AN ASSESSMENT OF THE BYCATCH GENERATED IN THE INSIDE COMMERCIAL SHRIMP FISHERY IN SOUTHEASTERN NORTH CAROLINA, 2004 & 2005

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ABSTRACT

The shrimp trawl fishery in the inside waters of North Carolina is controversial because of its bycatch or discards, especially the capture of commercial and recreationally valuable species such as southern and summer flounder, weakfish, spot, Atlantic croaker, and blue crabs. Although several bycatch studies were executed in North Carolina's inside waters, few characterized the bycatch or thoroughly covered the southern region from New River south along the Intracoastal Waterway (ICWW) to the South Carolina line. The purpose of this study was to fully describe and quantify the bycatch generated from a commercial shrimp fisherman during the shrimp season from April through November in 2004 and 2005. We conducted 120 trips and 253 tows in five regions in the southern district; the ICWW of Brunswick, New Hanover, and Onslow Counties, and the Cape Fear and New Rivers. For each tow, we determined the catch per unit effort (Kg/tow/min) for shrimp and bycatch, the bycatch to shrimp ratio, the length frequencies of shrimp and bycatch, and the condition of the discarded bycatch. Additionally, we evaluated the short term survivability of the bycatch. We found the catch rates for shrimp and bycatch were statistically similar, and a bycatch to shrimp ratio of 0.79 for the months and regions combined. There were seasonal differences in catch rates for shrimp and bycatch for the sites combined, and also in Brunswick County. Shrimp catch rates increased significantly in the summer and fall from the spring with the highest catch rates in May, August and September and lowest in October and November. In Brunswick County, catch rates for shrimp were lower in April and May than July, October and November. Bycatch catch rates were lowest in October and November and highest in May, August and September with similar trends in Brunswick County. Fifty-three percent of the *Paralichthys spp.* captured by weight were *P. lethostigma* (southern flounder) and they were larger sized fish than *P. dentatus* (summer). The length frequencies of the bycatch indicate that principally juveniles of their respective species were caught during the summer months and larger fish in the spring and fall. This trend did not hold up with smooth butterfly ray or *Paralichthys spp*. in which fish size generally increased from July to November. In most cases, the release condition of the discarded fish bycatch was moribund or dead, but the majority of the animals showed none to mild physical signs of damage from the trawling process. Bycatch mortality was likely due to the extended deck time to collect the biological data. The survivability study found 52.5% alive-healthy, 7.3% alive-weak, and 40.2% dead after an average holding time of 3 hr 38 min. Survival rates increased with cull times of 30 min or less. Atlantic croaker, spot and weakfish survival decreased with a rise in water temperature (ºC). Additionally, as the degree of physical damage increased and fish size decreased, survival rate declined. The results of this bycatch characterization study provide detailed information to manage the shrimp fishery in the southeastern region.

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I. INTRODUCTION

Commercial shrimping continues to be the most important fishery in the gulf and southeastern regions of the United States and nationally (NOAA Fisheries, Southeast Region Current Bycatch Priorities and Implementation Plan FY04 and FY05 Draft). Most shrimp is harvested using otter trawls, which is a nonselective type of gear. Hence, in capturing shrimp, trawls also catch non-target organisms, which is referred to collectively as bycatch or discards (Crowder & Murawski, 1998). Fish trawls also generate discards, but those from shrimp trawlers are often greater because they use smaller sized mesh (Howell & Langan, 1992). Estimates indicate that 60-80% of the catch in the U.S. commercial shrimp fishery are discards (National Marine Fisheries Service, 1995). These discards are the portion of the bycatch that is not kept for sale and is usually returned to the water (North Carolina Division of Marine Fisheries (NCDMF, 1999). Discards are one of the most significant issues affecting marine fisheries management (Davis, 2002; Crowder & Murawski, 1998). Nearly 80% of the biomass landed in the shrimp trawl fisheries in the southeastern U.S. are juvenile finfish (Murray *et al*, 1992), and include Atlantic croaker, weakfish (Diamond *et al*., 2000) and blue crab, which are commercially valuable as adults (Murray *et al*, 1992). Also, sea turtles, which are federally protected, can be captured unintentionally, although since the implementation of turtle excluder devices (TED) in U.S. waters, the bycatch of sea turtles has decreased by 97% without affecting the shrimp catch or damaging the gear (Bache, 2000). The ratio of bycatch to shrimp from trawls worldwide averages 5 Kilogram (Kg) bycatch to 1 Kg shrimp (Alverson *et al*., 1994), in the Gulf of Maine northern shrimp fishery 1.14 lb of seven fish species to 1 lb shrimp (Howell & Langan, 1992), and in North Carolina, the ratio ranges from 1.5-18 Kg finfish to 1 Kg shrimp (Johnson, 2003; NCDMF, 1999; Coale *et al*, 1994). Bycatch in the North Carolina shrimp fishery can consist of up to 92 different species (Diamond-Tissue, 1999). The potential impacts of discarding and bycatch mortality include: the population structure, such as recruitment declines, biomass, and future yield, ecological, such as the unknown influences on predator – prey relationships (Alverson *et al*, 1994; Howell & Langan, 1992; Perra, 1992), as well as economic and ethical (Crowder & Murawski, 1998). The loss of species to bycatch can subsequently influence management decisions in the short and long term (NCDMF, 1999; Crowder & Murawski, 1998).

Both federal and state laws require trawls to use forms of bycatch reduction devices (BRD) for sea turtles, Turtle Excluder Device (TED), and for finfish, Fish Excluder Device (FED). Although these bycatch reduction devices are currently implemented, additional methods to reduce bycatch continue to be developed or augmented. Despite these efforts bycatch in commercial shrimp trawls continues to draw controversy to the shrimp industry. Environmental and sportfishing groups are concerned that shrimp fishing catches and kills a large proportion of commercially and recreationally important species of finfish and invertebrates. Commercial shrimpers also do not want to waste the resource, and are fearful that the aforementioned concerns will see more management restrictions or loss of traditional fishing grounds or gear used (Murray *et al*., 1991). The economic view of discards claims that when the bycatch from one fishery precludes the use by other fisheries then the resources are not being directed to their highest and best use (Crowder & Murawski, 1998). For example, if large numbers of young fish are discarded, then the future yield from these individuals disappears (Crowder & Murawski, 1998).

A central concern regarding bycatch involves its condition and mortality, both observed and unobserved. Trawls may last from 20 up to 90 or more minutes. Once the catch is onboard, shrimp is sorted from bycatch. Extended tow times, prolonged cull times, changes in temperature, and prolonged periods of air exposure are factors that directly affect the survival rate in some species (Davis, 2002; Davis and Olla, 2002; Ross and Hockenson, 1997; Howell & Langan, 1992). Also, size of the fish can preclude survival as smaller individuals show higher mortality rates (Davis and Olla, 2002; Richards *et al*, 1995; Howell & Langan, 1992). For example, smaller size fish are more susceptible to changes in temperature, such as from water to air, because their body core temperature will elevate at a faster rate (Davis et al, 2001). The physical effects of towing can cause bruising, lacerations, or exhaustion from sustained swimming (Davis, 2002; Kaiser & Spencer, 1995). Thus, the physiological and physical stresses of being dragged in a net with other fish, and then followed by deck time in the culling process can severely limit the chance of survival for the individual when later discarded. Furthermore, discarded animals are more vulnerable to aerial or aquatic predators (Ross and Hokenson, 1997).

Commercial shrimp fishing is North Carolina's largest and most profitable fishery, which was valued at an average of $15.6 million from 1990-2004 (www.ncfisheries.net/statistics) followed by the blue crab fishery. Three penaeid shrimp species are harvested in North Carolina: pink (*Penaeus duorarum*) in the spring, brown (*P. aztecus*) in the summer, and white shrimp (*P. setiferus*) in the early spring and throughout the fall. Brown shrimp is the chief species captured in North Carolina (NCDMF, 1999). Nearly 80% of the shrimp landed in North Carolina comes from trawlers in inside waters, such as bays, estuaries, tidal creeks and the Intracoastal Waterway (ICWW) (NCDMF, 1999). Along the central North Carolina coast, the estuaries are large and wide, as in Pamlico Sound, and to a lesser extent in Core and Bogue Sounds. In Pamlico Sound, shrimp fishermen use vessels that average 40 ft long and geared with double rigs, four-barreled otter trawls, or skimmer trawls (NCDMF, 1999). Here a trip may last for several days with tows lasting one to three hours both day and night (NCDMF, 1999). Shrimpers in Core Sound use similar gear as in Pamlico, but here fishing occurs mainly at night, and usually for one night. From 1994 - 2003, Pamlico Sound landed close to 50% of all shrimp harvested in the inside waters, followed by Core Sound with approximately 10.5%, and then New River nearing 5.5% (NCDMF, personal communication). In southeastern North Carolina, an inside shrimp fishery exists as well, but it contributes to ~1.4% of the statewide landings of inland caught shrimp (NCDMF, personal communication). The southern region ranges from New River in Onslow County south to the South Carolina state line near Calabash in Brunswick County. This region covers 95 miles, where fishing includes the ICWW, major rivers, and some tidal creeks. The habitat that encompasses the ICWW in the southern region begins to change from open estuaries, which are fed by small tidal creeks, to strips of estuaries with narrow channels. Only 3% of the total water area is available for shrimping, compared to 56% in Pamlico, and 33% in the northern and 8% in the central regions (NCDMF, Shrimp FMP issue paper "The recreational shrimp trawl fishery in North Carolina"). Shrimp fishermen in the southern region operate mainly out of small vessels between 18-25 ft and most pull a single rig otter trawl, which ranges from 25 to 50 ft head rope (NCDMF, personal communication 2005), and most fishing is conducted during daylight hours (NCDMF, 1999).

Trawling in the estuaries of North Carolina has a controversial history. In 1988, the Inland Committee submitted a motion to the North Carolina General Assembly to ban shrimp trawling in estuarine waters (NCDMF, 1999). In 1997, Representative Frank Mitchell sponsored

House Bill 274 to ban inland trawling once again. In both cases, NCDMF responded by enacting new rules to address specific concerns. Recently in 2003 the issue resurfaced, and this time it targeted the inside fishery in southeastern North Carolina. Representative Bonner Stiller of Brunswick County made legislative attempts for the state General Assembly to ban shrimp trawling in all of the inside waters of Brunswick and New Hanover Counties. The specific concerns raised were the impacts that estuarine trawling has on juvenile fishes, invertebrates, and shrimp populations, and the nature of the estuarine habitat in this region. However, due to the lack of scientific data on this fishery, primarily the bycatch generated, the matter was postponed until research on the issue was completed, and NCDMF revised the shrimp fishery management plan.

The purpose of this research study was to fully characterize the bycatch generated by a commercial shrimp fisherman working in the inside waters of southeastern North Carolina. We assessed the catch generated from April through November 2004 and 2005, and fished in authorized areas from New River to the South Carolina line. In this characterization, we quantified the catch per unit effort (Kg/tow/min), and length frequency of the shrimp and bycatch, classified the physical condition of the individuals, and evaluated the short term survivability of the finfish. Our hypotheses assumed that (1) the bycatch generated will be minimal because the trawls were fitted with two bycatch reduction devices, a Florida Fish Excluder (FFE) and Turtle Excluder Device (TED) (2) the bycatch entrained will be little in size because the trawl mesh size is small and fishing will occur when juveniles are in the estuaries (3) the bycatch will not sustain many physical injuries and the survival rate will be high because the tow time will be shorter and the overall catch less compared to those in large trawlers.

II. MATERIALS AND METHODS

Fishing took place from New River south to the South Carolina line with emphasis in Brunswick County (Figure 1). We conducted 120 trips and 253 tows from April through November 2004 and 2005, which averaged about two tows per trip. Fishing occurred Monday through Friday as per North Carolina Fisheries Rules for Coastal Waters, by Proclamation, and during daylight hours. The fishing area was divided into five regions: Brunswick County, Cape Fear River, New Hanover County, Onslow County, and New River (Table 1, Figure 1). Not all of the regions were fished throughout sampling season, because of various closures authorized by North Carolina Division of Marine Fisheries (NCDMF) (Appendix I – 2004 and 2005 NCDMF Shrimp Proclamations).

In this study, we used commercial fishing gear to catch the three shrimp species, pink (*Penaeus duorarum*), brown (*P. aztecus),* and white (*P. setiferus*), that occur in the southeastern region. Fishing took place on the 24 foot (ft) Diamond Shrimp Trawler "Draw Play" that is owned and operated by D. McCuiston. We used single-rig otter trawls, and the trawl type depended on the target species. For pink shrimp, we used a mongoose trawl with a 30 foot (ft) head rope and 4.3 x 2.2 ft doors. For brown shrimp, we used two sizes of two-seam trawls a 50 ft and a 58 ft head rope both with 80 mesh wings and 6 x 3 ft doors. For white shrimp, we used the aforementioned mongoose trawl and two two-seam trawls each with 50 ft head rope, but one had 80 and the other 160 mesh wings. All tailbags were 1½ in stretch mesh. Since we used a mechanical winch to deploy and retrieve the trawls, all nets were fitted with a diamond shaped Florida Fish Excluder (FFE) with a 6 x 6 in inside area opening which is designed to reduce finfish bycatch, and a 31 in diameter aluminum Turtle Excluder Device (TED) which is intended to reduce turtle bycatch. We abided by NC Marine Fisheries Commission Fisheries Rules for Coastal Waters 2003 and recent rule changes.

Tow duration depended on the fishing site as some regions the legal fishing area encompassed a small area in which to sample or included obstacles that limited towing, such as known hangs, or catch volume. A tow started when the doors hit the water and ended when the doors reached the surface. Each trawl transect (lat lon) and distance (Km) was recorded using a global positioning system (GPS). Water depth (ft), surface salinity (parts per thousand – ppt) and temperature (ºC) were logged at the start and end of each tow. Tidal cycle (ebb, flood, slack) and phase (early, mid, late), water conditions and weather were also recorded. We tested whether water depth varied regionally, and if surface water salinity and temperature differed monthly using either an oneway ANOVA followed by Tukey's HSD multiple comparisons tests was used, if the data passed Levene's HOV. If it failed the HOV, a Kruskal-Wallis test was used, and Tamhane's multiple comparisons test was applied because it takes into account unequal variances. All of the data were analyzed using SPSS Version 9.0 statistical software.

A. Catch per Unit Effort (CPUE)

The catch from each tow was separated into shrimp and bycatch, and the cull time (min) was recorded. The cull time began when the net was emptied into the culling box, and ended when shrimp and bycatch were separated. The shrimp catch was weighed to the nearest 0.02 kilogram (Kg) when using the 15 Kg maximum capacity EXTECH hanging scale and 0.25 gram (g) when using the 30 g maximum capacity Pesola hanging scale. The count of shrimp, number of shrimp per pound, is a common method that fishers and managers use to classify the size of shrimp. For each tow, a three pound random sample of shrimp was taken, when possible, and enumerated to determine the number of shrimp per pound (#/lb) (*note: In 2004, we did not start recording shrimp count regularly until late August*). The bycatch was separated to species and the total weight (Kg) of each species was recorded. A subsample of the bycatch was taken when there was a large amount of bycatch. We took a total of 11 subsamples, N=4 in 2004 and N=8 in 2005. A subsample averaged 5.15Kg, which was about half a basket. Any large size individuals, such as a stingray or shark, or blue crabs were not included in the subsample. The total weight of each species in the subsample was calculated by the following formula from Johnson (2003):

$$\text{Total Kg}_{\text{sp.X}} = (\text{Kg}_{\text{sp.X}} \text{ in SS / total Kg SS}) \text{ x total Kg}_{\text{bycatch}}$$

The weight of the catch (Kg), e.g. shrimp, fish species, crabs etc., and the tow time (minutes) for each trawl were used to generate a value for catch per unit effort (CPUE) as kilograms per tow per minute (Kg/tow/min).

The catch rates for shrimp, bycatch, and six bycatch categories - invertebrates, blue crab, fish (all), commercial and recreational finfish (C&RFF), and other (non commercial or recreational) finfish (OtherFF), and *Paralichthys spp.* (*P. lethostigma, dentatus* and *albigutta*) - were tested against month and region to determine whether these factors affected the catch rate. We $\log_{10}$ transformed the 2005 southern and summer flounder data to meet assumptions for ANOVA to analyze their catch rate versus month and region. The bycatch designations were delineated based on the management needs of NCDMF. Since we did not sample the five regions every month, the data were not balanced to analyze the two variables together with CPUE. If the data passed Levene's test of homogeneity of variances (HOV), an oneway ANOVA followed by Tukey's HSD multiple comparisons tests was used. If the data failed Levene's HOV, a Kruskal-Wallis test was used, and Tamhane's multiple comparisons test was applied because it takes into account unequal variances. The catch rates of shrimp, bycatch, the six bycatch categories for all the sites combined were analyzed against five environmental parameters, water depth, surface salinity and temperature, tidal phase and tow time using backward Regression analysis (Logothetis & McCuiston, 2005; Howell & Langan, 1992; Ricker, 1973) followed by a post hoc test, which was either Tukey's HSD for equal variances or Tamhane's for unequal variances multiple comparisons tests. We excluded depth when comparing catch rates within a region because the depth was fairly consistent.

B. Length Frequency

For each tow, the total length of the catch was measured: total length in millimeters (mm TL) was recorded for shrimp (tip of rostrum to tip of tail), fish and various invertebrates; total and fork length (mm TL, FL) were measured for sharks; disk width (mm DW) was recorded for skates and rays; and carapace width (mm CW) was logged for blue crab and other similar crab species. All the individuals of a species were measured unless there were large quantities. In this instance, a random subsample of at least 50 representatives of a shrimp species or 35 of a bycatch species was measured. For shrimp, we used the subsample taken to determine the shrimp count to evaluate species composition and shrimp size.

The size of the shrimp, pink, brown and white species combined, was analyzed against month and region separately to determine whether these factors affected shrimp size. We applied Kruskal-Wallis test followed by Tamhane's multiple comparison test. The relationship of four environmental parameters, water depth, surface salinity and temperature, and tide phase were analyzed using backward Regression.

Bycatch length frequencies were evaluated for the top seven bycatch species of commercial and recreational importance - Atlantic croaker (*Micropogonias undulatus*), blue crab (*Callinectes sapidus*), spot (*Leiostomus xanthurus*), weakfish (*Cynoscion regalis*), smooth butterfly ray (*Gymnura altavela*), *Paralichthys spp.*, and Atlantic menhaden (*Brevoortia tyrannus*). We compared the sizes of the three *Paralichthys spp*. to each other, and the sampling months and regions. Since we did not sample all of the five regions every month, the data were not balanced to analyze the two variables together with length. If the data passed Levene's test of homogeneity of variances (HOV), an oneway ANOVA followed by Tukey's HSD multiple comparisons tests was used. If the data failed the HOV, a Kruskal-Wallis and Tamhane's multiple comparisons tests were applied. To test whether there was a difference between southern (*P. lethostigma*) and summer (*P. dentatus*) flounder in 2005 and month or region, a t-test or Mann-Whitney test was used. Length frequency was also tested against the environmental parameters, water depth, surface salinity and temperature and tidal phase, using backward regression followed by a post hoc test either Tukey's HSD or Tamhane's multiple comparisons tests.

<u>Post-Release Index of Condition (PRIC) and Mortality Proxy Index (MPI)</u>

Surveys of post-release index of condition (Logothetis & McCuiston, 2005; Heuter, 1994; and Richards *et al*, 1995) and mortality proxy index (Logothetis & McCuiston, 2005; Hoag, 1975) were conducted on the bycatch individuals that were measured before they were discarded (Table 2a, b). The indices were a method to evaluate the condition of the individuals after being towed in a net, spending time on deck, and the influence of the environmental conditions, water depth, surface salinity and temperature, and tidal phase.

All the bycatch combined and the six top ranked species were targeted for analysis. For both indices we examined whether there was a significant difference in the proportion of individuals per Post-Release Index of Condition or Mortality Proxy Index category. If the data passed Levene's test of homogeneity of variances (HOV), a oneway ANOVA followed by Tukey's HSD multiple comparisons tests were applied. If the data failed Levene's HOV, a Kruskal-Wallis test and Tamhane's multiple comparisons tests were used.

C. Survivability

The survivability study was designed to evaluate the short term survival of the fish, elasmobranchs and finfish, bycatch after being towed through a net. Specimens were collected during the entire the culling process, because typically bycatch was discarded throughout the culls. The fish were weighed and then placed into a 128 qt insulated Igloo marine cooler. We aimed to hold one Kg of fish for each bout to maintain consistency between trips and avoid overcrowding. The cooler held ambient seawater with a Keep-Alive™ (model KA5) circulation pump with a venturie line for aeration, and the pump was powered by a marine battery. Water temperature was monitored with a thermometer, and water quality was evaluated visually, e.g. amount and color or foam produced. The water was changed as needed to maintain ambient temperature and water quality, which occurred more frequently during the hot summer months. Start time was the time the first individuals were added and end time was the time the last individual was removed. Ninety-eight percent of the subsamples were taken from the first tow of the trip to maximize holding time.

At the end of the holding bout, the condition of each individual was evaluated as alive-healthy, alive-weak, and dead (Johnson 99-EP-07; Coale *et al*, 1994) before discarding. These categories are an abridged version of the post release index of condition used herein, and they correlate to those used by U.S. fisheries observers which are excellent and good (alive-healthy), fair or poor (alive-weak), and moribund (dead) (Richards *et al*, 1995).

2004 & 2005 combined

We compared whether the proportions in each category differed among each other using a Kruskall-Wallis and Tamhane's multiple comparisions tests. To test the affect of cull time on survival, the alive-healthy and alive-weak categories were combined into one alive group. Analysis was conducted on fish (all), C&RFF, and OtherFF categories plus the five species with the highest frequency of occurrence in the survivability study, overall rank, and commercial and recreational value: Atlantic croaker, spot, weakfish, *Paralichthys spp.* and Atlantic menhaden. Cull time was sorted into four discrete groups for analysis, 0-15 minutes (min), 16-30 min, 31-45 min, 46-60+min (Ross & Hokenson, 1997). The survivability data was converted into a proportion of alive, termed survival rate. We tested whether there was a difference in the survival rate among the four cull groups. Depending upon the outcome of Levene's HOV, we used oneway ANOVA or Kruskal-Wallis test followed by a post hoc test either Tukey's HSD or Tamhane's multiple comparisons tests. The survival rate was also tested against tow time (min) and distance (Km), and water depth, surface salinity and temperature using backward regression analysis. Additionally, we used Regression to analyze whether total catch weight (Kg) influenced cull time (min), and to determine whether survival rate (proportion alive) was related to cull time.

2005

In addition to classifying survival status (alive-healthy, alive-weak or dead), we recorded the mortality proxy index, and the size of each fish at the end of each bout and before release in 2005. Seven species were selected for analysis based on their commercial and recreational importance and rank: Atlantic croaker, spot, weakfish, pinfish, southern flounder, summer flounder, and Atlantic menhaden. These fish were examined to evaluate the affect of physical damage and fish size on survival status. We tested whether survival status the seven fish species combined and separately was related to the level of physical damage, e.g. mortality proxy index, and fish size using either ANOVA and Tukey's HSD multiple comparisons test, or Kruskal-Wallis and Tamhane's multiple comparisons test. The data were too unbalanced to apply a two-way analysis of variance to test whether fish size affected survival status or the degree of physical damage for each species. For each species, the proportion in each survival group was analyzed related to fish size, holding time (hr), cull time (min), tow time (min), and water depth, surface salinity and surface temperature using backward regression (Ross and Hokenson, 1997).

The data were not further divided into cull group (Ross and Hokenson, 1997) because the sample sizes became too small.

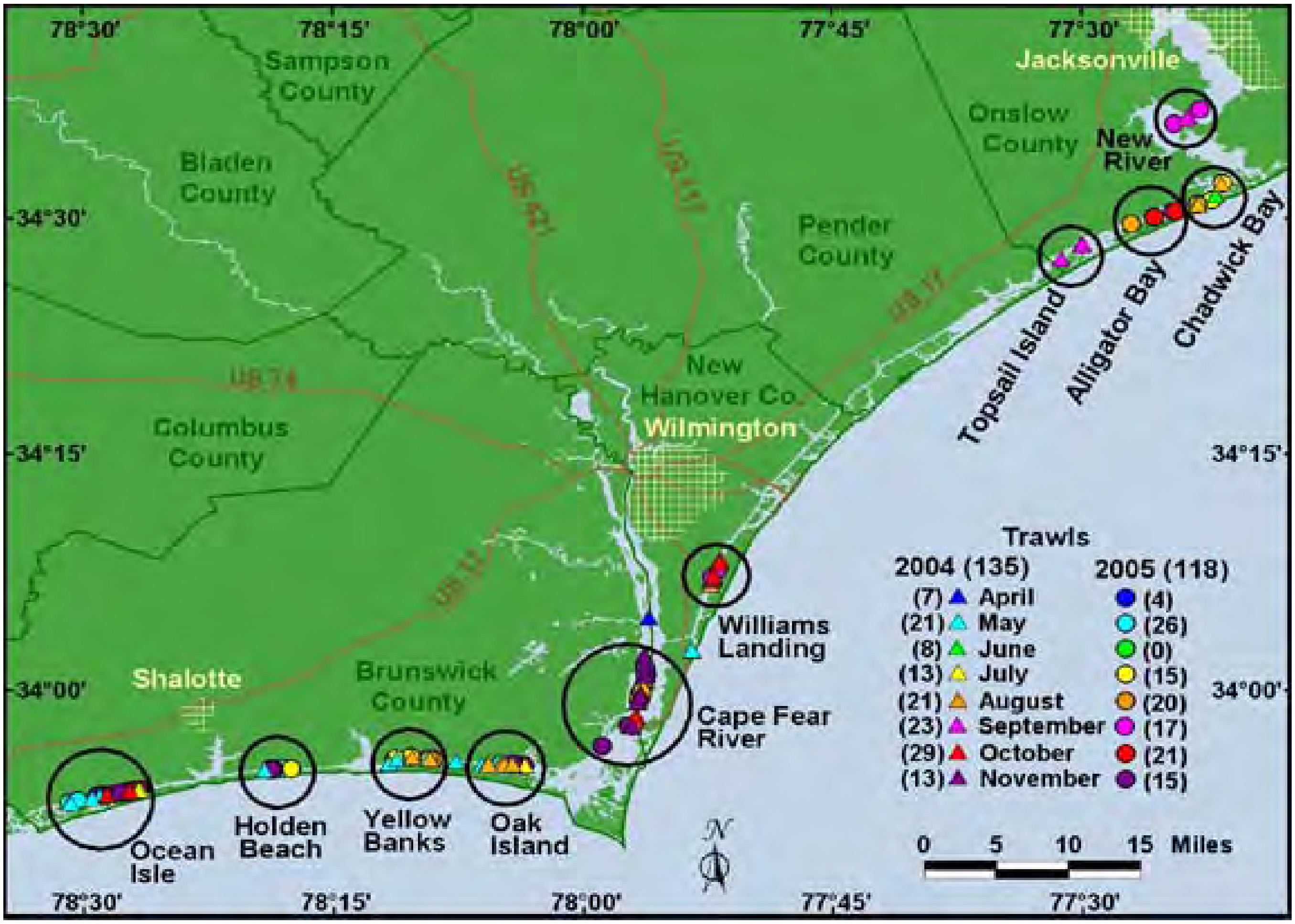


Figure 1: Map showing the sampling areas within the five regions from south to north in southeastern North Carolina: Brunswick County, Cape Fear River, New Hanover and Onslow Counties, and New River. We conducted N=253 trawls from April to November 2004 and 2005.

Table 1: We executed 120 trips executed in 2004 (N=64) and 2005 (N=56), and collected data on N=253 tows. The total number of tows per month is shown by region.

Region	Code	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Total
Brunswick	**B**	**2**	**31**	**-**	**23**	**20**	**12**	**21**	**13**	**122**
Oak Island	OKI	-	8	-	12	10	-	-	4	**34**
Yellow Banks	YB	-	8	-	7	6	-	-	-	**21**
Holden Beach	HB	-	2	-	2	-	-	-	2	**6**
Ocean Isle Beach	OIB	2	10	-	2	4	12	21	7	**58**
Sunset Beach	SSB	-	3	-	-	-	-	-	-	**3**
Cape Fear River	**CFR**	**9**	**14**	**2**	**2**	**6**	**6**	**25**	**15**	**79**
New Hanover	**NH**	**-**	**2**	**2**	**-**	**7**	**12**	**2**	**-**	**25**
Williams Landing	WL	-	-	2	-	7	12	2	-	**23**
Carolina Beach Yacht Basin	CBYB	-	2	-	-	-	-	-	-	**2**
Onlsow	**O**	**-**	**-**	**4**	**3**	**8**	**6**	**2**	**-**	**21**
Chadwick Bay	CB	-	-	2	3	3	-	-	-	**8**
Alligator Bay	AB	-	-	2	-	4	2	2	-	**10**
Stumps Sound	SS	-	-	-	-	1	4	-	-	**5**
New River	**NR**	**-**	**-**	**-**	**-**	**-**	**4**	**-**	**-**	**4**
TOTAL		**11**	**47**	**8**	**28**	**41**	**40**	**50**	**28**	**253**

Note: The locations within each county are arranged from north to south or east to west depending on their orientation.

Table 2a: Post Release Index of Condition (PRIC)

1 - Good	No revival time required when the fish is returned to the water. Rapid swimming away from the boat, and usually accompanied by a vigorous splash.
2 - Fair	No revival time required. Slow but strong swimming away from the boat upon release.
3 - Poor	Short revival time required (up to 30 seconds). Once revived, slow but sometimes atypical swimming away from boat upon release.
4 - Very Poor	Revival time more than 30 seconds. Limited or no swimming upon release. Respiration is evident.
5 - Dead	Dead, moribund or unable to revive after a long submergence time.

Table 2b: Mortality Proxy Index (MPI)

1 - None	No apparent physical damage.
2 - Mild	Bleeding (yes/no), general cuts and abrasions, and scale loss.
3 - Moderate	Moderate bleeding, bulging around the eyes, or fins or body caused by constriction of trawl webbing.
4 - Severe	Severe bleeding or bruising caused by constriction of the trawl webbing.
5 - Very Severe	Smashed or torn specimens caused by constriction of the trawl webbing.

III. RESULTS

A. Catch per Unit Effort

Overall, we caught more shrimp by weight (4648.4 Kg) than bycatch (3659.02 Kg), and shrimp composed 55.95 % of the catch (Table 3). In 2004, blue crab and Atlatic croaker ranked as the number one and two bycatch species caught by weight (Kg) respectively, but in 2005 they switched places (Figure 2). The quantity of both species was greater than the previous year with an 89% increase in the weight of Atlantic croaker from 2004 to 2005. The large proportion of Atlantic croaker in 2005 was landed principally in late April while we were "hunting" for the shrimp crop. More weakfish and squid were caught in 2004, whereas we captured nearly half the 2004 quantity in 2005 (Figure 2).

The overall average catch rate (Kg/tow/min) for 2004 and 2005 month and region combined was 0.479 ± 0.043 standard error (SE) for shrimp and 0.368 ± 0.025 SE for bycatch (Table 4). There was no significant difference between the catch rates of shrimp and bycatch (M-W Z=1.186, df=1, P=0.276). The overall catch ratio of bycatch to shrimp (bycatch:shrimp) was 0.79, which indicates that for every Kg of shrimp caught there was 0.79 Kg of bycatch captured (Table 5). When comparing the catch rates of shrimp per month, we found significantly higher catch rates for bycatch than shrimp in April (M-W Z=7.55, df=1, P=0.006), May (M-W Z=57.24, df=1, P<0.001) and June (M-W Z=9.28, df=1, P=0.002) (Table 6; Figure 3), which was reflected in the bycatch:shrimp ratios. By contrast in October (M-W X^2=18.33, df=1, P<0.001) and November (M-W Z=23.34, df=1, P<0.001), the catch rates of shrimp were significantly greater than that of bycatch, and the bycatch:shrimp ratios were less than one. From July through September, there was no difference between the shrimp and bycatch catch rates. Regionally, the catch rates for shrimp and bycatch were significantly different in New River (t-test t=-5.21, df=1, P=0.001) and the bycatch:shrimp ratio was 5.0 (Table 6, Figure 4). In Brunswick County, the overall catch rate of shrimp to bycatch was not statistically significant (M-W Z=-0.38, df=1, P=0.353). In May, the catch rate for bycatch was greater than it was for shrimp (M-W Z= -6.54, df=1, P<0.001) (Figure 5). By contrast, shrimp catch rates were higher than those for bycatch in October (M-W Z=-4.23, df=1, P<0.001) and November (M-W Z=-3.13, df=1, P=0.001).

Shrimp

There was a significant difference in shrimp CPUE versus month when the data were combined by region over the two sampling years, Kruskal-Wallis (K-W) X^2=105.53, df=7, P< 0.001 (Table 6, Figure 6). Monthly catch rates for shrimp were significantly lower in April, May and June compared to July through November. Sampling month affected the catch rates in Brunswick County and the Cape Fear River. Catch rates in Brunswick were significantly greater in July, October and November than in April and May (K-W X^2=64.13, df=6, P<0.001) (Figure 5), although there were only two tows executed in April (Table 1). In the Cape Fear River, the catch rates for September and October were higher than those in April, May and June (K-W X^2=64.13, df=6, P<0.001), and again there were two tows in June and July.

There was no difference in shrimp catch rates among the five regions, ANOVA F=0.61, df=4, P=0.66 (Table 6).

Bycatch

There was a significant difference in the catch rate of bycatch versus month for the five regions combined for 2004 and 2005 (K-W X^2=49.74, df=7, P<0.001) (Table 6, Figure 7). May and September had higher catch rates than October and November, and the catch rate in August was greater than in November. The monthly catch rates for bycatch varied in Brunswick County (K-W X^2=37.96, df=6, P<0.001). Here the catch rates in May and July through October were greater than in November, and in May the catch rate was higher than in October. Monthly differences in catch rates were found within the bycatch categories, invertebrates, blue crab, fish (all), commercial and recreational finfish (C&RFF), other finfish (OtherFF) and *Paralichthys spp*. Regionally, bycatch catch rates were significantly different (K-W X^2=15.55, df=4, P=0.004), but no differences between the regions were detected. The pattern was similar for fish (all) (K-W X^2=11.67, df=4, P=0.02), commercial and recreational finfish (K-W X^2=9.54, df=4, P=0.049), other finfish (X^2=32.33, df=4, P<0.001), and *Paralichthys spp*. (K-W X^2=30.83, df=4, P<0.001). There were no regional differences in catch rates for invertebrate.

In Brunswick County, bycatch catch rates were highest in May, July, August and September than in October or November (K-W X^2=37.96, df=6, P<0.001) (Table 6, Figure 5). This trend was fairly consistent within the bycatch categories, invertebrates (K-W X^2=40.55, df=6, P<0.001), blue crab (K-W X^2=33.77, df=6, P<0.001), fish (all) (K-W X^2=33.39, df=6, P<0.001), commercial and recreation finfish (K-W X^2=26.07, df=6, P<0.001) and other finfish (K-W X^2=19.23, df=6, P=0.004), except for *Paralichthys spp*. Monthly catch rates for bycatch were the same in the Cape Fear River (K-W X^2=17.08, df=7, P=0.017), New Hanover County. In Onlsow County, the catch rate for blue crab was higher in October than June (K-W X^2=10.99, df=4, P=0.027).

Two turtles were captured during the study a Kemp's ridley (*Lepidochelys kempii*) in 2004 and a diamondback terrapin (*Malaclemys terrapin*) in 2005. Both animals appeared unharmed by our gear and released alive. The Kemp's ridley had a puncture wound and was transported to the Karen Beasley Sea Turtle Rescue and Rehabilitation Center in Topsail Island, North Carolina, and the wound was treated by NC State University Veterinarians before released.

Flatfish

The species composition of flatfish by weight (Kg) showed that 71 % of the flatfish captured were *Paralichthys spp*. (Figure 8a). Bay whiff comprised 15.91% of the flatfish caught followed by hogchoker at 10.13 %. In 2005, 52.8 % by weight of the flatfish were southern, 17.76 % summer, and 0.5 % gulf flounder (*P. albigutta*) (Figure 8b). *Paralichthys spp*. catch rates for both years were outlined above. For 2005, there was no difference in the monthly catch rates for southern (ANOVA F=1.074, df=6, P=0.39) or summer flounder (ANOVA F=0.389, df=6, P=0.88). There was a higher catch rate of summer flounder in the Cape Fear River than in Brunswick County (ANOVA F=3.895, df=3, P=0.016). No differences in southern flounder catch rates were found among the sampling regions (ANOVA F=1.92, df=3, P=0.136).

Environmental Parameters and Catch per Unit Effort

Water depth showed a regional association with the deepest in the Cape Fear River and the shallowest in New River (K-W X^2=112.23, df=4, P<0.001) (Figure 9a). We found that surface water salinity (ANOVA F=10.11, df=7, P<0.001) and temperature (K-W X^2=197.51, df=7, P<0.001) varied significantly with month (Figures 9b). More tows were executed during an ebb (N=130) than flood (N=112) tide, and 11 tows occurred during transitional tides, e.g. changing from ebb to flood or visa versa (Figure 9c). Tow times varied monthly (ANOVA F=3.54, df=7 P<0.001) and regionally (K-W X^2=19.86, df=4, P<0.001) (Figure 9d, e). Longer tows occured in October than in June or July, and in Brunswick County and Cape Fear River.

For all sites combined, the catch rates of shrimp, invertebrates, blue crab, all fish, other finfish and *Paralichthys spp*. were all negatively associated to water depth (Table 7); however, the linear relationships were weak as shown by the R^2 values. The catch rate of bycatch collectively increased from ebb to flood tide (Table 7) The total catch weight showed a slight positive relationship with the tow time (Regression F=12.29, df=1, P<0.001 R^2=0.062).

In Brunswick County, surface salinity positively affected the catch rates of bycatch, and fish (all), and other finfish (Table 7). By contrast, tow time inversely affected the the catch rates of bycatch, fish (all), and commercial and recreational finfish. The blue crab catch rate increased along with surface water temperature. Shrimp, commercial and recreational finfish and *Paralichthys spp*. catch rates were not affected by the environmental parameters measured. In the Cape Fear River, the shrimp catch rate increased during a flood tide (Table 7). The catch rates of bycatch, fish (all) and other finfish were inversely associated with water salinity. An increase in water salinity raised the catch rate in other finfish in New Hanover County (Table 7). In Onslow County, the catch rates for bycatch and all of the bycatch categories except *Paralichthys spp*. were negatively associated with water salinity (Table 7). New River data were not analyzed because of the sample size (N=4). Few of these relationships were robust as shown by the goodness of fit (R^2) values, except for those in New Hanover and Onlsow Counties, and blue crab in Brunswick County.

Table 3: Species rank by weight (Kg) listed in order from largest to smallest.

Species	*Scientific Name*	Rank	Total Wt. (Kg)	Wt. (%)
SHRIMP	***Penaeus spp.***	**1**	**4648.4**	**55.95**
BYCATCH		**2**	**3659.02**	**44.05**
Atlantic croaker	*Micropogonias undulatus*	1	1013.05	27.69
Blue crab	*Callinectes sapidus*	2	838.64	22.92
Spot	*Leiostomus xanthurus*	3	305.52	8.35
Weakfish	*Cynoscion regalis*	4	229.84	6.28
Pinfish	*Lagodon rhomboides*	5	220.36	6.02
Squid	*Lolliguncula brevis*	6	188.84	5.16
Smooth butterfly ray	*Gymnura altavela*	7	156.29	4.27
Paralichthys spp.	*P. albigutta, dentatus, lethostigmata*	8	141.83	3.88
Atlantic cutlassfish	*Trichiurus lepturus*	9	112.33	3.07
Inshore lizardfish	*Synodus foetens*	10	57.73	1.58
Silver perch	*Bairdiella chrysoura*	11	47.40	1.29
Atlantic menhaden	*Brevoortia tyrannus*	12	43.93	1.20
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	13	41.03	1.12
Bay whiff	*Citharichthys spilopterus*	14	33.18	0.91
Mantis shrimp	*Squila empusa*	15	27.89	0.76
Hogchoker	*Trinectes maculatus*	16	27.65	0.75
Bay anchovy	*Anchoa mitchilli*	17	26.35	0.72
Southern hake	*Urophycis floridana*	18	25.17	0.69
Star drum	*Stellifer lanceolatus*	19	23.12	0.63
Pigfish	*Orthopristis chrysoptera*	20	19.46	0.53
Atlantic stingray	*Dasyatis sabina*	21	18.4	0.50
Lookdown	*Selene vomer*	22	16.03	0.44
Striped anchovy	*Anchoa hepsetus*	23	14.45	0.39
Southern stingray	*Dasyatis americana*	24	13.95	0.38
Atlantic spadefish	*Chaetodipterus faber*	25	13.91	0.38
Ocellated Flounder	*Ancylopsetta quadrocellata*	26	9.53	0.26
Northern searobin	*Prionotus carolinus*	27	9.43	0.26
Spotfin mojarra	*Eucinostomus argenteus*	28	7.93	0.22
Southern kingfish	*Menticirrhus americanus*	29	7.08	0.19
White perch	*Morone americanus*	30	6.95	0.19
Oyster toadfish	*Opsanus tau*	31	6.42	0.17
Cownose ray	*Rhinoptera bonasus*	32	6.17	0.17
Blackcheek tonguefish	*Symphurus plagiusa*	33	5.66	0.15
Harvestfish	*Peprilus alepidotus*	34	5.55	0.15
Speckled trout	*Cynoscion nebulosus*	35	5.52	0.15

Species	*Scientific Name*	Rank	Kg	%
Bluefish	*Pomatomus saltatrix*	36	5.28	0.14
Bank seabass	*Centropristis ocyurus*	37	4.76	0.13
Conger eel	*Conger oceanicus*	38	4.39	0.12
Butterfish	*Peprilus triacanthus*	39	4.10	0.11
Striped mullet	*Mugil cephalus*	40	3.69	0.10
Northern puffer	*Sphoeroides maculatus*	41	3.30	0.090
Jellies	P. CNIDARIA	42	3.29	0.090
Atlantic thread herring	*Opisthonema oglinum*	43	3.14	0.086
Kemp's ridley sea turtle	*Lepidochelys kempii*	44	2.94	0.080
Spanish mackerel	*Scomberomorus maculatus*	45	2.80	0.077
Cannonball jellies	*Stomolophus meleagris*	46	2.2	0.060
Striped searobin	*Prionotus evolans*	47	2.09	0.057
Longnose gar	*Lepisosteus osseus*	48	2.06	0.056
Horseshoe crab	*Limulus polyphemus*	49	2.04	0.056
Cobia	*Pachycentron canadum*	50	2.01	0.055
Sheepshead minnow	*Archosargus probatocephalus*	51	1.99	0.054
Spider crab	*Libinia dubia*	52	1.86	0.051
Windowpane flounder	*Scophthalmus aquosus*	53	1.82	0.049
Planehead filefish	*Monocanthus hispidus*	54	1.71	0.047
Moon jelly	*Aurelia aurita*	55	1.61	0.044
Sea cucumber	C. Holothuroids	56	1.5	0.041
Clearnose skate	*Raja elganteria*	57	1.28	0.035
Bonnethead shark	*Sphryrna tiburo*	58	1.18	0.032
Sandbar shark	*Carcharhinus plumbeus*	59	1.18	0/032
Sea nettle	*Crysaora quinquecirrha*	60	1.06	0.029
Northern quahog	*Mercenaria mercenaria*	61	0.97	0.026
Ladyfish	*Elops saurus*	62	0.92	0.025
Tripletail	*Lobotes surinamensis*	63	0.86	0.025
Threadfin shad	*Dorosoma pretenense*	64	0.85	0.023
Northern kingfish	*Menticirrhus saxatilis*	65	0.82	0.023
Gizzard shad	*Dorosoma cepedianum*	66	0.81	0.022
Striped burrfish	*Chilomycterus schoepfi*	67	0.81	0.022
Scalloped hammerhead	*Sphyrna zygaena*	68	0.74	0.022
Cusk eel	*Brosme brosme*	69	0.71	0.020
Channel catfish	*Ictalurus punctuatus*	70	0.59	0.019
Ascidian	C. Ascidiacea	71	0.58	0.016
Leopard searobin	*Prionotus scitulus*	72	0.58	0.016
Channeled whelk	*Busycon canaliculatum*	73	0.54	0.015
Gulf flounder	*Paralichthys albigutta*	74	0.5	0.014
Northern stargazer	*Astroscopus guttatus*	75	0.43	0.014

Species	***Scientific Name***	**Rank**	**Kg**	**%**
Northern pipefish	*Syngnathus fuscus*	76	0.41	0.012
Florida stone crab	*Menippe mercenaria*	77	0.37	0.011
Flatclaw hermit crab	*Pagurus pollicaris*	78	0.29	0.010
Atlantic moonfish	*Selene setapinnis*	79	0.23	0.008
Gag grouper	*Mycteroperca phenax*	80	0.22	0.006
Diamondback terrapin	*Malaclemys terrapin*	81	0.2	0.006
Scaled sardine	*Harengula jaguana*	82	0.19	0.005
Atlantic bumper	*Chloroscombrus chrysurus*	83	0.18	0.005
Blotched swimming crab	*Portunus spinimanus*	84	0.17	0.005
King mackerel	*Scomberomorus cavalla*	85	0.16	0.005
Forbes sea star	*Asteria forbesi*	86	0.16	0.004
Lady crab	*Ovalipes stephensoni*	87	0.15	0.004
Comb jellies	O. Berioda	88	0.14	0.004
Banded drum	*Larimus fasciatus*	89	0.09	0.003
Sharptail goby	*Gobionellus boleosoma*	90	0.068	0.002
Goby sp.	*Gobiidae*	91	0.067	0.002
Gray snapper (Juv.)	*Lutjanus griseus*	92	0.058	0.001
Florida pompano	*Trachinotus carolinus*	93	0.052	0.001
Blood ark	*Anadara ovalis*	94	0.04	0.001
Sargassum swimming crab	*Portunus sayi*	95	0.04	0.001
Horseye jack	*Caranx latus*	96	0.04	0.001
Scad	*Decopterus sp.*	97	0.04	0.001
Big headed searobin	*Prionotus longispinosus*	98	0.037	<0.001
Guanguanche	*Sphyraena guachancho*	99	0.023	<0.001
Sharksucker	*Echeneis naucrates*	100	0.022	<0.001
Black drum	*Pogonias cromis*	101	0.022	<0.001
Speckled crab	*Arenaeus cribrarius*	102	0.02	<0.001
Roughback batfish	*Ogcocephalus parvus*	103	0.017	<0.001
Yellow jack	*Caranx bartgolomaei*	104	0.014	<0.001
Black seabass	*Centropristis striata*	105	0.009	<0.001
Halfbeak (1/2 only)	*Belonidae*	106	0.005	<0.001
Brown rock shrimp	*Sicyonia brevirostris*	107	0.004	<0.001
Sardine sp.	*Engraulidae*	108	0.004	<0.001
Great barracuda	*Sphyraena barracuda*	109	0.003	<0.001

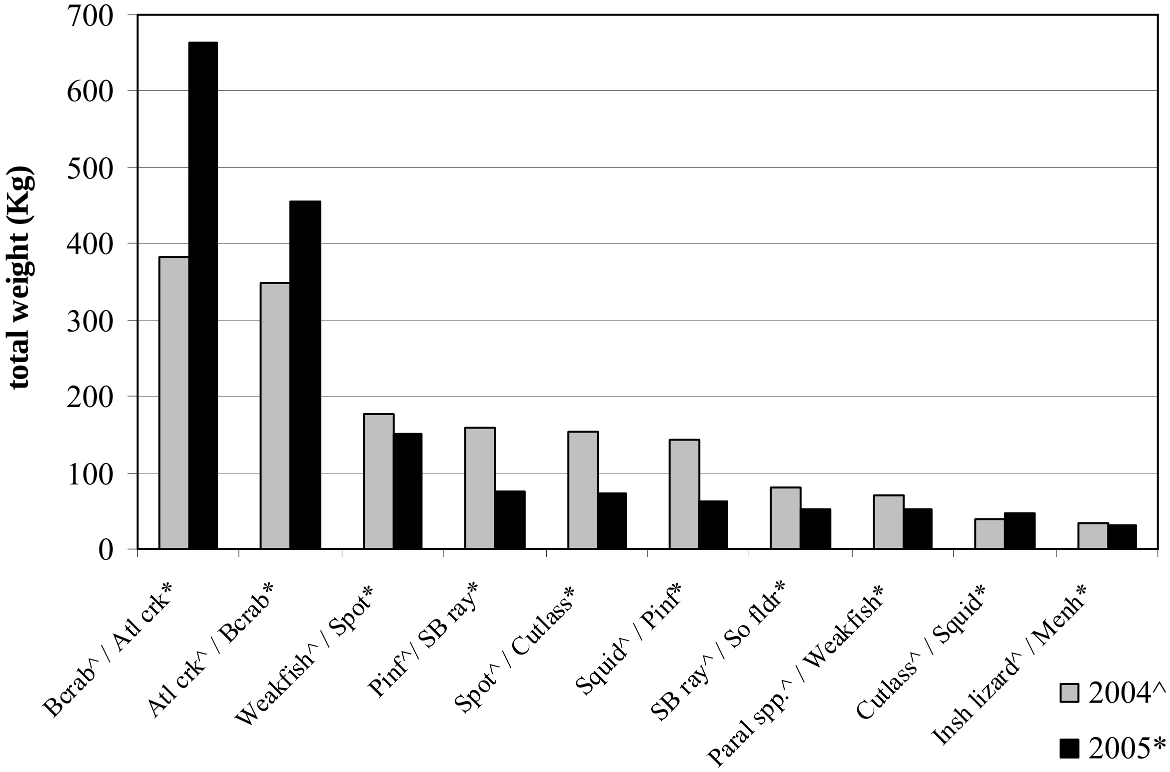


Figure 2: The top 10 bycatch species by weight (Kg) in ranking order for 2004^ / 2005*.

Table 4: Mean (± Standard Error) catch rates (Kg/tow/min) for 2004 and 2005.

Region	Species	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Total
All Regions	Shrimp	0.067 (0.027)	0.083 (0.011)	0.045 (0.022)	0.424 (0.092)	0.776 (0.180)	0.608 (0.106)	0.578 (0.065)	0.707 (0.116)	0.479 (0.043)
	Bycatch	0.918 (0.366)	0.382 (0.028)	0.270 (0.057)	0.400 (0.079)	0.382 (0.049)	0.492 (0.064)	0.238 (0.023)	0.134 (0.017)	0.368 (0.025)
	Inverts	0.054 (0.031)	0.125 (0.017)	0.083 (0.021)	0.138 (0.030)	0.131 (0.020)	0.138 (0.019)	0.077 (0.012)	0.025 (0.004)	0.105 (0.007)
	Blue crab	0.878 (0.013)	0.084 (0.013)	0.103 (0.019)	0.103 (0.030)	0.102 (0.019)	0.121 (0.016)	0.064 (0.011)	0.015 (0.004)	0.080 (0.007)
	Fish (all)	0.878 (0.368)	0.279 (0.024)	0.246 90.061)	0.322 (0.059)	0.278 (0.039)	0.361 (0.060)	0.158 (0.015)	0.106 (0.014)	0.280 (0.023)
	C&RFF	0.775 (0.369)	0.775 (0.022)	0.097 (0.023)	0.201 (0.046)	0.126 (0.019)	0.220 (0.036)	0.118 (0.012)	0.075 (0.013)	0.182 (0.020)
	OtherFF	0.090 (0.025)	0.090 (0.008)	0.102 (0.042)	0.070 (0.015)	0.091 (0.014)	0.115 (0.035)	0.033 (0.004)	0.031 (0.003)	0.072 (0.007)
Brunswick	Shrimp	0.059 (0.027)	0.077 (0.013)	-	0.459 (0.106)	0.664 (0.174)	0.488 (0.156)	0.669 (0.098)	1.033 (0.174)	0.488 (0.156)
	Bycatch	0.498 (0.118)	0.446 (0.032)	-	0.345 (0.045)	0.319 (0.041)	0.332 (0.054)	0.259 (0.035)	0.109 (0.013)	0.332 (0.054)
	Inverts	0.257 (0.055)	0.181 (0.018)	-	0.109 (0.015)	0.134 (0.017)	0.190 (0.044)	0.111 (0.023)	0.021 (0.006)	0.190 (0.044)
	Blue crab	0.098 (0.047)	0.122 (0.016)	-	0.068 (0.010)	0.086 (0.009)	0.165 (0.034)	0.101 (0.021)	0.016 (0.005)	0.165 (0.034)
	Fish (all)	0.333 (0.107)	0.300 (0.030)	-	0.307 (0.049)	0.229 (0.039)	0.139 (0.030)	0.142 (0.018)	0.083 (0.009)	0.139 (0.030)
	C&RFF	0.179 (0.113)	0.208 (0.026)	-	0.188 (0.037)	0.107 (0.018)	0.116 (0.030)	0.097 (0.013)	0.051 (0.009)	0.116 (0.030)
	OtherFF	0.092 (0.013)	0.068 (0.008)	-	0.078 (0.018)	0.087 (0.019)	0.024 (0.005)	0.042 (0.008)	0.032 (0.004)	0.024 (0.005)
Cape Fear River	Shrimp	0.069 (0.027)	0.100 (0.023)	0.055 (0.024)	0.589 (0.361)	0.723 (0.211)	1.615 (0.253)	0.573 (0.093)	0.380 (0.089)	0.474 (0.062)
	Bycatch	1.011 (0.446)	0.446 (0.032)	0.311 (0.088)	1.455 (0.776)	0.768 (0.229)	0.308 (0.136)	0.182 (0.029)	0.160 (0.031)	0.384 (0.069)
	Inverts	0.009 (0.003)	0.181 (0.018)	0.114 (0.052)	0.584 (0.246)	0.271 (0.108)	0.102 (0.043)	0.037 (0.008)	0.029 (0.006)	0.067 (0.016)
	Blue crab	0.008 (0.003)	0.122 (0.016)	0.108 (0.048)	0.583 (0.247)	0.269 (0.108)	0.102 (0.043)	0.028 (0.008)	0.013 (0.006)	0.061 (0.016)
	Fish (all)	0.999 (0.443)	0.300 (0.030)	0.272 (0.045)	0.880 (0.549)	0.493 (0.169)	0.225 (0.123)	0.145 (0.022)	0.129 (0.026)	0.318 (0.064)
	C&RFF	0.907 (0.443)	0.208 (0.026)	0.159 (0.010)	0.613 (0.479)	0.220 (0.077)	0.181 (0.108)	0.121 (0.020)	0.099 (0.023)	0.244 (0.060)
	OtherFF	0.089 (0.031)	0.068 (0.008)	0.013 (0.006)	0.026 (0.008)	0.057 (0.023)	0.039 (0.015)	0.019 (0.003)	0.029 (0.006)	0.046 (0.006)
New Hanover [1]	Shrimp	-	0.047 (0.012)	0.096 (0.087)	-	1.088 (0.581)	0.562 (0.177)	0.082 (0.006)	-	0.592 (0.190)
	Bycatch	-	0.243 (0.026)	0.387 (0.171)	-	0.303 (0.059)	0.557 (0.073)	0.409 (0.037)	-	0.435 (0.046)
	Inverts	-	0.055 (0.004)	0.065 (0.049)	-	0.096 (0.018)	0.104 (0.028)	0.127 (0.011)	-	0.096 (0.015)
	Blue crab	-	0.042 (0.010)	0.001 (<0.001)	-	0.080 (0.015)	0.046 (0.021)	0.046 (0.010)	-	0.068 (0.012)
	Fish (all)	-	0.198 (0.010)	0.418 (0.175)	-	0.228 (0.068)	0.460 (0.077)	0.268 (0.034)	-	0.355 (0.048)

NH con't	Species	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Total
	C&RFF	-	0.142 (0.013)	0.143 (0.037)	-	0.132 90.044)	0.280 (0.056)	0.177 (0.014)	-	0.208 (0.032)
	OtherFF	-	0.049 (<0.001)	0.195 (0.145)	-	0.070 (0.026)	0.108 (0.028)	0.077 (0.015)	-	0.097 (0.019)
Onslow	Shrimp	-	-	0.014 (0.009)	0.052 (0.014)	0.819 (0.667)	0.254 (0.041)	0.170 (0.010)	-	0.421 (0.275)
	Bycatch	-	-	0.190 (0.065)	0.121 (0.014)	0.319 (0.104)	0.135 (0.020)	0.525 (0.070)	-	0.404 (0.106)
	Inverts	-	-	0.077 (0.031)	0.061 (0.024)	0.049 (0.024)	0.015 (0.006)	0.139 (0.018)	-	0.097 (0.021)
	Blue crab	-	-	0.011 (0.005)	0.049 (0.019)	0.034 (0.015)	0.015 (0.006)	0.128 (0.013)	-	0.066 (0.016)
	Fish (all)	-	-	0.147 (0.062)	0.061 (0.013)	0.283 (0.097)	0.113 (0.021)	0.376 (0.042)	-	0.320 (0.094)
	C&RFF	-	-	0.043 (0.017)	0.019 (0.009)	0.098 (0.046)	0.059 (0.002)	0.253 (0.013)	-	0.128 (0.036)
	OtherFF	-	-	0.101 (0.044)	0.041 (0.012)	0.144 (0.044)	0.046 (0.047)	0.069 (0.012)	-	0.163 (0.048)
New River [2]	Shrimp	-	-	-	-	-	0.267 (0.116)	-	-	0.267 (0.116)
	Bycatch	-	-	-	-	-	1.413 (0.187)	-	-	1.413 (0.187)
	Inverts	-	-	-	-	-	0.231 (0.049)	-	-	0.231 (0.049)
	Blue crab	-	-	-	-	-	0.221 (0.055)	-	-	0.221 (0.055)
	Fish (all)	-	-	-	-	-	1.213 (0.161)	-	-	1.213 (0.161)
	C&RFF	-	-	-	-	-	0.606 (0.130)	-	-	0.606 (0.130)
	OtherFF	-	-	-	-	-	0.574 (0.252)	-	-	0.574 (0.252)

Inverts - Invertebrates
Fish (all) = sharks and finfish
C&RFF = commercial and recreational finfish
OtherFF = noncommercial or recreational finfish
[a]New Hanover – 1 tow Sep 05
[b]New River – opening day only (Sep 04 and 05)

Table 5: Bycatch to Shrimp ratio (B:S) for 2004 and 2005.

Region	Ratio	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	Total
All Regions	B:S	7.48	5.07	6.65	1.15	0.54	0.83	0.39	0.22	**0.79**
	I:S	2.38	1.81	2.18	0.41	0.19	0.24	0.13	0.04	**0.23**
	BC:S	1.10	1.26	1.17	0.32	0.15	0.21	0.11	0.03	**0.18**
	allF:S	64.88	5.67	6.01	1.25	0.57	0.88	0.39	0.27	**0.91**
	FF:S	6.37	2.34	4.71	0.46	0.21	0.38	0.16	0.13	**0.32**
	C&RFF:S	30.54	2.39	4.71	0.54	0.17	0.38	0.19	0.12	**0.39**
	OFF:S	3.90	1.01	1.99	0.17	0.13	0.19	0.05	0.05	**0.15**
Brunswick	B:S	7.94	6.80	-	0.84	0.54	0.65	0.40	0.11	**0.69**
	I:S	4.06	3.05		0.26	0.24	0.37	0.18	0.02	**0.30**
	BC:S	1.66	2.12		0.16	0.16	0.31	0.16	0.02	**0.22**
	allF:S	5.41	5.62		0.95	0.50	0.61	0.46	0.21	**0.68**
	FF:S	4.56	3.25		0.54	0.24	0.05	0.07	0.03	**0.27**
	C&RFF:S	3.14	2.94		0.45	0.17	0.24	0.15	0.05	**0.28**
	OFF:S	1.42	1.07		0.19	0.14	0.05	0.06	0.03	**0.12**
Cape Fear River	B:S	14.43	2.61	6.02	2.54	0.97	0.23	0.30	0.47	**0.80**
	I:S	0.11	0.10	2.07	1.06	0.37	0.07	0.06	0.09	**0.15**
	BC:S	0.10	0.07	1.97	1.06	0.37	0.07	0.05	0.04	**0.13**
	allF:S	27.53	5.87	5.48	2.57	0.84	0.17	0.23	0.41	**1.08**
	FF:S	1.77	0.92	3.63	0.05	0.16	0.17	0.23	0.36	**0.28**
	C&RFF:S	12.82	1.55	3.32	0.98	0.26	0.14	0.19	0.29	**0.50**
	OFF:S	1.40	0.92	0.31	0.05	0.08	0.03	0.03	0.09	**0.10**
New Hanover	B:S	-	5.04	5.38	-	0.28	0.92	5.08	-	**0.68**
	I:S		1.13	0.96		0.09	0.17	1.58		**0.15**
	BC:S		0.89	0.01		0.07	0.13	0.58		**0.11**
	allF:S		4.06	5.79		0.21	0.94	3.36		**0.64**
	FF:S		3.93	4.78		0.18	0.57	3.18		**0.44**
	C&RFF:S		2.94	1.92		0.12	0.46	2.21		**0.33**
	OFF:S		0.99	2.86		0.06	0.18	0.97		**0.15**
Onslow	B:S	-	-	10.68	1.96	0.48	0.53	3.11		**0.72**
	I:S			4.59	1.12	0.07	0.06	0.82		**0.16**
	BC:S			0.76	0.88	0.05	0.06	0.76		**0.11**
	allF:S			8.00	2.30	0.88	1.02	4.53		**1.16**
	FF:S			7.82	0.59	0.23	0.17	0.41		**0.29**
	C&RFF:S			2.29	0.25	0.13	0.24	1.49		**0.23**
	OFF:S			5.54	0.59	0.22	0.17	0.41		**0.27**
New River	B:S						4.99			**4.99**
	I:S						0.78			**0.78**
	BC:S						0.74			**0.74**
	allF:S						6.60			**6.60**
	FF:S						2.51			**2.51**
	C&RFF:S						2.30			**2.30**
	OFF:S						1.89			**1.89**

I=Invertebrates, BC=Blue crab, allF=Fish (all), C&RFF=Commercial & Recreational finfish, OFF= Other finfish

Table 6: Relationship of month and region relative to catch rate (K/tow/min) for April through November 2004 and 2005. A P-value of ≤ 0.05 denoted significance.

FISHING REGION	MONTH				REGION			
	test	**P-value**	**NS / S**	**Post hoc**	**test**	**P-value**	**NS / S**	**Post hoc**
REGIONS Combined								
Shrimp	K-W	<0.001	S	APR, MAY JUN < JUL, AUG, SEP, OCT, NOV	ANOVA	0.377	NS	
Bycatch (all)	K-W	<0.001	S	NOV < MAY, AUG, SEP OCT < MAY, SEP	K-W	0.004	S	No differences btw regions
Invertebrates	K-W	<0.001	S	NOV < MAY, JUL, AUG, SEP, OCT	ANOVA	0.274	NS	
Blue crab	K-W	<0.001	S	APR < AUG, SEP NOV < MAY, AUG, SEP, OCT	ANOVA	0.282	NS	
Fish (all)	K-W	<0.001	S	OCT, NOV < MAY NOV < JUL, AUG, SEP	K-W	0.02	S	No differences btw regions
C&R FF	K-W	0.003	S	NOV < MAY, SEP	K-W	0.049	S	No differences btw regions
Other FF	K-W	<0.001	S	OCT, NOV < MAY, AUG	K-W	<0.001	S	No differences btw regions
Paralichthys spp.	K-W	0.007	S	NOV < SEP	K-W	<0.001	S	No differences btw regions
BRUNSWICK								
Shrimp	K-W	<0.001	S	APR, MAY < JUL, OCT, NOV				
Bycatch (all)	K-W	<0.001	S	NOV < MAY, JUL, AUG, SEP, OCT OCT < MAY				
Invertebrates	K-W	<0.001	S	NOV < MAY, JUL, AUG, SEP, OCT				
Blue crab	K-W	<0.001	S	NOV < MAY, JUL, AUG, SEP, OCT				
Fish (all)	K-W	<0.001	S	SEP, OCT, NOV < MAY NOV < JUL, AUG, SEP, OCT				
C&R FF	K-W	<0.001	S	OCT, NOV < MAY NOV < JUL				
Other FF	K-W	0.004	S	SEP, NOV < MAY				
Paralichthys spp.	K-W	<0.001	S	No differences btw months				
CAPE FEAR RIVER								
Shrimp	K-W	<0.001	S	APR, MAY, JUN < SEP, OCT				
Bycatch (all)	K-W	0.017	S	No differences btw months				
Invertebrates	K-W	<0.001	S	No differences btw months				
Blue crab	K-W	<0.001	S	No differences btw months				
Fish (all)	K-W	0.017	S	No differences btw months				
C&R FF	K-W	0.46	NS					
Other FF	K-W	<0.001	S	No differences btw months				
Paralichthys spp.	K-W	<0.001	S	No differences btw months				
NEW HANOVER								
Shrimp	ANOVA	0.475	NS					
Bycatch (all)	ANOVA	0.12	NS					
Invertebrates	ANOVA	0.856	NS					
Blue crab	ANOVA	0.423	NS					
Fish (all)	ANOVA	0.235	NS					
C&R FF	ANOVA	0.34	NS					
Other FF	ANOVA	0.486	NS					
Paralichthys spp.	K-W	0.031	S	No differences btw months				

FISHING REGIONS	MONTH				
	test	P-value	NS / S	Post hoc	
ONSLOW					
Shrimp	ANOVA	0.738	NS		
Bycatch (all)	ANOVA	0.229	NS		
Invertebrates	ANOVA	0.452	NS		
Blue crab	ANOVA	0.028	S	JUN < OCT	
Fish (all)	ANOVA	0.268	NS		
C&R FF	ANOVA	0.062	NS		
Other FF	ANOVA	0.448	NS		
Paralichthys spp.	K-W	0.117	NS		
ONSLOW – New River,					
NA {New River sampled opening day: 3 Sep 04 and 22 Sep 05}					

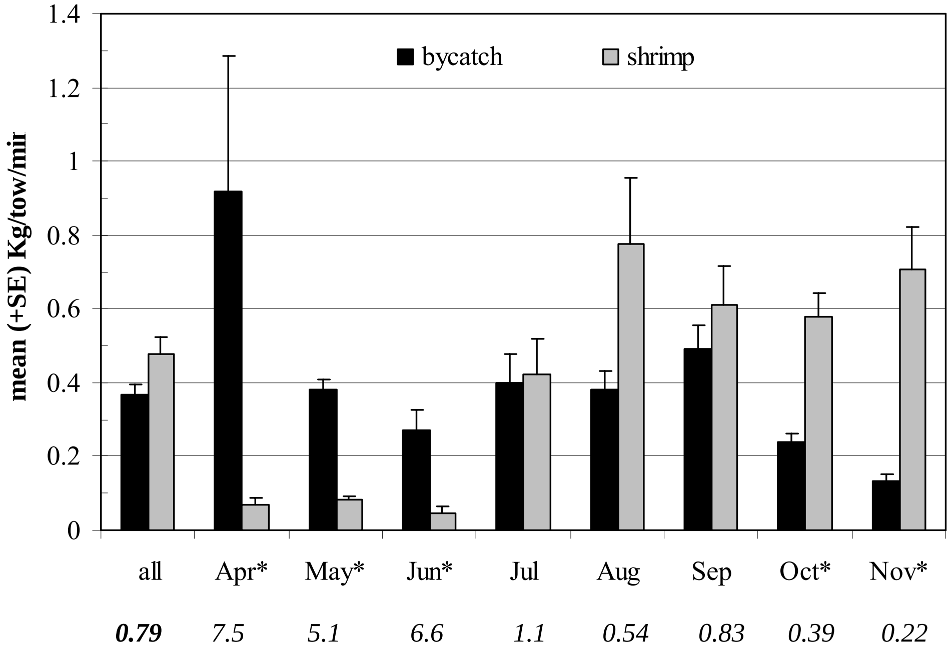


Figure 3: Mean (+ Standard Error) catch per unit effort (Kg/tow/min) of shrimp compared to bycatch per month for 2004 and 2005 combined. The months marked with an asterisk (*) indicate that there was a significant difference between the shrimp and bycatch catch rates with a Mann-Whitney test. The *bycatch:shrimp* ratio is shown below each month.

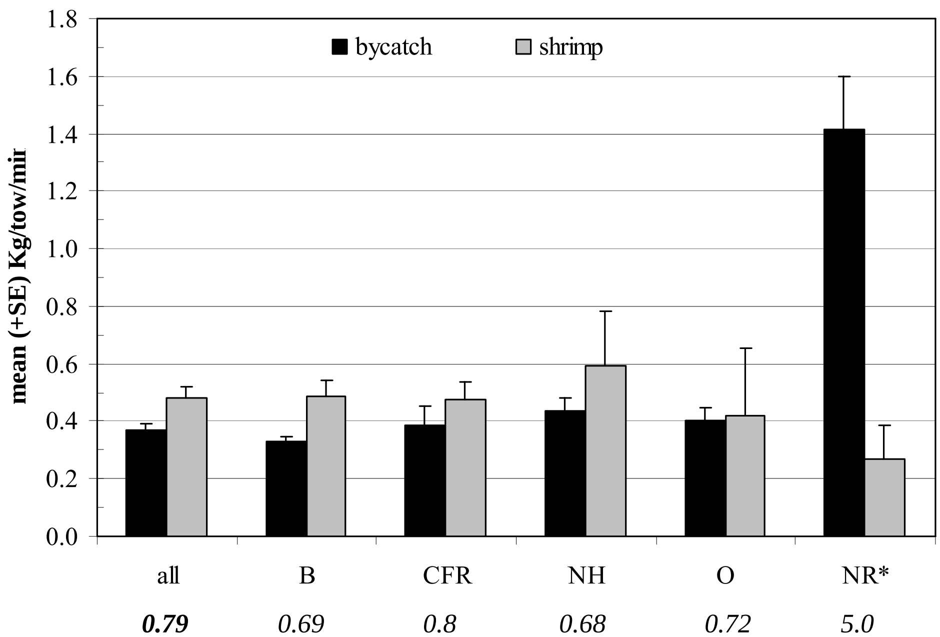


Figure 4: Mean (+ Standard Error) catch per unit effort (Kg/tow/min) of shrimp versus bycatch per region. The region marked with an asterisk (*) indicates that there was a significant difference between the shrimp and bycatch catch rates using a two-sided t-test. The *bycatch:shrimp* ratio is shown below each month.

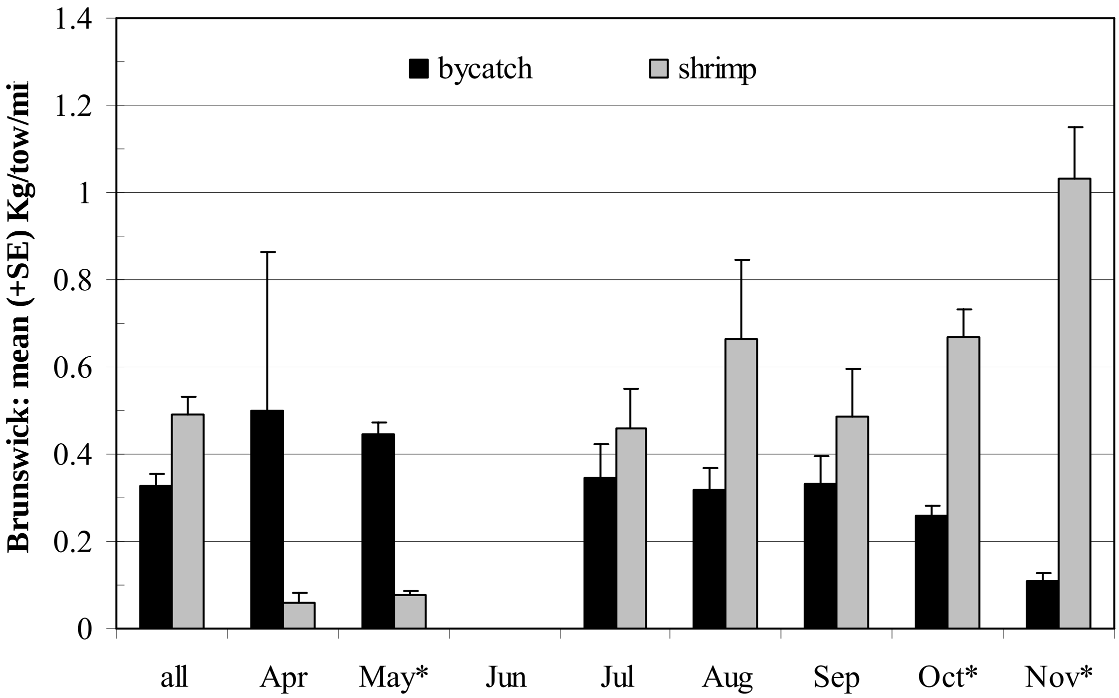


Figure 5: Mean (+Standard Error) catch rate of shrimp and bycatch in Brunswick County per month. The asterisk (*) indicate a significant difference between the shrimp and bycatch catch rates that month. Monthly differences were found in the catch rates of shrimp (Apr, May < Jun, Oct, Nov), and bycatch (Nov < May, Jul, Aug, Sep, Oct: and Oct < May).

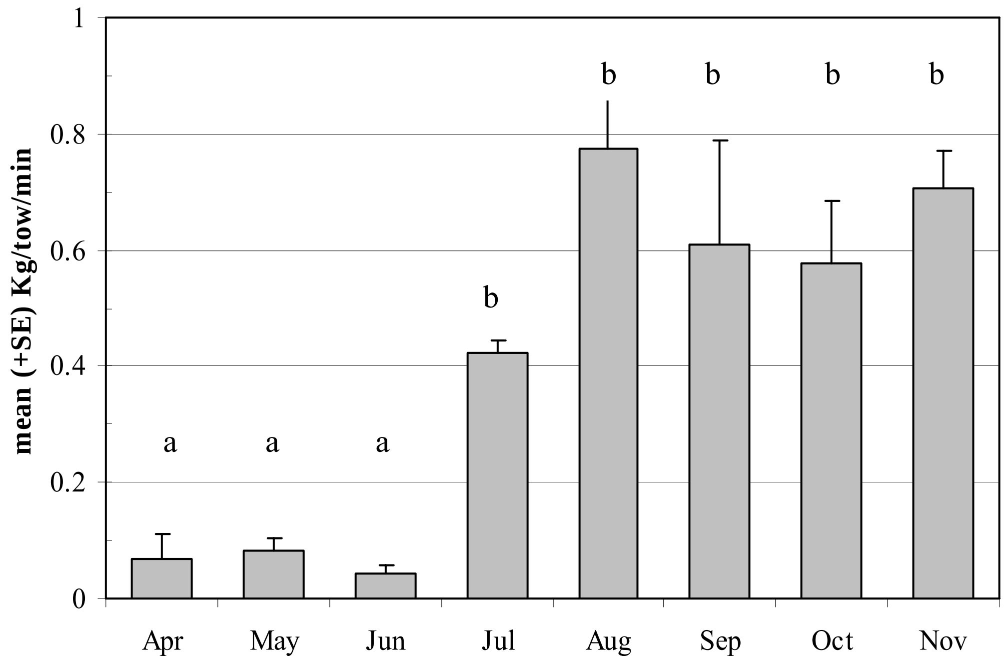


Figure 6: Mean + Standard Error (SE) catch rate of shrimp plotted versus month for the five regions combined and the two study years. Differences in catch rates among the months were found (K-W P<0.001): Apr, May, Jun < Jul, Aug, Sep, Oct, Nov (*Apr=May=Jun; Jul=Aug=Sep=Oct=Nov*).

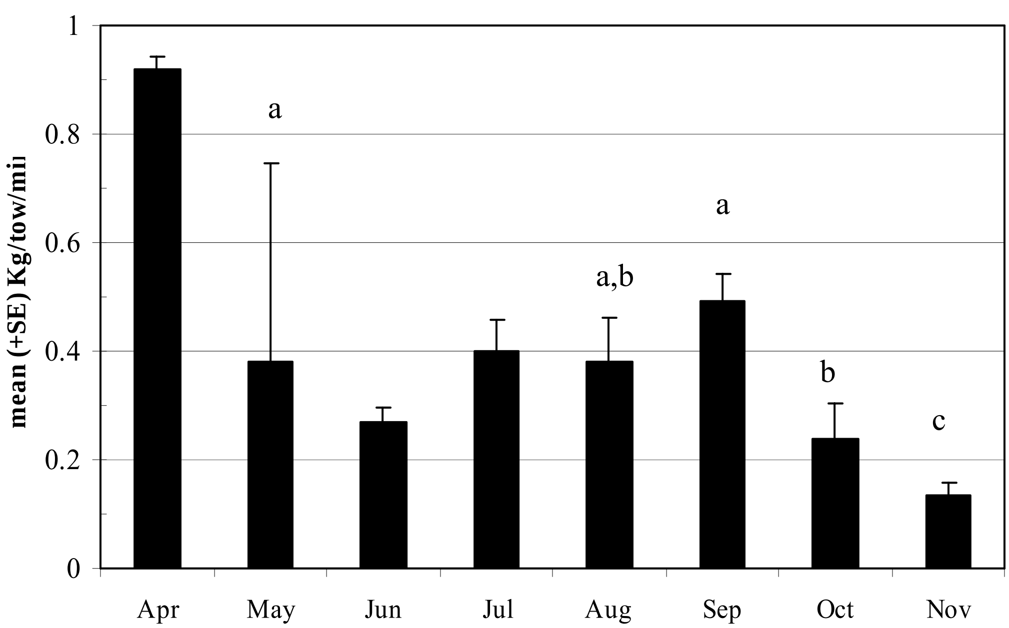


Figure 7: Mean + Standard Error (SE) catch rate of bycatch plotted versus month for the five regions combined and the two study years. Differences in catch rates among the months were found (K-W P<0.001): Nov (c) < May, Aug, Sep (a); Oct (b) < May, Sep (a). Those without letters indicate that the numbers were equal to all the months (*Apr, Jun, Jul = all*).

(a)

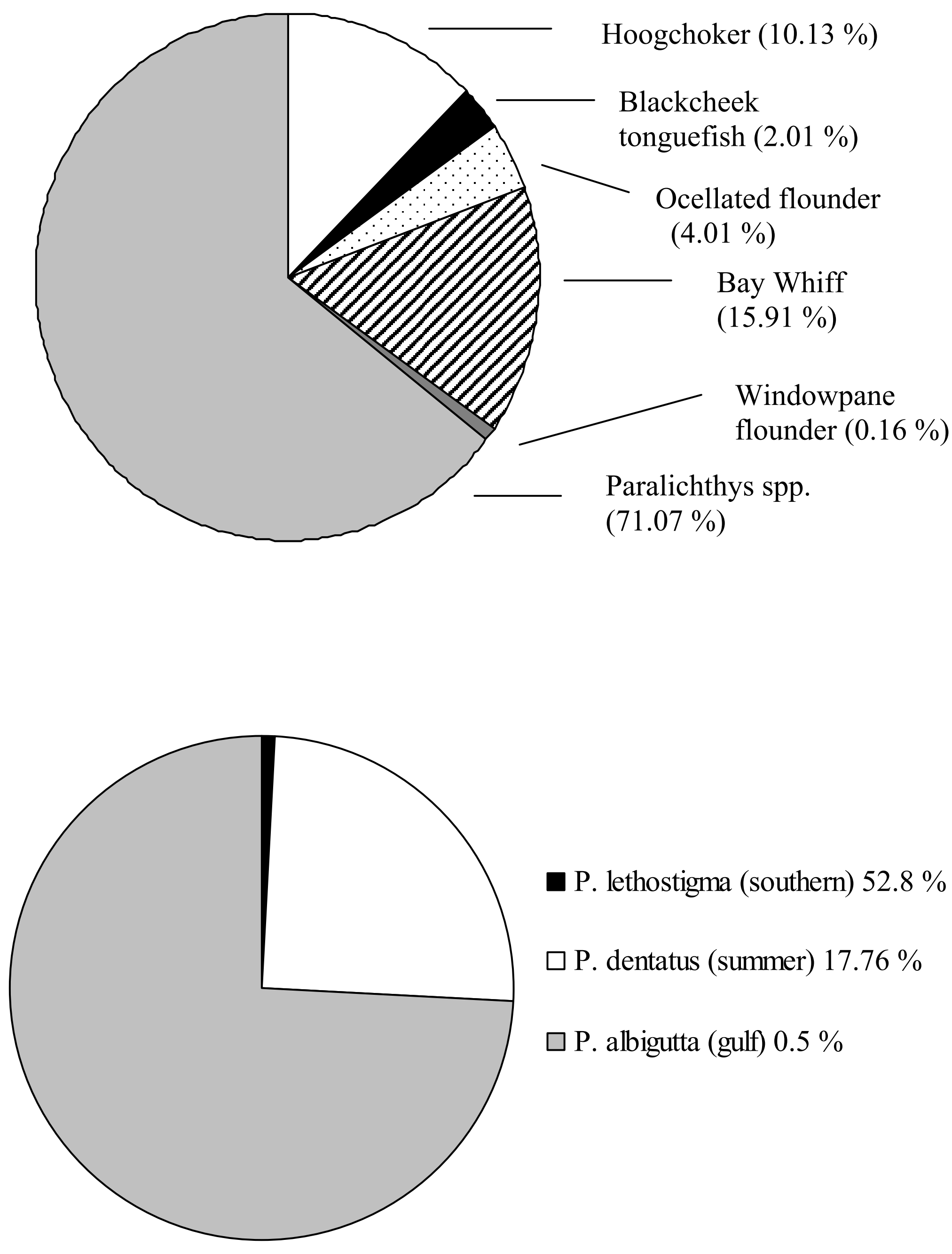


Figure 8a,b: (a) Flatfish composition by weight for 2004 and 2005 (b) *Paralichthys spp*. composition by weight for 2005.

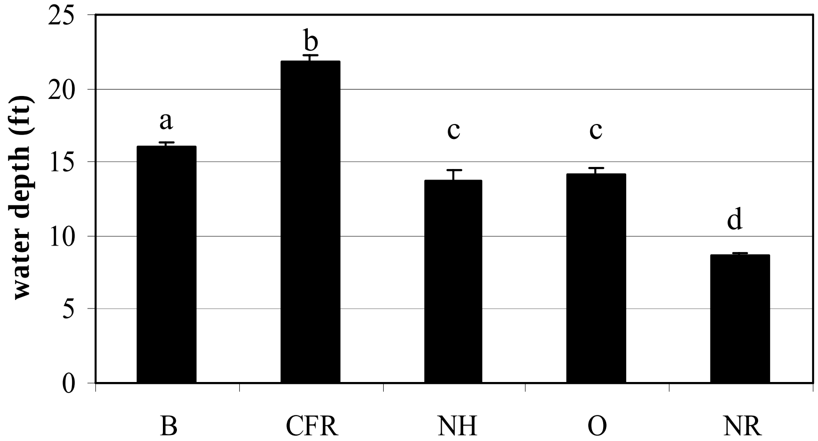


Figure 9a: The range in water depth (ft) among the five sampling regions, Brunswick (B), Cape Fear River (CFR), New Hanover (NH), Onslow (O) and New River (NR). Water depth was consistent within each site. The deepest water was in the Cape Fear River and shallowest in New River: NR < NH, O < B < CFR (*NH=O*).

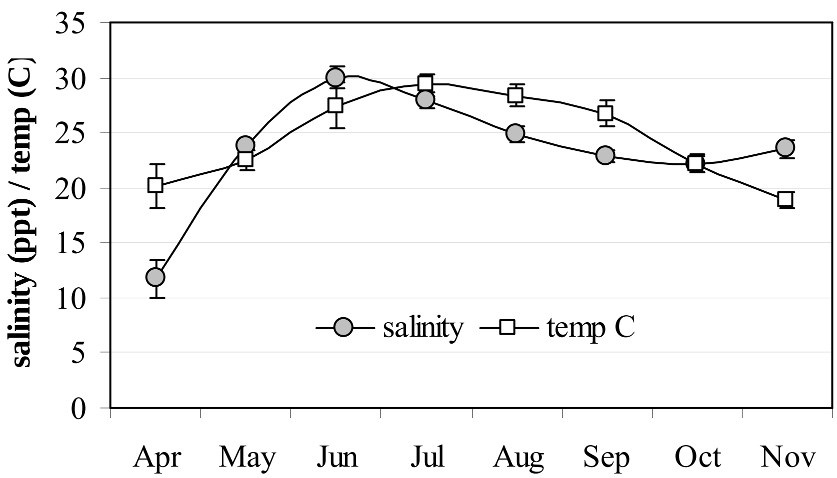


Figure 9b: The range in surface water salinity (ppt) and temperature (°C) over the eight month sampling period in 2004 and 2005. Salinity and temperature fluctuated seasonally. Salinity was higher in the summer and lower in April and the fall: Apr < May, Jul-Nov; Sep, Oct < Jun, Jul. Temperature increased from spring to summer and then declined from summer to fall: Apr, May < Sep < Aug < Jul; Apr, May < Jun; May < Nov; Oct, Nov < Jun < Jul.

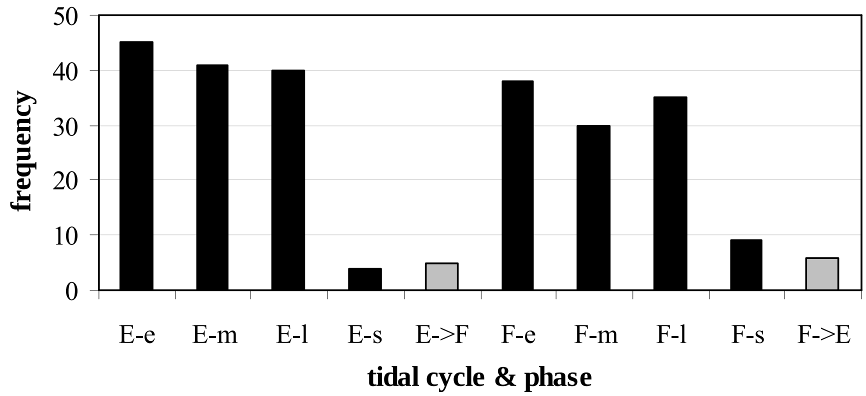
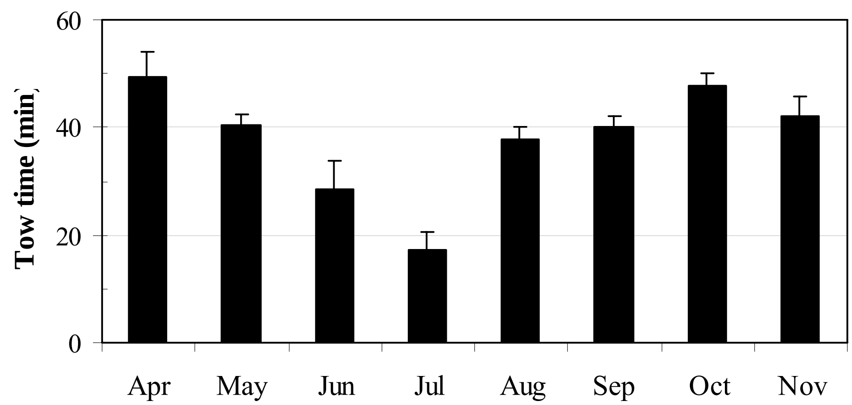
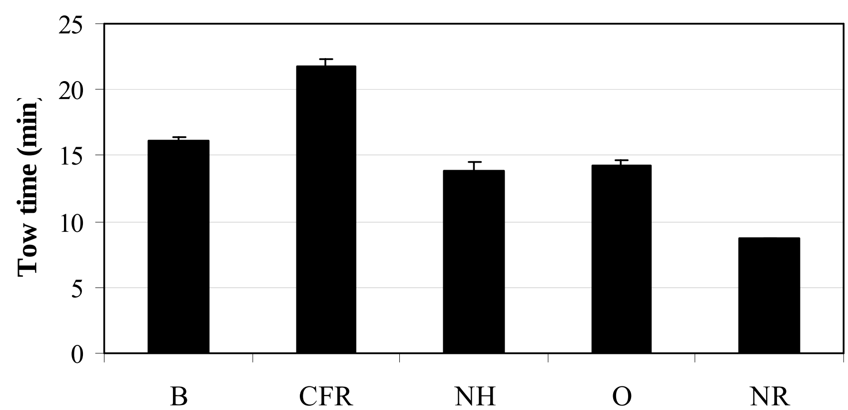


Figure 9c: Frequency of tows during ebb (E) and flood (F) tides and the phase of each: early (e), mid (m), late (l) and slack (s). More tows were executed during ebb (N=130) than flood (N=112) tides, and 11 occurred at transitional tides (gray bars), e.g. changing from ebb to flood (E->F).



d)



e)

Figure 9d, e: Mean tow times varied monthly and regionally. The longest tows were in October compared to June and July. Tows in Brunswick County (B) and the Cape Fear River (CFR) were longer than in New River (NR).

Table 7: Relates the catch rates (Kg/tow/min) of shrimp and bycatch to five environmental parameters{water depth (ft), surface salinity (ppt) and temperature (ºC) tide (ebb/flood: early, mid, late), tow time (min)} for the regions combined and separately. New River was not included because only four tows were conducted. The results were determined using backward Regression analysis using a P-value of ≤ 0.05 to denote significance. The symbol after the R^2 value indicates whether the relationship was positive (+) or inverse (-). R^2 values in **bold** denote $R^2 \geq 0.30$ and signifies that the variable had a moderate to strong relationship to catch rate. Those in *italics* are $R^2 < 0.1$, which means the variable had a slight association to catch rate.

	Depth (ft)	**Salinity (ppt)**	**Temp (°C)**	**Tide**	**Tow time (min)**	**Comments**
REGIONS Combined						
Shrimp	P<0.001 *R^2=0.005(-)*	-	-	-	-	- association w/↑ in ft
Bycatch (all)	-	-	-	P=0.023 R^2=0.012(+)	-	↑ from ebb to flood tide
Invertebrates	P<0.001 R^2=0.032(-)	-	-	-	-	- association w/↑ in ft
Blue crab	P<0.001 *R^2=0.008(-)*	-	-	-	-	- association w/↑ in ft
Fish (all)	P<0.001 *R^2=0.002(-)*	-	-	-	-	- association w/↑ in ft
C&R FF	-	-	-	-	-	
Other FF	P<0.001 R^2=0.067(-)	-	-	-	-	- association w/↑ in ft
Paralichthys spp.	P<0.001 R^2=0.047(-)	-	-	-	-	- association w/↑ in ft
BRUNSWICK						
Shrimp	-	-	-	-	-	
Bycatch (all)	-	P=0.014 R^2=0.054(+)	-	-	P=0.048 R^2=0.034(-)	+ association w/↑ in ppt - association w/↑ in tow min
Invertebrates	-	-	-	-	-	
Blue crab	-	-	P=0.028 R^2=0.206(+)	-	-	+ association w/↑ in °C
Fish (all)	-	P=0.004 R^2=0.078(+)	-	-	P=0.001 R^2=0.101(-)	+ association w/↑ in ppt - association w/↑ in tow min
C&R FF	-	-	-	-	P=0.004 R^2=0.069(-)	+ association w/↑ in ppt - association w/↑ in tow min
Other FF	-	P=0.01 R^2=0.063(+)	-	-	P=0.014 R^2=0.058(-)	+ association w/↑ in ppt - association w/↑ in tow min
Paralichthys spp.	-	-	-	-	-	
CAPE FEAR RIVER						
Shrimp	-	-	-	P=0.025 R^2=0.046(+)	-	↑ from ebb to flood tide
Bycatch (all)	-	P=0.027 R^2=0.073(-)	-	-	-	- association w/↑ in ppt
Invertebrates	-	-	-	-	-	
Blue crab	-	-	-	-	-	

Fish (all)	-	P=0.038 R^2=0.051(-)	-	-	-	- association w/↑ in ppt
C&R FF	-	-	-	-	-	
Other FF	-	P=0.002 R^2=0.109(-)	-	-	-	- association w/↑ in ppt
Paralichthys spp.	-	-	-	-	-	
NEW HANOVER						
Shrimp	-	-	-	-	-	
Bycatch (all)	-	-	-	-	-	
Invertebrates	-	-	-	-	-	
Blue crab	-	-	-	-	-	
Fish (all)	-	-	-	-	-	
C&R FF	-	-	-	-	-	
Other FF	-	P=0.019 **R^2=0.229(+)**	-	-	-	+ association w/↑ in ppt
Paralichthys spp.	-	-	-	-	-	
ONSLOW						
Shrimp	-	-	-	-	-	
Bycatch (all)	-	P=0.001 **R^2=0.481(-)**	-	-	-	- association w/↑ in ppt
Invertebrates	-	P=0.002 **R^2=0.412(-)**	-	-	-	- association w/↑ in ppt
Blue crab	-	P<0.001 **R^2=0.652(-)**	-	-	-	- association w/↑ in ppt
Fish (all)	-	P=0.001 **R^2=0.434(-)**	-	-	-	- association w/↑ in ppt
C&R FF	-	P=0.004 **R^2=0.375(-)**	-	-	-	- association w/↑ in ppt
Other FF	-	P=0.018 **R^2=0.264(-)**	-	-	-	- association w/↑ in ppt
Paralichthys spp.	-	-	-	-	-	

B. Length Frequency

Shrimp

Shrimp averaged 112.3 ± 0.186 SE mm TL or 55.6 count (N=15,771 measured) over the two study years (Table 8). In general, the monthly trend for the shrimp count was inversely related to length frequency with the smaller counts paired to larger sized shrimp and larger counts for smaller shrimp. The relative frequency in the size of the shrimp and number measured per species is shown in Figure 10. Pink and white shrimp were significantly bigger than brown shrimp, and there was no difference in the size of pink and white shrimp (K-W X^2=612.21, df=2, P<0.001).

Shrimp length frequency varied significantly among the eight months (K-W X^2=2379.11, df=7, P<0.001), and five regions (K-W X^2=615.21, df=4, P<0.001) sampled in 2004 and 2005 (Table 9). Shrimp were largest in April and smallest in June, and biggest overall in the Cape Fear River. In Brunswick County, shrimp caught in April and May were significantly larger than those captured from July through November (K-W X^2=542.43, df=6, P<0.001) (Table 9). Similarly in the Cape Fear River, the biggest shrimp were captured in April and May (K-W X^2=2182.76, df=7, P<0.001) (Table 9). Shrimp in New Hanover were largest in October and smallest in June (K-W X^2=125.2, df=4, P<0.001) (Table 9). In Onlsow, the biggest shrimp were landed in July and September and the littlest in June (K-W X^2=99.10, df=4, P<0.001) (Table 9).

Bycatch

All of the seven species analyzed showed seasonal and regional variations in size (Table 10). The bycatch caught were principally juvenile to sub-adult specimens based on their size. The length frequency of Atlantic croaker averaged ± Standard Error 139 ± 0.393 mm TL (Figure 11a). Fish size was related to sampling month (K-W X^2=801.5, df=7, P<0.001) and region (K-W X^2=313.75, df=4, P<0.001) (Table 10, Figure 11b, c). Generally, larger sized Atlantic croaker were caught in the spring and then the fall. They were biggest in the Cape Fear River and smallest in Onslow County. We measured N=2920 female and N=2769 male blue crabs, Females were (103.62 ± 0.76 mm CW) significantly wider than males (88.1 ± 0.67 mm CW) (t-test t=-15.38, df=5634, P<0.001) (Figure 12a). Blue crabs of both sexes combined were a mean size of 96 ± 0.52 mm CW, which is approximately 3 7/8 in. The length frequency of all blue crabs was tested against each variable month and region. The size of blue crabs were larger in the spring and fall and smallest in the summer (K-W X^2=330.24, df=7, P<0.001) (Table 10, Figure 12b). The biggest blue crabs were caught in the New and Cape Fear Rivers and the smallest in New Hanover County (K-W X^2=400.87, df=4, P<0.001) (Table 10, Figure 12c). The overall mean size of spot was 104.43 ± 0.39 mm TL (Figure 13a). Spot size differed significantly from April and May, September through November, and June through August (K-W X^2=1037.58, df=7, P<0.001) (Table 10, Figure 13b). Spot length was largest in the Cape Fear compared to the other four regions (K-W X^2=404.08, df=4, P<0.001) (Table 10, Figure 13c). Weakfish averaged 113.93 ±0.58 mm TL in size (Figure 14a). Bigger weakfish were caught in April and May followed by November, and the smallest in July and September (K-W X^2=876.84, df=7, P<0.001) (Table 10, Figure 14b). We found larger size weakfish in the Cape Fear River while the variations among the remaining sites were minor (K-W X^2=411.82, df=4, P<0.001) (Table 10, Figure 14c). Smooth butterfly rays were a mean size of 328.15 ± 5.48 mm DW (Figure 15a). Larger rays were caught in July, August and September compared to those in April and May (K-W X^2=53.48, df=6, P<0.001) (Figure 15b). Regionally, the sizes varied with the smallest sized rays in Brunswick County compared to the other four sites (K-W X^2=54.23, df=4, P<0.001) (Table 10, Figure 15b\c). The three species of *Paralichthys* (*lethostigma* (southern), *dentatus* (summer), and *albigutta* (gulf) combined were a mean size of 191.7 2.79 mm TL (Figure 16a), which equates to 7.5 in. Fish captured in April and June were significantly larger than those from May, and this mean size steadily rose from July into November (K-W X^2=144.25, df=7, P<0.001) (Table 10, Figure 16b). *Paralichthys spp.* from New River were significantly larger than those from the other four sites, and fish in Brunswick County were the smallest (K-W X^2=37.96, df=4, P<0.001) (Table 10, Figure 16c). In 2005, summer flounder were significantly smaller in size than southern, and both species were not different from gulf flounder (N=2) (K-W X^2=242.78, df=2, P<0.001) (Figure 16d). In every month and region in which southern and summer flounder were both caught, southern flounder were always significantly larger than summer, except in Onslow County (Figure 16e, f). For southern flounder, the largest were captured in May and smallest in August (K-W X^2=18.08, df=5, P=0.003). For summer flounder, smaller fish were caught in May compared to those in July through November (K-W X^2=147.94, df=5, P<0.001). Bigger southern flounder were captured in Brunswick County and New River than in Onlsow County (K-W X^2=27.64, df=3, P<0.001), and larger summer flounder were landed in the Cape Fear River and New Hanover County compared to those in Brunswick County (K-W X^2=93.38, df=4, P<0.001). The overall mean size of Atlantic menhaden was 130.91 ± 0.1.25 mm TL (Figure 17a). Significant differences in fish size were found with those caught in April and May larger in size than in October and November (K-W X^2=314.38, df=7, P<0.001) (Table 10, Figure 17b). Only six fish were caught between June and July, and there was a large amount of variability in the size of Atlantic menhaden captured in August and September. Bigger Atlantic menhaden were caught in New Hanover County than all other sites (K-W X^2=87.01, df=4, P<0.001) (Table 10, Figure 17c).

Environmental Parameters and Length Frequency

Shrimp size was positively associated to water depth and negatively to salinity, although the influence of these two parameters was minimal due to the small R^2 values (Table 11). The length frequencies of the six bycatch species were all associated with multiple environmental parameters (Table 11). The influence of most of these parameters was minimal, which is reflected in the small R^2 values. One exception is the length frequency of Atlantic menhaden, which showed a mild positive relationship to depth.

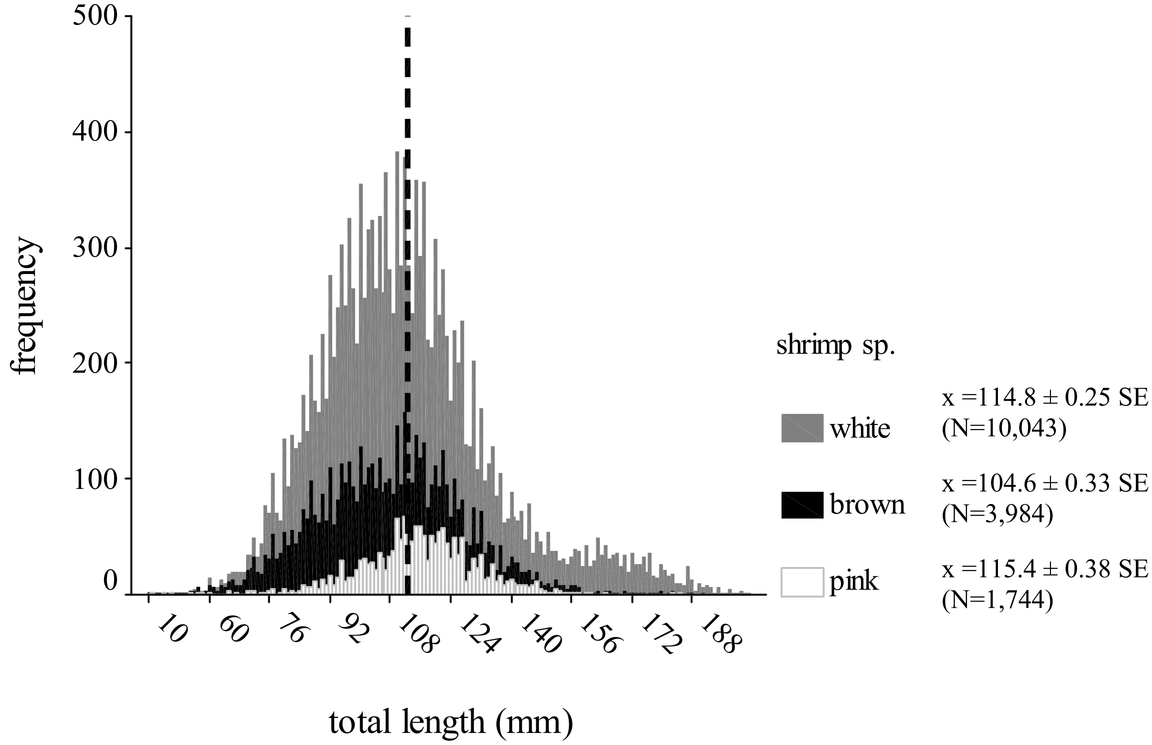


Figure 10: Length frequency histogram showing the size of shrimp per species. The mean ± Standard Error (SE) shrimp size was 112.3 ± 0.186 mm TL (---) for the N=15,771 measured in 2004 and 2005. Mean sizes of shrimp differed by species: brown < white, pink (*white=pink).*

Table 8: Average shrimp size (mm TL) and count (#/lb) recorded from 2004 and 2005 tows.

region	Brunswick		Cape Fear Rv.		New Hanover		Onslow		New Rv.		All	
month	mm	count	mm	count	mm	count	mm	count	mm	count	mm	count
Apr	120.2	-	162	15.1	-	-	-	-	-	-	**152.6**	**15.1**
May	117.4	35.3	161.3	13.2	105.9	-	-	-	-	-	**128.6**	**25.4**
Jun	-	-	88.2	-	91.2	-	100.8	-	-	-	**92.1**	-
Jul	106.9	48.1	91.5	78.7	-	-	121.6	37.2	-	-	**107.1**	**49.8**
Aug	108.9	57.2	97	85.4	104.2	92.5	117.6	39.7	-	-	**107.9**	**57.7**
Sep	109.6	55.9	95.8	95.8	103.8	72.9[a]	119	41.5	110.7	42.6	**107.5**	**52.9**
Oct	104	66.4	111	63.4	117	72[b]	113	43.9	-	-	**107.8**	**63.7**
Nov	107.7	65.2	125.4	38.9	-	-	-	-	-	-	**114.6**	**61**
All	**109.6**	**56.1**	**122.2**	**35.9**	**103.5**	**71.7**	**116.3**	**41.7**	**110.7**	**42.6**	112.3	55.6

[a] N=1 tow in 2005
[b] N=1 tow in Oct 2004

Table 9: Length frequency data for shrimp per month and region and among the five sampling regions for 2004 and 2005 tows. The P-values are given under month and region, and a significant difference was denoted at P ≤ 0.05.

Group	Month	Post hoc	Region	Post hoc
Shrimp	<0.001	Jun < Jul-Oct < Nov < May < Apr *(Jul=Aug=Sep=Oct)*	<0.001	NH < B < O < CFR *(CFR = NR)*
Brunswick	<0.001	Oct < Jul < Aug, Sep, Nov < Apr, May *(Apr=May; Aug=Sep=Nov)*	-	-
Cape Fear River	<0.001	Jun < Aug, Sep < Oct < Nov < Apr, May *(Jun=Jul, Aug=Sep)*	-	-
New Hanover	<0.001	Jun < Aug, Sep] < Oct *(May = Jun-Oct; Aug=Sep)*	-	-
Onslow	<0.001	Jun < Oct < Jul, Sep; Jun < Aug *(Jul=Aug=Sep)*	-	-
New River	NA	sampled only in Sep	-	-

Table 10: Relationship of month (April through November 2004-2005) and region (Brunswick (B), Cape Fear River (CFR), New Hanover (NH), Onslow (O), and New River (NR)) relative to bycatch length frequency. The six species listed were the top ranking species caught of commercial and recreational importance. A P-value of ≤ 0.05 denoted significance.

Group	Month	Post hoc	Region	Post hoc
Atlantic croaker	<0.001	Jul < Aug < Sep < Oct, Nov < Apr, May; Jul < Aug < Jun *(Apr=May; May=Jun, Sep-Oct; Oct=Nov)*	<0.001	O < NR < B < CFR *(B = NH)*
Blue crab	<0.001	Jul, Aug < Sep, Oct < Apr, May, Nov; *(Apr=May=Jun=Sep=Oct; Apr, Oct=Nov; Jun=Aug; Jul=Aug)*	<0.001	NH < B < O < CFR < NR
Spot	<0.001	Jun, Jul, Aug < Sep,Oct, Nov < May < Apr; Sep < Nov *(Jun=Jul; Sep=Oct)*	<0.001	B < NH < CFR; O, NR < CFR; *(B = O, NR)*
Weakfish	<0.001	Jul, Sep < Aug, Oct < Nov < Apr, May; Jul < Sep *(Apr=May; Jun=all; Aug=Oct)*	<0.001	NH < B < CFR; NH < O, CFR; *(NR = all)*
Smooth butterfly ray	<0.001	Apr, May < Jul, Aug, Sep *(Apr=May=Jun=Oct; Jun=Jul=Aug=Sep=Oct)* [a]Nov	<0.001	B < CFR, NH, O *(B=NR; CFR=NH=O=NR)*
Paralichthys spp.	<0.001	May < Aug < Sep, Oct; May < Apr, Jun; Jul < Sep, Oct *(Apr=Jun-Nov; Sep=Oct)*	<0.001	B < CFR, NH, O < NR *(CFR=NH=O)*
Atlantic menhaden	<0.001	(Nov < Oct) < (Apr < May)[b] *(Aug, Sep=all)*	<0.001	NR <B <CFR <NH; NR <O < NH

[a]Smooth butterfly ray: none captured in November
[b]Atlantic menhaden: Jun N=1, Jul N=5

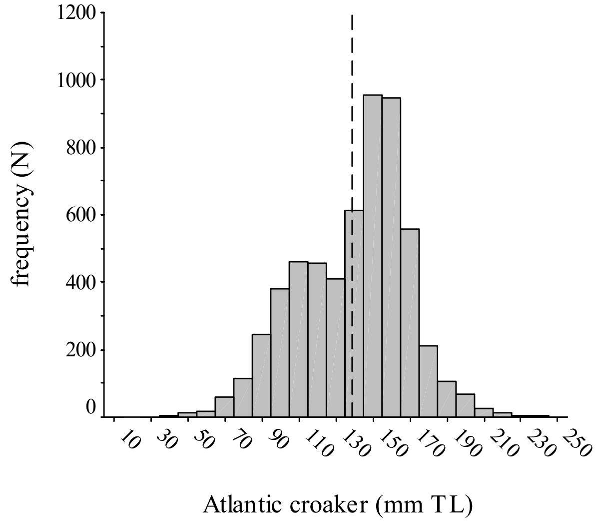


Figure 11a: Atlantic croaker length frequency. N=5,666 measured and (---) line indicates the mean ± SE at 139 ±0.39 mm TL.

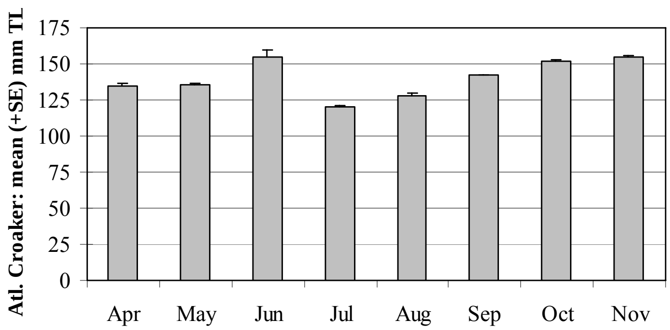


Figure 11b: Atlantic croaker total length (mm TL) versus month: Jul < Aug < Sep < Oct, Nov < Apr, May; Jul < Aug < Jun (*Apr=May; May=Jun, Sep-Oct; Oct=Nov*).

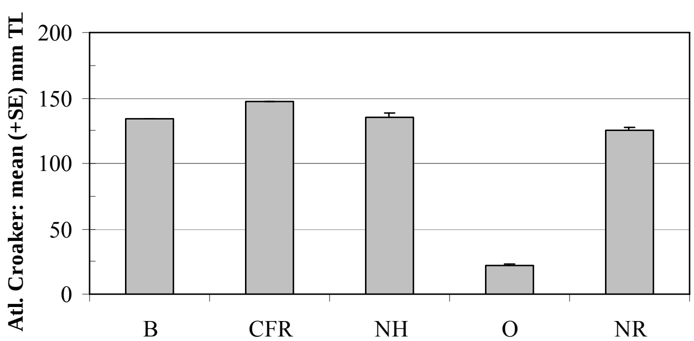


Figure 11c: Atlantic croaker total length (mm TL) versus region: Onslow (O) < New River (NR) < Brunswick (B) < Cape Fear River (CFR) (*B=New Hanover (NH)*).

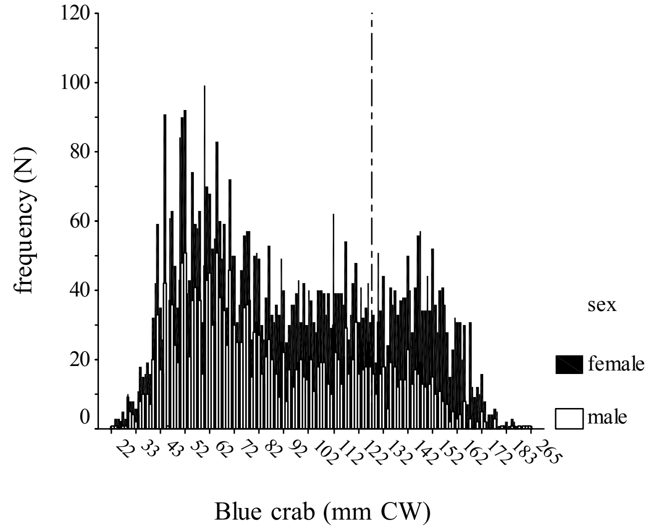
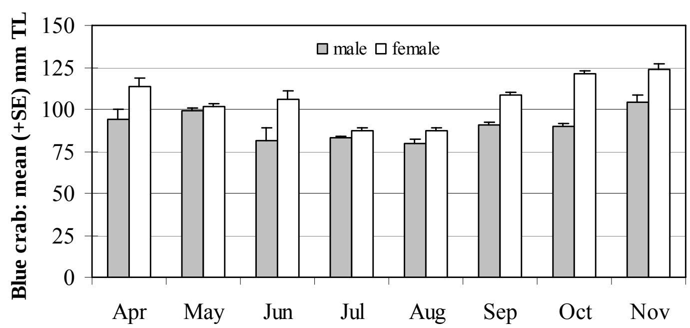
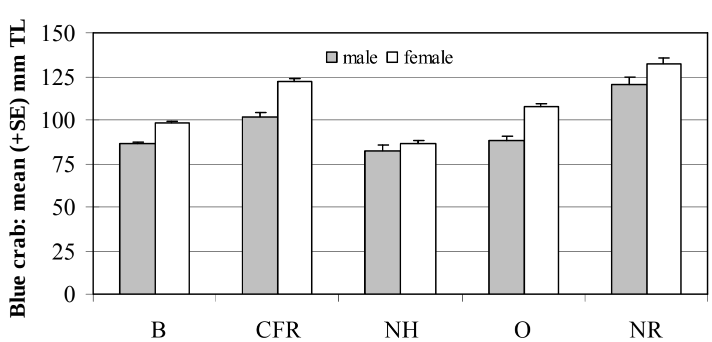


Figure 12a: Length frequency for the N=2,920 female and N=2,769 male blue crabs measured. Mean ± SE was 103.6 ± 0.52 mm CW for female and 88.38 ± 0.75 for male blue crabs. The dashed (---) line indicates the 5 in minimum size limit in North Carolina.



12b: Blue crab carapace width (mm CW) versus month: Jul, Aug < Sep, Oct < Apr, May, Nov (*Apr=Ma=Jun=Sep=Oct; Apr, Oct=Nov; Jun, Jul=Aug)* results are for both sexes combined.



12c: Blue crab carapace width (mm CW) versus region: New Hanover (NH) < Brunswick (B) < Onslow (O) < Cape Fear River (CFR) < New River (NR) results are for both sexes combined.

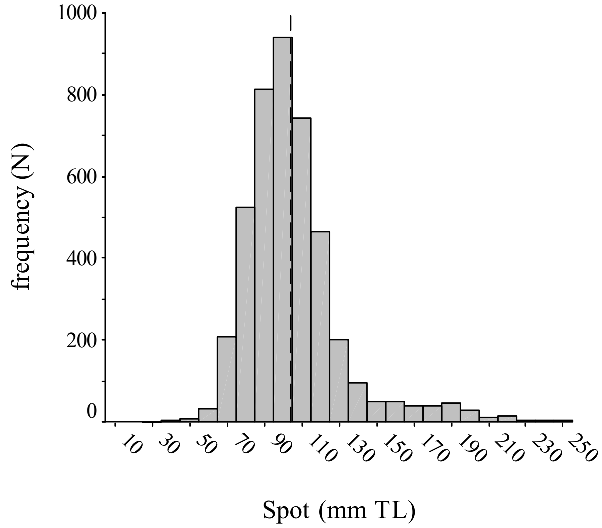


Figure 13a: Spot length frequency. N=4,305 measured and (---) line indicates the mean ± SE at 104.43 ±0.39 mm TL.

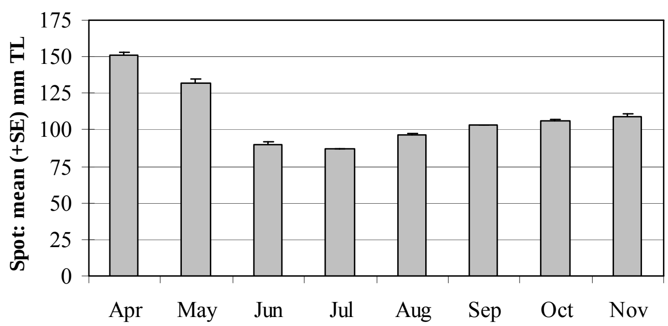


Figure 13b: Spot total length (mm TL) versus month: Jun, Jul, Aug < Sep, Oct, Nov < May < Apr; Sep < Nov (*Jun=Jul; Sep=Oct*).

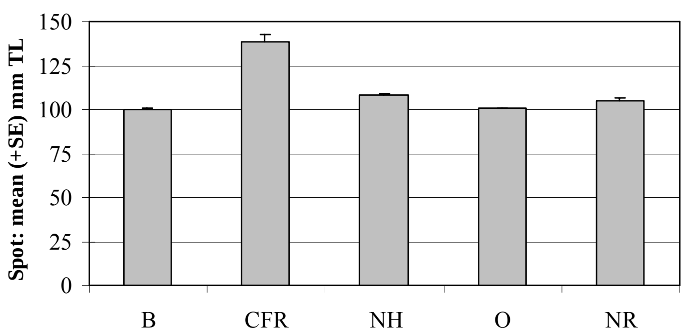


Figure 13c: Spot total length (mm TL) versus region: Brunswick (B) < New Hanover (NH) < Cape Fear River (CFR); Onslow (O), New River (NR) < Cape Fear River (CFR) (*B=O, NR*).

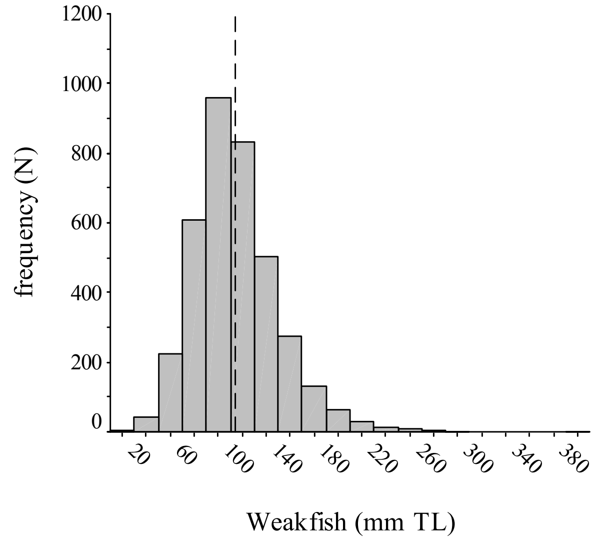


Figure 14a: Weakfish length frequency. N=3,700 measured and (---) line indicates the mean ± SE at113.93 ±0.58 mm TL.

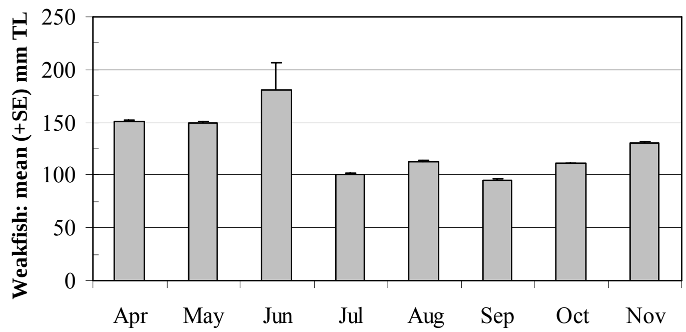


Figure 14b: Weakfish total length (mm TL) versus month: Jul, Sep < Aug, Oct < Nov < Apr, May; Jul < Sep < Nov (*Apr=May; Jun=all; Aug=Oct*).

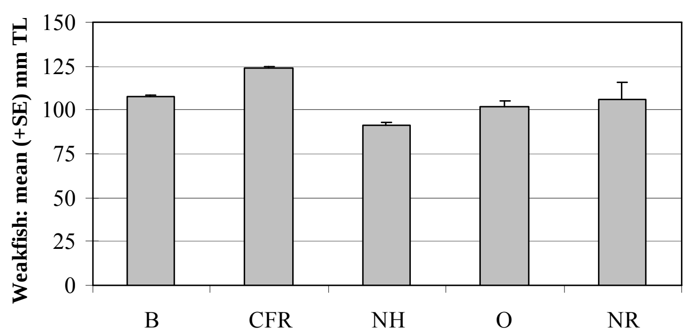


Figure 14c: Weakfish total length (mm TL) versus region: New Hanover (NH) < Brunswick (B) Cape Fear River (CFR); New Hanover (NH) < Onslow (O), Cape Fear River (CFR) (*NR=all*).

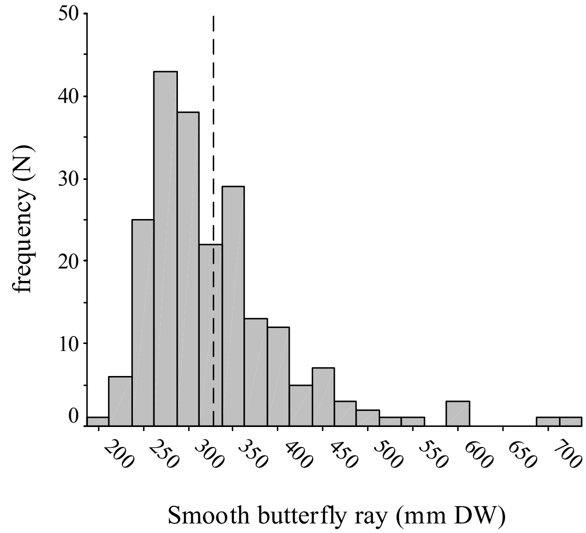


Figure 15a: Smooth butterfly ray length frequency. N=213 measured and (---) line indicates the mean ± SE at 328.14 ± 5.48.

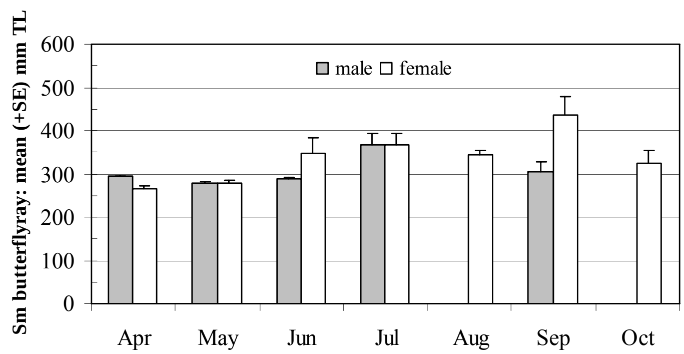


Figure 15b: Smooth butterfly ray disk width (mm DW) versus month (note: none were captured in November): Apr, May < Jul, Aug, Sep (*Apr=May=Jun=Oct; Jun=Jul=Aug=Sep=Oct*).

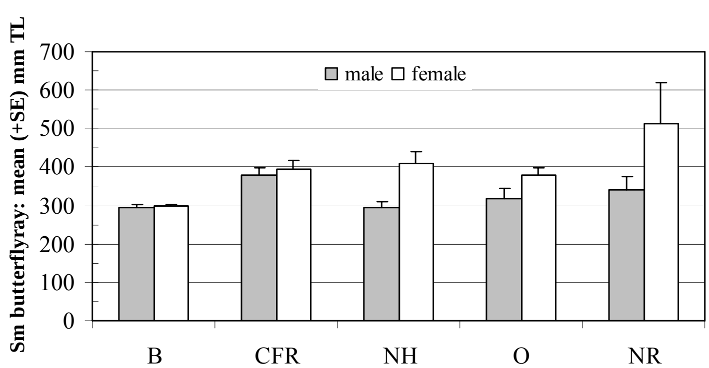


Figure 15c: Smooth butterfly ray disk width (mm DW) versus region: New Hanover (NH) < Brunswick (B) Cape Fear River (CFR); New Hanover (NH) < Onslow (O), Cape Fear River (CFR) (*NR=all*).

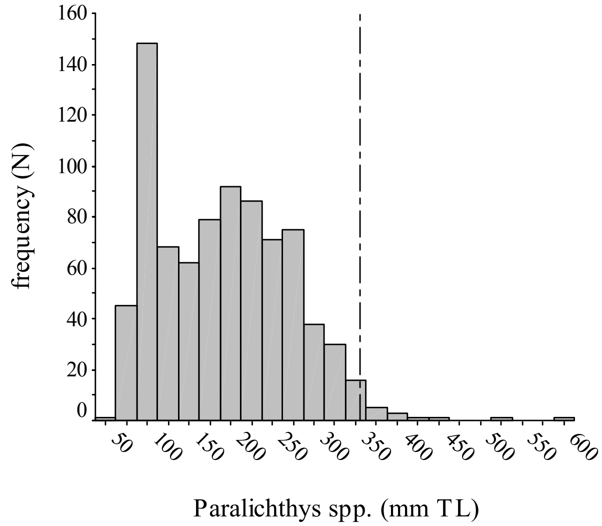


Figure 16a: *Paralichthys spp*. length frequency. N=823 measured and mean ± SE was 191.7 ± 2.79 mm TL. The dashed (---) line indicates the 14in size limit for *P. lethostigma* and *dentatus* in North Carolina.

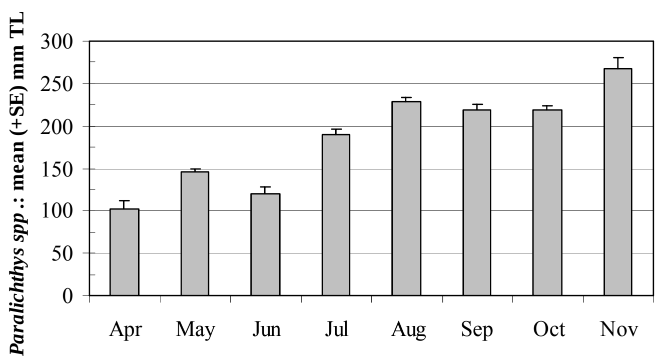


Figure 16b: *Paralichthys spp*. total length (mm TL) versus month: May < Aug < Sep, Oct; May < Apr, Jun; Jul < Sep, Oct (*Apr=Jun-Nov; Sep=Oct*).

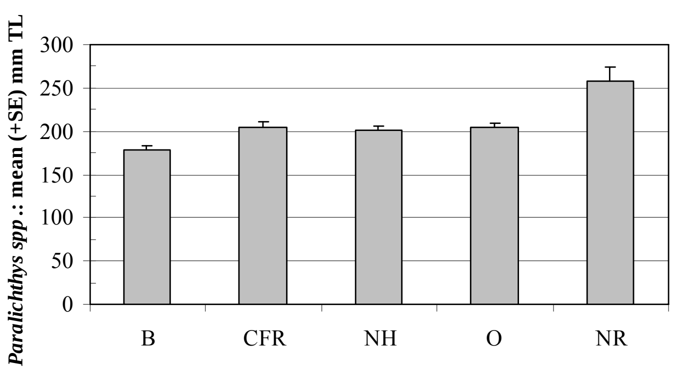


Figure 16c: *Paralichthys spp*. total length (mm TL) versus region: Brunswick (B) < Cape Fear River (CFR), New Hanover (NH), Onslow (O) < New River (NR).

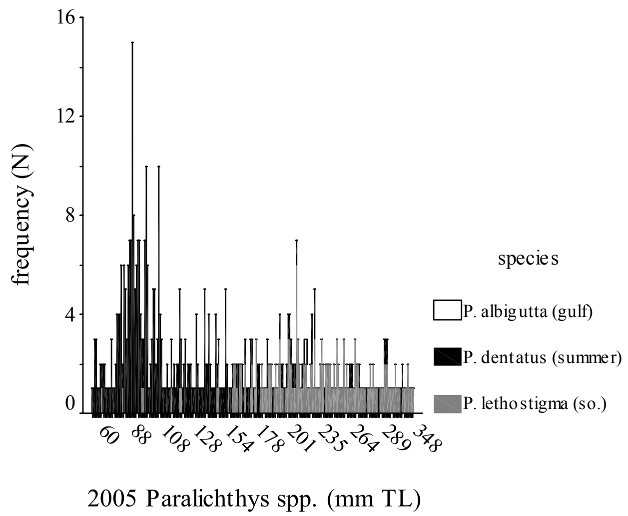


Figure 16d: 2005 *Paralichthys spp*. length frequency for gulf flounder (mean 256.5 ± 34.5, N=2), summer flounder (123.1 ± 2.71, N=298), and southern flounder (236.77 ± 4.5, N=169) measured. Species size was significantly different: summer < southern flounder (gulf =southern, summer).

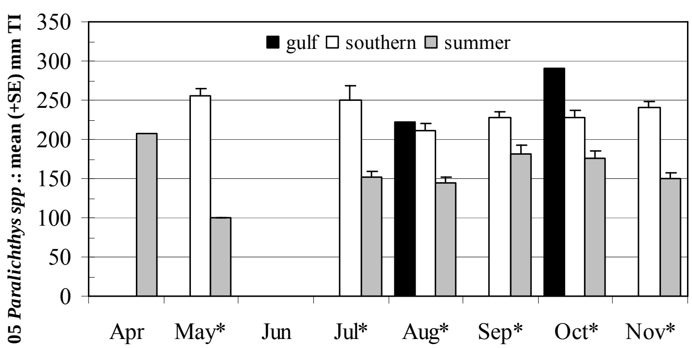


Figure 16e: 2005 *Paralichthys spp*. total length (mm TL) versus month: southern flounder Aug < May (*May,Aug=Jul=Sep=Oct=Nov*); summer flounder May < Jul, Aug, Sep, Oct, Nov (*Jul=Aug=Sep=Oct=Nov*). Month* indicates southern < summer.

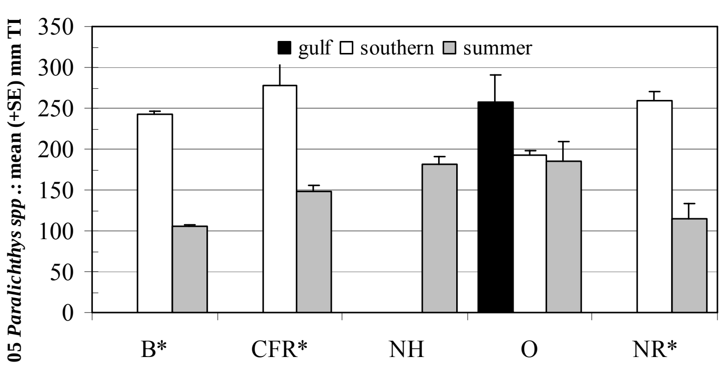


Figure 16f: 2005 *Paralichthys spp*. total length (mm TL) versus region for the three species: southern flounder Onslow (O) < Brunswick (B), New River (NR) (*B=CFR=NR; CFR=O*); summer flounder Brunswick (B) < Cape Fear River (CFR), New Hanover (NH) (*CFR=NH; B+O=NR*). Month* indicates southern < summer.

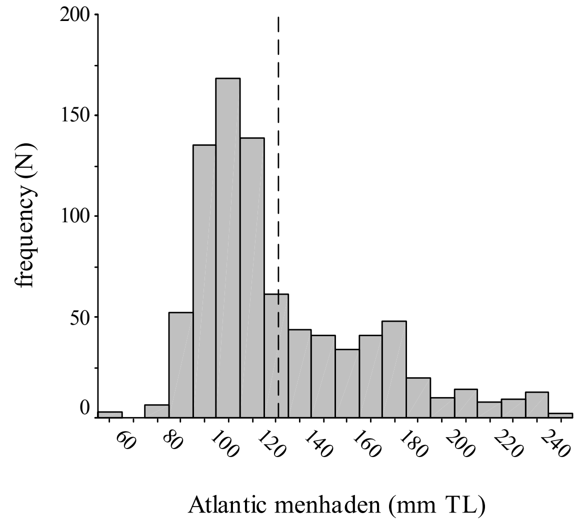


Figure 17a: Atlantic menhaden length frequency. N=848 measured and (---) line indicates the mean ± SE at 130.91 ± 1.25.

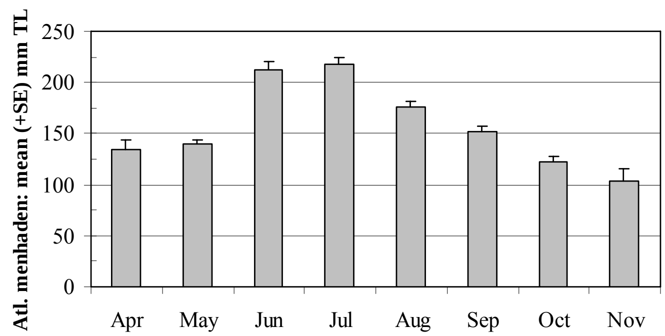


Figure 17b: Atlantic menhaden total length (mm TL) versus month: [Nov < Oct] < [Apr < May] (*Aug, Sep =all*).

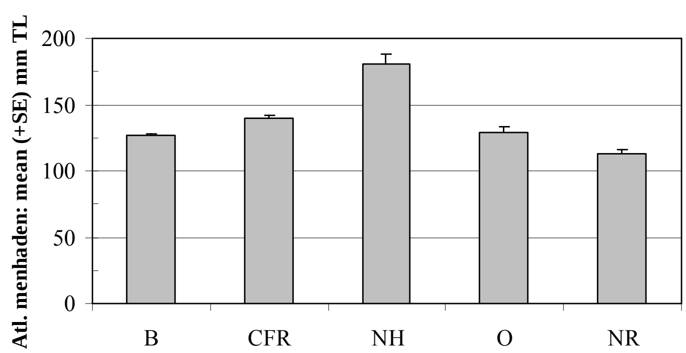


Figure 17c: Atlantic menhaden total length (mm TL) versus region: New River (NR) < Brunswick (B) < Cape Fear River (CFR) < New Hanover (NH): New River (NR) < Onslow (O) < New Hanover (NH).

Table 11: Relates the length frequency (mm TL, CW) for shrimp and bycatch and environmental parameters {depth, salinity, temperature, and tide (ebb/flood: early, mid, late)} for the five regions combined. The results were determined using backward Regression analysis using a p-value of P≤ 0.05 to denote significance. The R^2 value and (±) indicate the degree of and direction of the association between size and the parameter. The degree of goodness of fit is classified as Slight < 0.10, 0.10 < Mild < 0.33, 0.33 < Moderate < 0.66, and Strong > 0.66.

Group	**Depth (ft)**	**Salinity (ppt)**	**Temp (ºC)**	**Tide phase**	**Comments**
Shrimp	P<0.001 R^2=0.006 (+)	P<0.001 R^2=0.012 (-)	-	-	Depth and salinity associations were slight.
Atlantic croaker	P<0.001 R^2=0.011 (+)	-	-	P=0.013 R^2=0.001 (-)	Depth and tide associations were slight.
Blue crab	P<0.001 R^2=0.017 (+)	P<0.001 R^2=0.034 (-)	-	-	Depth and salinity associations were slight.
Spot	P<0.001 R^2=0.027 (-)	P<0.001 R^2=0.029 (+)	-	-	Depth and salinity associations were slight.
Weakfish	P<0.001 R^2=0.046 (+)	P<0.001 R^2=0.024 (+)	-	P=0.002 R^2<0.0001 (no line)	Parameters' associations on fish size were minimal.
Smooth butterfly ray	-	P<0.001 R^2=0.092 (-)	P<0.001 R^2=0.044 (+)	-	Salinity and temperature associations were slight.
Paralichthys spp.	-	P=0.001 R^2=0.033 (-)	-	-	Salinity association was slight.
Atlantic menhaden	P<0.001 **R^2=0.18 (+)**		P<0.001 R^2=0.005 (+)	P<0.001 R^2=0.083 (+)	Depth had a mild positive (+) association. Temperature and tide associations were slight.

C. Post Release Index of Condition (PRIC) & Mortality Proxy Index (MPI)

Results for the Post Release Index of Condition showed that 74.7% of all fish species were dead, versus 17.3% alive and in good condition (Table 12). The proportion of dead individuals was significantly greater than those alive in good, fair, poor, and v. poor condition (K-W X^2=1799.5, df=4, P<0.001) (Table 13). The high mortality reported in this index resulted from the extended time it took to process the bycatch. The better release conditions for *Paralichthys spp*. were slightly biased as we generally sorted and processed them ahead of others, because of their relatively large size compared to other species and commercial value. For all species, the Mortality Proxy Index found that 58.7% of the specimens showed no physical damage, 34.9% experienced mild damage, and few had severe injuries (K-W X^2=1482.71, df=4, P<0.001) (Table 12). Of those with mild damage, only a handful (N=12) of them bled. The proportion of Atlantic croaker that showed no physical damage was significantly greater than those with mild, moderate, severe and v. severe (K-W X^2=246.9, df=4, P<0.001) (Table 12, 13). Most of the blue crabs exhibited no apparent physical damage (K-W X^2=186.68, df=4, P<0.001) (Table 12, 13). We did not track claw loss because many dropped claws in separating them from shrimp or fish, or while in the basket. More spot experienced mild damage than none, moderate, severe and v. severe (K-W X^2=128.45, df=4, P<0.001) (Table 12, 13). Most weakfish showed no damage compared to mild, moderate and severe (K-W X^2=102.63, df=4, P<0.001) (Table 12, 13). Many *Paralichthys spp*. had either none or mild physical damage, but there was no difference in the proportions (ANOVA F=1.62, df=4, P=0.173) (Table 12, 13). Smooth butterfly ray showed little to no physical damage overall (Table 12, 13). The proportion of smooth butterfly rays with no damage was significantly greater than those with moderate injuries (ANOVA F=3.95, df=3, P<0.001).

Table 12: Percent represented per category for post release index of condition and mortality proxy index for all the measured finfish and the top five marketable bycatch species captured by weight in 2004 and 2005. The numeric value represents the percent per category.

		Post release index of condition					**Mortality proxy index**				
species	**N**	**Good**	**Fair**	**Poor**	**v. Poor**	**Dead**	**None**	**Mild**	**Moderate**	**Severe**	**v. Severe**
All Fish	**37,080**	**17.3**	**2.2**	**2.5**	**3.3**	**74.7**	**58.7**	**34.9**	**4.3**	**1.2**	**0.93**
Atlantic croaker	5,620	5.0	7.1	10.7	13.9	63.3	50.7	43.4	4.9	0.9	0.1
Blue crab	5,919	92.0	1.1	0.7	0.8	5.4	97.8	1.0	0.9	0.2	0.1
Spot	4,188	0.2	0.5	1.0	2.9	95.4	38.3	58.9	2.0	0.5	0.3
Weakfish	3,671	0.4	0.1	0.4	1.7	97.4	70.3	26.5	2.2	0.8	0.2
Smooth butterfly ray	236	31.4	9.3	8.0	5.9	45.4	44.1	45.8	8.8	1.3	0
Paralichthys spp.	356	12.7	5.8	3.2	4.7	73.6	49.8	45.0	3.7	0.9	0.6

Table 13: Results of the statistical analysis testing whether there was a difference between the proportion of individuals per category for each index. A difference of $P \leq 0.05$ was considered significant.

	Post release index of condition			**Mortality proxy index**		
Species	**Test**	**P-value**	**Post hoc**	**Test**	**P-value**	**Post hoc[1]**
All Fish	**K-W**	**<0.001**	**Fair, Poor, v.Poor < Fair < Good < Dead; Poor < Fair** ***(Fair, Poor = v.Poor)***	**K-W**	**<0.001**	**Mod, Sev, v.Sev < Mild < None; Sev < Mod** ***(Mod, Sev = v.Sev)***
Atlantic croaker	K-W	<0.001	Good, Fair, Poor, v.Poor < Dead *(Good = Fair; v.Poor = Dead)*	K-W	<0.001	Sev, v.Sev < Mod < Mild < None *(Sev = v.Sev)*
Blue crab	K-W	<0.001	Fair, Poor, v.Poor, Dead < Good; v.Poor < Dead *(Fair = Poor=v.Poor; Poor, v.Poor = Dead)*	K-W	<0.001	Mild, Mod, Sev, v.Sev < None *(Mild = Mod = Sev = v.Sev)*
Spot	K-W	<0.001	Fair, Poor, v.Poor < Dead *(Good=Fair = Poor= v.Poor)*	K-W	<0.001	Mod, Sev, v.Sev. < None < Mild *(Mod = Sev = v.Sev)*
Weakfish	K-W	<0.001	Poor < v.Poor < Dead *(N=1 for Good, Fair)*	K-W	<0.001	Mod, Sev, v.Sev < Mild < None *(Mod = Sev = v.Sev)*
Smooth butterfly ray	ANOVA	<0.001	Good, Poor < Good, Dead *(Good=Fair = Poor= v.Poor)*	ANOVA	0.01	Mod < None *(None = Mild = Sev; Mild= Mod = Sev)*
Paralichthys spp.	K-W	<0.001	Fair, Poor, v.Poor < Dead *(Good=Dead; Fair=Poor= v.Poor)*	ANOVA	0.173	-

Post hoc[1]: Mod = Moderate
Sev = Severe
v.Sev = very Severe

D. Survivability

2004 & 2005

Sixty percent of the fish were alive at the end of the survivability bouts in the two years of the study. The mean holding time for 2004 and 2005 was 3 hour (hr) 38 min with the shortest holding time at 1 hr 4 min and the longest at 6 hr 49 min. On average, 0.93 Kg of fish were held with a minimum of 0.24 Kg and a maximum of 2.59 Kg.

The release condition of fish (all) was significantly more alive-healthy (52.5%, N=1824), followed by dead (40.2%, N=1700), and lastly alive-weak (7.3 %, N=212) (K-W X^2=193.44, df=2, P<0.001) (Figure 18a). This same pattern was seen in commercial and recreation finfish (K-W X^2=170.91, df=2, P<0.001), but not in other finfish (K-W X^2=141.18, df=2, P<0.001). The proportion of individuals in the alive-healthy category was significantly higher than in dead and alive-weak for Atlantic croaker (K-W X^2=182.17, df=2, P<0.001) and *Paralichthys spp.* (K-W X^2=89.37, df=2, P<0.001) (Figure 18b). The proportion of dead specimens was greater than that for alive-healthy and alive-weak for spot (K-W X^2=76.99, df=2, P<0.001), weakfish (K-W X^2=94.24, df=2, P<0.001), and Atlantic menhaden (K-W X^2=36.21, df=2, P<0.001) (Figure18b).

We analyzed the effect of cull time on the proportion of alive versus dead. Survival increased when cull time was 30 min or less for fish (all) (ANOVA, F= 12.47, df=3 P<0.001) and commercial and recreational finfish (K-W X^2=43.15, df=3, P<0.001) (Table 14). There was no difference in the survival rates for other finfish (ANOVA, F= 1.91, df=3 P=0.132) Atlantic croaker (K-W X^2=28.71, df=3, P<0.001) and spot (K-W X^2=10.33, df=3, P=0.016) showed greater survival rates when the cull time was 30 minutes or less than at 46 minutes and above. The trend for weakfish (K-W X^2=15.06, df=3, P=0.002) was similar but with a few nuances. The survival rate of *Paralichthys spp.* (ANOVA, F= 1.13, df=3 P=0.341) and Atlantic menhaden (ANOVA, F= 0.42, df=3 P=0.743) was not affected by cull time (Table 14).

Survivability of all fish varied monthly with the lowest proportion alive in July compared to the proportion in September, October and November (K-W X^2=28.14, df=7, P<0.001) (Figure 19). Similarly, the mean total catch weight (Kg) varied significantly among the months with a small total catch in June compared to August through November, and in May compared to that in September and October (K-W X^2=47.28, df=7, P<0.001) (Figure 19). We found that with heavier catches the cull time increased (Regression F=202.92, df=1, P<0.001) (Figure 20a), and survival rate declined with extended cull times (Regression F=25.01, df-1, P<0.001) (Figure 20b). The proportion alive-healthy was lowest in July and August compared to May and November, and in July it was also lower than September and October (ANOVA F=5.72, df=7, P<0.001). There was a lower proportion of alive-weak in June than October (K-W X^2=15.69, df=7, P=0.028).

Environmental Parameters and Survivability 2004 & 2005

Survival rate of fish (all), commercial and recreational finfish, other finfish, and the individual fish species was affected by tow time (min), and water depth, salinity and temperature (ºC), but not tow distance (Table 15). For all fish, the survival rate was related negatively to water depth and positively to temperature (Regression F=20.09, df=2, P<0.001) (Table 15). Survival of commercial and recreational finfish showed a mild positive association with salinity and a moderate one with temperature (Regression F=36.45, df=2, P<0.001) (Table 15). For other finfish, survival increased with a rise in water depth (Regression F=5.05, df=1, P=0.027) (Table 15). Both Atlantic croaker and spot survival declined as water tempertature rose (Regression A.c. F=19.32, df=1, P<0.001, spot F=18.48, df=12, P<0.001) (Table 15, Figure 21). The survival rate of weakfish increased with longer tow times and deeper water, and decreased with a rise salinity and temperature (Regression F=32.35, df=4, P<0.001) (Table 15). For *Paralichthys spp.*, the survival rate was inversely related to water depth and temperature (Regression F=5.58, df=2, P=0.005) (Table 15). The survival of Atlantic menhaden showed a slight negative association to salinity (Regression F=6.66, df=12, P=0.012) (Table 15). Overall, the influence of the environmental parameters on the survival rates of the five species was negligible given the small R^2 values.

2005

The 2005 survivability study indicated that fish survival status was also affected by the degree of apparent physical damage, and fish size. More alive-healthy and dead fish showed none to mild physical damage than moderate or severe injuries (K-W a-h X^2=23.158, df=3, P<0.001; d X^2=21.92, df=3, P<0.001) (Figure 22). Alive-weak fish mainly experienced mild physical damage (K-W X^2=16.5, df=3, P=0.001). Atlantic croaker and spot that were alive-healthy were larger in size than those that were alive-weak or dead (K-W A.c. X^2=41.95, df=2, P<0.001; spot X^2=28.85, df=2, P<0.001) (Figure 23). Alive-healthy and -weak weakfish were significantly bigger fish than those that were dead (ANOVA F=19.1, df=2, P<0.001) (Figure 23). Survival status was not affected by fish size in pinfish (ANOVA F=2.3, df=2, P=0.109), southern (ANOVA F=1.49, df=2, P=0.241) or summer flounder (ANOVA F=0.24, df=2, P=0.788), and Atlantic menhaden (ANOVA F=0.28, df=2, P=0.756).

Environmental Parameters and Survivability 2005

Fish survival was related to several of the independent environmental parameters measured (Tables 16, 17). Atlantic croaker survival was compromised by the holding time in the cooler, and water depth, but survival increased somewhat with a rise in surface water temperature. Likewise for spot, longer a holding time decreased the proportion of alive-healthy and –weak individuals (Figure 24). For spot and weakfish, mortality increased due to extended tow and cull times, and higher surface salinity. Spot mortality increased with extended cull and tow times, and also with a rise in water salinity. The proportion of alive-healthy and –weak weakfish declined as cull time, salinity and temperature rose. Weakfish mortality increased as fish size decreased and temperatures increased (Figure 25). Pinfish survival declined with longer hold times and higher surface salinity, but rose with longer cull times, deeper water and warmer water temperature. Menhaden survival was positively associated with fish size, tow and hold times, and water salinity and temperature. The proportion of alive-healthy southern flounder declined with extended cull times but rose with longer tow times. For summer flounder, the percentage of alive-healthy fish increased in larger sized fish, longer tow times, and higher water temperatures, but decreased with extended hold times and elevated salinity. Mortality in summer flounder declined with an increase in cull time but increased strongly with high water temperature.

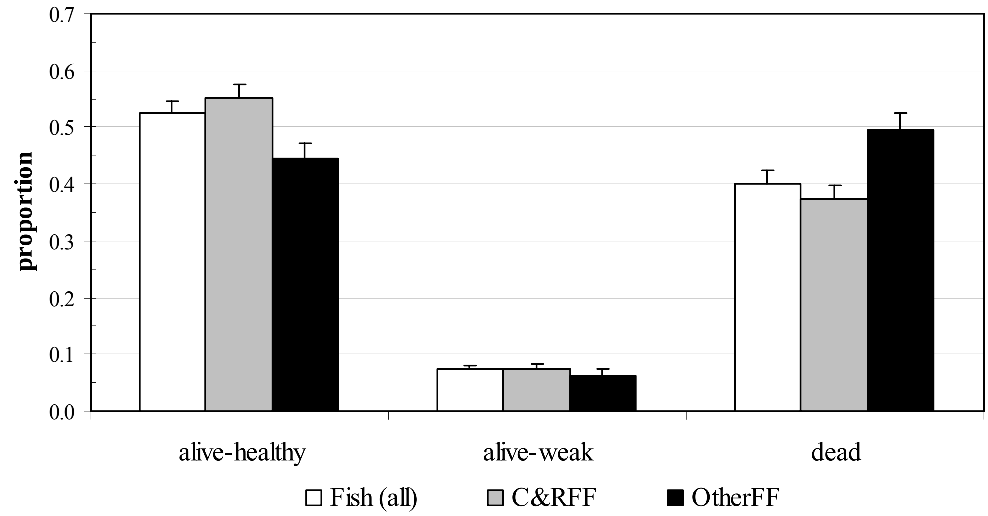


Figure 18a: The proportion of all fish (Fish (all)), commercial & recreational finfish (C&RFF) and other finfish (OtherFF) allocated to each survival status category. Differences in the proportions were found: Fish (all) and C&RFF alive-weak < dead < alive-healthy; OtherFF alive-weak < alive-healthy (*alive-healthy=dead*).

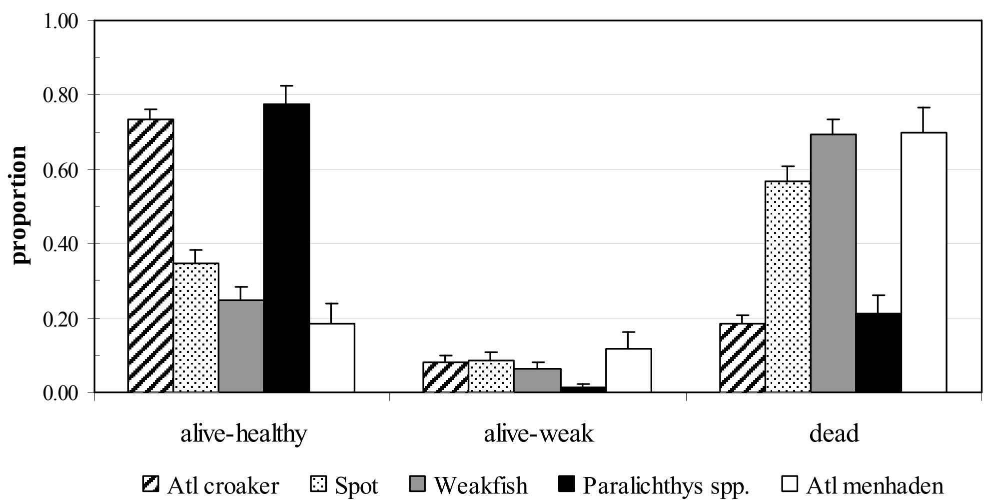


Figure 18b: The proportion of five fish species allocated to each survival status category. Differences in the proportions were found: Atlantic croaker and *Paralichthys spp*. alive-weak < dead < alive-healthy; spot and weakfish alive-weak < alive-healthy < dead; Atlantic menhaden alive-healthy < dead (*alive-healthy* = *alive-weak*).

Table 14: Bycatch survival rates (proportion (%) alive) listed for the four cull periods for each species. Data are from N=116 tows in 2004 and 2005. A P-value of ≤ 0.05 denoted significance.

Category	Cull Period	N	% alive	Test	P-value	Post hoc	Comments
Fish (all)	1 (0-15 min)	34	74.3	K-W	< 0.001	4 < 1,2 3 < 1 *(1=2, 2=3)*	Greater % survive when cull time is less than 31 min.
	2 (16-30 min)	33	66.1				
	3 (31-45 min)	28	51.3				
	4 (46-60+ min)	23	40.3				
C&RFF	1 (0-15 min)	34	79.7	K-W	< 0.001	4 < 3 < 1 4 < 2	Greater % survive when cull time is less than 31 min.
	2 (16-30 min)	33	70.3				
	3 (31-45 min)	28	54.9				
	4 (46-60+ min)	23	35.8				
OtherFF	1 (0-15 min)	34	54.9	ANOVA	0.132	*(1=2=3=4)*	No difference in % survival among the 4 cull groups.
	2 (16-30 min)	33	56.2				
	3 (31-45 min)	28	39.4				
	4 (46-60+ min)	23	45.0				
Atlantic croaker	1 (0-15 min)	34	87.4	K-W	< 0.001	4 < 1,2	Greater % survive when cull time is less than 31 min.
	2 (16-30 min)	32	91.3				
	3 (31-45 min)	28	76.5				
	4 (46-60+ min)	22	56.7				
Spot	1 (0-15 min)	29	51.9	K-W	0.016	4 < 1,2	Greater % survive when cull time is less than 31 min.
	2 (16-30 min)	22	50.3				
	3 (31-45 min)	22	32.0				
	4 (46-60+ min)	22	18.5				
Weakfish	1 (0-15 min)	28	41.5	K-W	0.002	3, 4 < 1 4 < 2	Greater % survive when cull time is less than 31 min.
	2 (16-30 min)	28	28.9				
	3 (31-45 min)	28	12.9				
	4 (46-60+ min)	22	3.2				
	2 (16-30 min)	24	45.2				
	3 (31-45 min)	23	51.0				
	4 (46-60+ min)	20	41.7				
Paralichthys spp.	1 (0-15 min)	31	38.7	ANOVA	0.341	*(1=2=3=4)*	No difference in % survival among the 4 cull groups.
	2 (16-30 min)	22	61.4				
	3 (31-45 min)	26	50.0				
	4 (46-60+ min)	22	39.7				
Atlantic menhaden	1 (0-15 min)	24	17.4	ANOVA	0.743	*(1=2=3=4)*	No difference in % survival among the 4 cull groups.
	2 (16-30 min)	16	13.5				
	3 (31-45 min)	16	10.7				
	4 (46-60+ min)	14	7.14				

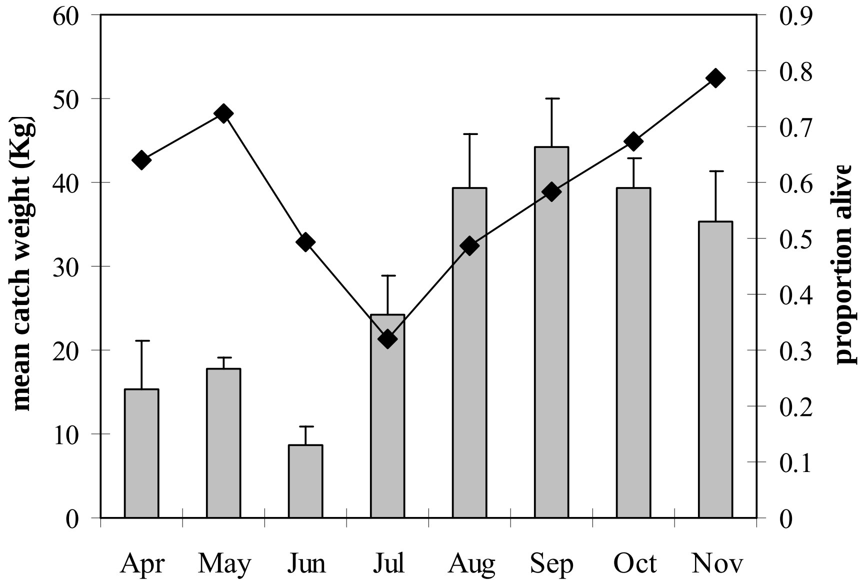


Figure 19: The relationship between total catch weight (Kg) (bars) and the proportion of fish that survived (diamonds with line). Catch weight varied per month: May < Sep, Oct; Jun < Aug-Nov (*Apr=Jul=Sep=Oct=Nov: May=all but Sep, Oct; Aug=all but Jun*). The proportion alive differed monthly with the lowest survival in July compared to September, October and November (*Apr=May=Jun=Aug=Sep=Oct=Nov*).

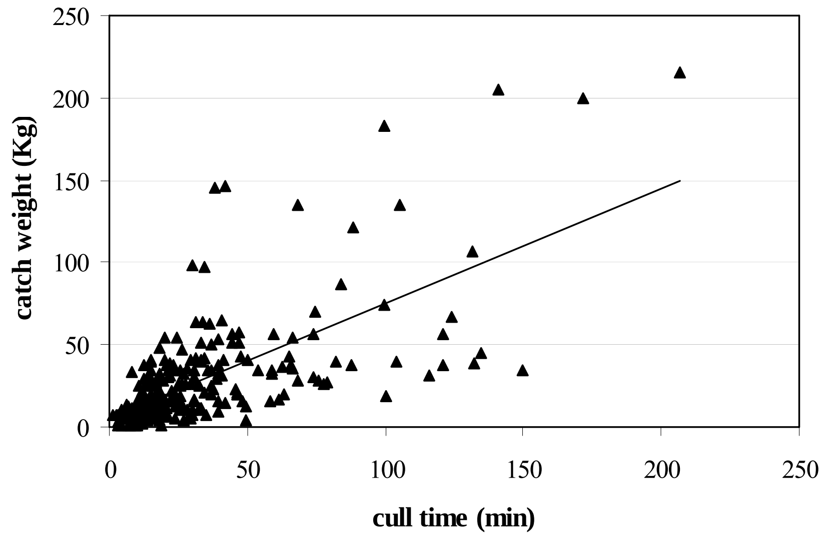


Figure 20a: There was a mild positive relationship of cull time to catch weight ($P<0.001$, $R^2=0.178$).

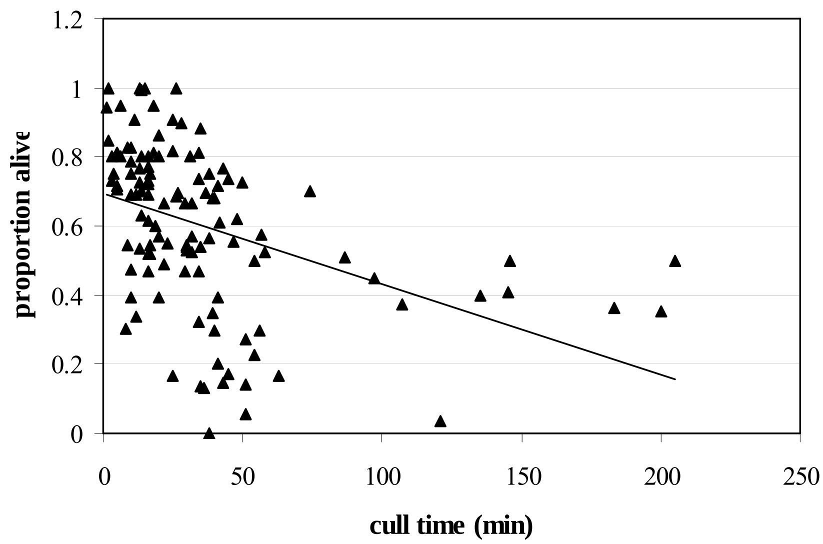


Figure 20b: There was a moderate inverse relationship of cull time to proportion alive ($P<0.001$, $R^2=0.45$).

Table 15: Relates survival rate and environmental parameters for 2004 and 2005. The P and R^2 = values indicate significance and goodness of fit respectively, and a dash (-) designate no significance for a particular parameter. The R^2 value and (±) indicate the degree of and direction of the association between size and the parameter. The degree of goodness of fit is classified as Slight < 0.10, 0.10 < Mild < 0.33, 0.33 < Moderate < 0.66, and Strong > 0.66.

Bycatch Group / Species	Tow Time (min)	Tow Distance (Km)	Depth (ft)	Salinity (ppt)	Temp (ºC)	Comments
Fish (all)	-	-	-	P=0.023 R^2=0.086 (-)		Slight assoc. w/ ↑ depth.
					P<0.001 R^2=0.186 (+)	Mild association w/ ↑ temp.
C&RFF	-	-	-	P=0.013 R^2=0.119 (-)		Mild association w/ ↑ salinity.
					P<0.001 R^2=0.367 (-)	Moderate association w/ ↑ temp.
OtherFF	-	-	P=0.027 R^2=0.046 (+)	-	-	Slight association w/ ↑ depth.
Atlantic croaker	-	-	-	-	P<0.001 R^2=0.159 (-)	Slight association w/ ↑ temp.
Spot	-	-	-	-	P<0.001 R^2=0.17 (-)	Slight association w/ ↑ temp.
Weakfish	P=0.036[a] R^2=0.031 (+)	-	-	-	-	Slight association w/ ↑ tow time
	-		P<0.001[a] R^2=0.361 (+)	-	-	Moderate association w/ ↑ depth.
	-		-	P=0.002 R^2=0.18 (-)	-	Mild association w/ ↑ salinity.
	-		-	-	P<0.001 R^2=0.34 (-)	Moderate association w/ ↑ temp.
Paralichthys spp.	-	-	P=0.044 R^2=0.014 (-)	-		Slight association w/ ↑ depth.
					P=0.003 R^2=0.063 (-)	Slight association w/ ↑ temp.
Atlantic menhaden	-	-	-	P<0.001 R^2=0.081 (-)	-	Slight association w/ ↑ salinity.

[a]Weakfish: The + association of survival rate to tow time and water depth may be related to fishing site, because in 2004 we caught a lot of weakfish in CFR late in the season and the CFR has deepest depth of all the sampling sites.

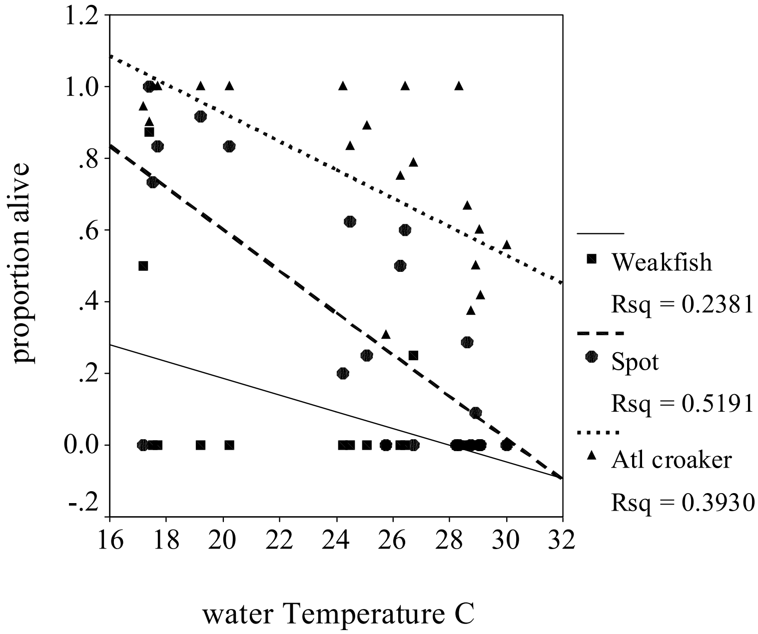


Figure 21: Relationship of survival rate to surface water temperature (°C) for Atlantic croaker, spot and weakfish for 2004 and 2005.

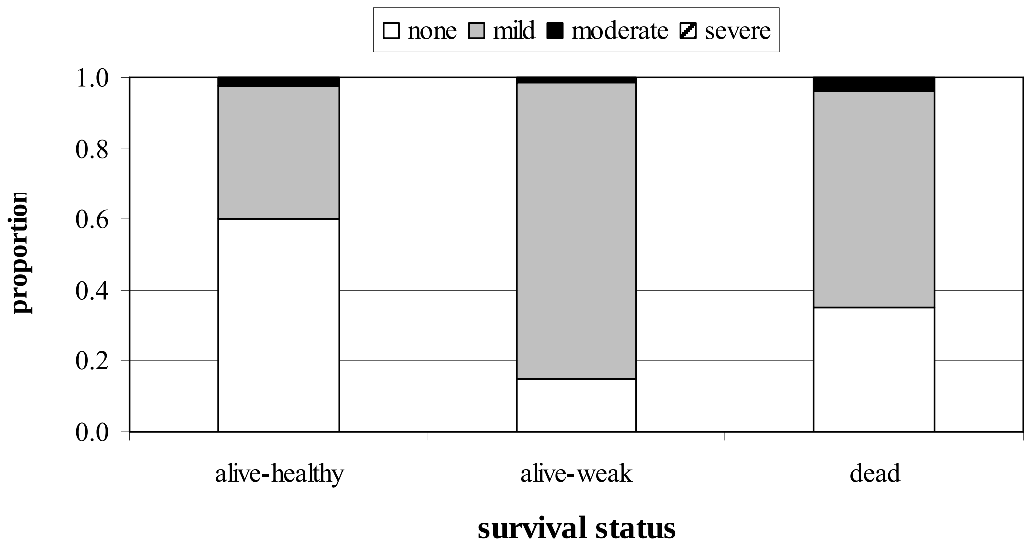


Figure 22: The proportion of fish in 2005 with physical injuries distributed among the three survival categories. More alive-healthy and dead fish exhibited none or mild damage than those with moderate or severe physical injuries. A greater proportion of alive-weak fish showed mild injuries compared to none, moderate or severe ones.

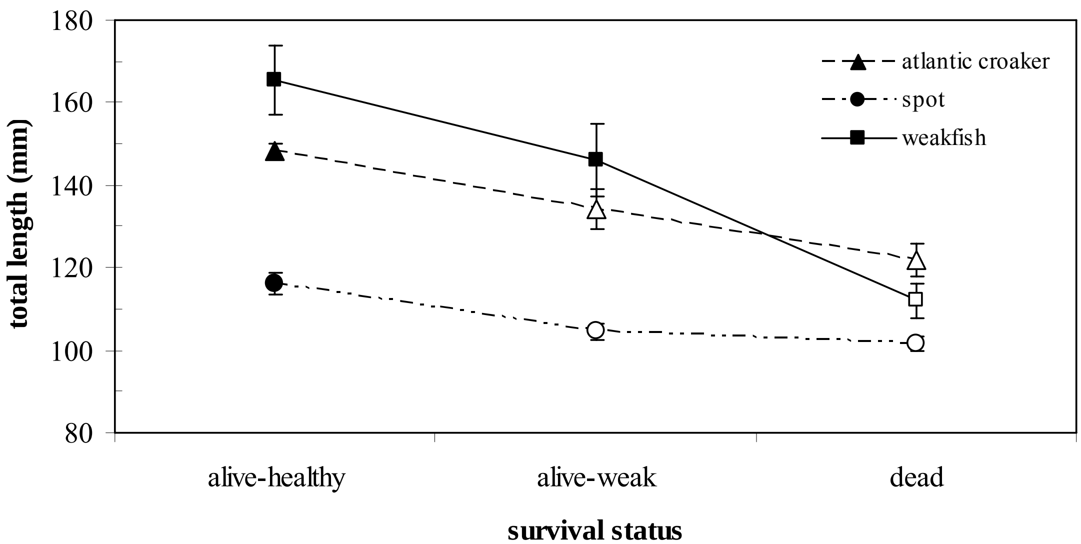


Figure 23: Survival status of Atlantic croaker, spot and weakfish related to mean fish size (mm TL ± SE) for 2005. For Atlantic croaker and spot, the alive-healthy fish (black symbol) were significantly larger than those in alive-weak or dead categories (white symbol). Weakfish alive-healthy and –weak categories (black symbol) had significantly bigger fish than the dead category (white symbol).

Table 16: Results of the Regression analysis testing whether the proportion of individuals per survival category {alive-healthy (ah), alive-weak (aw), dead (d)} in 2005 was correlated to fish length, hold, cull, and tow times, water depth, and surface water salinity and temperature. A difference of P ≤ 0.05 was considered significant. A slash indicates that no Regression was run because the sample size was small (N ≤ 6).

Species		Regression results				
		N	F	df	R^2	P-value
Atlantic croaker	a-h	227	28.87	4	0.342	<0.001
	a-w	27	6.648	3	0.377	<0.001
	d	59	11.86	4	0.468	<0.001
Spot	a-h	90	44.60	4	0.677	<0.001
	a-w	41	20.63	2	0.52	<0.001
	d	124	30.59	6	0.611	<0.001
Weakfish	a-h	17	10.49	5	0.827	<0.001
	a-w	12	$7.9 \times 10^{+15}$	5	1.0	<0.001
	d	71	29.26	7	0.765	<0.001
Pinfish	a-h	43	10.76	3	0.453	<0.001
	a-w	1	/	/	/	/
	d	20	23.5	4	0.862	<0.001
Atlantic menhaden	a-h	6	/	/	/	/
	a-w	8	$6.2 \times 10^{+14}$	5	1.0	<0.001
	d	27	8.09	4	0.595	<0.001
Southern flounder	a-h	33	10.08	2	0.419	<0.001
	a-w	1	/	/	/	/
	d	2	/	/	/	/
Summer flounder	a-h	13	26.07	1	0.703	<0.001
	a-w	0	/	/	/	/

Table 17: Relationship between the proportion per survival group {alive-healthy (a-h), alive-weak (a-w), dead (d)} and seven independent variables determined using backward Regression. The number denoted at a particular variable is the R^2 value, and it indicates whether the variable was significant at $P \leq 0.05$. The symbol after the R^2 value indicates whether the relationship was positive (+) or inverse (-). R^2 values in **bold** denote $R^2 \geq 0.30$ and signifies that the variable had a moderate to strong relationship to survival status. Those in *italics* are $R^2 < 0.1$, which means the variable had a slight association to survival status. No statistics were run if $N \leq 6$.

Species	Survival status	Fish Length (mm TL) Mean (+SE)	N	NS / S	Variable						
					Fish Length	Hold Time (hr)	Cull time (min)	Tow time (min)	Depth (ft)	Salinity (ppt)	Temperature (°C)
					Mean Min Max	**4:30** 1:48 6:82	**36.8** 1 200	**43.2** 17 73	**16.9** 8.2 28.5	**22.2** 9 31.5	**24.1** 17 31.6
Atlantic croaker	a-h	148.3 (1.53)	227	S	-	-	0.196(-)	-	*0.062(+)*	*0.0828(-)*	-
	a-w	134.16 (4.86)	37	S	-	0.148(-)	-	-	0.047(-)	-	0.108(+)
	d	121.95 (4.01)	59	S	*0.007(+)*	*0.055(-)*	-	-	**0.326(+)**	-	*0.091(+)*
Spot	a-h	116.26 (2.56)	90	S	-	**0.567(-)**	-	*0.006(+)*	*0.010(+)*	*0.062(+)*	-
	a-w	104.46 (2.09)	41	S	-	**0.344(-)**	-	-	*0.065(-)*	-	-
	d	101.49 (1.87)	124	S	-	*<0.001(+)*	0.216(+)	**0.324(+)**	*<0.001(+)*	0.102(+)	*0.008(+)*
Weakfish	a-h	165.47 (8.27)	17	S	*0.008(-)*	0.177(-)	**0.309(-)**	-	-	0.278(-)	*<0.001(+)*
	a-w	146.08 (8.76)	12	S	-	-	**0.360(-)**	*0.072(+)*	0.239(+)	*0.034(+)*	0.288(-)
	d	112.03 (4.16)	71	S	**0.322(-)**	*0.056(-)*	-	**0.553(-)**	0.124(-)	0.181(+)	**0.395(+)**
Pinfish	a-h	114.49 (4.53)	43	S	-	0.148(-)	-	-	0.122(-)	-	0.214(+)
	a-w	115	1	-							
	d	98.55 (4.93)	20	S	-	-	**0.326(-)**	*<0.001(+)*	**0.369(+)**	0.266(-)	-
Atlantic menhaden	a-h	127.67 (11.91)	6	-							
	a-w	130.37 (13.95)	8	S	-	**0.927(-)**	-	**0.503(-)**	*< 0.001(-)*	**0.640(+)**	0.288(+)
	d	121.78 (5.46)	27	S	0.291(+)	-	*0.013(+)*	-	-	*0.016(+)*	*0.099(-)*
Southern flounder	a-h	247.82 (6.81)	33	S	-	-	**0.326(-)**	0.108(+)	-	-	-
	a-w	210	1	-							
	d	205 (32.5)	2	-							
Summer flounder	a-h	157.46 (19.29)	13	S	**0.703(+)**	**0.752(-)**	*0.026(+)*	**0.305(+)**	*0.02(-)*	**0.349(-)**	**0.345(+)**
	a-w	-	0	-							
	d	148.7 (14.0)	10	NS	-	*0.005(+)*	**0.360(-)**	-	-	-	**0.969(+)**

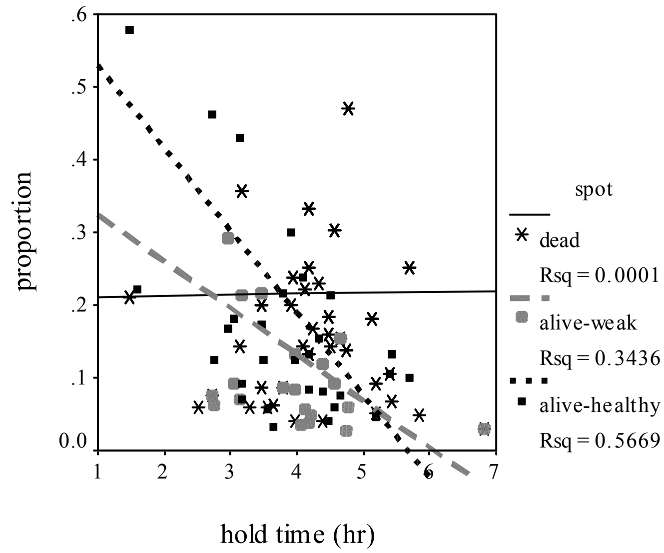


Figure 24: Extended holding time in the cooler decreased spot survival.

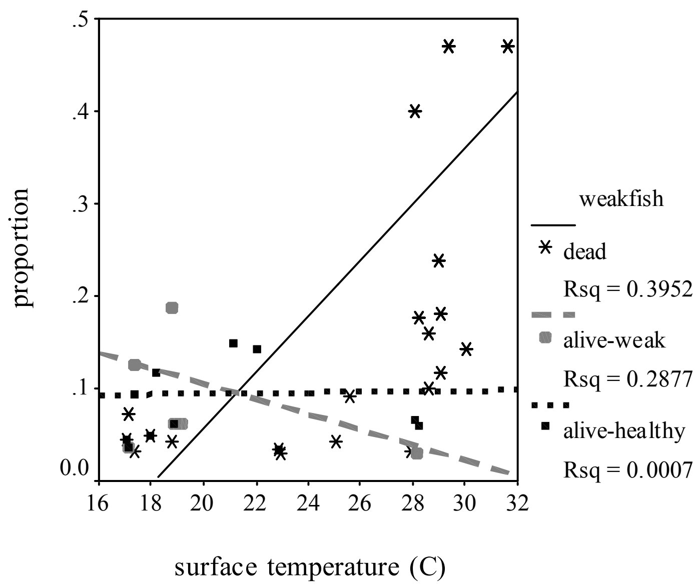


Figure 25: Surface water temperature (°C) reduced weakfish survival.

IV. DISCUSSION

The overall result of this study does not support on of our hypotheses because we found no difference in the shrimp and bycatch catch rates for a commercial shrimp fisherman using all the required bycatch reduction devices to fish in the inside waters of southeastern North Carolina. Based on size, most of the bycatch was comprised of juvenile or sub-adults of their species, and the smallest sized ones were principally caught in mid summer, which supports our hypothesis. Overall the bycatch showed none or few visible signs of damage from the process of collecting them, which supports our hypothesis; however, most specimens were dead before discard. The survivability study showed that nearly 60% of all the fish were alive at the end of the bouts, which supports our hypothesis. A greater proportion of finfish survived when cull times were below 30 minutes, and at water temperatures that were less than ~25 ºC (~77 ºF).

Although the catch rates of shrimp and bycatch did not differ. The larger catch rates of bycatch to shrimp in the spring compared to the higher catch rates of shrimp than bycatch in the late summer and fall point out apparent seasonal differences. Looking at the shrimp and bycatch separately, we found that the bycatch catch rates for all the months were fairly similar to each other, except in October and November; whereas, the shrimp catch rates showed a marked increase starting in July. This is important because it shows that the quantity of bycatch itself generally changes little during the shrimp season, except in the fall. By contrast, the quantity of shrimp changes significantly from spring to summer. Hence, most of the differences in monthly catch rates stemmed from fluctuations in the shrimp catch not the bycatch. Some of this change in shrimp volume could be related to what part of the shrimp crop was available to access because NCDMF manages the fishery in the southern district based on shrimp size. For example, all of the ICWW in Brunswick County was closed to shrimping in 2005 from 26 June through 8 July not from a paucity of shrimp, but to allow the shrimp to grow to a marketable size. Regionally, there were no differences found in catch rates between shrimp and bycatch, apart from New River. Also, the catch rates among the five regions were generally similar for bycatch and shrimp except for Brunswick County. Overall shrimp and bycatch catch rates were not affected by seasonal fluctuations in surface water salinity and temperature or by variations tow time. However within regions, the environmental parameters affected the catch rates. For example, the catch rate of blue crabs in Brunswick County increased with the rising water temperature. In Onlsow County, elevated water salinity reduced the catch rate of bycatch and all the various bycatch groups analyzed except *Paralichthys spp*. Water depth was fairly consistent within the regions, although it differed among them. This may explain associations, albeit minor, found with catch rate for the combined regions. Tidal phase was important to the shrimp catch rate in the Cape Fear River as we often timed the tows to the appropriate tide. The fact that we found a minor relationship with total catch weight and tow time suggests that tow time was less affected by catch weight than region. Each region sampled had distinct physical characteristics and held different management restrictions.

In comparing our catch data to those from other North Carolina studies, we find that the data share similarities in species rank but not in catch quantity. In one study that characterized the bycatch from shrimp trawls in North Carolina, Diamond-Tissue (unpublished data, 1999) sampled in Pamlico Sound (N=16 tows in 5 trips), and the Cape Fear River (n=24 tows in 5 trips) monthly from July through October 1995, and Core Sound (n=4 tows in 2 trips) in August 1995.

Unlike our results, this study found that total weight of the penaeid shrimp catch exceeded that of the bycatch. Our results were likely affected by the extremely large catch of Atlantic croaker in April in the Cape Fear River. The Diamond-Tissue study found that the Cape Fear River yielded the largest shrimp landings, and Pamlico Sound produced the highest bycatch by weight. Six of their top ten bycatch species were also in our top ten, and they included Atlantic croaker (1), weakfish (2), spot (3), blue crab (4), Atlantic cutlassfish (8), and squid (9). For the Cape Fear River, another six species overlapped with those in our rank for this region and they include: weakfish (1), Atlantic croaker (2), star drum (3), blue crab (4), Atlantic cutlassfish (5), and pinfish (8). A study on the discards from shrimp trawls in Core Sound North Carolina found lower catches of shrimp than bycatch compared to our results. They reported 20% of the catch was shrimp with a mean shrimp catch rate of 12.5 Kg/tow/hr (0.208 Kg/min), and recorded bycatch to shrimp ratios of 5.67:1, and fish to shrimp ratios of 3.11:1 Kg weight (Johnson, 2003). Results from Coale *et al*. (1991) yielded an average bycatch catch rate of 0.66 Kg/tow/min, nearly twice ours, and fish to shrimp ratio of 8.41:1 Kg weight for otter trawl at night near Harkers Island, North Carolina. The latter two studies found blue crab the number one bycatch species by weight, followed by spot, which resembles our results. The migration of Atlantic croaker from number two in 2004 to number one in 2005 resulted from the very large volume of fish caught on 26 April 2005 in the Cape Fear River, which totaled nearly 200 Kg in two tows. The water temperature hovered around 17 °C, and thus the cool water kept the fish around longer than normal. By comparison, the water temperature averaged 21.8°C in late April 2004, and no exorbitant amount of fish was caught. The 2005 temperature fell more within the normal range for this time of year and area in the Cape Fear River (www.uncwil.edu/cmsr/aquaticecology/lcfrp).

Pink and white roe shrimp were targeted in the spring, but with little product, except larger quantities of bycatch. By contrast from late summer through fall the catch rate for shrimp was usually greater than that of bycatch, which was also indicated in the catch ratios. Brown shrimp was the principal species targeted from mid to late summer and then followed by white shrimp in late summer and fall. NCDMF's landing data shows that the spring fishery has a lot of inter-annual variation; whereas, the summer and fall shrimp landings appear fairly steady from 1994 to 2003. Although pink shrimp are harvested in southeast North Carolina, their range is concentrated to Florida's Gulf coast (Miget & Haby, 2000), which may explain the vacillations in spring shrimp landings in southeastern North Carolina. Also, the spring shrimp fishery comprises only about 3.5% of the state's shrimp landings (NCDMF, landing data). We noticed that when there is cold winter preceeding the shrimp season as in 2004 and 2005, the production of pink and also survival of the overwintering white shrimp were both poor. Over 60% of the shrimp landed in the Gulf and southeastern United States are brown shrimp (Miget & Haby, 2000). From 1994 to 2003, approximately 11% of the brown shrimp landed in North Carolina came from Brunswick and New Hanover Counties (NCDMF, landing data), which indicates that for such a small geographic area, produces a decent amount of brown shrimp. In North Carolina, white shrimp comprise nearly 40% of the shrimp landed, with around 17% coming from Brunswick and New Hanover Counties, which includes the Cape Fear River. Shrimp are an annual crop, so variations in the yearly landings are considered the results of environmental conditions and fishing effort (NCDMF, 1999). Overall, shrimp landings between 1994-2003 in Brunswick and New Hanover Counties totaled approximately 309,000 pounds in 2,040 trips in the spring, around 4,600,000 pounds in 12,500 trips in the summer, and about 5,000,000 pounds in 11,200 trips (NCDMF, landings data). Pink, brown and white shrimp can easily rebound from population declines with favorable environmental conditions (NCDMF, 1999). A bigger threat to shrimp stocks comes from pollution or habitat loss, such as declines in salt marsh acreage, which are nursery areas for juvenile shrimp.

Besides the pink and white shrimp caught in the spring, the mean sizes of brown and white shrimp in New Hanover and Brunswick Counties, and the Cape Fear and New Rivers kept relatively stable for the reminder of the season. Most of the shrimp caught in Onslow County was the summer crop of brown shrimp, and their mean size remained stable from July to September. During the summer shrimp season in southeastern North Carolina, there is gradual species shift from brown to white. This happens as the brown shrimp become large and are harvested or move out of the inland waters, and while the white shrimp outgrow the primary nursery areas and enter the secondary nursery areas, like the ICWW. However, weather or other phenomena can affect the growth of shrimp. This is because shrimp physiology is affected by salinity, and growth is related mainly to water temperature (Miget and Haby, 2000). In 2004, four tropical storms hit southeast North Carolina between mid August and early September. As soon as the estuaries would start to show signs of returning to balance after one storm another storm would strike. The storms caused large volumes of rain that lead to a rapid drop in the water salinity. This in turn seemed to force smaller sized shrimp out of estuarine nursery habitats into the waterways prematurely. The larger shrimp then are forced to go somewhere, so they leave the waterway for the ocean. In addition, the freshwater influxes flushed out juvenile blue crabs, small flounder, and other fish. Indeed, these storms impacted the brown and white shrimp in the estuaries, and subsequently NCDMF's management of the inland shrimp fisheries. The size of brown shrimp changed little between August and September, and the size of white shrimp decreased from August to September in 2004, which yielded a high count per pound. Subsequently, in 2004 Brunswick County remained closed throughout mid November 2004 to protect the white shrimp. Generally, NCDMF will close areas in or all of Brunswick or New Hanover to shrimping in late July or early August to protect the small white shrimp. However, if the white shrimp arrive before the brown shrimp are of harvestable size, areas may remain closed until September or even November (NCDMF, personal communication).

Throughout the study period and among the fishing regions, the catch rate for all fish was greater than any of the other bycatch groups. Even though blue crab was the second most dominant bycatch species by weight, its catch rate always remained much lower than that for fish. Other than the aforementioned April spike in Atlantic croaker, the catch rate for bycatch, all fish and invertebrates peaked in July, August and September followed closely by May. The September spike was probably related to the trips in New River in September, because catches in New River usually contained large volumes of pinfish. Most of the New Hanover trips took place in July and August of 2004. Coinciding with these spikes in bycatch were elevated water temperatures during the coinciding months and the regions. These trends correspond with reproductive cycles of invertebrates and fish that rely on estuaries for spawning or juvenile growth and development. Typically, fish move in to spawn in April and May, then through the summer the juveniles grow and then they begin to migrate out in late summer and early fall (Miller *et al*, 1985).

Given that the smallest fish of the six species analyzed were collected from July through September, indicates that high juvenile fish abundance in estuaries at this time. Also, this period coincides with the peak brown shrimp and the early white shrimp seasons. In most cases, some areas may be closed to shrimping. For instance, sections of the ICWW in Onslow and Pender Counties are managed as Special Secondary Nursery Areas (SSNA 15A NCAC 03R.0105), which means that they automatically close to trawling on May 14 and open when NCDMF decides that the shrimp are a suitable size, which is typically after August 15 (NCDMF, Shrimp FMP issue paper for ICWW and Sounds from New River to Rich's Inlet). Other areas are managed by proclamation, such as Brunswick County, and Cape Fear and New Rivers. These management regimes help to protect the pre-mature harvest of small shrimp, but also juvenile fish. In the revised Shrimp FMP, the Williams Landing area of New Hanover County will be managed as a SSNA.

Another possible explanation for the small size fish captured is that the bycatch reduction devices (BRDs) used may be size selective. One study found that of the five different BRDs tested each one selected smaller or larger sized weakfish, spot and Atlantic menhaden compared to the control depending on the design (Rulifson *et al*, 1992). However, neither of the BRDs that we used was tested in the referenced study. Some commercial shrimpers think that the hard TEDs they use may deflect larger flounder, but this is apocryphal information. Tests by NCDMF on the effectiveness of various BRDs in reducing bycatch found that the overall number for penaeid shrimp and crabs, spot, Atlantic croaker, southern flounder, harvestfish and weakfish decreased with a FFE designed with a diamond shaped escapement opening that measures at least 6½ x 5½ in for the inside diameter (McKenna *et al*, 1996). North Carolina requires that the inside diameter for all diamond shaped FFE is either 6½ x 5½ in or 6 x 6 in in size (NC DMF Proclamation SH-9-97).

Paralichthys spp. was the eighth most common species group captured by weight; however, because of its commercial and recreational importance in North Carolina, the catch rate of *Paralichthys spp*. was given special attention. Although *Paralichthys spp*. were the most dominant of the flatfish in terms of catch rate and weight, by number fewer were captured than other flatfish species. For example, nearly all of the N=823 *Paralichthys spp*. that were caught were also measured. By contrast, more than N=1217 bay whiff were caught but only this number was measured, because when we caught a large quantity we recorded only the subsample. Gulf (*P. albigutta*), summer (*P. dentatus*) and southern (*P. lethostigma*) flounder attain lengths of 940 and 760 mm respectively, while bay whiff is a small sized fish that reaches 200 mm (Robins & Ray 1986). Although the catch rates for *Paralichthys spp*. showed minimal monthly and no regional differences, the smaller sized *Paralichthys spp*. caught from July through September suggests that a greater number were caught during this time, especially in New Hanover County.

Our 2005 data shows that we caught more southern flounder by weight; however, there was a greater number of individual summer flounder captured based on the number measured of each species. Both the summer and southern flounder species comprise a large proportion of the North Carolina finfish landings (NCDMF, 2004), and the state's stock status listed summer as concerned and southern as overfished (www.ncfisheries.net/stocks/index, NCDMF 2004). The intense fishing pressure caused the southern flounder stocks to consist principally of age one and two fish, which can impact recruitment (NCDMF, 2004). High demand for flounder led to an increase in fishing effort for both species. In North Carolina, the commercial fishery for summer flounder occurs during the winter months mostly in ocean trawls, while the fishery for southern flounder runs from late summer and fall in estuarine gill nets and pound nets. Both summer and southern flounder spawn in the fall and early winter in the ocean, and the post-larvae enter the estuaries in the winter and early spring. The mean size of both species fell below the published average for summer flounder at 275 mm TL age-0 and 355 mm TL age-1 (Terceiro, 2006), and for southern flounder age-1 between 266-309 mm TL (NCDMF, 2004). This suggests that we predominately captured young of the year founder, but perhaps the summer flounder were younger as they were on average smaller than the southern flounder we caught. Unlike summer flounder, the southern flounder return to estuaries in the fall after spawning in the ocean (NCDMF, 2004), which make them vulnerable to late season fisheries, such as blue crab or shrimp, as well as cold temperatures. Concern for the catch of sub-legal flounder in shrimp trawls was addressed during the development of the 2005 Shrimp FMP. Several rivers in the Pamlico region are now closed to shrimping due to high incidence of southern flounder in shrimp trawls. Given the manner in which NCDMF manages the shrimp resource in the southeast region sub-legal flounder and other juvenile species may benefit, because most areas remain closed when they are little in size. In addition, over the last 10 years NCDMF has recorded a decrease of at least 25% in the number of commercial shrimpers in the southeast region (NCDMF, Shrimp FMP issue papers 2005), which may further reduce fishing pressure on juveniles.

Since the bycatch consisted of mostly juvenile to sub-adult individuals and nearly all were discarded, trawling for shrimp in the inland waters could potentially affect juvenile recruitment if there was heavy fishing pressure in one place for an extended duration. Atlantic croaker is considered a species of concern in North Carolina. One study showed that the ocean juvenile stage is the most critical affecting the Atlantic croaker population in the Atlantic and Gulf, and in the Atlantic, the early juvenile stage (40-80 mm) is the next most important (Diamond *et al*, 2000). The size of Atlantic croaker captured in this study was larger than the early juvenile stage. Atlantic croaker ranged from 120-180 mm TL, which is or is approaching the sexual maturity stage of 2-3 years for males (130-230 mm) and females (180-230 mm) (NCDMF, 2004). Weakfish spawn near inlets from March through September with peak spawning time in May and June (NCDMF, 2004). Both adults and young weakfish spend the summers in the estuaries and migrate to the ocean in the fall when water temperatures begin to decline. Although the size at age for weakfish varies, a one year old fish is approximately 180 mm, and a two year old fish is 255 mm (NCDMF, 2004). Given that most of the weakfish caught in this study were between 70-140 mm TL indicates that we captured mostly young of the year individuals. Studies on shrimp trawls that were performed as a means to assess the stock suggest that discarded weakfish, particularly young of the year fish, suffer high mortality rates (NCDMF, 1999) as other species apparently do as well (Davis, 2002). Our survivability data supports this given that the survivability of weakfish was about 40 % even when the cull times were short. Currently, the weakfish status North Carolina is classified as viable. The population of spot is also considered viable in North Carolina, but data indicate that the size of spot is decreasing (NCDMF, 1999). Spot is a short lived species, and their population size fluctuates annually. When spot are between 18.6-21.5 mm TL around two to three years, they are considered mature (NCDMF, 1999). Spot captured in this study were mainly juveniles based on the size range. In North Carolina shrimp trawls, spot comprises a large proportion of the finfish bycatch along with Atlantic croaker and weakfish (Johnson, 2003; Diamond-Tissue, 1999; Rulifson *et al*, 1992). This trend supports the notion that smaller sized animals are more abundant in the estuaries during the summer months.

Although most of the bycatch exhibited minimal physical damage, the majority of species did not survive by the time of release. This high mortality was likely due to the processing time for the bycatch. Prior to the species being evaluated for their release condition, they first endured the initial culling process, further sorting of the bycatch into species, and then weighing and measuring of each species that preceded it. The fact that we recorded little to no physical damage on the animals may be explained from the tow time. In the inside waters in southeast North Carolina, the tow times are relatively short (<1 hr) because of size of the fishing area and net sized, which are smaller than those used in larger water-bodies. So, even if the catch is large enough to fill the tail bag, fish are not pressed against the net or each other for very long. By contrast, tow times for ocean trawlers range from one to two hours depending on season and catch volume (NCDMF personal communication), which increases the amount of time in the tailbag and potentially escalating the degree of physical damage.

An animal released that was ranked in good or fair release condition and with none to little physical damage does not preclude it from subsequent mortality. Our 2005 survivability data showed that fish with an increased proportion of mild physical damage or small in size were more likely to be in fair to poor release condition or deceased after several hours. Therefore, abrasions however minor could significantly decrease survival among fishes. Physical damage does not alone account for or avert mortality. Stress and subsequent mortality are often the result of the interaction of physical, e.g. abrasions from the webbing, and physiological factors, e.g. elevated levels of cortisol (Davis *et a*l, 2001; Barton & Iwama, 1991) or lactic acid (Davis *et a*l, 2001; Beamish, 1966). There are several classes of stressors: 1) capture stressors – net entrainment, crushing, wounding, sustained swimming 2) fishing conditions – tow time, light conditions, anoxia, air and water temperature, time on deck, handling procedures 3) biological attributes – behavior, size, and species (Davis, 2002), many of which we addressed in this study.

The increased survivability in fish that experienced shorter cull times and cooler water temperatures was expected, because other studies on fish survivability in shrimp and fish trawls found similar results (Johnson, 2003; Davis, 2002; Davis and Olla, 2002; Ross and Hokenson, 1997). Time on deck or amount of air exposure can negatively affect the survival rate of fishes (Davis & Olla, 2002; Davis *et al*, 2001; Ross & Hokenson, 1997; Richards *et al*, 1995). Our data shows not only that survival rates were dependent on cull time but also species related. Although Atlantic croaker, weakfish and spot are all sciaenids, their survivability varied with cull time. For example, we found that the survival rate for Atlantic croaker was greater than for spot, and survival rate for spot was higher than for weakfish. Data from shrimp trawls in Core Sound and the Neuse River in North Carolina also found more Atlantic croaker than spot survived after being towed in shrimp trawls (Johnson, 2003). The overall survival rates for fish in that study were 22% alive and 78% dead compared to 60% alive and 40% dead in this one, which may be related to the differences in methodology as well as tow times and catch volume. Interspecies variability in survival was observed in other studies (Davis, 2002; Kaiser and Spencer, 1995) and also noted within flatfishes (Alverson *et al*, 1994). We showed in 2005 that southern flounder survival was aided by abbreviated cull times, but not for summer flounder as other variables were more influential than cull time. *S*urvival in American plaice (*Hippoglossoides platessoides*) and witch flounder (*Glyptocephalus cynoglossus*) showed greater survival with shorter cull times (Ross & Hokenson, 1997). Similarly, Pacific halibut (*Hippoglossoides stenolepis*) mortality declined with a decrease in deck time (Richards *et al*, 1995). Additionally, lesser-spotted dogfish (*Scyliorhinus canicula*) were strongly resilient to the impacts of trawling unlike plaice (*Pleuronectes platessa*) and dab (*Limanda limanda*) (Kaiser & Spencer, 1995).

Survivability was positively associated to fish length for the three most commonly occurring fish species. We found that smaller size Atlantic croaker, spot and weakfish experienced lower survivability than larger ones. One explanation for the effect of size is that smaller sized fish fatigue more easily once caught in the net, and sustain more injuries in passing along the trawl webbing (Davis and Olla, 2002). Also, there is a positive allometric relationship between fish size and swimming with the metabolic cost greater in smaller fish (Helfman *et al*, 1997). The survival rates of Atlantic croaker, spot and weakfish additionally declined with rising water temperature. These results were consistent with those of other studies that found smaller sized fish showed decreased survivability with longer periods of air exposure (Davis and Olla, 2002; Davis *et al*, 2001; Ross and Hokenson, 1997) or deck time (Richards *et al*, 1995), or increases temperature (Davis *et al*, 2001). For example, small sized lingcod (*Ophiodon elongates*) were more susceptible to air exposure than large fish in a laboratory study (Davis and Olla, 2002).

The role of temperature is an important parameter that influences survival because of its central role in the life history and physiology of fish species. Sablefish that were abruptly transferred to higher temperatures showed an increase in mortality within 48 hours (Davis *et al*, 2001). Physiological responses to the temperature differentials caused elevated blood cortisol, lactate, glucose, and sodium concentrations in sablefish when there was no mortality (Davis *et al*, 2001). We found that survival rates for fish declined in the summer months, which coincided with larger sized catches. Since we found relationships between catch rate and cull time and survival rate and cull time, and also recorded smaller sized fish and higher water temperatures in the summer, suggests that seasonality influences the potential survival of discarded fish.

Several studies suggest that many fish suffer from delayed mortality after release - from three days in sablefish (Olla *et al*, 1997), 12 days for lingcod (Davis & Olla, 2002; Albin & Karpov, 1998), and up to 30 days for Pacific halibut (Davis & Olla, 2001). Forty-one percent of cuckoo rays (*Raja naevus*) that were alive at the time of capture had some bruising and pink wings died within five days (Kaiser & Spencer, 1995). In the same study, 68% of the flatfish were missing scales and bruised, and of those that were alive at capture and retained, 40% were dead five days later. Although we did not test survival rates over an extended time such as days or weeks, we have some anecdotal data that indicated some delayed mortality. We donated a variety of fish species, e.g. Atlantic croaker, spot, Atlantic spadefish, and lookdown, from the survivability study to the North Carolina Aquarium at Fort Fisher. All of the individuals were classified in good release condition with no physical damage at the end of the holding period. However, many of those specimens observed one day later were either swimming near the surface or were dead, showing redness and mild bleeding, or were thriving on exhibit nearly seven months later. Live discards are additionally susceptible to avian predators. For example, 28% of witch flounder (*Glyptocephalus cynoglossus*) and 63% of pollock (*Pollachius virens*) returned to the water were eaten by seabirds, which were mostly gulls (*Larus* spp.), but fewer were eaten when their time on deck was less than 30 minutes (Ross & Hokenson, 1997). Both sea gulls (*Larus spp*.) and brown pelicans (*Pelecanus occidentalis*) followed the boat during the trawls and waited (sometimes patiently) beside the boat for the discards. We noted that avian predation was more intense in the spring and fall than the summer, which coincided with when food was more easily available.

Despite the use of bycatch reduction devices and state management of the fishery, we still caught a large amount of non-targeted species. Questions remain such as: 1) How much bycatch is acceptable? 2) What ratios are acceptable? 3) What impacts do the discards have on the stocks? 4) Are further bycatch reduction efforts necessary in a region where the number of commercial fishers decreases annually?

V. RECOMMENDATIONS

1) Encourage shorter tows and faster cull times. This may help decrease bycatch mortality by limiting the amount of air exposure before releasing bycatch.
2) Emphasize regional management efforts for the inside shrimp fishery.
3) Promote the use of Special Secondary Nursery Areas (SSNA) in managing shrimp especially in areas of inconsistent shrimp production. This could conserve the shrimp until they reach an appropriate size, protect juvenile fish and invertebrates, and releases NCDMF of sampling constraints and managing by proclamation. The revised Shrimp FMP added the area encompassed by Williams Landing in New Hanover County for management as a SSNA.
4) Endorse future studies that focus on characterizing bycatch, especially those with a regional approach.
5) Continue to investigate means to reduce bycatch.

VI. IMPACTS AND BENEFITS

The results of this study were used by NCDMF to revise the Shrimp Fishery Management Plan, which to date awaits final approval by the NC Marine Fisheries Commission. The data herein can be used by NCDMF to manage these regions. Future studies stemming from this project are being developed.

VII. EXTENSION OF RESULTS

The results of this study were presented on January 18, 2005 to the NC MFC Southeast Regional Advisory Committee at their meeting in Wilmington, NC and on 14 March 2006 at the First Annual Fisheries Forum in New Bern, NC. This project was a feature article written by K. Angione in the Early Summer 2005 edition of Coastwatch, which is a North Carolina Sea Grant Publication.

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X. APPENDIX I

List of the Relevant NCDMF 2004 and 2005 Proclamations for shrimp and crab trawling.

Year	Proclamation	Date	Action	Location
2004	SH-5	1 May	CLOSE	B, CFR, O, P
	SH-6	14 May	OPEN	P
	SH-7	30 May	CLOSE	B, NH
	SH-11	30 Jul	OPEN	B
	SH-12	23 Jul	Cont' SH-6	P
	SH-14	1 Aug	CLOSE	B
	SH-18	29 Aug	CLOSE	B
	SH-19	3 Sep	OPEN	NR, O
	SH-20	14 Sep	OPEN	NR, P
	SH-23	15 Oct	OPEN	P
	SH-24	20 Oct	OPEN	B, O
	SH-25	12 Nov	OPEN	B, NH
2005	SH-2	1 May	OPEN	CFR, NR, O, P
	SH-4	1 Jul	CLOSE	B, NH
	SH-6	1 Jul	OPEN	P
	SH-7	13 Jul	OPEN	B
	SH-11	17 Aug	OPEN	O
	SH-13	21 Aug	CLOSE	B, CFR
	SH-15	2 Sep	CLOSE	O
	SH-16	22 Sep	OPEN	NR
	SH-17	11 Nov	OPEN	B, BH, O

2004 NCDMF Proclamations for shrimp and crab trawling

SH-5-2004 PROCLAMATION

RE: Shrimping and Crab Trawling

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that effective at 12:01 A.M., Saturday, May 1, 2004, all coastal waters south of Marker #45 near Bogue Inlet to the South Carolina line will close to shrimping and crab trawling, except the following areas, which will remain open until further notice:

AREA DESCRIPTIONS - SOUTHERN DISTRICT:

I. ATLANTIC OCEAN

II. Onslow County

A. Bogue Inlet Channel

B. Intracoastal Waterway Channel (ICWW) ONLY - from Bogue Inlet to Marker #45 at Swansboro

C. Intracoastal Waterway - channel only from Marker #45 at Swansboro to Marker #63 south of Brown's Inlet.

D. West Channel - (Island Channel) - main channel only from ICWW Buoy#47A to ICWW Marker #45B.

E. West Channel - main channel only from ICWW Marker #48 to Bogue Inlet.

F. Banks Channel - main channel only from Bogue Inlet to Bear Inlet.

G. Saunders Creek - main channel only from ICWW Marker #55 to Bear Inlet.

H. Bear Creek - from the ICWW to Bear Inlet

I. Muddy Creek - main channel only, from Bear Creek to Saunders Creek.

J. Shacklefoot Channel - from ICWW Marker #59 to Bear Inlet including the area known locally as the "Horseshoe".

K. Uniflite Boat Basin - dredged portion only, from ICWW near Marker #55 to the upstream end of the dredged portion.

L. Brown's Inlet area - main channels only, from ICWW Markers #61 and #63 to the Inlet. (Map 2)

M. Intracoastal Waterway - channel only from Marker #63 south of Brown's Inlet to Marker #49 at Morris Landing. [The area between Marker #17 north of Alligator Bay to the Surf City bridge closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b)]. N. New River - that area downstream from a line running from Gray Point 34° 37.6373' N – 77° 22.3605' W, running southeasterly to a point on the east shore 34° 37.1622' N – 77° 21.5527' W. Also, the area downstream from the Highway 172 Bridge bounded on the north by a line beginning near Pollocks Point 34° 34.9167' N – 77° 23.9500' W; running southeasterly to Jarretts Point 34° 34.6333' N – 77° 22.9167' W; running southeasterly to Wilkins Bluff 34° 34.2333' N – 77° 21.6500' W; running southwesterly to a point on the north side of the marked navigation channel 34° 33.9500' N – 77° 21.8833' W, across from Marker #17; running along the north side of the channel to the ICWW; and bounded on the south by a line beginning at the N.C. Highway 172 Bridge 34° 34.6333' N – 77° 23.9500' W; running easterly to Ferry Point 34° 34.0000' N – 77° 23.8167' W; running southeasterly to Poverty Point 34° 34.1167' N – 77° 23.1333'W;following the south shore of the river to Hatch Point 34° 33.1333' N – 77° 21.7833' W; and running southeasterly to ICWW Marker #2. All tributaries and that area west of a line beginning at a point near Stones Landing 34° 36.2043' N – 77°

26.3166' W; then following the danger area line for the Stone's Bay Rifle Range to a point on the east shore, 34° 37.0579' N – 77° 26.1124' W, shall remain closed. The area upstream of the Highway 172 Bridge closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b).

O. Intracoastal Waterway - from Marker #49 at Morris Landing to the Highway 210/50 Bridge at Surf City and 100 feet on either side of the ICWW. All bays, creeks and tributaries, including dredged canals will remain closed. (This area closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b).

P. New River Inlet - from ICWW Marker #72A to New River Inlet. All tributaries will remain closed.

III. Pender County

A. Intracoastal Waterway Channel only - from Highway 210/50 Bridge at Surf City to ICWW Marker #114, (Futch Creek). B. Sloop Point Area - that area from the ICWW marked channel to 100 feet either side of the ICWW channel between the Highway 210/50 Bridge at Surf City and Marker #93. All bays, creeks, and tributaries including dredged canals will remain closed.

C. Topsail Sound - from ICWW Marker #86 to Topsail Inlet.

D. Marker #98 Channel - main channel only, from ICWW Flasher #98 to New Topsail Inlet.

E. Green Channel - main channel only, from ICWW Marker #105 to Rich Inlet.

F. Nixon Channel - main channel only, from the ICWW to Rich Inlet.

G. Butler Creek - (Utley's Channel) - main channel only, from the ICWW north of Marker #112 to Nixon Channel.

H. That area west of the ICWW Channel from Marker #93 near Sloop Point to Marker #105 at Green's Channel, from the ICWW channel to the marsh line bordering the ICWW. All bays, creeks, and tributaries, including dredged canals will remain closedIV. New Hanover County

A. Intracoastal Waterway Channel only - from Marker #114 (Futch Creek) to Marker #163 at Snows Cut.

B. Mason Channel - main channel only, from the ICWW opposite the mouth of Page's Creek to Mason Inlet.

C. Carolina Beach Boat Basin - from ICWW Marker #161 to the municipal docks.

D. Stokley's Cut - (Old Moores Inlet Channel) - from the ICWW near Marker #125 to Old Moore Inlet, including the dredged basin. All tributaries to the channel and the basin will remain closed.

E. Lee's Cut (Spring Landing Channel) - from the Intracoastal Waterway to U.S. Highway 74 Bridge at Banks Channel, including the area known locally as "The Lagoon". All tributaries to the channel and lagoon will remain closed.

F. Banks Channel - from U.S. Highway #74 Bridge to Masonboro Inlet.

G. Mott Channel - from the ICWW near Marker #127 to Banks Channel, including the area known locally as the "The Borrow Pit" or "The Everett Hole" located adjacent to Mott Channel from Marker #22 to near Marker #26.

V. Brunswick County

A. Cape Fear River - all waters south of a line beginning at a point on the west shore 34° 04.6040'N –77° 56.4780' W; running easterly to a point on the east shore 34° 04.7920'N – 77°55.4740'W

Those areas south of a line beginning at a point on the south side of the Spoil Island at the intersection of the ICWW and the Cape Fear River Ship Channel at 34° 01.5780' N – 77° 56.0010' W, running easterly to a point on the east shore of the Cape Fear River 34° 01.7230' N – 77° 55.0101' W including those areas south of the area opened and east of the ICWW known as "Dow Chemical Bay: and "Radar Dome Bay", will remain closed.

B. Elizabeth River - main channel only, including Lower Dutchman Creek from the ICWW to the Cape Fear River. All tributaries of Elizabeth River and Dutchman Creek, that portion of Elizabeth River west of the ICWW Marker #7, and that portion of Dutchman Creek north of the ICWW will remain closed

C. Intracoastal Waterway Channel (ICWW) only - from Marker #1 (Southport) to the South Carolina State Line.

D. Eastern Channel (Montgomery Slough) - main channel only, from Blue Water Point Marina to Lockwoods Folly Inlet including the channel from ICWW Marker #36 to Blue Water Point Marina

E. Lockwoods Folly River Inlet Channel - from the ICWW to the Atlantic Ocean

F. Shallotte River Inlet - from the ICWW Marker #75 to the Atlantic Ocean.

G. Jinks Creek – from the ICWW to Tubb’s Inlet.

H. Bonaparte Creek - main channel only from the ICWW Marker #111 to Little River Inlet.

SH-6-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following restrictions will apply to shrimping and crab trawling effective at 5:00 P.M. Friday, May 14, 2004:

I. SUSPENSION OF RULE

The portion of the N.C. Fisheries Rules for Coastal Waters 15A NCAC 3R .0103 (15) (d), which reads "Mallard Bay Area, all waters northwest of the IWW from Beacon No. 93 34° 23' 54"N – 77° 36' 43"W; to Beacon No. 96 34° 22' 34N – 77° 38' 48"W." remains suspended.

II. PENDER COUNTY

The following portion of the ICW contained in the description above will remain open effective at 5:00 P.M., Friday, May 14, 2004: That area west of the ICW Channel from Marker #93 to Marker #96, from the ICW channel to the marsh line bordering the ICW. All bays, creeks, and tributaries, including dredged canals will remain closed.

SH-7-2004 PROCLAMATION

RE: SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas will close to shrimping and crab trawling effective one hour before sunset, Sunday, May 30, 2004:

NEW HANOVER/BRUNSWICK COUNTY

Carolina Beach Boat Basin - from Intracoastal Waterway Marker #161 to the Municipal Docks.

Intracoastal Waterway - Marker #1 at Southport to the South Carolina State line.

SH-11-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling, effective at 8:00 a.m., Tuesday, July 20, 2004:

BRUNSWICK COUNTY

Intracoastal Waterway (ICW) - main channel only, from Marker #1 at Southport to Marker #18, and main channel only, from Marker #71 behind Holden Beach to Marker #101 near Seaside.

SH-12-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following restrictions will apply to shrimping and crab trawling effective at 5:00 P.M. Friday, July 23, 2004:

I. SUSPENSION OF RULE

The portion of the N.C. Fisheries Rules for Coastal Waters 15A NCAC 3R .0103 (15) (d), which reads “Mallard Bay Area, all waters northwest of the IWW from Beacon No. 93 34° 23’ 54”N – 77° 36’ 43”W; to Beacon No. 96 34° 22’ 34N – 77° 38’ 48”W.” remains suspended.

II. PENDER COUNTY

The following portion of the ICW contained in the description above will remain open effective at 5:00 P.M., Friday, May 14, 2004: That area west of the ICW Channel from Marker #93 to Marker #96, from the ICW channel to the marsh line bordering the ICW. All bays, creeks, and tributaries, including dredged canals will remain closed.

SH-14-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL CLOSE to shrimping and crab trawling, effective at 5:00 p.m., Sunday, August 1, 2004:

BRUNSWICK COUNTY

Intracoastal Waterway (ICW) - main channel only, from Ocean Isle Beach Bridge to Marker #101 near Seaside.

SH-18-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL CLOSE to shrimping and crab trawling, effective at 5:00 p.m., Sunday, August 29, 2004:

BRUNSWICK COUNTY

Intracoastal Waterway (ICW) - from Marker #1 at Southport to Marker # 18.

SH-19-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling effective at 8:00 A.M., Friday, September 3, 2004.

ONSLOW COUNTY

New River - from the N.C. Highway 172 Bridge upstream to a line beginning at Hines Point 34° 36 .7833' N - 77° 23 .5833' W running to Low Point on the east shore 34° 36 .1333'N - 77° 23 .5000' W. That area west of a line beginning at a point near Stones Landing 34° 36.2043' N - 77° 26.3166' W, then following the danger area line for the Stone's Bay Rifle Range to a point on the east shore, 34° 37.0579' N - 77° 26.1124' W and all tributaries downstream of Hines Point will remain closed.

Chadwick Bay - all waters east and north of a line beginning on the north shore of Fullard Creek 34°

32 .2210' N - 77° 22 .8080' W running to Roses Point 34° 32 .2240' N - 77° 22 .2880' W then running to IWW Marker #6 with the exception of Bump's Creek and the dredged canal at Bayview.

SH-20-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling effective at 8:00 A.M., Tuesday, September 14, 2004.

ONSLOW/PENDER COUNTIES

New River - from the N.C. Highway 172 Bridge upstream to a line running from Gray Point 34° 37.5833' N - 77° 22.3833' W, running to a point on the east shore at 34° 37.1333' N - 77° 21.6333' W. That area west of a line beginning at a point near Stones Landing 34° 36.2043' N - 77° 26.3166' W, then following the danger area line for the Stone's Bay Rifle Range to a point on the east shore, 34° 37.0579' N - 77° 26.1124' W and all tributaries downstream of Gray Point will remain closed.

Intracoastal Waterway (ICW) - main ICW channel only from Marker #45 to Marker #49 and the ICW channel and 100 feet on either side from Marker #49 at Morris Landing to the Highway 210-50 Bridge at Surf City.

SH-23-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following restrictions will apply to shrimping and crab trawling effective at 5:00 P.M. Friday, October 15, 2004:

I. SUSPENSION OF RULE

The portion of the N.C. Fisheries Rules for Coastal Waters 15A NCAC 3R .0103 (15) (d), which reads "Mallard Bay Area, all waters northwest of the IWW from Beacon No. 93 34° 23' 54"N – 77° 36' 43"W; to Beacon No. 96 34° 22' 34N – 77° 38' 48"W." remains suspended.

II. PENDER COUNTY

The following portion of the ICW contained in the description above will remain open effective at 5:00 P.M., Friday, October 15, 2004: That area west of the ICW Channel from Marker #93 to Marker #96, from the ICW channel to the marsh line bordering the ICW. All bays, creeks, and tributaries, including dredged canals will remain closed.

SH-24-2004 PROCLAMATION

RE: 2004 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling, effective at 8:00 a.m., Wednesday, October 20, 2004:

ONSLOW COUNTY

Intracoastal Waterway (ICW) - main ICW channel only from the N.C. Highway 210 high rise bridge to Marker #17 north of Alligator Bay.

BRUNSWICK COUNTY

Intracoastal Waterway (ICW) - main channel only, from the Ocean Isle Beach Bridge to Marker #101 near Seaside.

SH-25-2004 PROCLAMATION

RE: SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling effective at 8:00 A.M., Friday November 12, 2004:

I. AREA DESCRIPTION

A. NEW HANOVER COUNTY

Carolina Beach Boat Basin - from ICW Marker #161 to the municipal docks.

B. BRUNSWICK COUNTY

Carolina Power And Light By-Pass Channel - dredged canal north of the Intracoastal Waterway (ICW) from the waterway to the Wildlife boat ramp and the dredged portion of Piney Point Creek south of the Intracoastal Waterway. ALL TRIBUTARIES OF THE CANALS WILL REMAIN CLOSED.

Intracoastal Waterway – main channel only from Marker # 1 at Southport to Marker # 71 and main channel only, from the Ocean Isle Beach bridge to the South Carolina State line.

Calabash River - south of a line beginning at a point on the south shore at 33° 53.1500’ N - 78° 33.8500' W, running to a point on the north shore at 33° 53.1500' N - 78° 33.6500' W.

2005 NCDMF Proclamations for shrimp and crab trawling

SH-2-2005 PROCLAMATION

RE: SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that effective at 12:01 A.M., Sunday, May 1, 2005, all coastal waters south of Marker #45 near Bogue Inlet to the South Carolina line will close to shrimping and crab trawling, except the following areas, which will remain open until further notice:

AREA DESCRIPTIONS - SOUTHERN DISTRICT:

I. ATLANTIC OCEAN

II. Onslow County

A. Bogue Inlet Channel - (Map 1)

B. Intracoastal Waterway Channel (ICWW) ONLY - from Bogue Inlet to Marker #45 at Swansboro (Map 1)

C. Intracoastal Waterway - channel only from Marker #45 at Swansboro to Marker #63 south of Brown's Inlet.(Maps 1 & 2)

D. West Channel - (Island Channel) - main channel only from ICWW Buoy#47A to ICWW Marker #45B. (Map 1)

E. West Channel - main channel only from ICWW Marker #48 to Bogue Inlet. (Map 1)

F. Banks Channel - main channel only from Bogue Inlet to Bear Inlet. (Maps 1 & 2)

G. Saunders Creek - main channel only from ICWW Marker #55 to Bear Inlet. (Map 2)

H. Bear Creek - from the ICWW to Bear Inlet (Map 2)

I. Muddy Creek - main channel only, from Bear Creek to Saunders Creek. (Map 2)

J. Shacklefoot Channel - from ICWW Marker #59 to Bear Inlet including the area known locally as the "Horseshoe". (Map 2)

K. Uniflite Boat Basin - dredged portion only, from ICWW near Marker #55 to the upstream end of the dredged portion. (Map2)

L. Brown's Inlet area - main channels only, from ICWW Markers #61 and #63 to the Inlet. (Map2)

M. Intracoastal Waterway - channel only from Marker #63 south of Brown's Inlet to Marker #49 at Morris Landing. [The area between Marker #17 north of Alligator Bay to the Surf City bridge closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b)]. (Maps 2,3 & 4)

N. New River - that area downstream from a line running from Gray Point 34° 37.6373' N – 77° 22.3605' W, running southeasterly to a point on the east shore 34° 37.1622' N – 77° 21.5527' W. Also, the area downstream from the Highway 172 Bridge bounded on the north by a line beginning near Pollocks Point 34° 34.9167' N – 77° 23.9500' W; running southeasterly to Jarretts Point 34° 34.6333' N – 77° 22.9167' W; running southeasterly to Wilkins Bluff 34° 34.2333' N – 77° 21.6500' W; running southwesterly to a point on the north side of the marked navigation channel 34° 33.9500' N – 77° 21.8833' W, across from Marker #17; running along the north side of the channel to the ICWW; and bounded on the south by a line beginning at the N.C. Highway 172 Bridge 34° 34.6333' N – 77° 23.9500' W; running easterly to Ferry Point 34° 34.0000' N – 77° 23.8167' W; running southeasterly to Poverty Point 34° 34.1167' N – 77° 23.1333'W; following the south shore of the river to Hatch Point 34° 33.1333' N – 77° 21.7833' W; and running southeasterly to ICWW Marker #2. All tributaries and that area west of a line beginning at a point near Stones Landing 34° 36.2043' N – 77° 26.3166' W; then following the danger area line for the Stone’s Bay Rifle Range to a point on the east shore, 34° 37.0579' N – 77° 26.1124' W, shall remain closed. The area upstream of the Highway 172 Bridge closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b). (Map 3)

O. Intracoastal Waterway - from Marker #49 at Morris Landing to the Highway 210/50 Bridge at Surf City and 100 feet on either side of the ICWW. All bays, creeks and tributaries, including dredged canals will remain closed. (This area closes on May 15 by Marine Fisheries Rule 15A NCAC 3N .0105(b). (Map 4)

P. New River Inlet - from ICWW Marker #72A to New River Inlet. All tributaries will remain closed. (Map 3)

III. Pender County

A. Intracoastal Waterway Channel only - from Highway 210/50 Bridge at Surf City to ICWW Marker #114, (Futch Creek). (Maps 4 & 5)

B. Sloop Point Area - that area from the ICWW marked channel to 100 feet either side of the ICWW channel between the Highway 210/50 Bridge at Surf City and Marker #93. All bays, creeks, and tributaries including dredged canals will remain closed. (Map 4)

C. Topsail Sound - from ICWW Marker #86 to Topsail Inlet. (Map 4)

D. Marker #98 Channel - main channel only, from ICWW Flasher #98 to New Topsail Inlet. (Map 5)

E. Green Channel - main channel only, from ICWW Marker #105 to Rich Inlet. (Map 5)

F. Nixon Channel - main channel only, from the ICWW to Rich Inlet. (Map 5)

G. Butler Creek - (Utley's Channel) - main channel only, from the ICWW north of Marker #112 to Nixon Channel. (Map 5)

H. That area west of the ICWW Channel from Marker #93 near Sloop Point to Marker #105 at Green's Channel, from the ICWW channel to the marsh line bordering the ICWW. All bays, creeks, and tributaries, including dredged canals will remain closed. (Maps 4 & 5)

IV. New Hanover County

A. Intracoastal Waterway Channel only - from Marker #114 (Futch Creek) to Marker #163 at Snows Cut. (Maps 5 & 6)

B. Mason Channel - main channel only, from the ICWW opposite the mouth of Page's Creek to Mason Inlet. (Map 5)

C. Carolina Beach Boat Basin - from ICWW Marker #161 to the municipal docks (Map 6).

D. Stokley's Cut - (Old Moores Inlet Channel) - from the ICWW near Marker #125 to Old Moore Inlet, including the dredged basin. All tributaries to the channel and the basin will remain closed. (Map 5)

E. Lee's Cut (Spring Landing Channel) - from the Intracoastal Waterway to U.S. Highway 74 Bridge at Banks Channel, including the area known locally as "The Lagoon". All tributaries to the channel and lagoon will remain closed. (Map 5)

F. Banks Channel - from U.S. Highway #74 Bridge to Masonboro Inlet. (Map 5)

G. Mott Channel - from the ICWW near Marker #127 to Banks Channel, including the area known locally as the "The Borrow Pit" or "The Everett Hole" located adjacent to Mott Channel from Marker #22 to near Marker #26. (Map 5)

V. Brunswick County

A. Cape Fear River - all waters south of a line beginning at a point on the west shore 34°04.6040’N 77°56.4780’W; running easterly to a point on the east shore 34°04.7920’N - 77°55.4740’W. (Maps 6 & 7)

Those areas south of a line beginning at a point on the south side of the Spoil Island at the intersection of the ICWW and the Cape Fear River Ship Channel at 34° 01.5780' N – 77° 56.0010' W, running easterly to a point on the east shore of the Cape Fear River 34° 01.7230' N – 77° 55.0101' W including those areas south of the area opened and east of the ICWW known as "Dow Chemical Bay: and "Radar Dome Bay", will remain closed.

B. Elizabeth River - main channel only, including Lower Dutchman Creek from the ICWW to the Cape Fear River. All tributaries of Elizabeth River and Dutchman Creek, that portion of Elizabeth River west of the ICWW Marker #7, and that portion of Dutchman Creek north of the ICWW will remain closed. (Map 7)

C. Intracoastal Waterway Channel (ICWW) only - from Marker #1 (Southport) to the South Carolina State Line. (Maps 7, 8, 9 & 10)

D. Eastern Channel (Montgomery Slough) - main channel only, from Blue Water Point Marina to Lockwoods Folly Inlet including the channel from ICWW Marker #36 to Blue Water Point Marina. (Map 8)

E. Lockwoods Folly River Inlet Channel - from the ICWW to the Atlantic Ocean. (Map 8)

F. Shallotte River Inlet - from the ICWW Marker #75 to the Atlantic Ocean. (Map 9)

G. Jinks Creek – from the ICWW to Tubb's Inlet. (MAP 10)

H. Bonaparte Creek - main channel only from the ICWW Marker #111 to Little River Inlet. (Map 10)

VI. GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182;113-221.1(b); 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103; 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Marine Fisheries Rule15A NCAC 3H .0103.

C. Shellfish Management Areas which have been designated by proclamation are closed to the use of trawl nets, longhaul seines, and swipe nets.

D. Hatched areas on the attached maps indicate those areas closed to shrimping and crab trawling.

E. All other rivers, bays, creeks, and tributaries of those areas opened to trawling will remain closed.

F. The Division of Marine Fisheries will mark the areas to be opened with signs insofar as may be practicable. No unauthorized removal or relocation of any such sign shall have the effect of changing the area opened, nor shall any such unauthorized removal or relocation or the absence of any sign affect the applicability of any proclamation pertaining to any such body of water or portion thereof. Where there is conflict between signs and maps, maps shall prevail.

SH-6-2005 PROCLAMATION

RE: 2005 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following restrictions will apply to shrimping and crab trawling effective at 12:00 Noon, Friday, July 1, 2005:

I. SUSPENSION OF RULE

The portion of the N.C. Fisheries Rules for Coastal Waters 15A NCAC 3R .0103 (15) (d), which reads "Mallard Bay Area, all waters northwest of the IWW from Beacon No. 93, 34° 23' 54"N – 77° 36' 43"W; to Beacon No. 96 34° 22' 34N – 77° 38' 48"W." remains suspended.

II. PENDER COUNTY

The following portion of the ICW contained in the description above will remain open effective at 12:00 Noon, Friday, July 1, 2005: That area west of the ICW Channel from Marker #93 to Marker #96, from the ICW channel to the marsh line bordering the ICW. All bays, creeks, and tributaries, including dredged canals will remain closed.

III. GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182; 113-221.1(b); 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103, 3I .0102, 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Fisheries Rule15A NCAC 3H .0103.

C. This action is being taken to enable the reopening of an area that has been designated as a nursery area, but has been routinely opened since 1984. A process to remove that designation, which is no longer valid, is underway. This proclamation supersedes portions of Proclamation SH-2-2005, dated April 27, 2005 that pertain to the areas described above and SH-4-2005, dated June 24, 2005.

SH-7-2005 PROCLAMATION

RE: 2005 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following area WILL OPEN to shrimping and crab trawling, effective at 8:00 a.m., Wednesday, July 13, 2005:

BRUNSWICK COUNTY

Intracoastal Waterway (ICW) - Main channel only, from Marker #1 at Southport to Marker # 101 at Seaside.

GENERAL INFORMATION:

A) This proclamation is issued under the authority of G.S. 113-182; 113-221 (e); 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103; 3L .0101 and .0202.

B) It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per 15A NCAC 3H .0103.

C) This proclamation supersedes portions of SH-4-2005, dated June 242005 that closed the above area.

SH-11-2005 PROCLAMATION

RE: SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas will open to shrimping and crab trawling effective at 8:00 A.M. Wednesday, August 17, 2005:

ONSLOW COUNTY

Intracoastal Waterway (ICW) – Main ICW channel only from Marker #17 north of Alligator Bay to Marker #49 at Morris Landing and the ICW channel and 100 feet on either side from Marker #49 to the Highway 210-50 bridge at Surf City.

GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182; 113-221.1; 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103; 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Marine Fisheries Rule 15A NCAC 3H .0103.

C. This action is being taken to allow harvest of shrimp in the area.

SH-13-2005 PROCLAMATION

RE: 2005 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas will close to shrimping and crab trawling, effective at 5:00 p.m., Sunday, August 21, 2005:

BRUNSWICK COUNTY

Cape Fear River - north of a line beginning at a point on the east shore of the Cape Fear River at the Fort Fisher Slip 33° 57.7167' N – 77° 56.4000' W; then running northwesterly to a point on the north end of Horseshoe Shoal spoil island 33° 58.0667' N – 77° 57.3333' W; then running along the eastern edge of the spoil island to a point on the south end of Horseshoe Shoal spoil island 33° 57.1167' N – 77° 58.0500' W; then running southwesterly to the middle of the Pfizer Chemical Company Pier, 33° 56.0500' N – 77° 59.1667' W. (See Map 1)

Intracoastal Waterway - from Marker #1 to Marker # 71A.

GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113-170.5; 113-182; 113-221.1; 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103; 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Marine Fisheries Rule15A NCAC 3H .0103.

C. This action is being taken to protect small white shrimp.

D. This proclamation supersedes portions of SH-2 -2005 dated April 27, 2005 and SH-7-2005 dated July 8, 2005 which opened these areas.

SH-15 2005 PROCLAMATION

RE: 2005 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL CLOSE to shrimping and crab trawling effective at 7:00 A.M., Friday, September 2, 2005.

AREA DESCRIPTION

A. ONSLOW COUNTY

Intracoastal Waterway (ICW) - from the N.C. Highway 210 highrise bridge to Marker #45.

II. GENERAL INFORMATION:

A. This proclamation is issued under the authority of N.C.G.S. 113-170.4; 113-170.5; 113-182; 113-221.1; 143B-289.52 and N.C. Marine Fisheries Rules 15A NCAC 3H .0103, 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per N.C. Marine Fisheries Rule 15A NCAC 3H .0103.

C. This action is being taken to protect small white shrimp in the area.

D. This proclamation supersedes portions of SH-11 2005 dated August 12, 2005, which opened these areas.

SH-19-2005 PROCLAMATION

RE: 2005 SHRIMPING AND CRAB TRAWLING

Preston P. Pate, Jr., Director, Division of Marine Fisheries, hereby announces that the following areas WILL OPEN to shrimping and crab trawling effective at 8:00 A.M., Friday, November 11, 2005.

ONSLOW / NEW HANOVER / BRUNSWICK COUNTIES

Intracoastal Waterway – main channel only from the Highway 210 high rise bridge to Marker # 45.

Carolina Beach Boat Basin - from Intracoastal Waterway Marker #161 to the Municipal Docks.

Cape Fear River - those areas south of a line beginning at a point on the west side of Silt Island 34° 00.2000' N - 77° 56.2833' W, running 277° (M) through Marker #30 to a point on the west side of the Cape Fear River at 34° 00.2000' N - 77° 57.3500' W. Those areas known as the Junkyard, By-Pass, Triangle, Sugarloaf, Dow Chemical Bay and Radar Dome Bay, will remain closed.

Intracoastal Waterway – main channel only from Marker #1 at Southport to the Oak Island Bridge and from the Holden Beach Bridge to Marker #71A.

GENERAL INFORMATION:

A. This proclamation is issued under the authority of G.S. 113-170.4; 113.170.5; 113-182; 113-221.1; 143B-289.52 and Marine Fisheries Rules 15A NCAC 3H .0103, 3L .0101 and .0202.

B. It is unlawful to violate the provisions of any proclamation issued by the Fisheries Director under his delegated authority per Marine Fisheries Rule 15A NCAC 3H .0103.