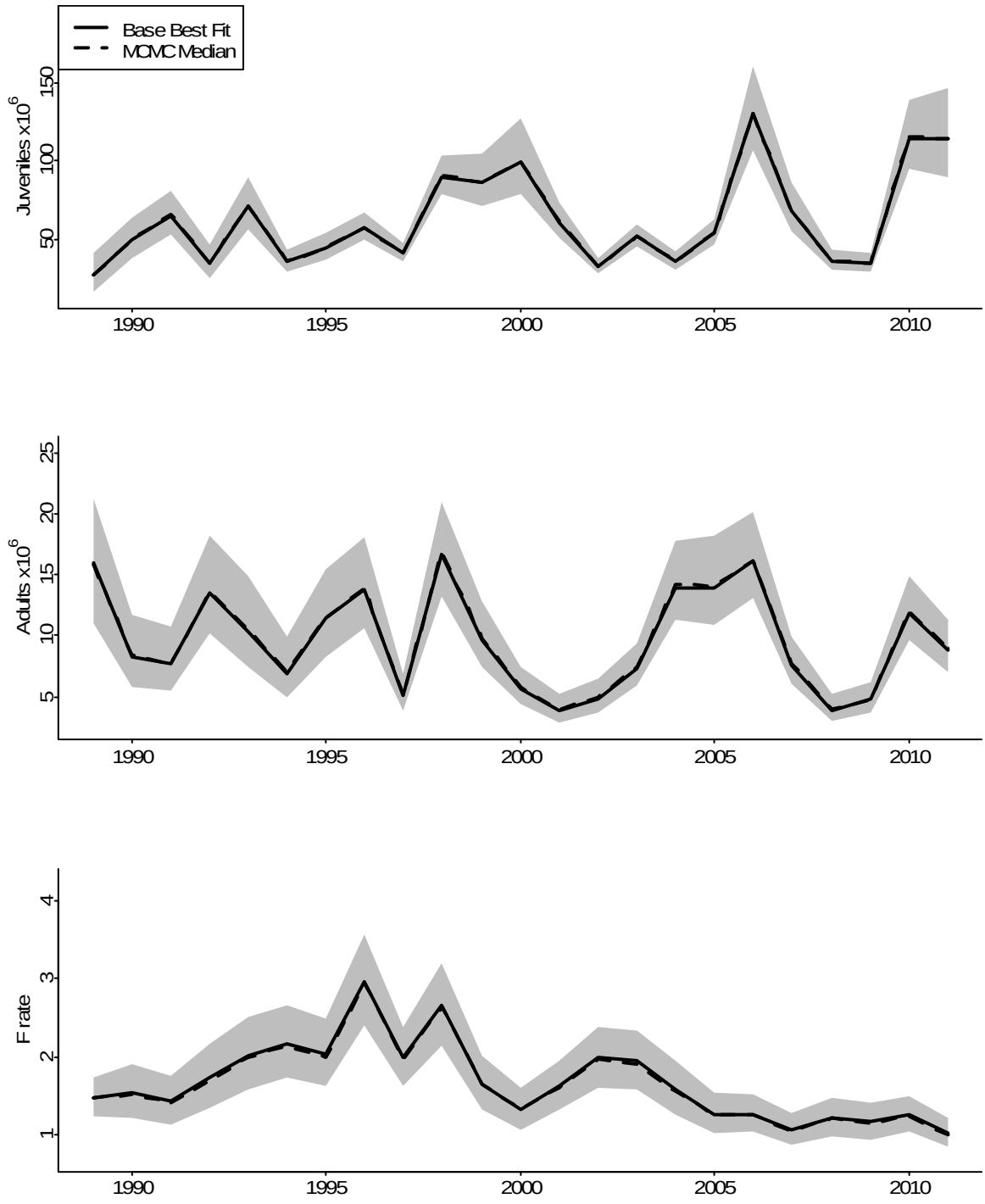

Figure 7.2.1.2. Atlantic stock predicted abundance of juveniles and adults at the start of the year (top two panes) and the F rate (bottom pane) from the base model run best fit (solid line) and the MCMC median estimate (dotted line). 95% confidence intervals are presented from the MCMC runs.

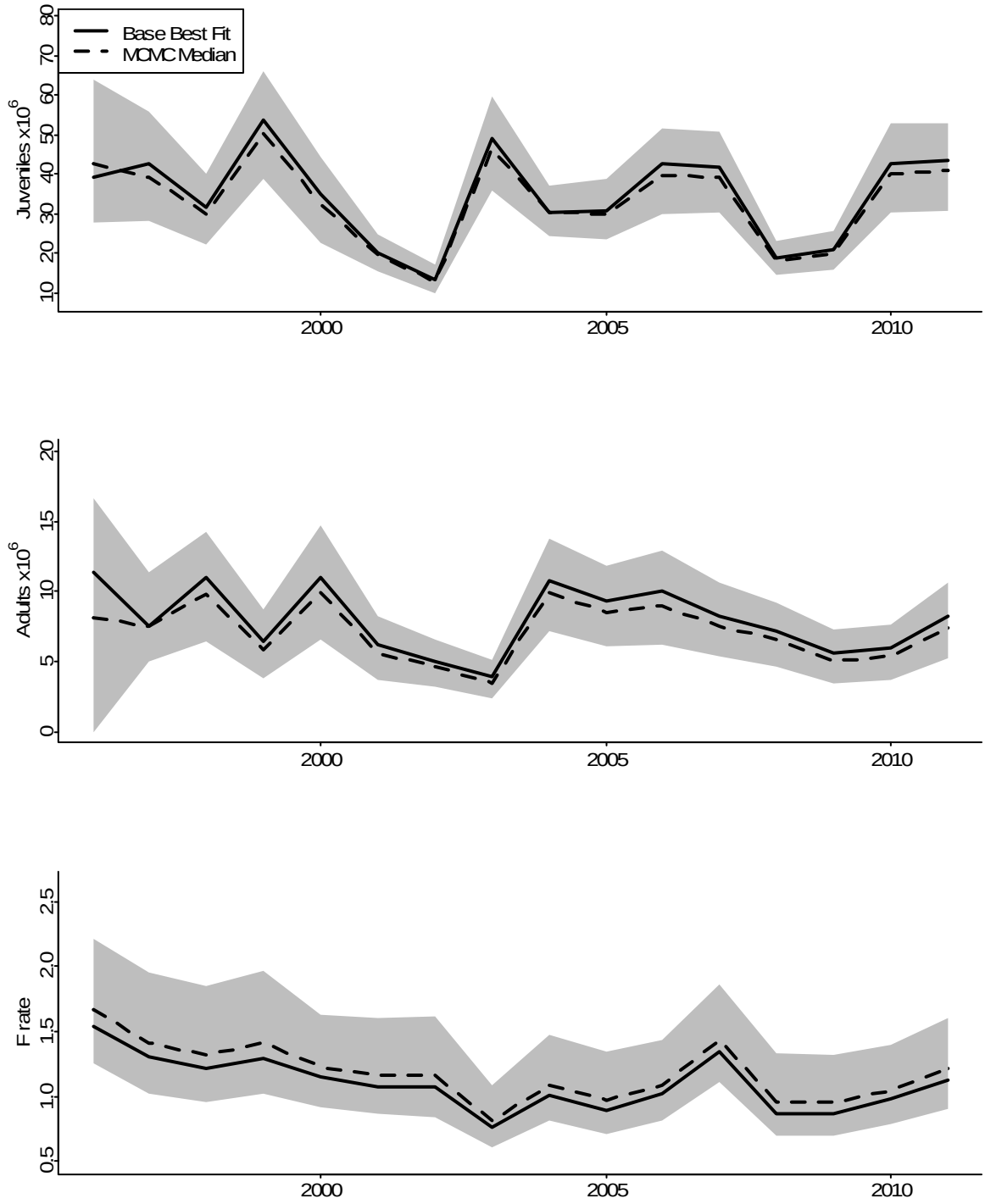

Figure 7.2.1.3. Estimated Gulf coast landings per stage relative to MSY as estimated in the two-stage model.

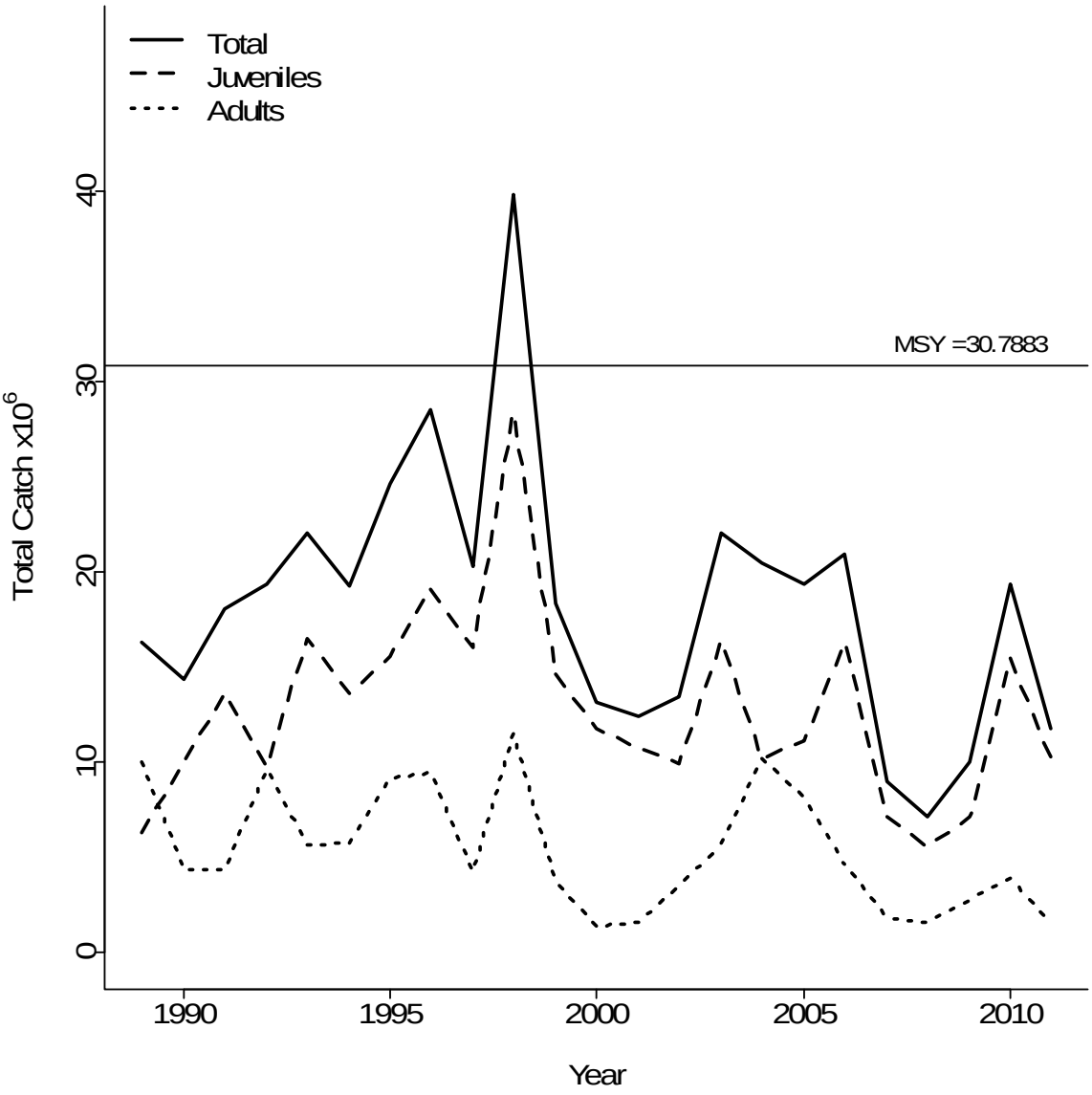

Figure 7.2.1.4. Gulf coast landings relative to MSY as estimated in ASPIC (top pane), and the estimated population abundance relative to landings from ASPIC (bottom pane).

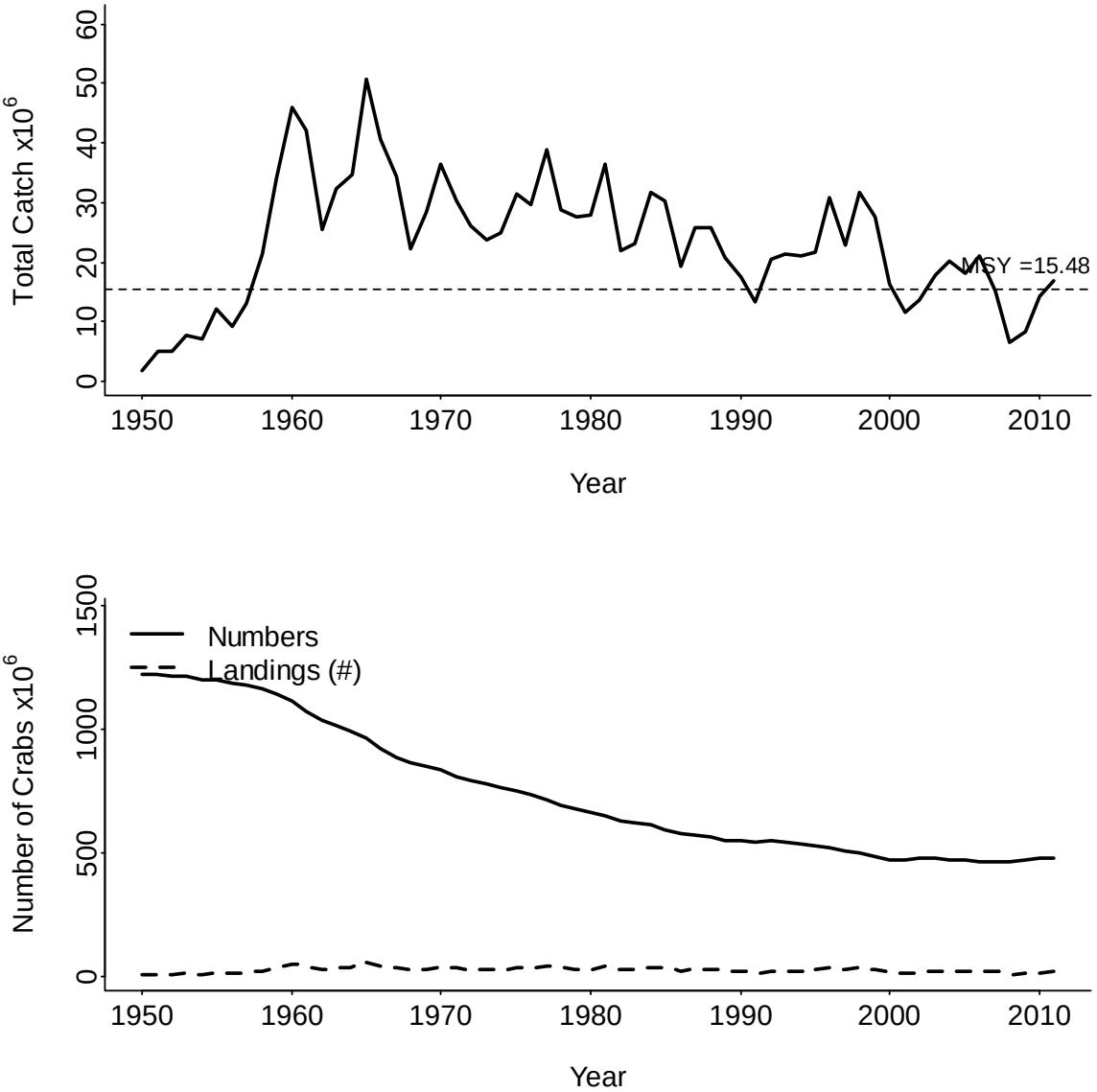

Figure 7.2.1.5. Gulf coast abundance of crabs relative to the median abundance at MSY and the limit reference point, which accounts for the high natural mortality rate of blue crabs, as estimated from SSRA.

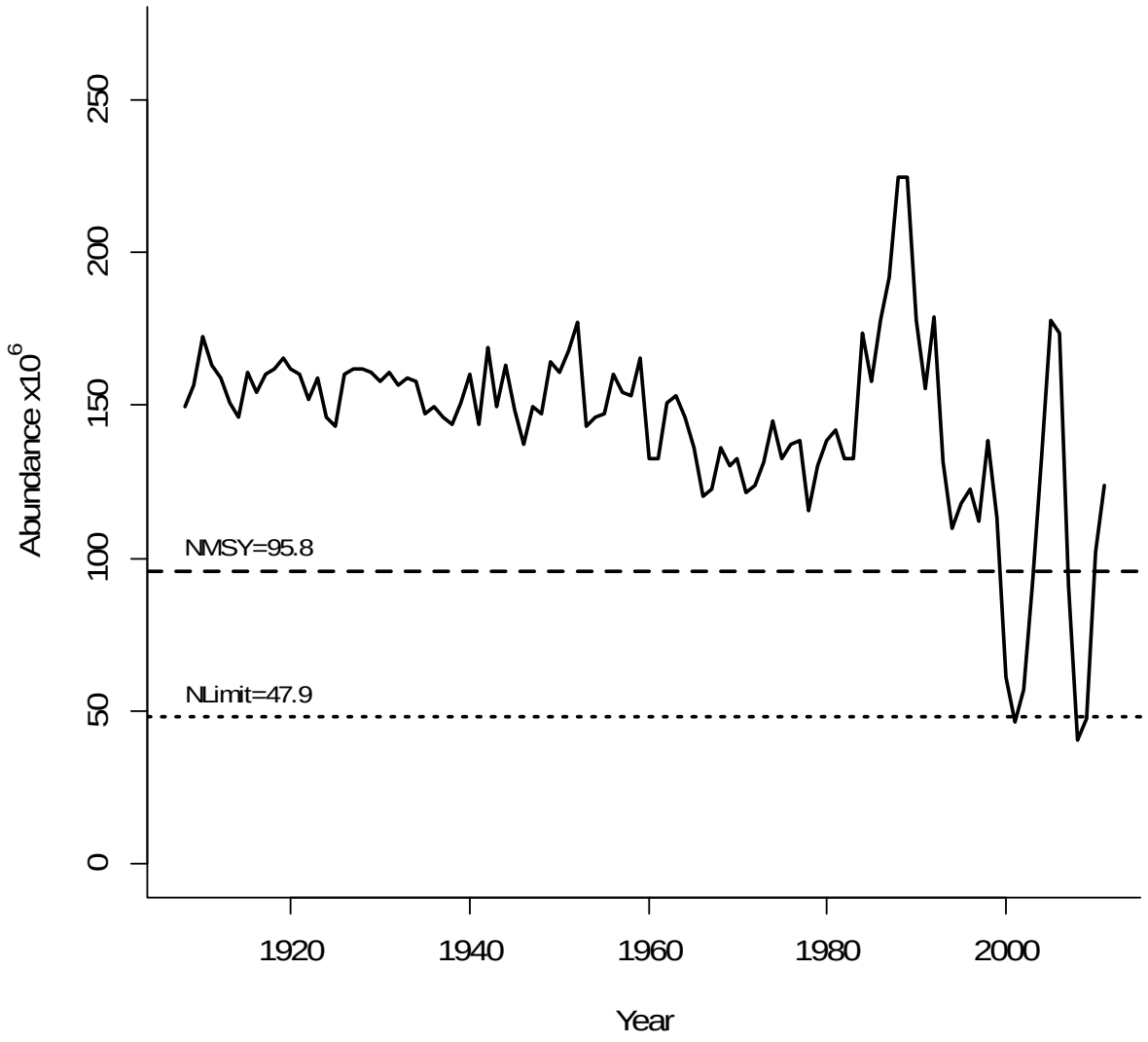

Figure 7.2.1.6. Gulf coast exploitation rate relative to the median MSY and limit reference point, which accounts for the high natural mortality rate of blue crabs, as estimated from SSRA.

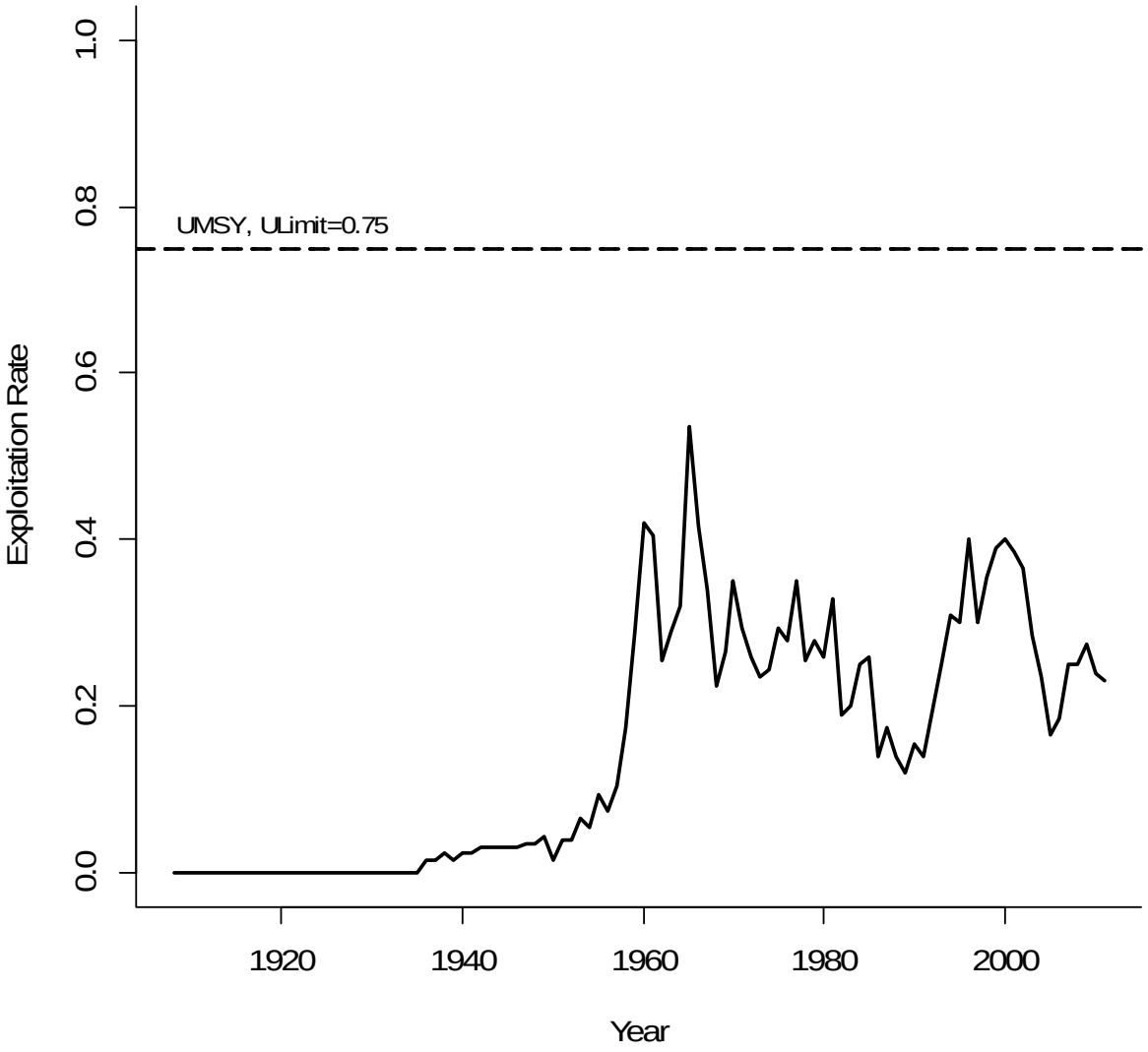

Figure 7.2.1.7. Estimated Atlantic coast landings per stage relative to MSY as estimated in the two-stage model.

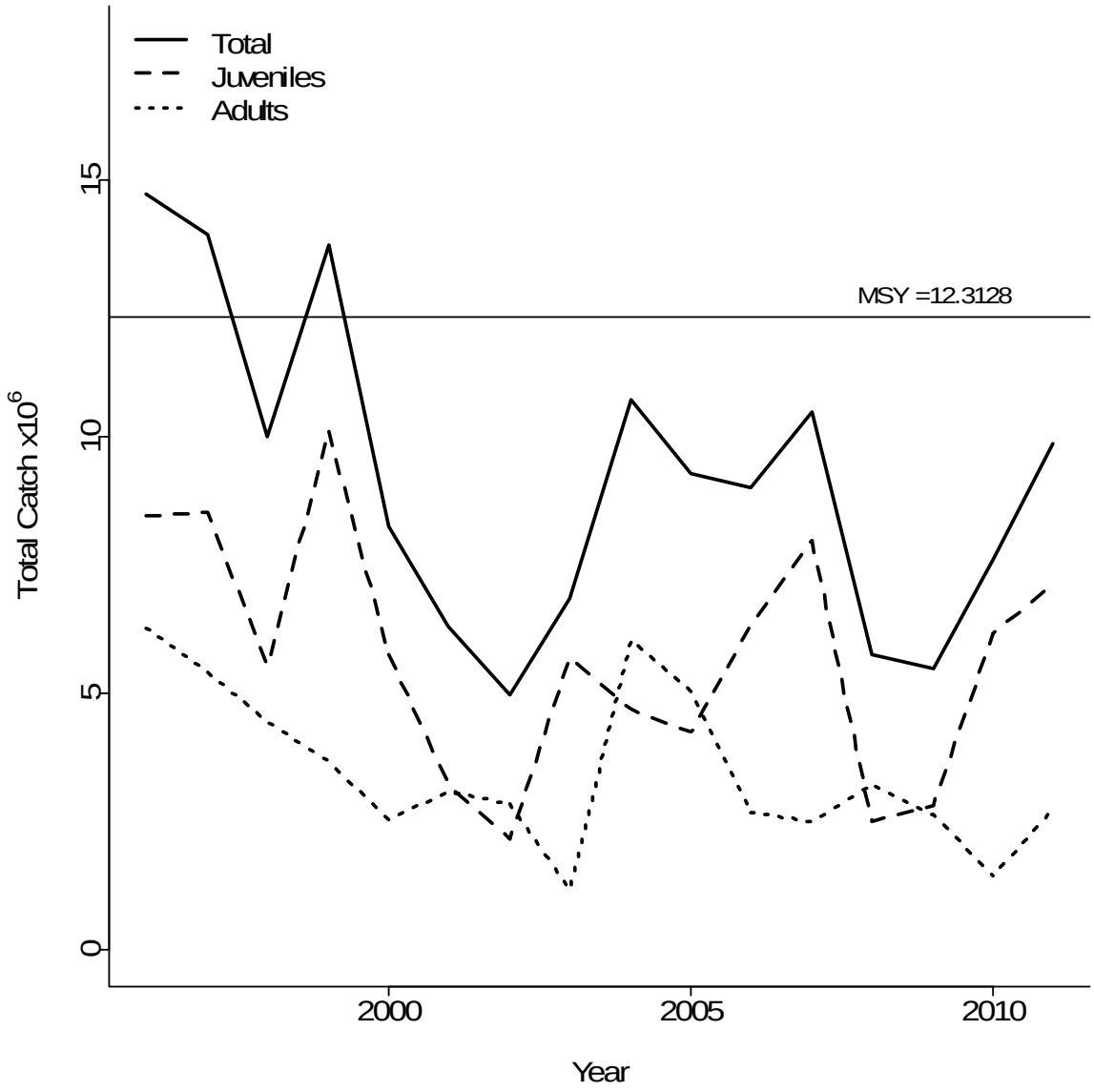

Figure 7.2.1.8. Atlantic coast landings relative to MSY as estimated in ASPIC (top pane), and the estimated population abundance relative to landings from ASPIC (bottom pane).

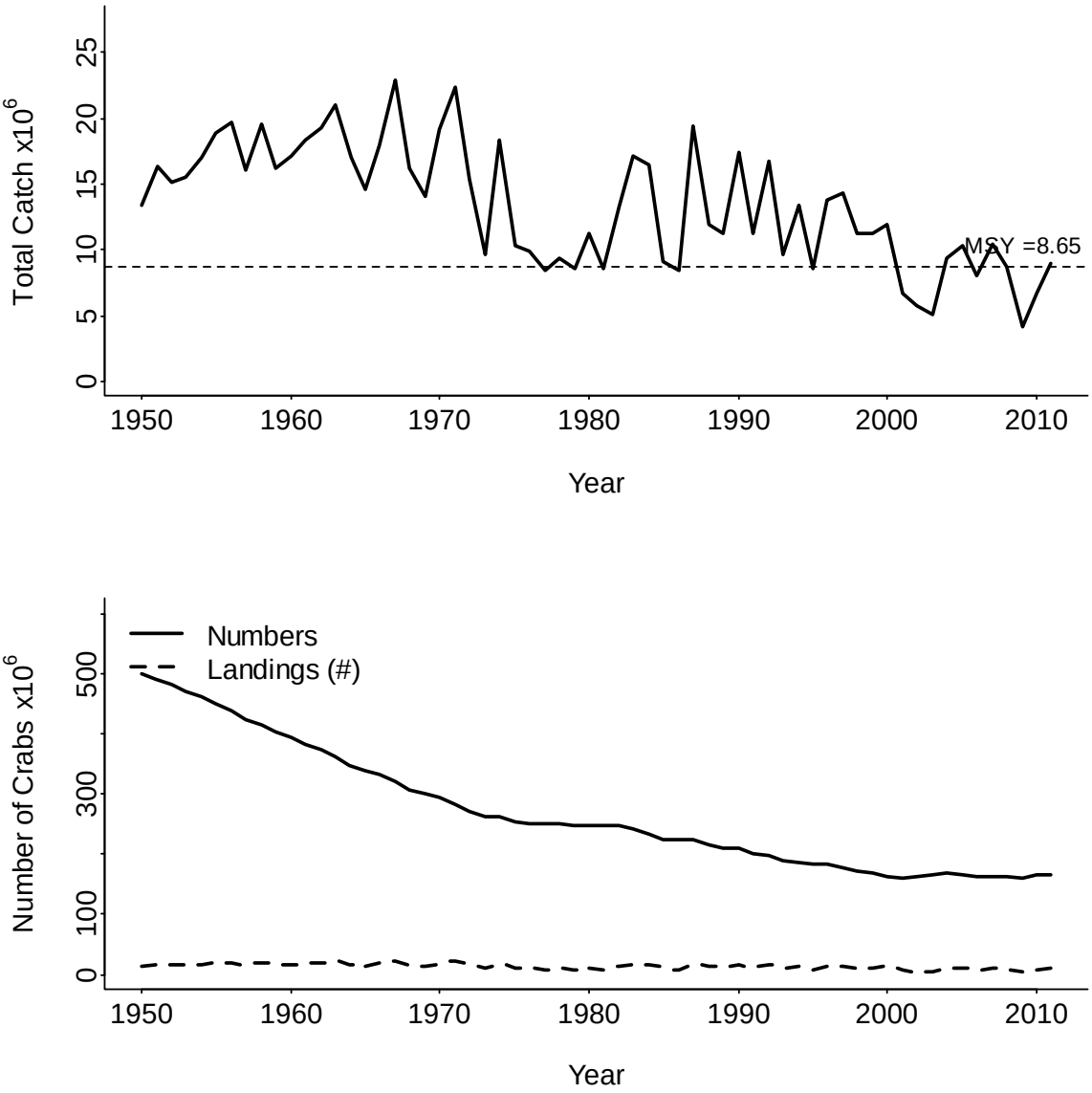

Figure 7.2.1.9. Atlantic coast abundance of crabs relative to the median abundance at MSY and the limit reference point, which accounts for the high natural mortality rate of blue crabs, as estimated from SSRA.

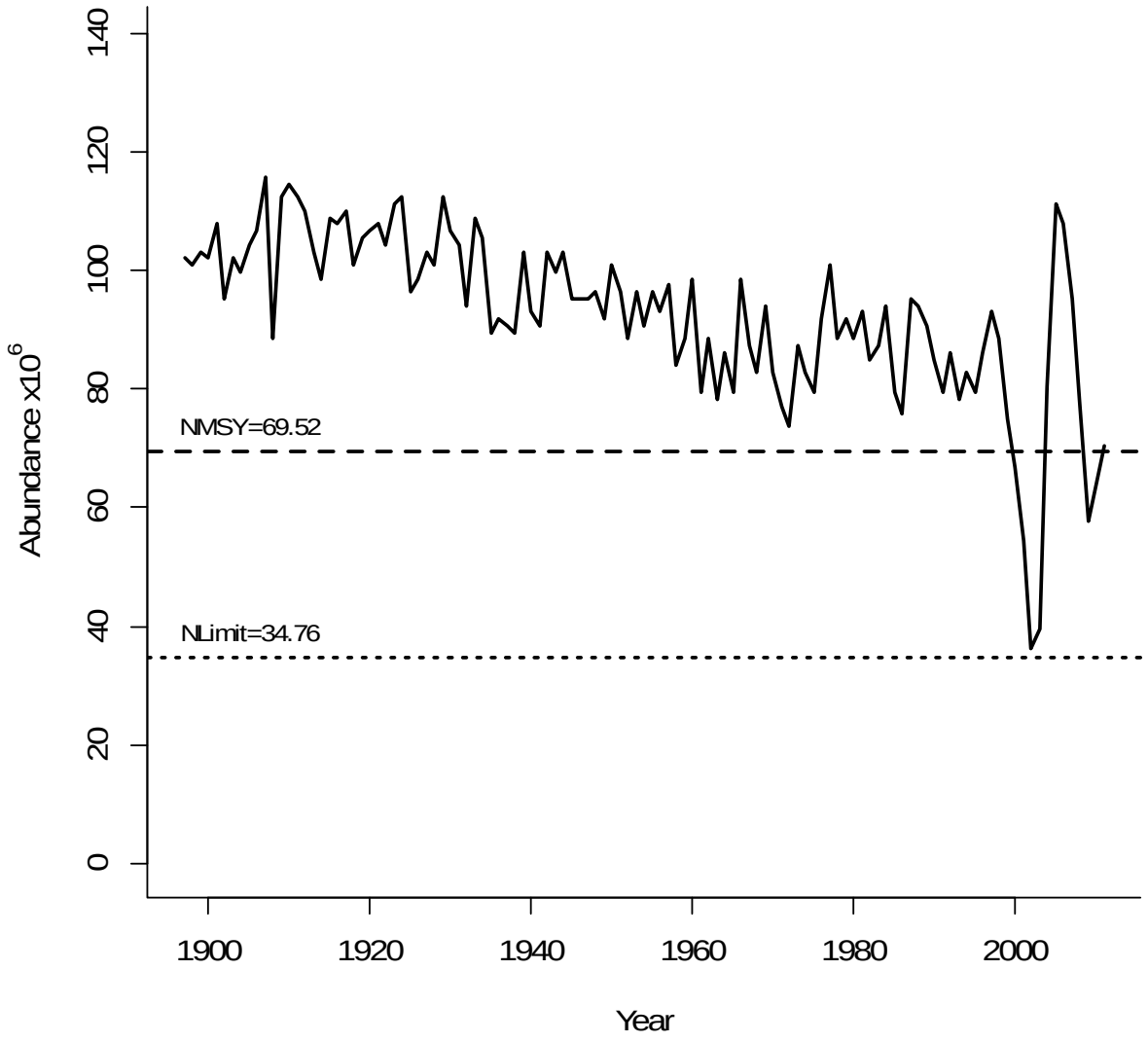

Figure 7.2.1.10. Atlantic coast exploitation rate relative to the median MSY and limit reference point, which accounts for the high natural mortality rate of blue crabs, as estimated from SSRA.

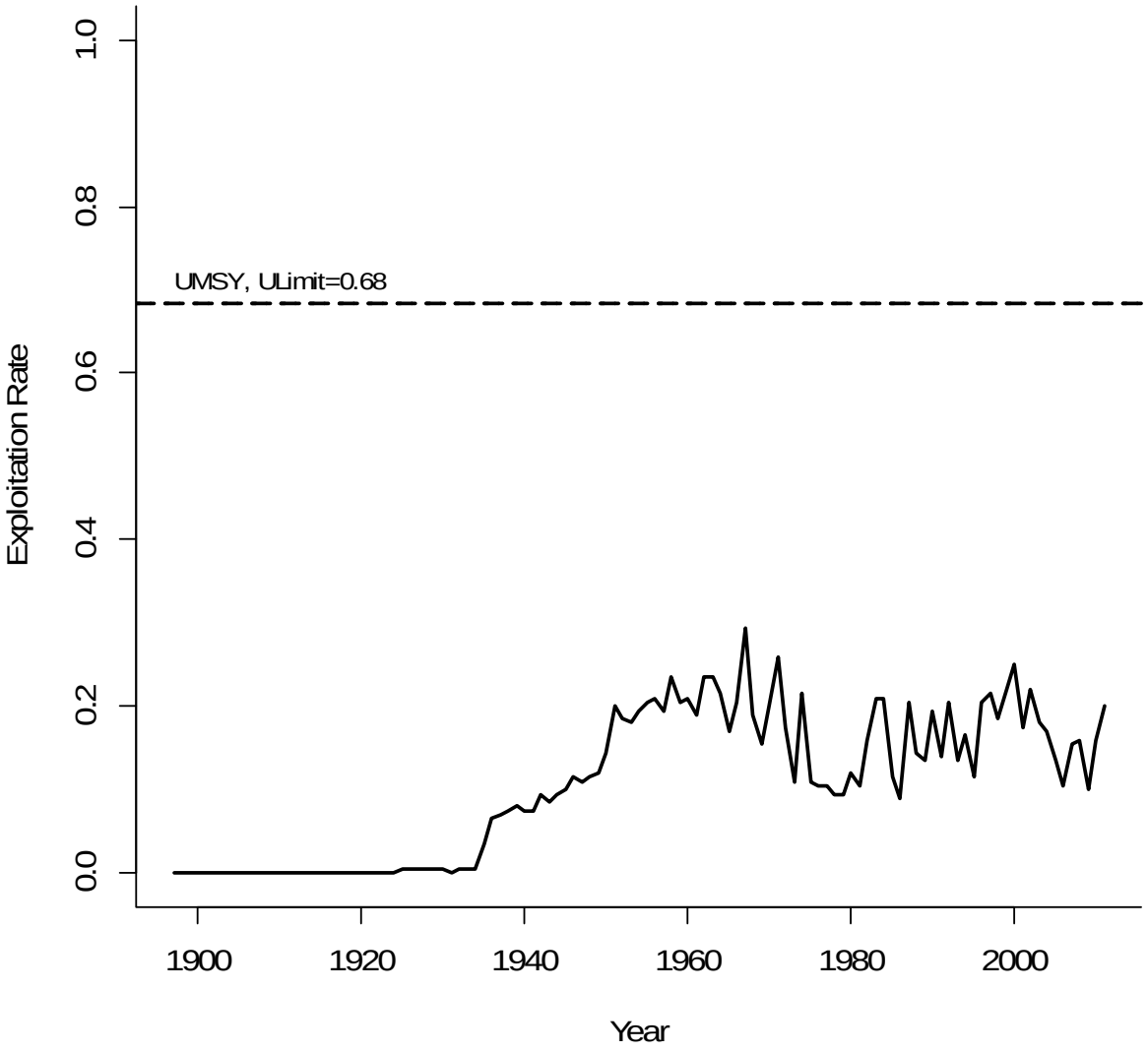

Figure 7.2.1.11. Gulf stock estimated stock recruitment relationship (top pane) with year-specific residuals (bottom pane).

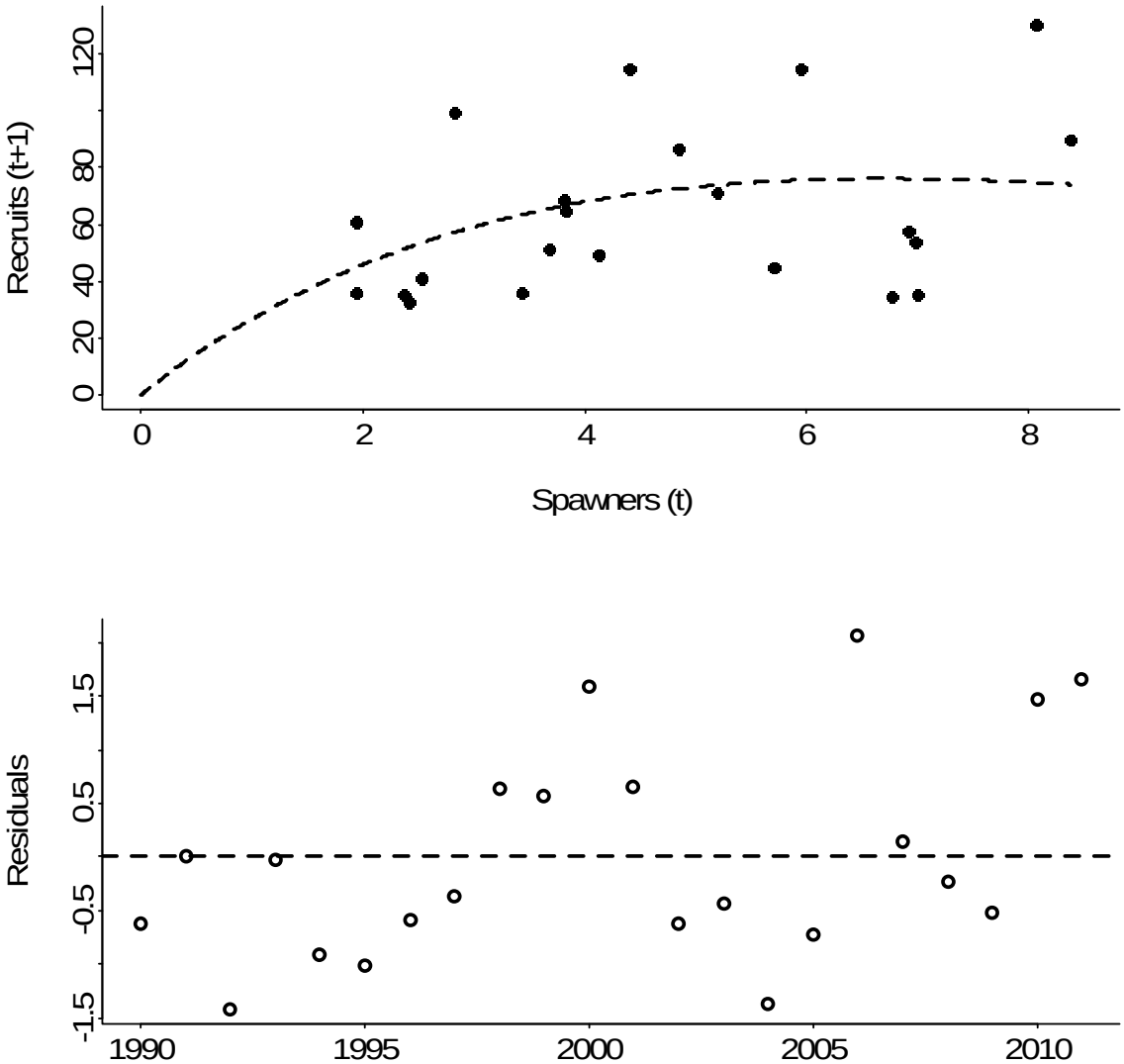

Figure 7.2.1.12. Atlantic stock estimated stock recruitment relationship (top pane) with year-specific residuals (bottom pane).

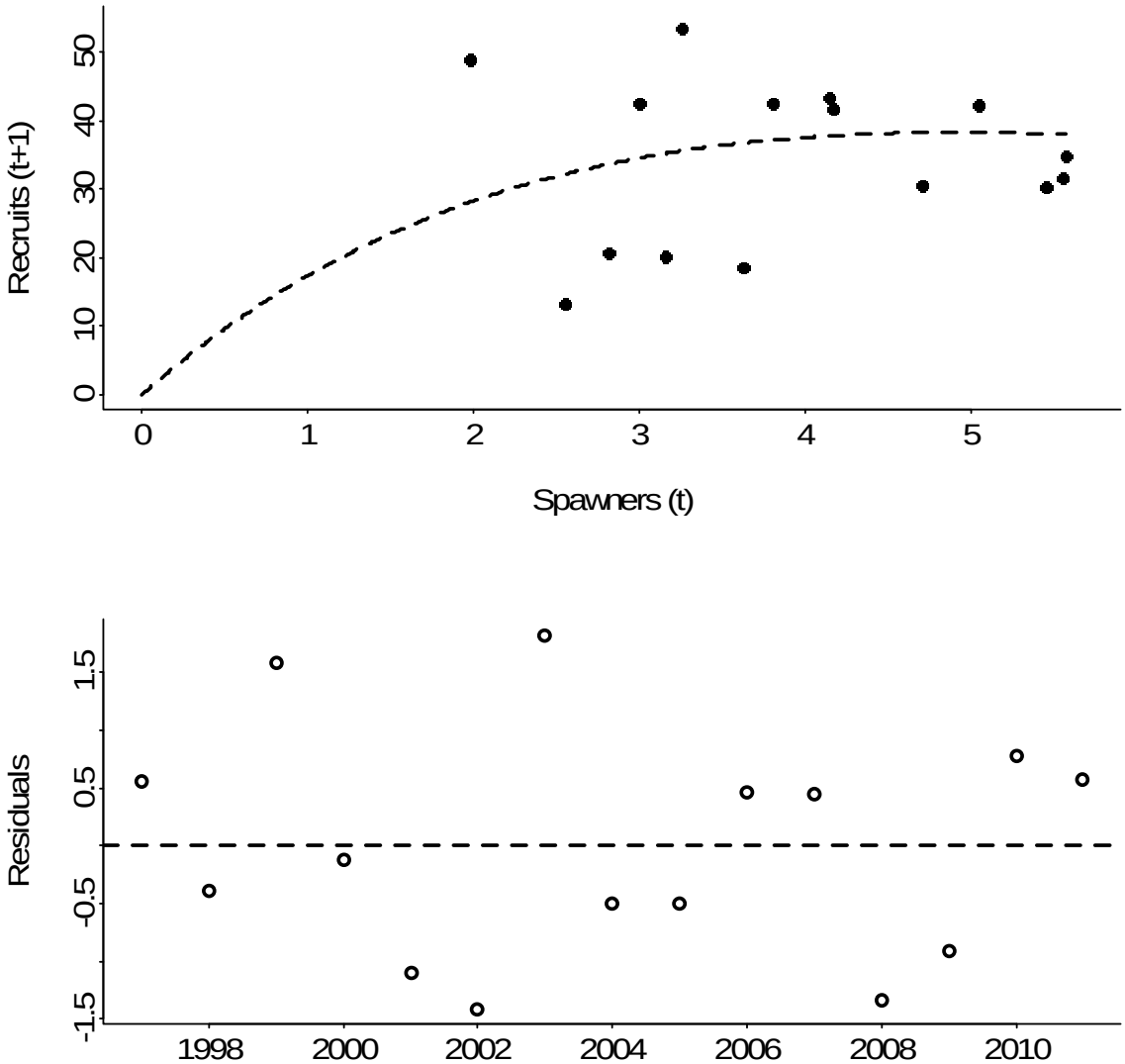

Figure 7.2.2.1. Gulf coast MCMC posterior distributions of the parameter estimates (not including year-specific F deviations and recruitment deviations) from the two-stage model.

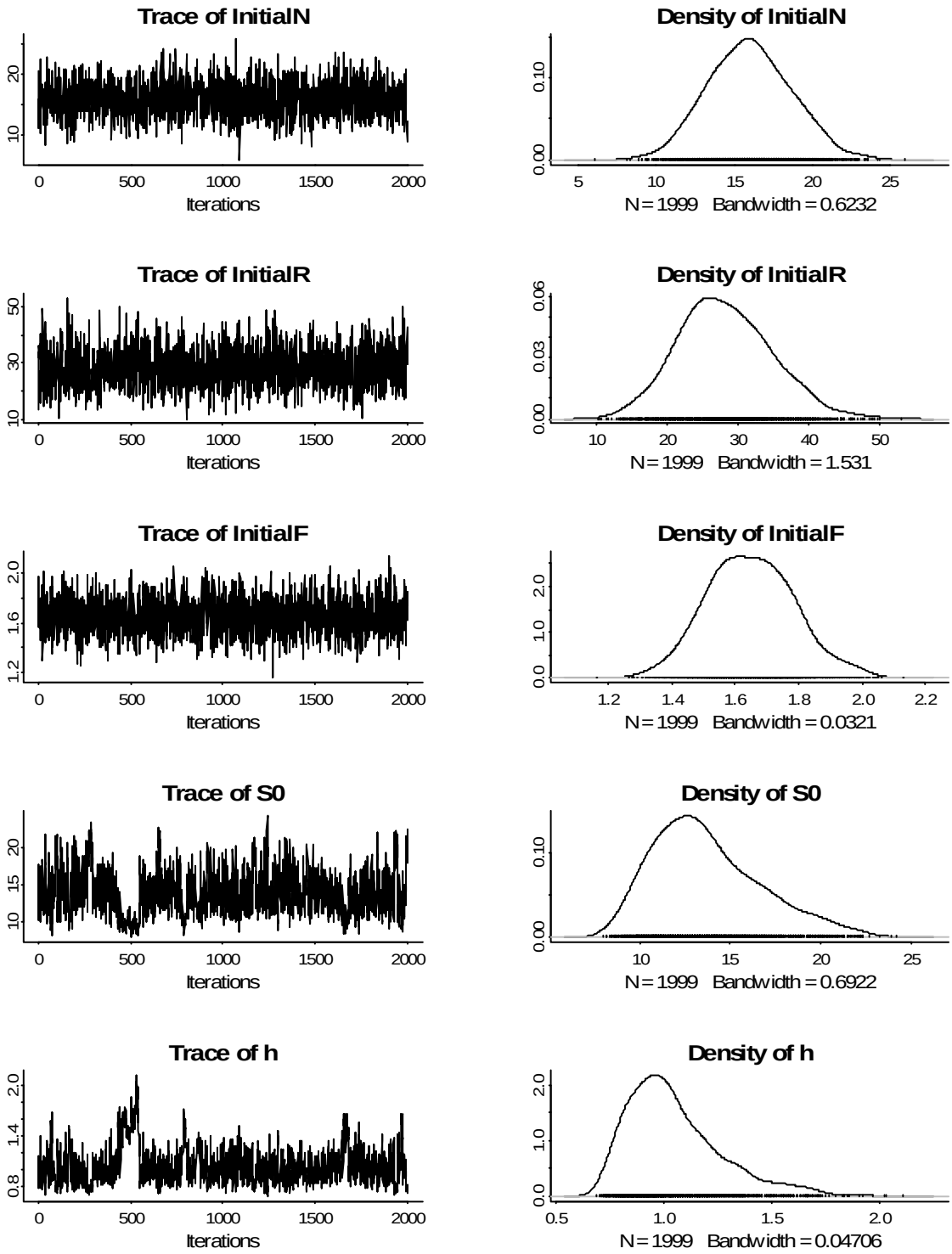

Figure 7.2.2.2. Gulf stock MCMC posterior distributions of the reference points from the two-stage base model.

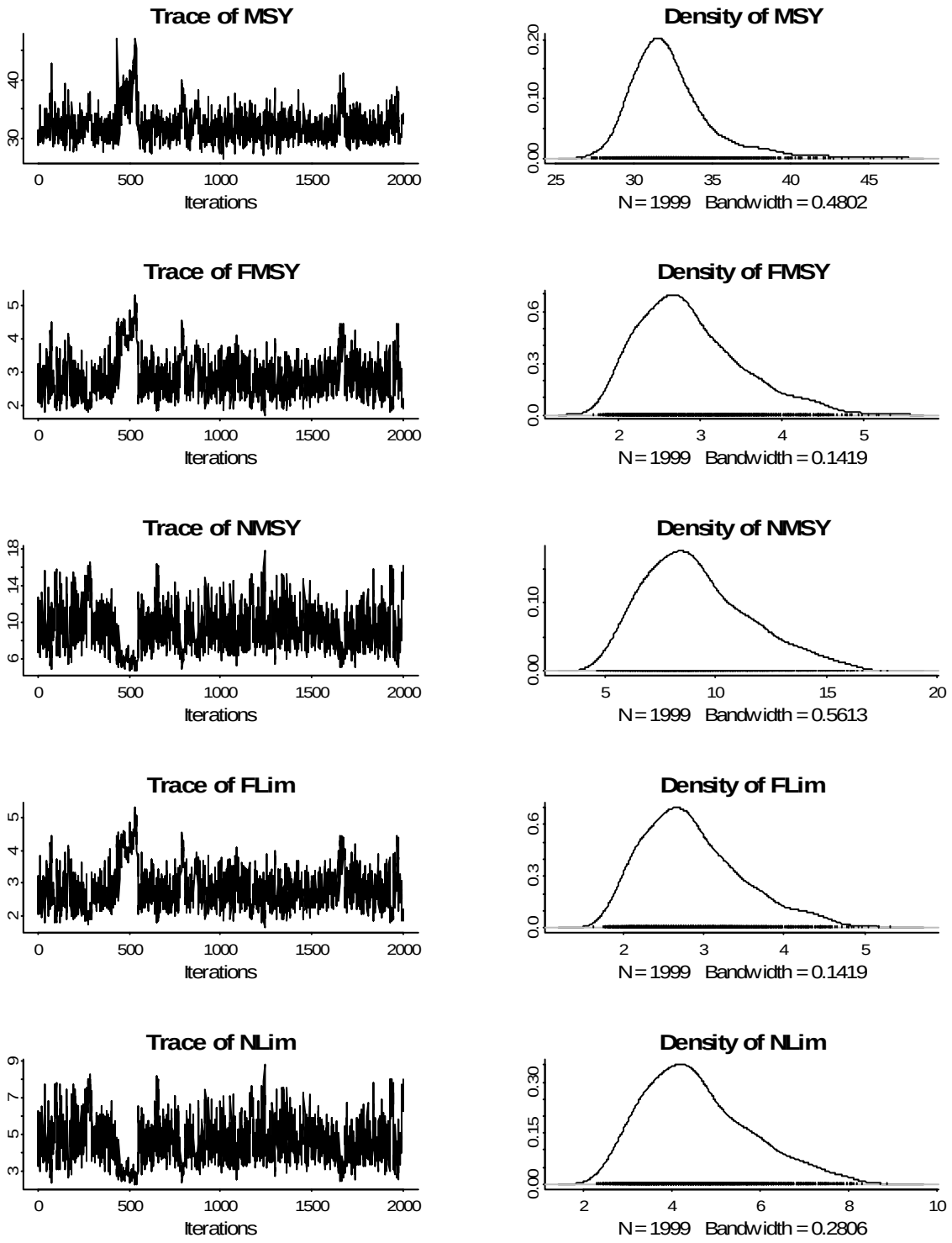

Figure 7.2.2.3. Atlantic stock MCMC posterior distributions of the parameter estimates (not including year-specific F deviations and recruitment deviations) from the two-stage base model.

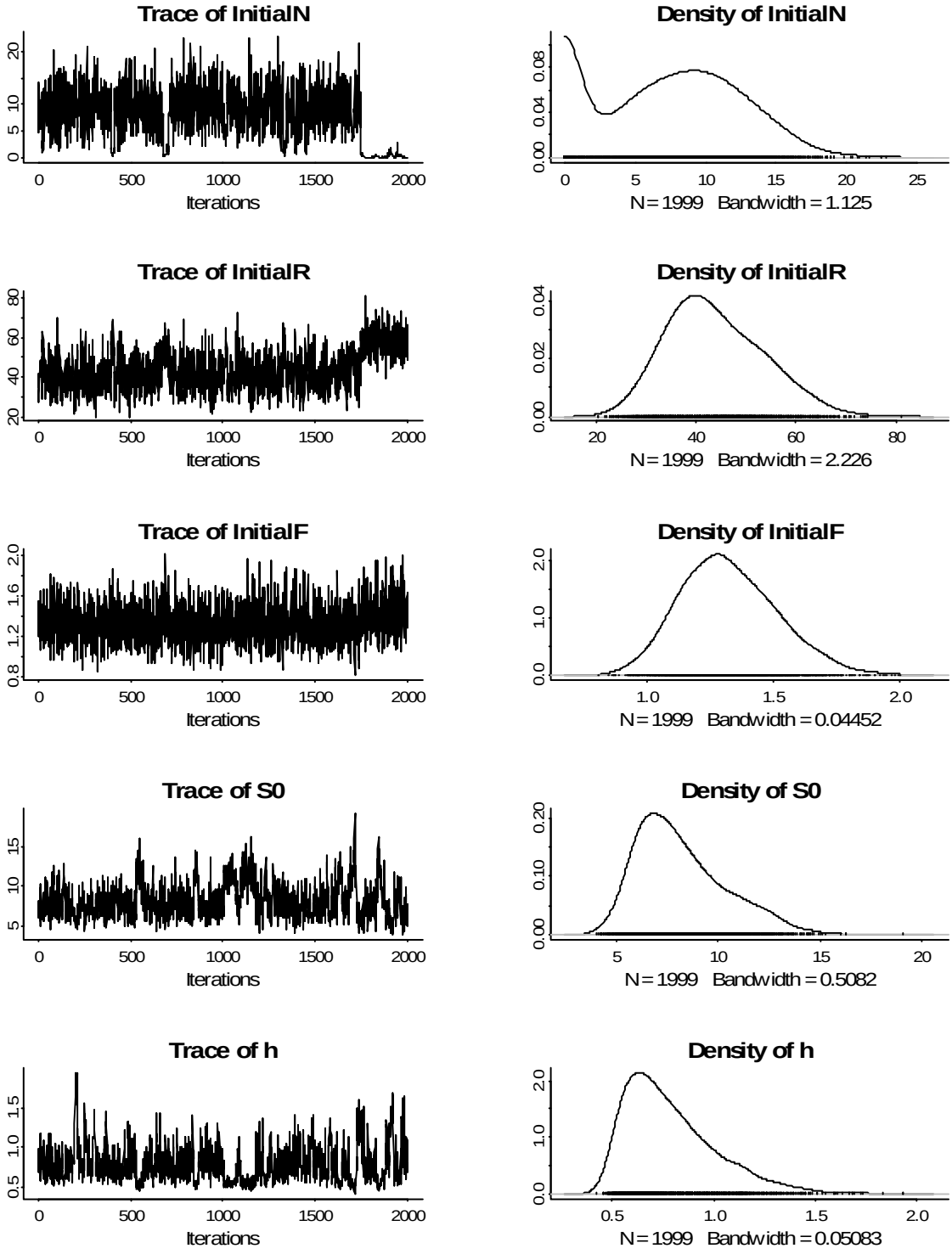

Figure 7.2.2.4. Atlantic stock MCMC posterior distributions of the reference points from the two-stage base model.

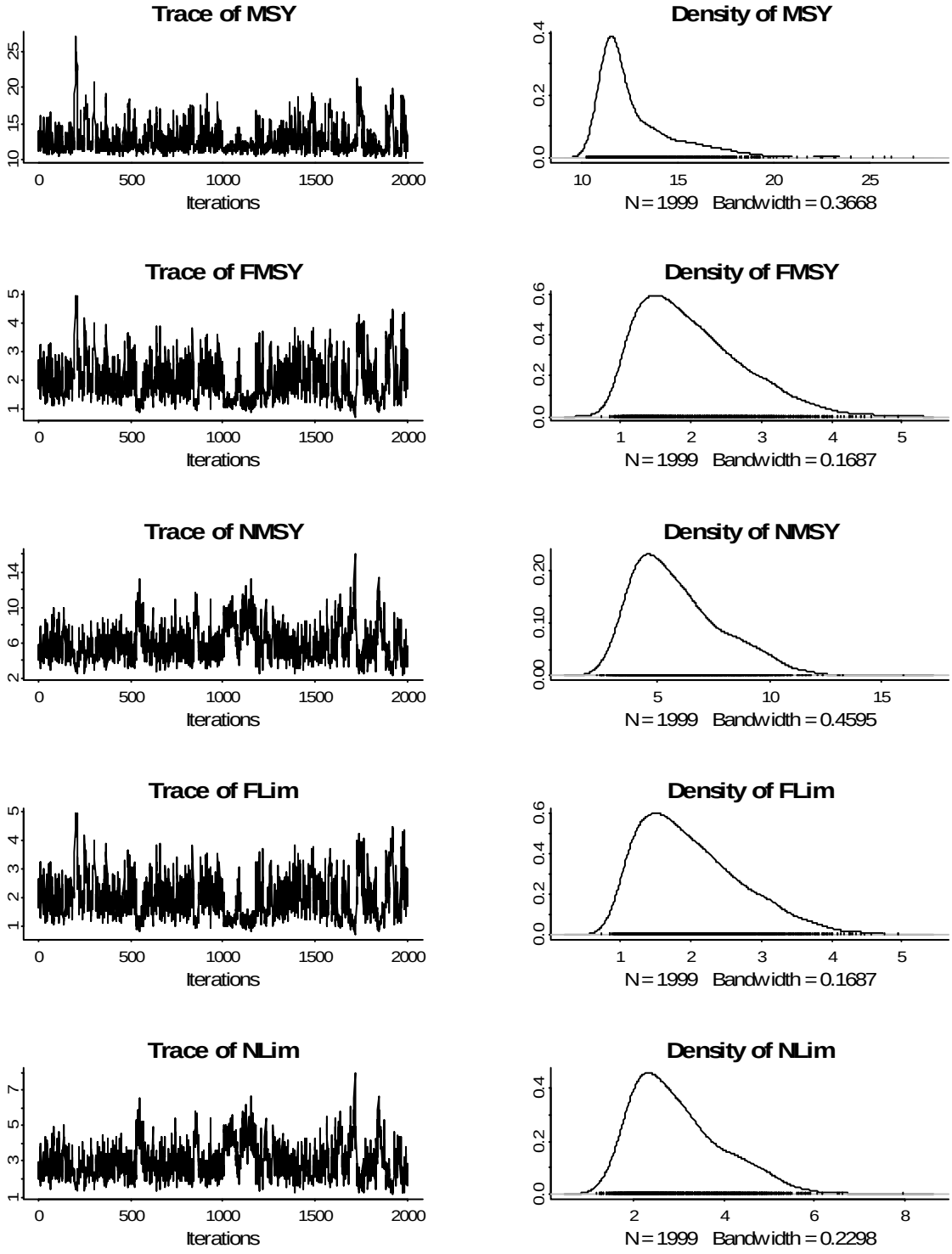

Figure 7.2.2.5. Gulf coast MCMC prior distributions of the reference points from the SSRA base model (initial U=0.3).

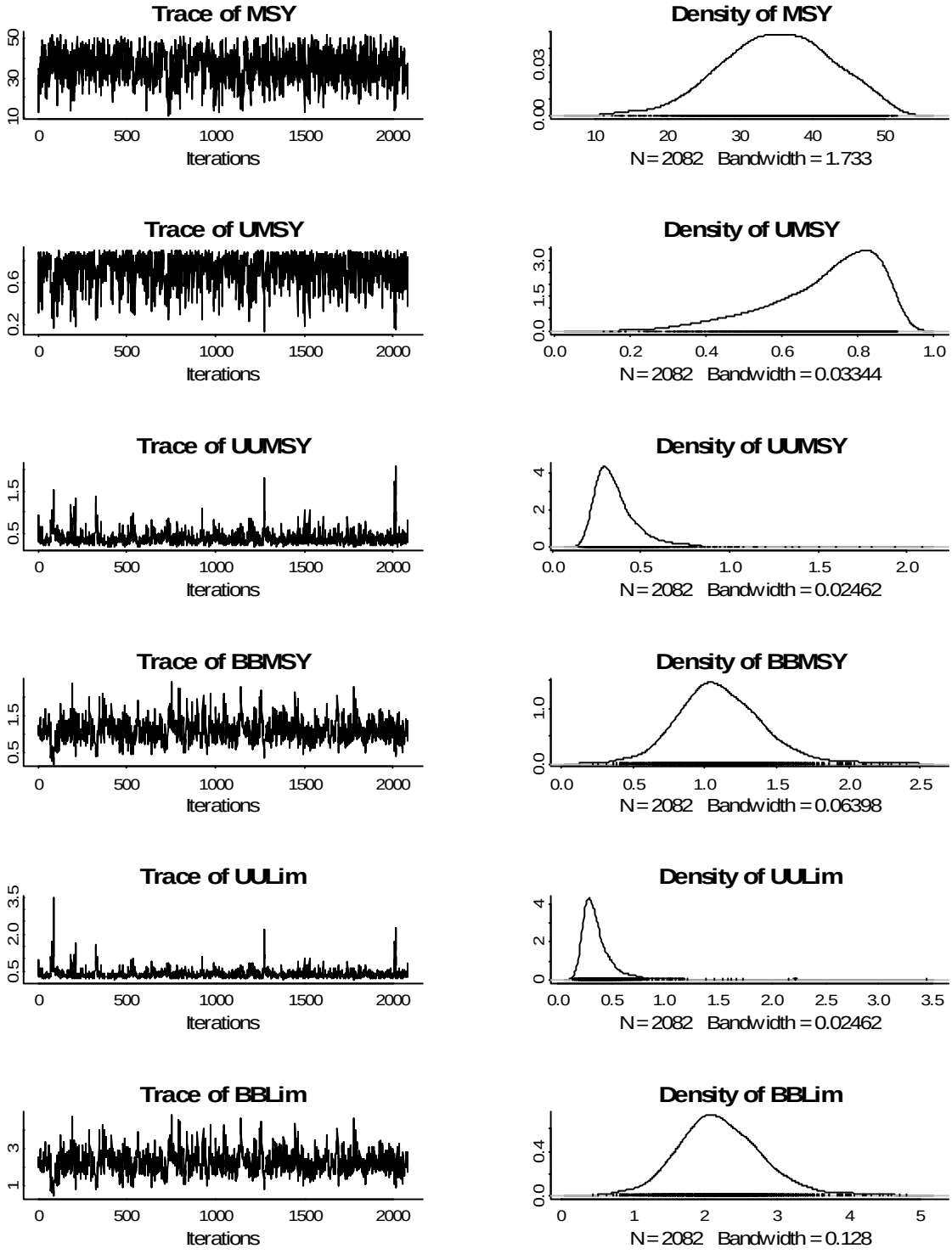

Figure 7.2.2.6. Atlantic coast MCMC prior distributions of the reference points from the SSRA base model (initial U=0.3).

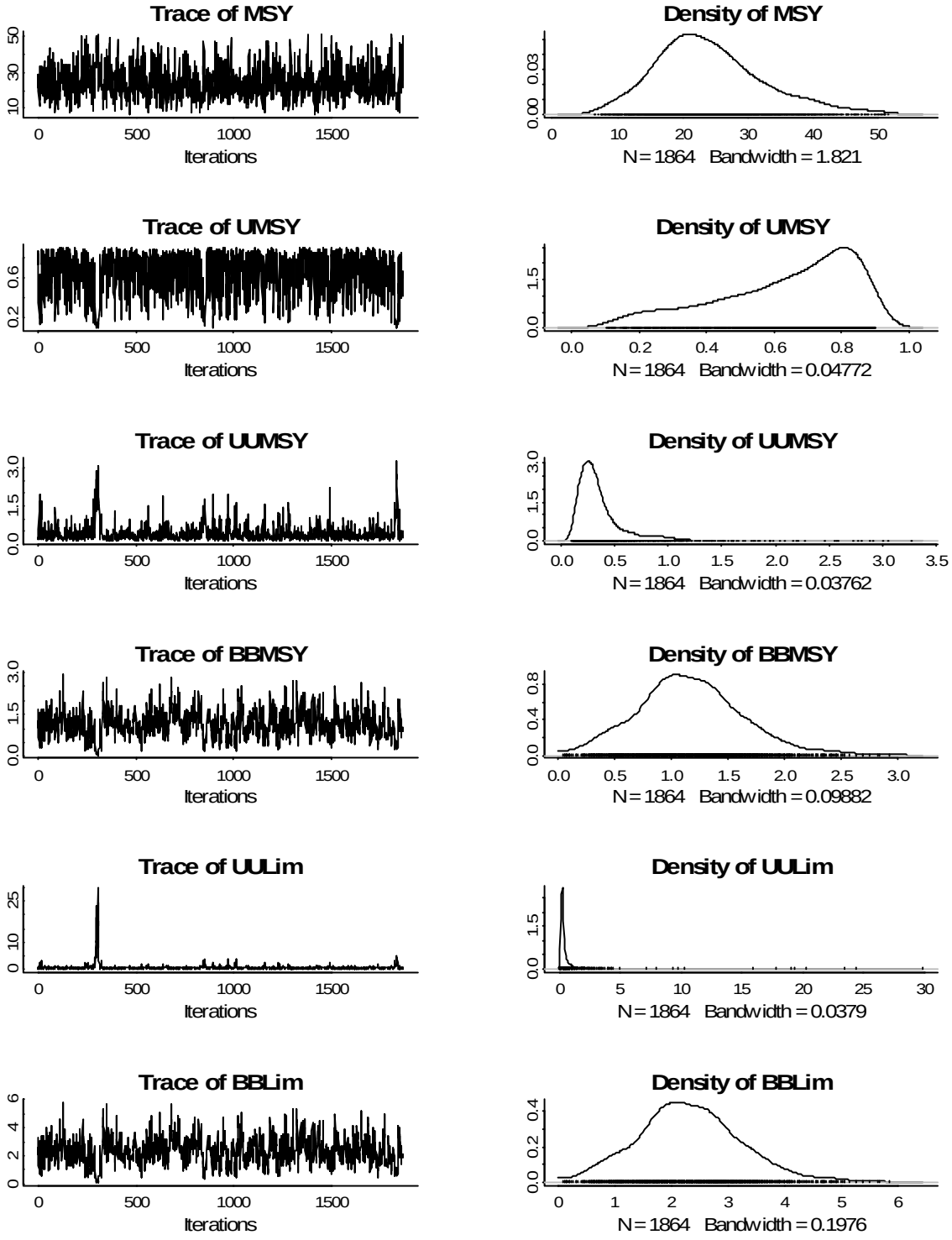

Figure 7.5.1. Gulf stock retrospective bias for adult abundances (top pane) and fishing rate (bottom pane). Note: the terminal year F was not estimated with this model.

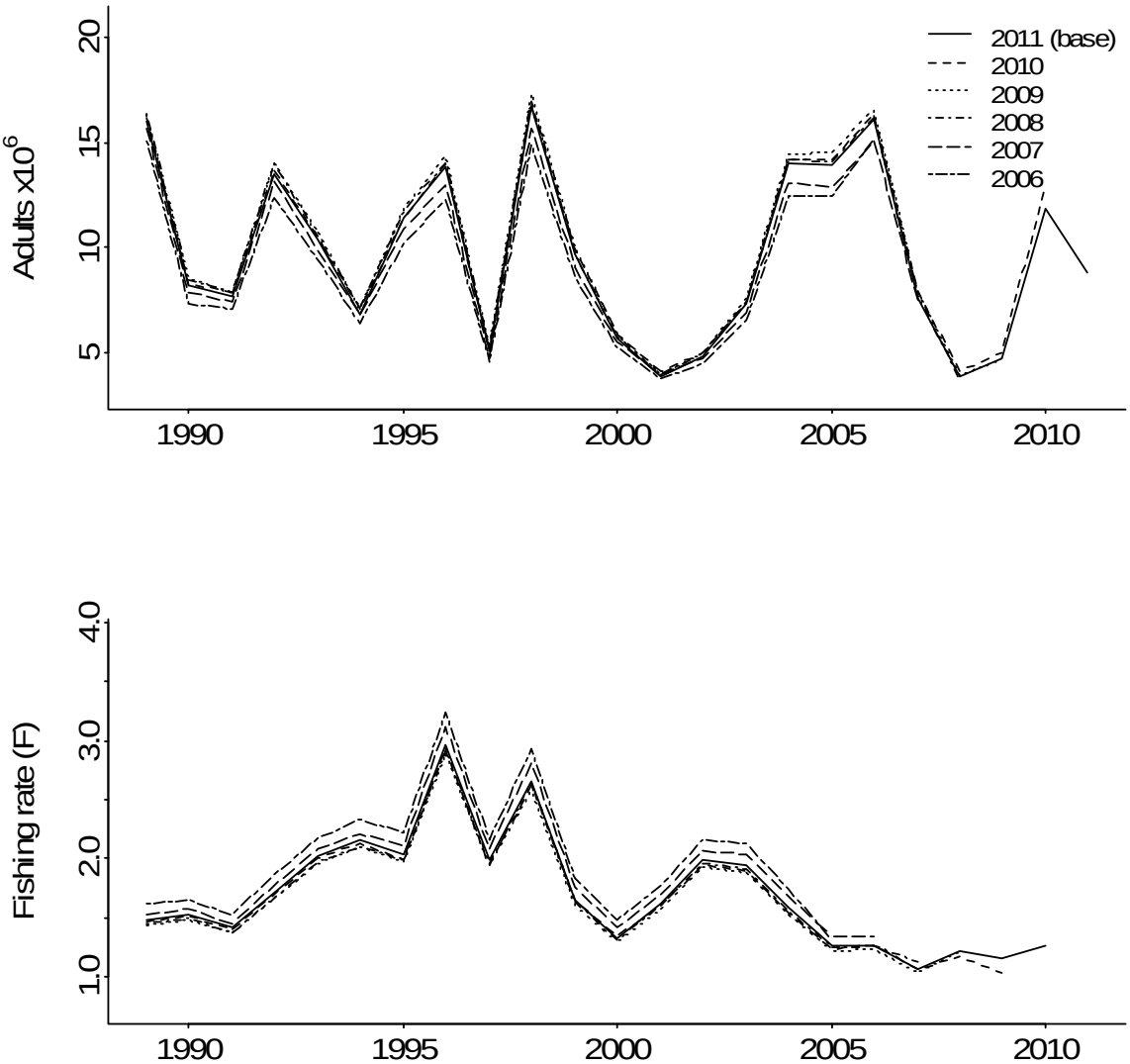

Figure 7.5.2. Atlantic stock retrospective bias for adult abundances (top pane) and fishing rate (bottom pane). Note: the terminal year F was not estimated with this model.

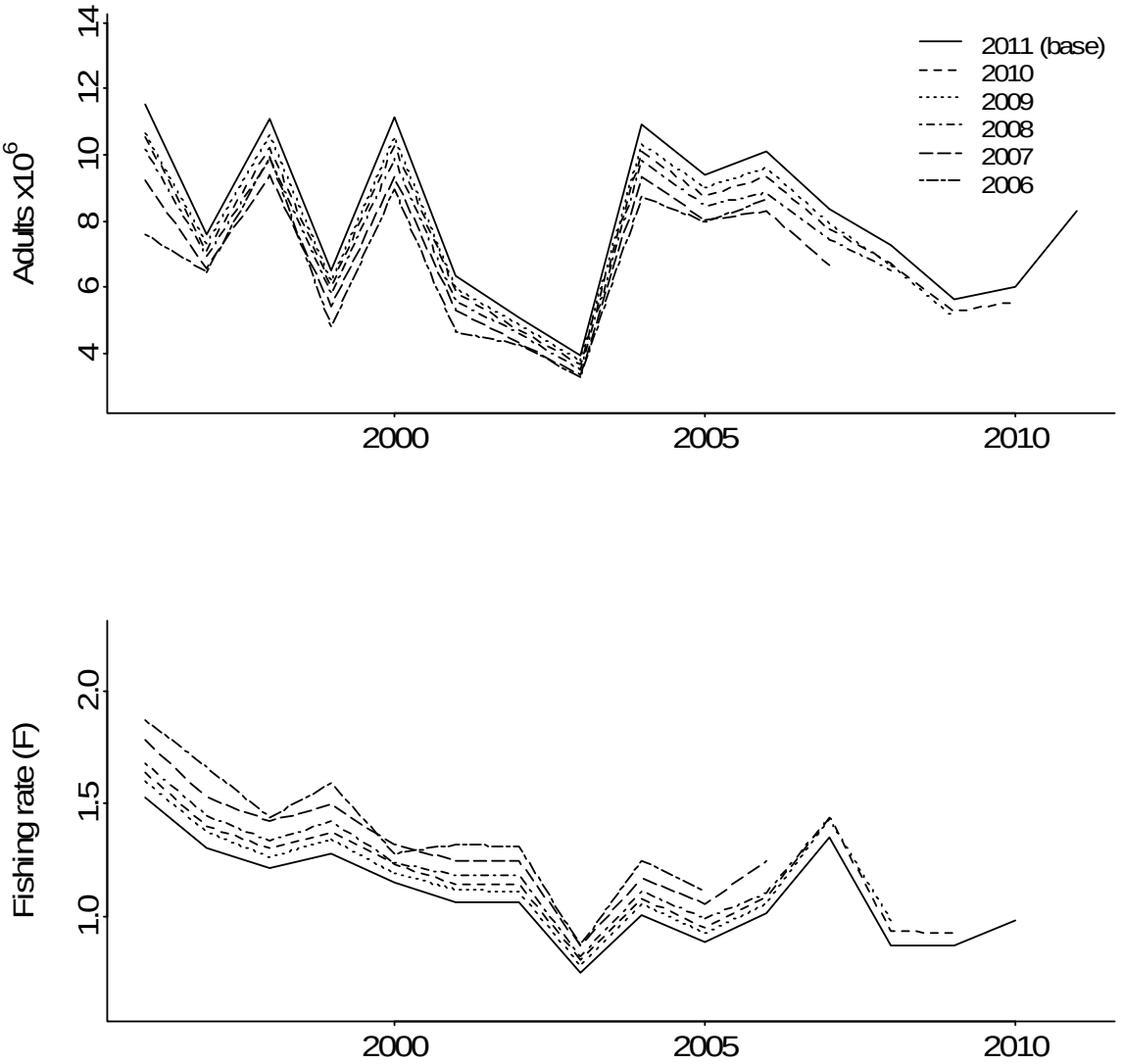

Figure 8.2.1. Gulf stock status from the two-stage model. All points below the control rule line are not overfished or undergoing overfishing relative to the default limits proposed in this assessment.

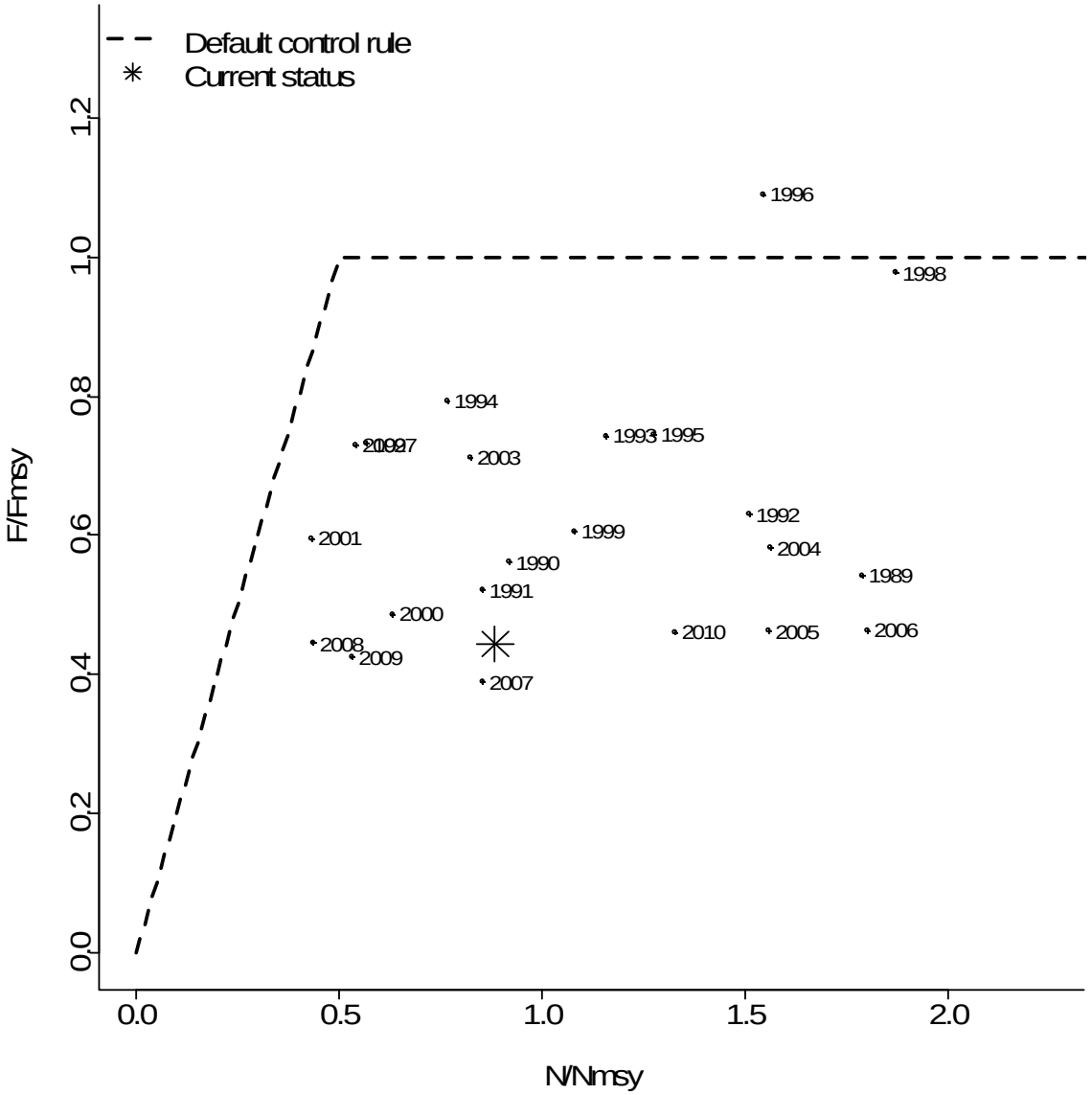

Figure 8.2.2. Atlantic stock status from the two-stage model. All points below the control rule line are not overfished or undergoing overfishing relative to the default limits proposed in this assessment.

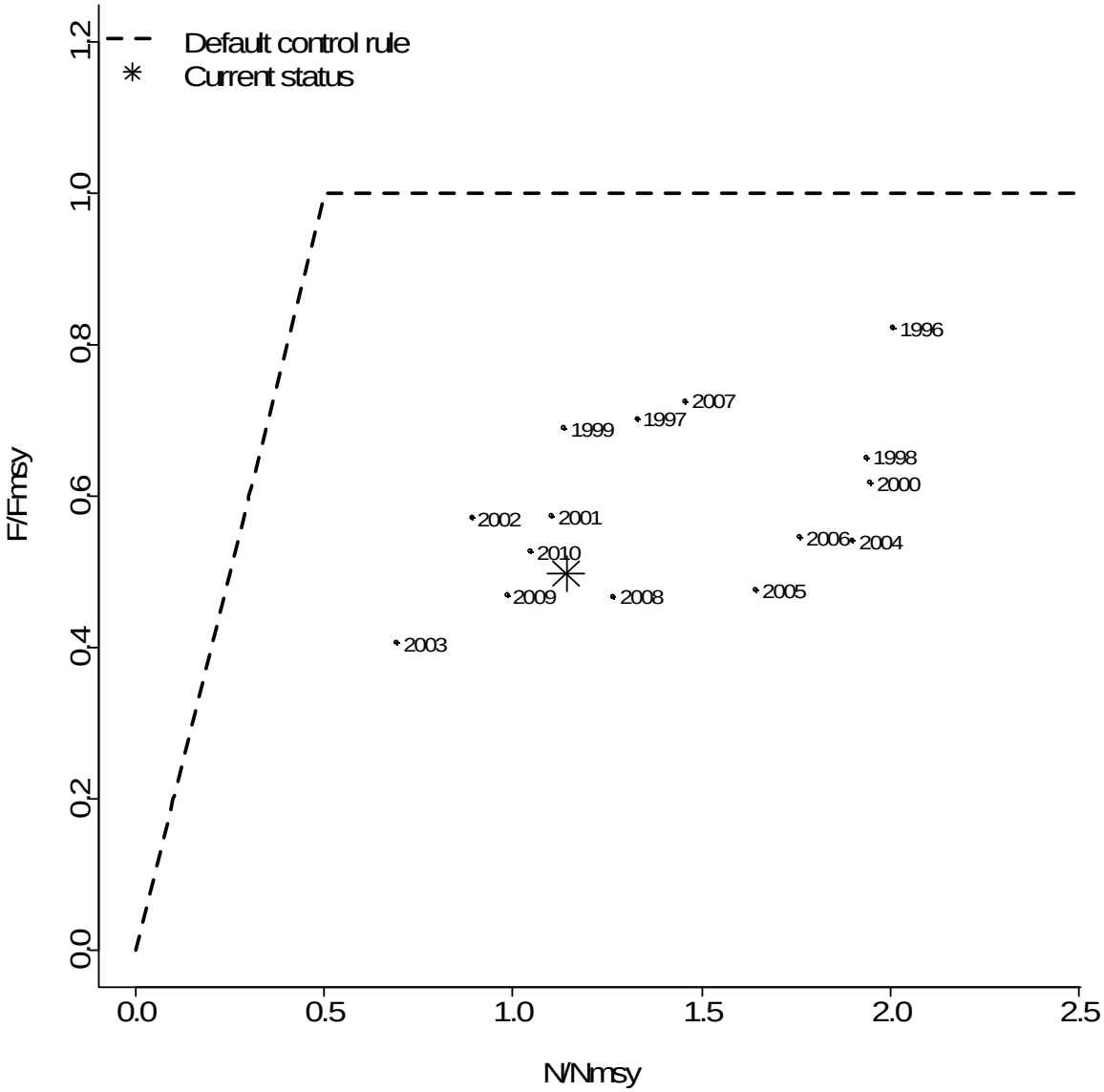

Figure 8.2.3. Gulf coast stock status relative to MSY-based target and limit from the two-stage model.

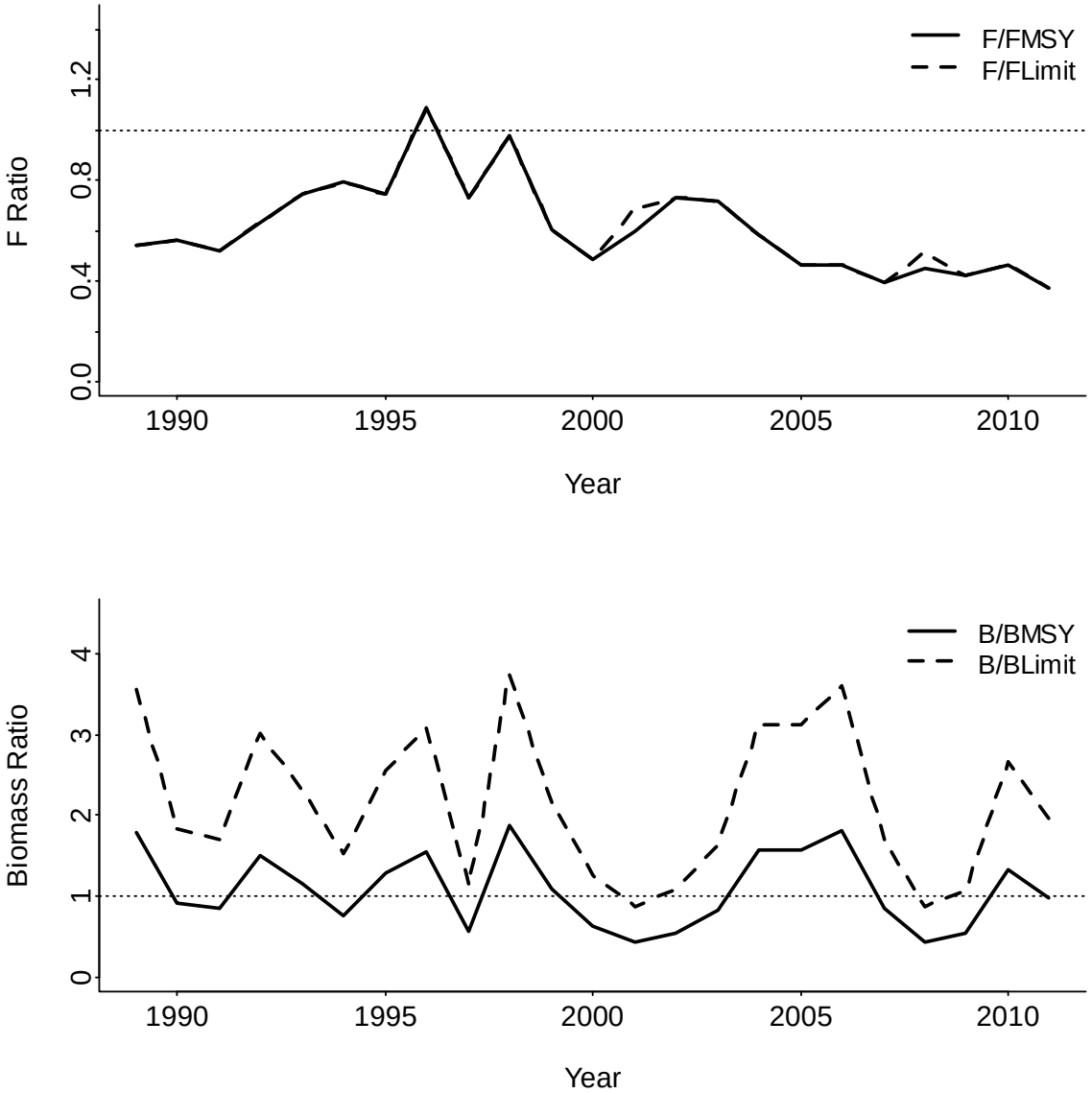

Figure 8.2.4. Atlantic coast stock status relative to MSY-based target and limit from the two-stage model.

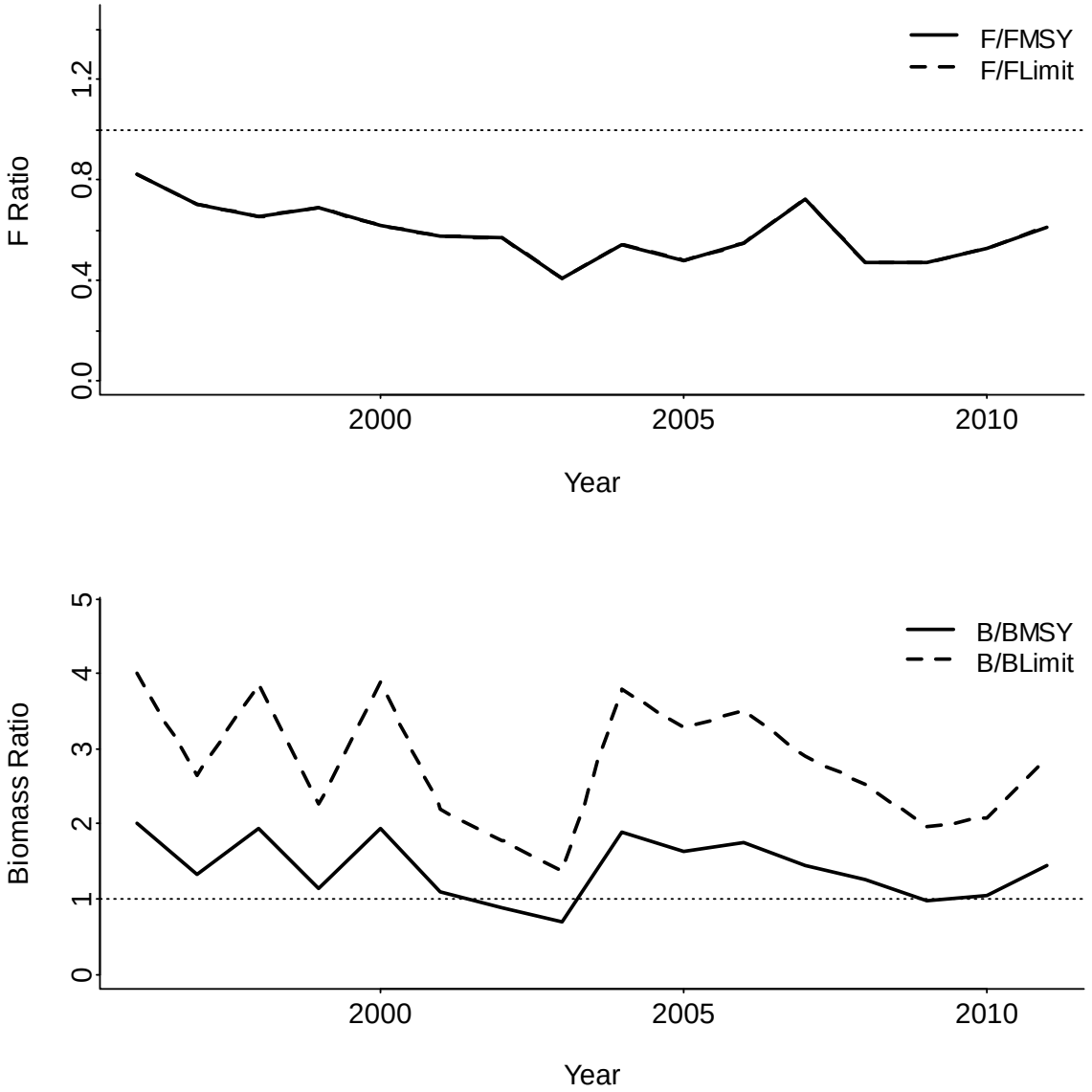

Figure 8.2.5. Gulf coast stock status relative to MSY-based target and limit from ASPIC.

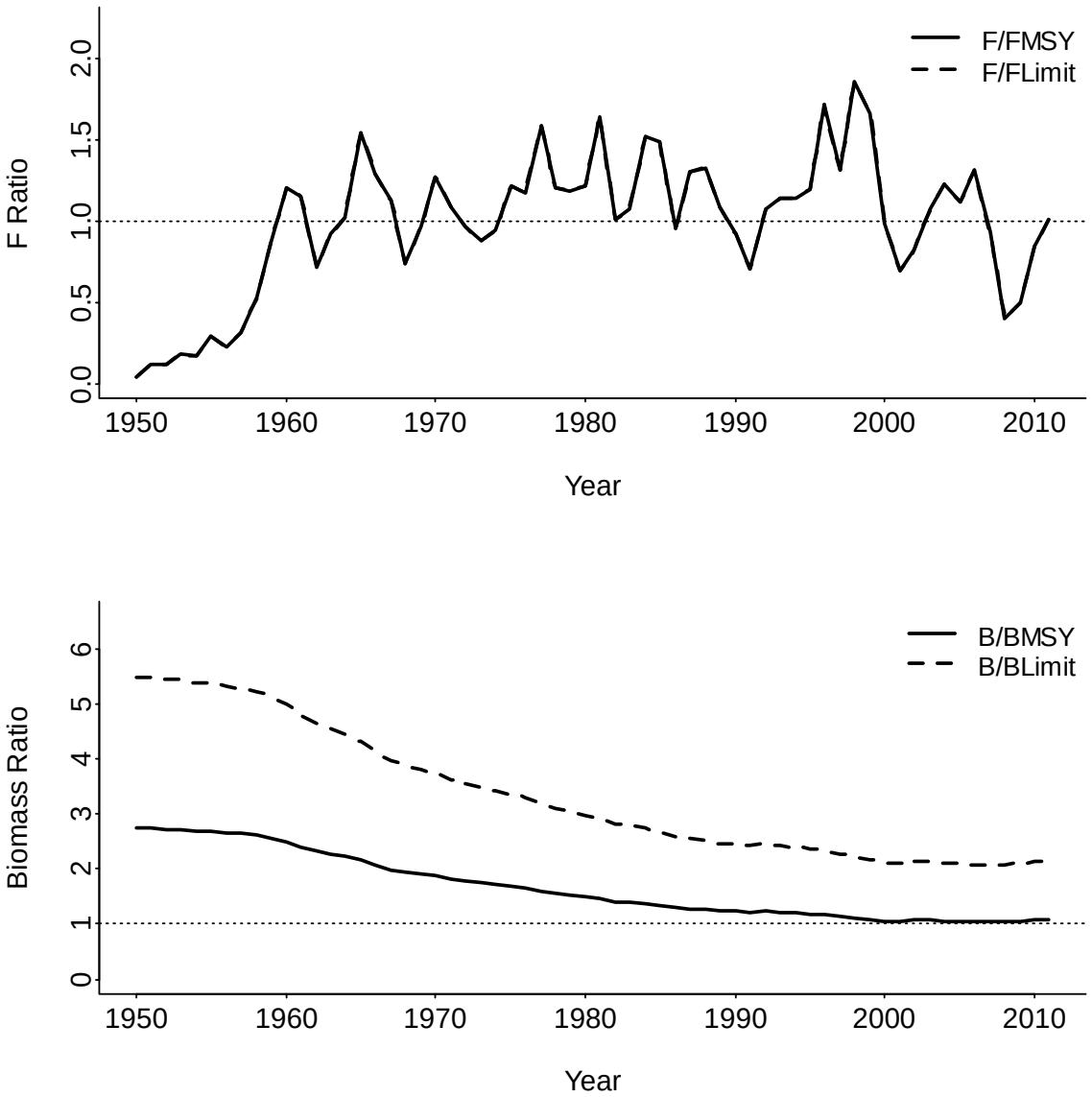

Figure 8.2.6. Atlantic coast stock status relative to MSY-based target and limit from ASPIC.

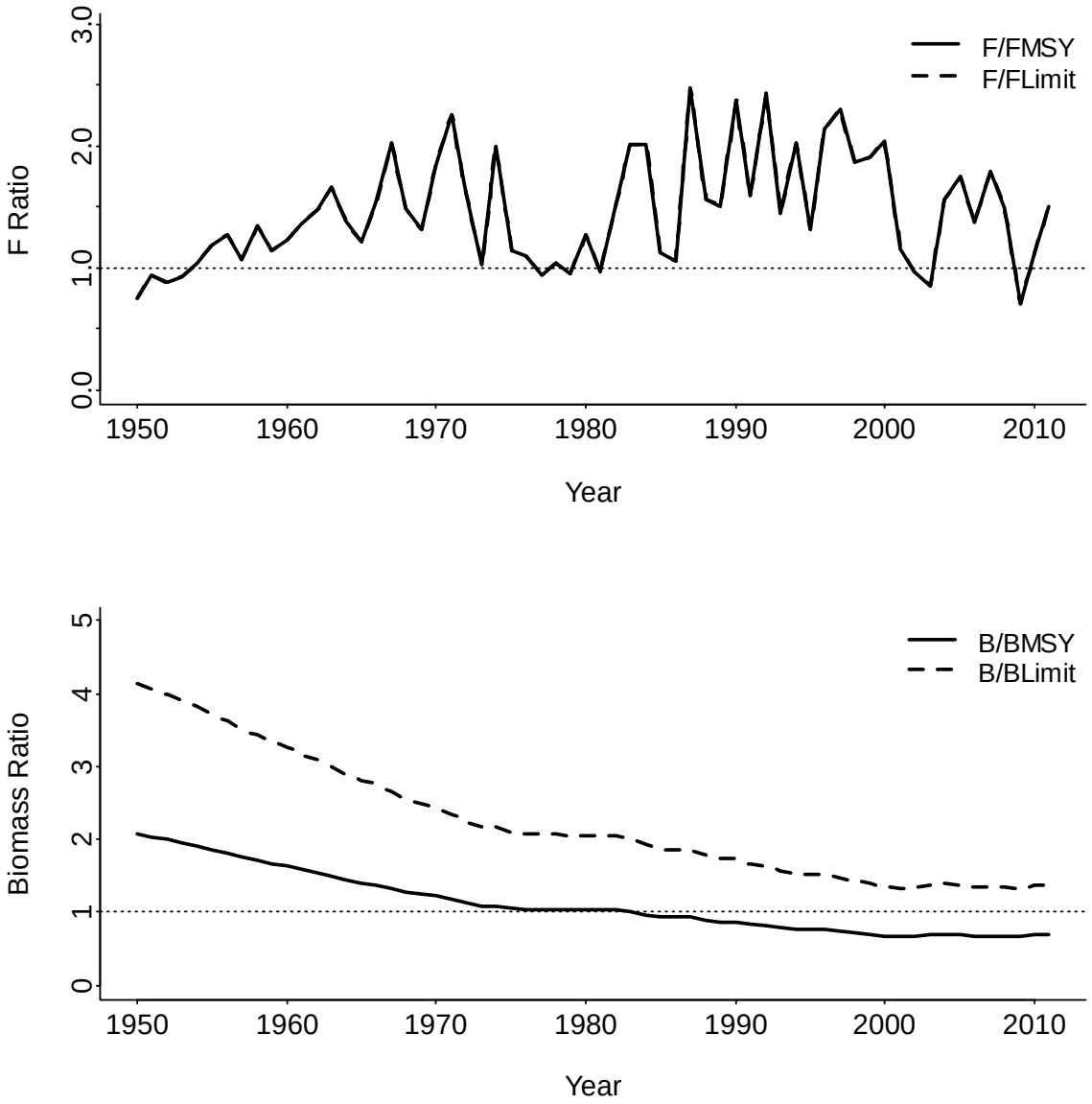

Figure 8.2.7. Gulf coast stock status relative to MSY-based target and limit from SSRA.

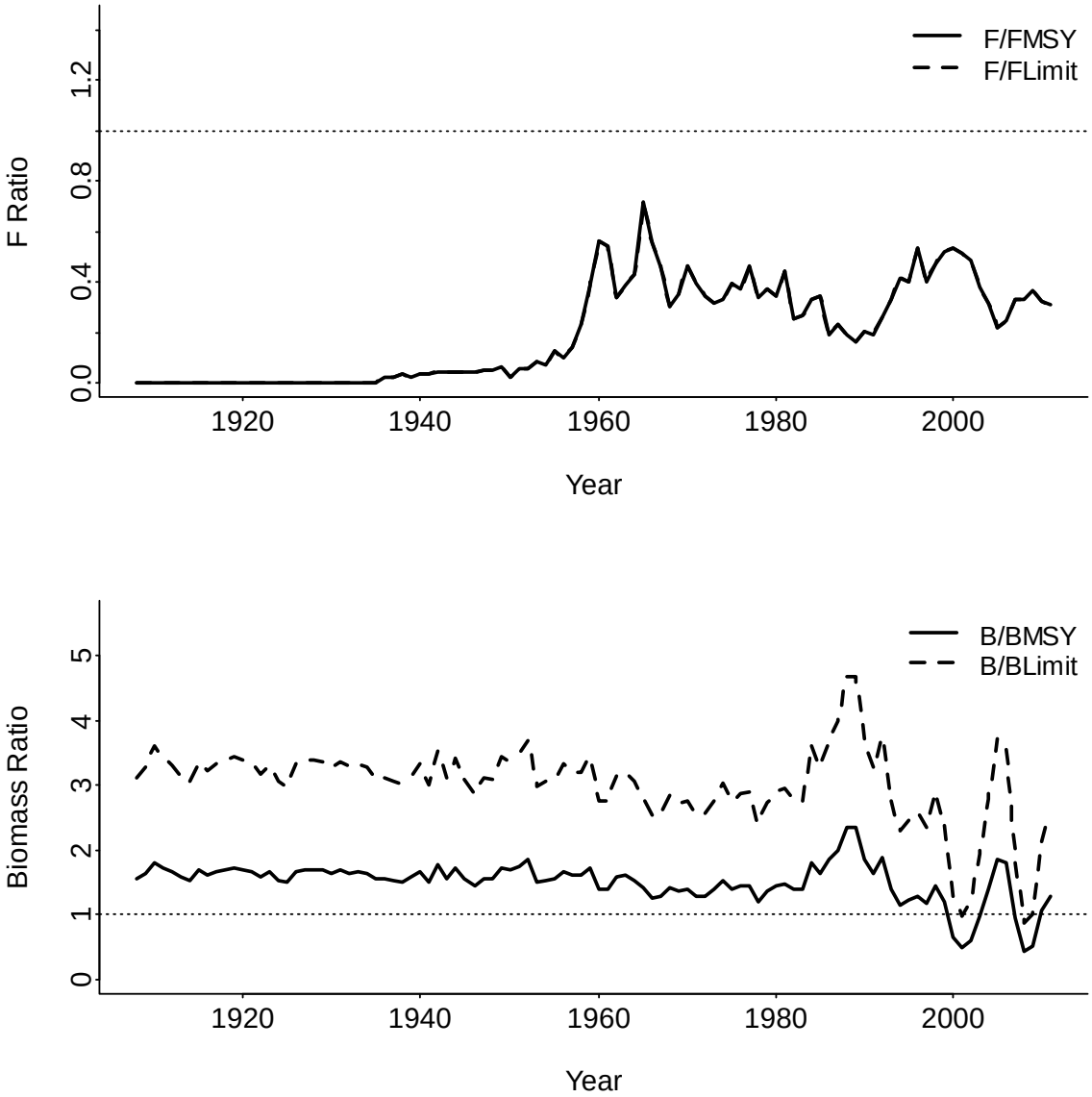
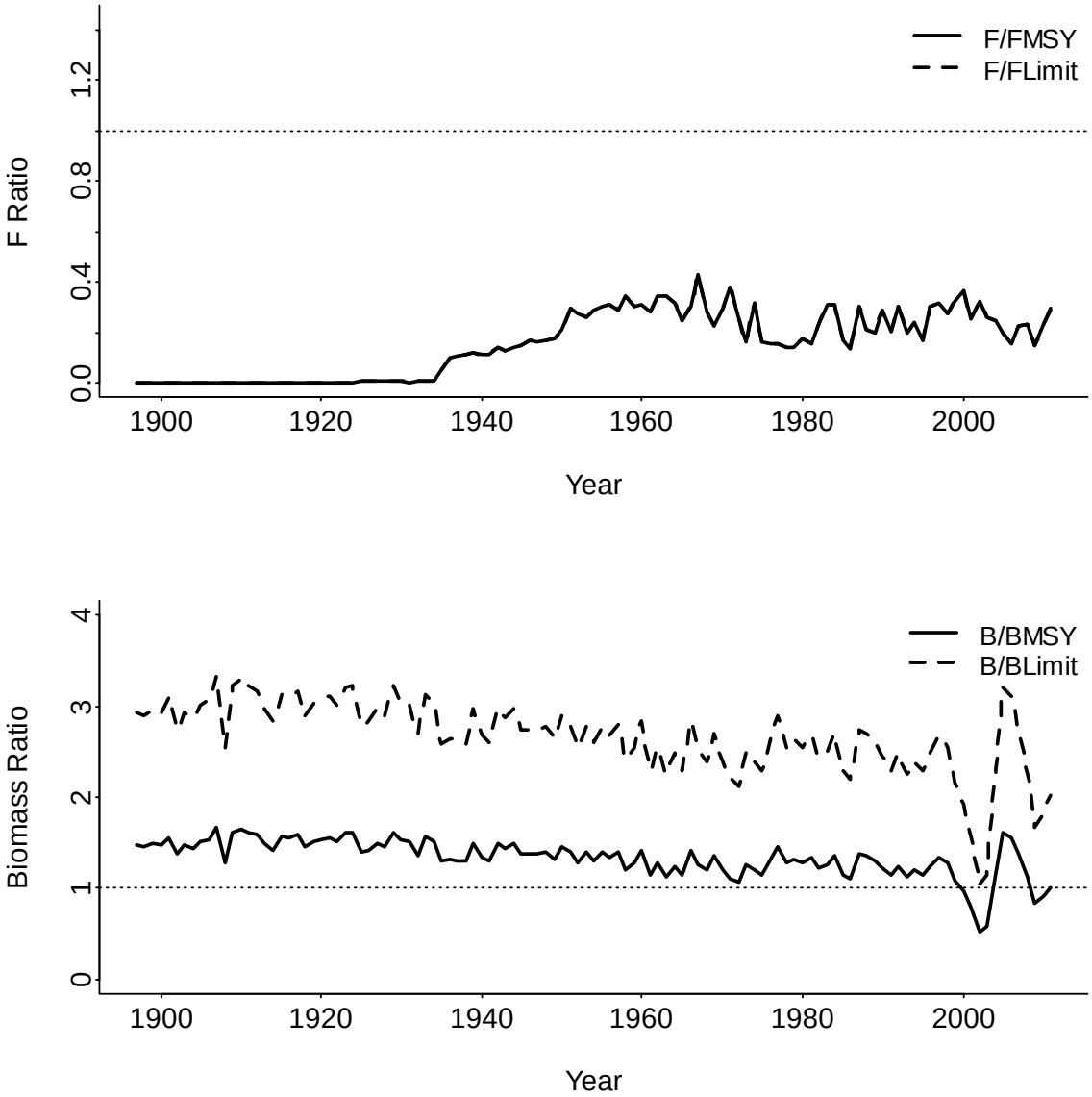
Figure 8.2.8. Atlantic coast stock status relative to MSY-based target and limit from SSRA.