

REDUCING SEA TURTLE DAMAGE TO CRAB  
POTS USING A LOW-PROFILE POT DESIGN  
IN CORE SOUND, NORTH CAROLINA

by

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## ABSTRACT

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The blue crab (*Callinectes sapidus*) supports North Carolina's most valuable commercial fishery; the value of hard blue crabs landed in 2000 was over \$30 million dollars. This lucrative fishery may be adversely affected by loggerhead sea turtles (*Caretta caretta*), which are listed as threatened under the Endangered Species Act of 1973. Crabbers in Core Sound, North Carolina, report that sea turtle damage to crab pots has become an increasingly serious issue. Turtles damage crab pots by overturning them while trying to get the bait, tearing up the bottoms and sides of the pots; this damage results in higher gear replacement costs and losses in crab catch. Experimental fishing was conducted to test for differences in crab catch and pot damage using three types of crab pots: low-profile, square mesh, and hexagonal mesh. The hexagonal mesh pot is the most common pot type used by crabbers in Core Sound, and the low-profile pot was designed to reduce the sea turtles' ability to overturn the pots. The number and size of all crabs caught in the experimental pots were recorded. An analysis of variance (ANOVA) was used to analyze the relationship between number of crabs caught per pot and the effect of pot type, location, date, the interaction of date and location, and the interaction of pot type and location. Tukey-Kramer multiple comparison tests were used to determine significant differences among treatments. There was no significant difference in crab catch between the low-profile and the square mesh pots at any of the three experimental fishing locations. There was a significant difference in catch between the low-profile and hexagonal mesh pots at one location. The low-profile pots sustained considerably less damage than both the square mesh and hexagonal mesh pot types. In interviews with 19 Core and Pamlico Sound crabbers, crabbers estimated that 62% of all crab pot damage, and 37% of lost crab catch, is due to sea turtle damage. The low-profile crab pot has the potential to improve this situation by allowing crabbers to maintain crab catch with a reduction in gear replacement costs.

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## 1. INTRODUCTION

A widely diverse group values both sea turtles and blue crabs (*Callinectes sapidus*) in North Carolina. These constituents can be divided into direct users and indirect users. Direct users include recreational and commercial crabbers, crab dealers, crab pot sellers, restaurants, and consumers; in 1997, approximately 5,000 individuals were directly engaged in blue crab harvesting activities in North Carolina (Blue Crab FMP 1998). People who use North Carolina water bodies recreationally and derive aesthetic value from the presence of sea turtles are also direct users. Indirect users include numerous non-profit organizations dedicated to sea turtle conservation, and any other special interest group or individual that believes sea turtles have existence value. Both sea turtles and blue crabs are valued culturally in eastern North Carolina.

Although a substantial turtle fishery flourished in the United States in the late 1800's, all seven species of sea turtles are now protected under the Endangered Species Act of 1973 (ESA) (Witzell 1994). However, the role of sea turtles has changed over the years, while blue crabs have been harvested in Core Sound since 1900 (Robinson 1970). Because North Carolina sounds and rivers provide habitat for both blue crabs and sea turtles, the interaction of these species is expected. Crabbers in Core Sound report that sea turtles are damaging crab pots, resulting in lost crab catch and increased gear replacement costs. This issue is unique because a federally protected species is adversely affecting a commercially valuable fishery; a possible solution may lie in the development of modified gear.

## **1.1 The blue crab fishery in North Carolina**

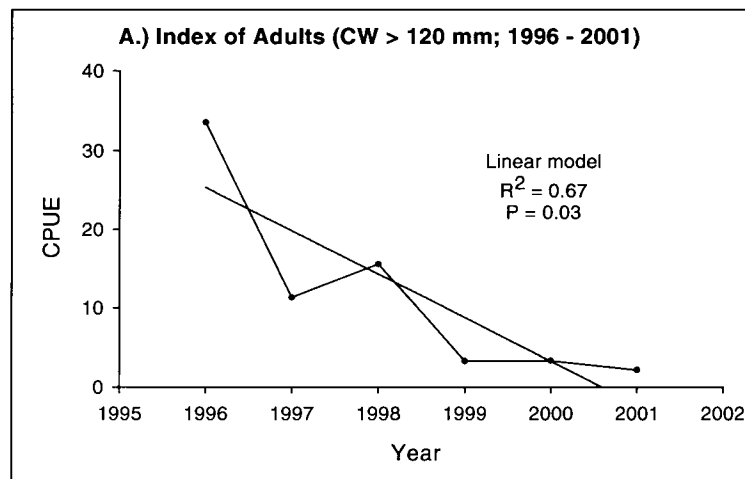
Blue crabs use many different habitats during their larval migrations from high-salinity ocean waters to the lower-salinity and freshwaters of North Carolina sounds, rivers, and creeks where they settle and grow (NCDMF 2001). Blue crabs are most commonly found in tidal marsh estuaries characterized by soft mud substrate and waters of moderate salinity (Blue Crab FMP 1998). Small blue crabs move into the marsh creeks and remain there until the following spring, when these juvenile crabs move into the sounds where they remain until maturity. From May to October, mature females congregate in high salinity waters such as river mouths, inlets, and along ocean beaches to spawn (Dudley & Judy 1973).

Blue crabs are most common in the U.S. from Long Island to Mexico, and are harvested both commercially and recreationally throughout their range (Blue Crab FMP 1998); the commercial gear type most commonly used in North Carolina waters are crab pots, which account for 95% of the total hard crab harvest (Blue Crab FMP 1998). The crab pot was developed in the Chesapeake Bay in 1928, and the first reported landings from crab pots in North Carolina were in 1953 (Blue Crab FMP 1998). Crab pots are divided into a lower chamber and an upper chamber, with four funnel entrances at the bottom of the pot. The smell of the bait attracts crabs to the pot, and once they are in the lower chamber, the crab pot design utilizes the natural response of crabs to move upward when trapped. Once crabs are in the upper chamber of the crab pot, it is nearly impossible for them to escape (Hart & Bahen 1980).

The peak months for crab pot landings are May through October (91% of the total landings), and the major water bodies for pot-caught crabs from 1994 to 1997 were Pamlico Sound (26%), Albemarle Sound (25%), the Pamlico River (13%), the Neuse River (7%), and the Bay River (5%) (Blue Crab FMP 1998). The blue crab fishery is the most valuable commercial

fishery in North Carolina (Henry & McKenna 1998); the value of hard blue crabs landed in 2000 was over \$30 million dollars (NCDMF 2001). However, loggerhead sea turtles (*Caretta caretta*) may be adversely affecting this lucrative fishery.

Sea turtle damage, recent decreases in blue crab numbers, and increased pressure in the form of more crabbers have stressed the industry. According to the Blue Crab FMP (1998), crab numbers may be down due to poor growth, survival, and recruitment after the hurricanes of 1999, although fishing capacity was already too high before that. The number of crab pots used in North Carolina from 1983 to 1993 increased by 98% (Henry & McKenna 1998), while the number of adult crabs (larger than five inches) caught from 1996 to 2001 decreased dramatically (Figure 1.1) (David Eggleston, NCSU, unpub. data).



**Figure 1.1**—Decline in adult blue crabs caught from 1996-2001 (from David Eggleston, NCSU, unpub. data).

## **1.2 Loggerhead sea turtles**

### **1.2.1 Status**

Loggerhead sea turtles have been listed as threatened under the Endangered Species Act (ESA) since 1978; a threatened species is defined as “any species which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.” In addition, Section 9 of the ESA makes it unlawful for a person to “take” a listed species; the “term take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect or attempt to engage in any such conduct” (FWS 2001). Loggerheads are also considered “endangered” by the World Conservation Union (IUCN) and are listed in Appendix I of the Convention on International Trade in Endangered Species Flora and Fauna (CITES) (STRP 2002). The loggerheads found in North Carolina are part of the northern subpopulation, which extends to the northeast coast of Florida. This population is stable or decreasing, based on the most recent National Marine Fisheries Service (NMFS) assessment (NMFS 2002). In January 2002, the Sea Turtle Restoration Project of the Turtle Island Restoration Network along with the Center for Biological Diversity formally petitioned NMFS and the U.S. Fish and Wildlife Service (FWS) to list the northern and Florida panhandle subpopulations as endangered species. The petition states that “the northern subpopulation has declined dramatically over the past 20 years” (STRP 2002). Both nesting and aerial surveys support these claims; there has been an average 3.2% per year decline in nests from 1973 to 1995 at one South Carolina nesting site, and aerial surveys reveal that overall nesting in the state declined by 26.4% over a five-year period. This decline in nesting is indicative of a decreasing northern subpopulation of loggerheads (STRP 2002).



### 1.2.2 Feeding ecology

Loggerheads are primarily carnivorous and feed on a wide variety of prey (Dodd 1988). Mollusks are the most common prey eaten (Plotkin *et al.* 1993), and are easily crushed by the loggerheads' substantial jaw muscles (Hendrickson 1980). Post-pelagic-stage loggerheads feed throughout the water column, but concentrate their foraging efforts on the bottom, becoming benthic foragers at about 40-50 cm carapace width (Bjorndal 1996). Adult loggerheads are primarily bottom feeders (Dodd 1988). Two quantitative analyses of loggerhead feeding habits found that crabs are an important part of the loggerheads' diet. In New York, crabs were the primary dietary component of loggerheads; over 90% of both Kemp's ridley (*Lepidochelys kempfi*) and loggerhead sea turtles consumed crabs (Burke *et al.* 1993). In Texas, crabs were the second most important prey item (Plotkin *et al.* 1993).

In North Carolina, loggerheads use the sounds and rivers as a benthic feeding habitat, feeding primarily on crustaceans, mollusks, and fish. Although Burke *et al.* (1993) state that "dietary habits cannot be extrapolated from one region to another," it is likely that loggerheads in Core Sound are foraging on blue crabs. Although no studies of loggerhead stomach contents in Core Sound have been published (Joanne Braun-McNeill, NMFS, pers. com. 2001), stable isotope research suggests that loggerheads are feeding on blue crabs in Core Sound. Researchers using stable isotope ratios to estimate age from growth layers of loggerhead humeri recently discovered a change in the layering pattern. The three distinct layering zones are thought to correspond to the turtles' transition from a pelagic to a benthic stage. In turtles between 47 and 68 cm straight carapace length (SCL), it is possible to identify the exact growth layer in the bone where the transition occurs, or the settlement line. The greater thickness of the growth layers external to the settlement line suggests an increase in growth rates after the turtles switch to a

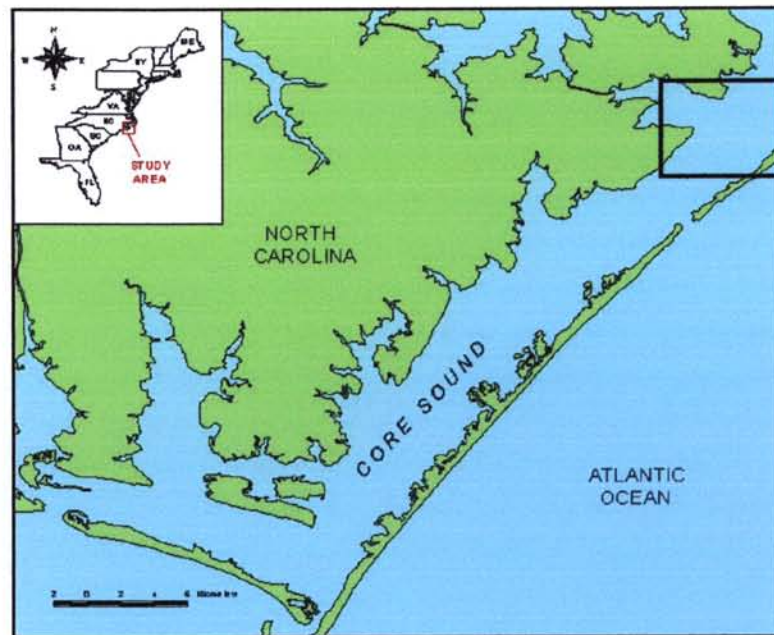
benthic diet. The bone tissue outside of the settlement line has stable isotope ratios that are consistent with feeding on benthic species, such as blue crabs (Snover *et al.* 1999).

### **1.2.3 Abundance in Core Sound**

Crabbers are primarily concerned with loggerheads because they are the most abundant sea turtle species in Core Sound (Epperly *et al.* 1995). According to crabbers, loggerheads also cause more serious damage to crab pots than green (*Chelonia mydas*) and Kemp's ridley sea turtles. Based on incidental captures by commercial fishermen, loggerheads are the most abundant species in Core and Pamlico Sounds (80%), followed by green (15%) and Kemp's ridley sea turtles (5%) (Epperly *et al.* 1995). Core Sound had the highest percentage of sea turtles sighted by recreational fishermen interviewed during the Marine Recreational Fishery Statistics Survey (MRFSS) conducted from 1989 to 1992, as well as the highest percentage of public sightings of sea turtles in North Carolina inshore and offshore waters (a total of 380 sightings from 1989 to 1992; the next highest was Pamlico Sound with 149 sightings). Turtles were observed in inshore waters from April to December, and sightings generally peaked in May and June. Core Sound (60%), Pamlico Sound (23%), and Bogue Sound (9%) accounted for the majority of inshore sightings. Turtles appeared to move into nearshore and inshore waters as temperatures increased in the spring, and moved to the offshore waters as temperatures decreased in late fall and early winter. The abundance of immature sea turtles in North Carolina inshore waters demonstrates the importance of Core Sound as habitat for several species of sea turtles (Epperly *et al.* 1995).

### 1.3 Description of the study site: Core Sound, NC

Core Sound is part of the Pamlico-Albemarle estuarine complex, which is one of the largest and most productive estuarine systems in North America (Epperly & Ross 1986) (Figure 1.2).



**Figure 1.2**—Map of the study site, Core Sound, North Carolina, with experimental fishing location outlined in black (courtesy of Larisa Avens).

Core Sound connects with the Atlantic Ocean through Barden and Drum Inlets, and is bordered by Pamlico Sound to the north and Back Sound to the south. Core Sound is a shallow water body, and experiences little freshwater inflow (Epperly & Ross 1986); the sound covers approximately 2,270 hectares and averages approximately 2 meters in depth (Dudley & Judy 1973). Salinity decreases with increasing distance from the inlets; Core Sound and eastern Pamlico Sound are polyhaline (18-30 o/oo). The shoreline around Core, Pamlico, Roanoke, and Croatan Sounds is composed of marsh grasses (*Spartina* and *Juncus*), while upland and swamp forests are more prevalent around Albemarle Sound (Epperly & Ross 1986).

The Pamlico-Core Sound area is the major inshore fishery producing area in North Carolina. Commercial fisheries landings are dominated by annual invertebrate species, such as blue crabs, which often exhibit extreme population size variations. Therefore, fishery production from the Pamlico-Core Sound area may vary annually (Epperly & Ross 1986); this uncertainty in fishery production is important to consider when developing new gear technologies to address sea turtle damage.

#### **1.4 The interaction of loggerhead sea turtles and the blue crab fishery**

The issue of sea turtles damaging crab pots was brought to the attention of researchers by a local crabber, Joe Benevides. Benevides constructed a low-profile pot designed to reduce the amount of turtle damage by hindering the sea turtles' ability to overturn the crab pots. Sea turtles damage crab pots primarily by overturning the pots while trying to get to the bait, tearing up the bottoms and sides of the pots. The objective of this study was twofold: (1) to determine, through experimental fishing, if a low-profile crab pot would reduce turtle damage without compromising crab catch; and (2) to determine the extent and magnitude of the problem through interviews with Core and Pamlico Sound crabbers.

## 2. EXPERIMENTAL FISHING

### 2.1 Methods

Experimental fishing was conducted on 29 days from June 6, 2001 to July 27, 2001. Fishing was conducted on a 23-foot commercial fishing boat, out of Atlantic, NC; shad and pinfish were commonly used as bait. Three types of crab pots, low-profile, square mesh, and hexagonal mesh (Table 2.1, Figures 2.1-2.3), were used to test for differences in crab catch and crab pot damage. The hexagonal mesh pot is the most common pot type used by commercial crabbers in Core Sound. Modeled after a lobster pot, the low-profile pot is compartmentalized lengthwise, has three funnel entrances rather than four, and has a bait well that extends to the top of the pot.

**Table 2.1**—Description of the three pot types used during experimental fishing.

Pot Type	Dimension (cm)	Wire Gauge Size
Low-profile	86.4 x 61.0 x 34.3	12.5
Square mesh	61.0 x 61.0 x 53.3	17
Hexagonal mesh	55.9 x 61.0 x 48.3	18



**Figure 2.1**—Low-profile pot.



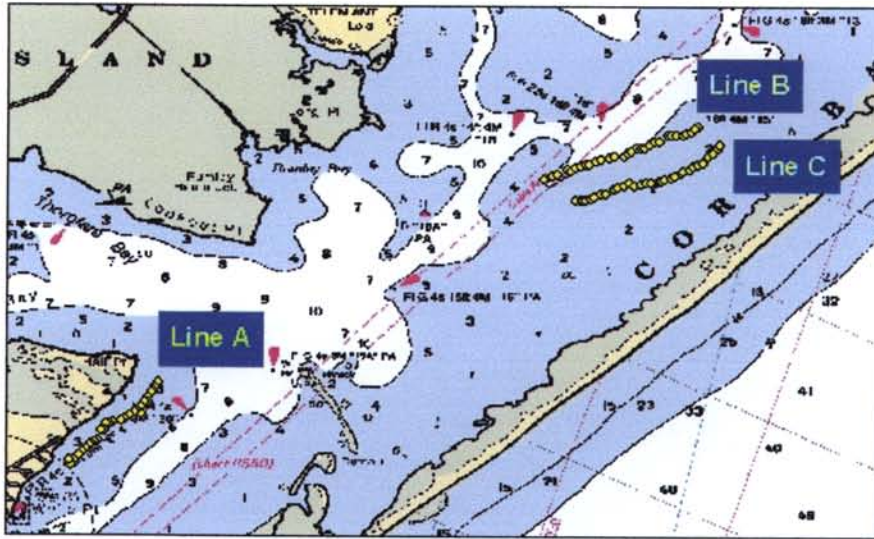
**Figure 2.2**—Square mesh pot.



**Figure 2.3**—Hexagonal mesh pot.

The experimental design consisted of three lines of crab pots in different areas of Core Sound (lines A, B, and C), with 30 crab pots in each line (Figure 2.4). Each line consisted of 10 pots of each type, in the repeating order of low-profile, square mesh, and hexagonal mesh. The size, sex, and number of all crabs caught in the experimental pots were recorded. Crab catch was

defined as the mean number of legal size crabs per pot, as commercial fishermen are most interested in this crab population. Legal crabs are all mature females, and males with a carapace width equal to or greater than five inches.



**Figure 2.4**—Map showing the location of experimental crab pots (created by Scott Chappell). Line A was located here from July 3 to July 27, 2001.

The line A pots were fished for the first time on June 6, 2001, the line B pots were fished for the first time on June 12, 2001, and the line C pots were fished for the first time on June 25, 2001. Due to low catch levels, line A was moved on July 3, 2001; the line A data presented here were obtained from the second location. Data for these analyses were used from 17 days starting on June 25, 2001, as this was the first day that at least two lines of pots were fished. An analysis of variance (ANOVA) was used to analyze the relationship between crab catch and the effect of pot type, location, date, the interaction of date and location, and the interaction of pot type and location. Tukey-Kramer multiple comparison tests were used to determine significant differences among treatments; tests were performed on all of the data as well as individually for each line. The Tukey-Kramer multiple comparison tests for individual lines were based on an

ANOVA that only included date and pot type as parameters. Data were transformed by log (x+1) due to the non-normality of the data and the high number of zero counts. All statistical analyses were conducted with S-plus 2000 software.

The experimental pots were all new at the outset of the experiment, to provide a baseline for collecting data on the amount of sea turtle damage. We were able to record crab pot damage on 22 of the 29 fishing days, and on the final fishing day we assigned each pot a value according to a damage index (Table 2.2).

**Table 2.2**—Damage index used to measure pot damage.

<b>Damage Rating</b>	<b>Description</b>
1	No damage
2	Minimal damage (e.g., bite marks on vinyl coating)
3	Bent wires, pot dented on bottom
4	Broken wires
5	Maximum damage (e.g., loose bait wells)

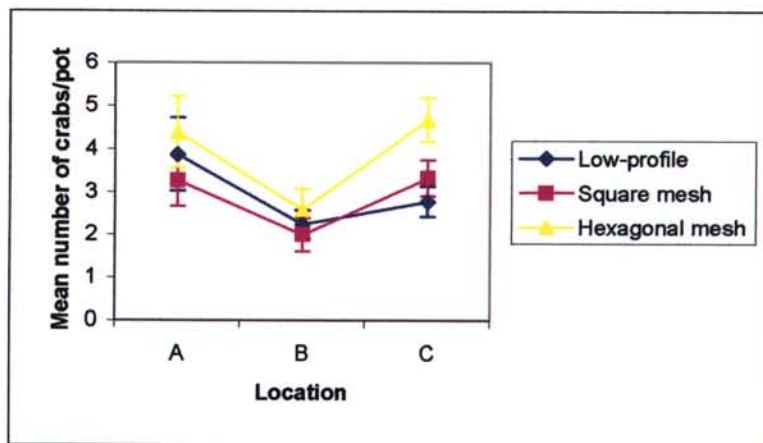
## **2.2 Results**

The results of the ANOVA allow us to conclude that pot type ( $p=0.001$ ), line location ( $p<0.001$ ), date ( $p<0.001$ ), and the interaction of date and location ( $p<0.001$ ) have a significant effect on crab catch at the  $\alpha=0.05$  level (Table 2.3). The isolated pot effect shows that within a line, crab catch varies with pot type ( $p=0.007$ ) (Figure 2.5). The low R-squared value suggests that other factors, such as environmental variability, affect crab catch but were not included in the ANOVA model. Tukey-Kramer multiple comparison tests for all lines combined show no difference in crab catch between the low-profile and square mesh pots, but a significant decrease in crab catch for the low-profile relative to the hexagonal mesh pots.

**Table 2.3**—ANOVA for log (x+1) of mean number crabs per pot, per day.

Source of Variation	Sum of Squares	d.f.	Mean Square	F-statistic	p-value
Line	49.82	2	24.91	49.66	<0.0001
Day	42.10	16	2.63	5.24	<0.0001
Pot	9.24	2	4.62	9.21	0.0001
Day:line	74.85	26	2.88	5.74	<0.0001
Pot:line	7.17	4	1.79	3.57	0.007
Total	183.18	50			

$R$ -squared = 22.44%, adj.  $R$ -squared = 19.38, Estimated SD = 0.71



**Figure 2.5**—Graph of legal size crab catch, showing the interaction of pot type and location.

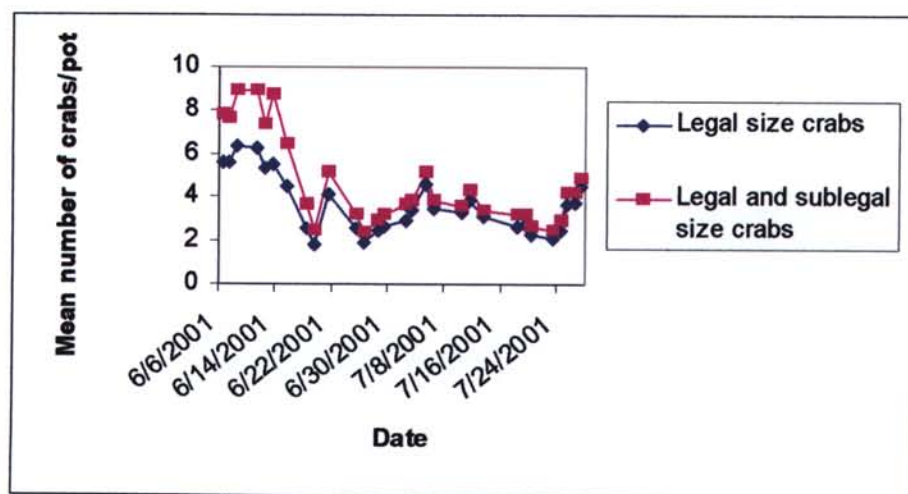
When lines were examined independently, Tukey-Kramer tests for lines A and B show no significant catch difference between the low-profile pot and any other pot type. The Tukey-Kramer test for line C shows no difference in crab catch between the low-profile and square mesh pots, but a significant decrease in crab catch for the low-profile relative to the hexagonal mesh pots (Figure 2.6). Although average crab catch in line A (3.86 crabs per pot) was similar to the high catch levels seen in line C (3.60 crabs per pot), there was no significant difference in catch between any of the pot types in line A. This suggests that variations in the level of crab catch cannot be explained by pot type alone.



<b>Line A</b>	Square mesh	Low-profile	Hexagonal mesh
<b>Line B</b>	Square mesh	Low-profile	Hexagonal mesh
<b>Line C</b>	Square mesh	Low-profile	Hexagonal mesh

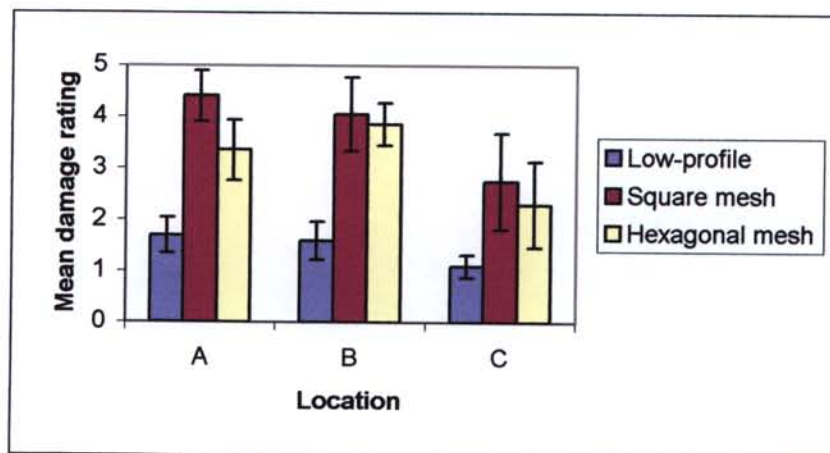
**Figure 2.6**— Results of Tukey-Kramer multiple comparison tests. Lines indicate no significant difference in crab catch between pot types.

The legal catch was an accurate representation of the total crab catch; there was little difference between the total catch per day and the legal catch per day (Figure 2.7). The mean size of the crabs caught in the low-profile pots ( $5.07\pm 0.74$ ), square mesh pots ( $5.16\pm 0.74$ ), and hexagonal mesh pots ( $5.24\pm 0.63$ ) show that, on average, the three different pot types caught the same size crabs.



**Figure 2.7**—Legal and total crab catch during experimental fishing.

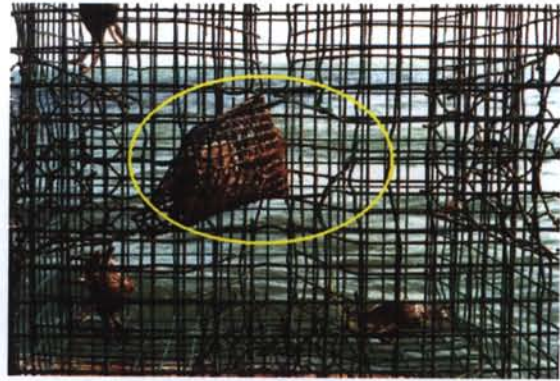
The mean damage ratings for the low-profile pot (1.47), square mesh pot (3.73), and hexagonal mesh pot (3.17) show that the low-profile pot sustained less damage than the other pot types (Figure 2.8). The low-profile pots were also damaged at a slower rate. After 14 fishing days, 3.3% of the low-profile pots, 20% of the square mesh pots, and 21.7% of the hexagonal mesh pots were damaged. At the end of the experimental fishing, 46.7% of the low-profile pots, 93.3% of the square mesh pots, and 90% of the hexagonal mesh pots were damaged. The mean damage ratings for line A (3.15), line B (3.17), and line C (2.05) show that damage level also varied with location. It is likely that there was less damage at line C because line C was located in a shallow area of Core Sound, where there were fewer turtles. The type of damage varied according to pot type. The most severe damage sustained by the low-profile pot was bite marks on the vinyl coating near the bait well (Figure 2.9), while many of the square mesh and hexagonal mesh pots were missing bait well covers, had dented pot bottoms, and had broken wires (Figure 2.10, 2.11). Other types of damage included mangled entryways, overturned pots, missing bait, and bent sides of the pots (Figure 2.12). Damage was generally concentrated on the pot bottoms or the upper, lateral sides of the pots where the crabs are located.



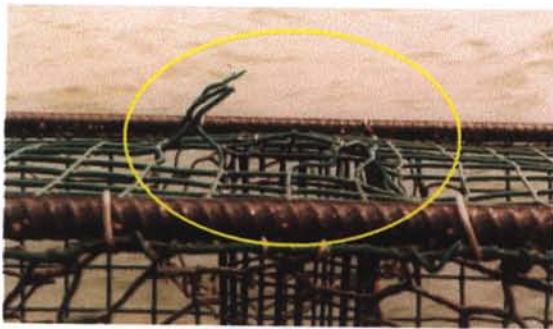
**Figure 2.8**—Mean damage rating for each pot type, by location. There is a consistent trend at all three locations of lower damage to the low-profile pots.



**Figure 2.9**—Bite mark on low-profile pot.



**Figure 2.10**—Loose bait well in square mesh pot.



**Figure 2.11**—Broken wires on bottom of square mesh pot.



**Figure 2.12**—Mangled side of crab pot.

### **3. INTERVIEWS WITH CRABBERS**

#### **3.1 Methods**

##### **3.1.1. Development of the survey instrument**

The survey was designed to gain information on the extent and level of sea turtle damage in the Core Sound area, including the estimated costs of turtle damage in terms of crab catch and pot repairs, the frequency of new turtle damage, and other locations where crabbers may have seen turtle damage (Appendix I). Six general categories of questions were used to address the issue of sea turtle damage to crab pots: 1) demographics; 2) sources and types of crab pot damage; 3) extent of sea turtle damage; 4) costs of sea turtle damage to crab pots; 5) sea turtle and crab fishery interactions; and 6) perceptions of the low-profile crab pot. Questions were both open-ended and close-ended, to provide an outlet for respondents to make additional suggestions on ways to deal with this issue. In lieu of a focus group, a draft copy of the survey was distributed to eight individuals who either had worked with crabbers, or had conducted surveys with fishermen. These individuals provided useful comments regarding question formatting, the type of questions that crabbers would be willing to answer, and additional questions that could provide valuable information. The survey was then modified according to these suggestions, and submitted to the Duke University Institutional Review Board for review and approval.

##### **3.1.2. Survey implementation**

The sample population consisted of Core and Pamlico Sound commercial crabbers. Efforts were focused on this population because the commercial crabber who designed the low-profile pot fishes in Core Sound, and there was potential for turtle damage in this area. A list of

licensed commercial crabbers was not available from the NC Division of Marine Fisheries (DMF); participants were selected using the snowball sampling method, by visiting local crab houses, and through contacts made while fishing in Core Sound. Snowball sampling is often used when it is difficult to identify potential respondents; once a few respondents are identified and interviewed, they are asked to identify others who might qualify as respondents (Rea & Parker 1997). Nineteen crabbers were interviewed from June 2001 to February 2002. The first two surveys were pretests, after which the survey was modified. Twelve of the surveys were conducted face-to-face, while seven of the surveys were conducted over the telephone. The face-to-face interviews were generally conducted in the crabbers' homes, and the telephone surveys were conducted between 7:00 p.m. and 9:00 p.m., Monday through Saturday.

### **3.1.3. Error structure**

The response group is a possible source of error. The response rate was 90.5%, which does not include unanswered calls; many respondents had caller ID, and were able to screen their phone calls. Because some crabbers participate in other fisheries, such as pound netting and shrimping, it was difficult to contact some of the respondents. Some crabbers were not interested in participating, and were concerned that the information they provided could somehow be used against them.

Another source of error is the sample size of the study. Because only 19 crabbers were interviewed, the survey results cannot be generalized to crabbers in eastern North Carolina. However, participants estimated that there were between five and 26 crabbers in Core Sound, so the survey results can be generalized to this sub-population of crabbers.

## **3.2 Results**

### **3.2.1 Demographics**

Of the 19 respondents, 63.2% crabbed primarily in Core Sound and 36.8% crabbed primarily in Pamlico Sound. Results were not divided into these two groups because most respondents crabbed in both areas. To obtain some general information on the crabbers' level of involvement in the blue crab fishery, participants were asked a series of demographic questions. All respondents were Caucasian males, with a mean age of 45 years. On average, respondents had 20 years of crabbing experience (n=19, S.D.=11.1). The survey population was moderately dependent on crabbing for their income; when asked which months out of the year that they crab, approximately 52% of respondents said that they crabbed for the whole season, from February or March through December (n=19). When asked what percentage of their fishing income was from crabbing, 42% of respondents said that they received 100% of their fishing income from crabbing (n=19). The number of pots fished ranged from 100 to 700 pots per crabber, with a mean number of 300 pots per crabber (n=19).

### **3.2.2 Sources and types of crab pot damage**

When respondents were asked to identify the primary cause of damage to their crab pots, approximately 79% of respondents indicated that sea turtles were the primary cause of damage (Figure 3.1). The most common types of damage seen were overturned pots and chewed bait wells, with fewer crushed and flipped over pots. One type of damage that I was unable to quantify was lost bait due to turtles overturning the crab pots. This type of damage is also important because it reduces the number of crabs that will be attracted to the crab pot, thereby reducing crab catch. Every respondent had seen some amount of turtle damage to their crab

pots; the mean percentage of pot damage caused by turtles was 61.6% (S.D.=35.3%) (Figure 3.2).

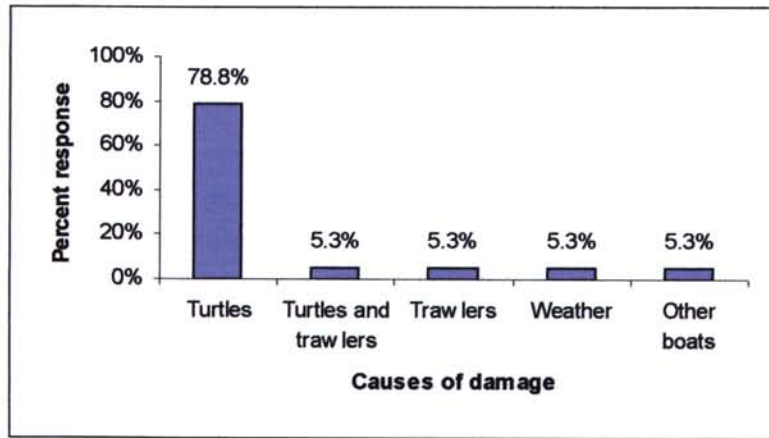


Figure 3.1—“What is the primary cause of damage to your crab pots?” (n=19)

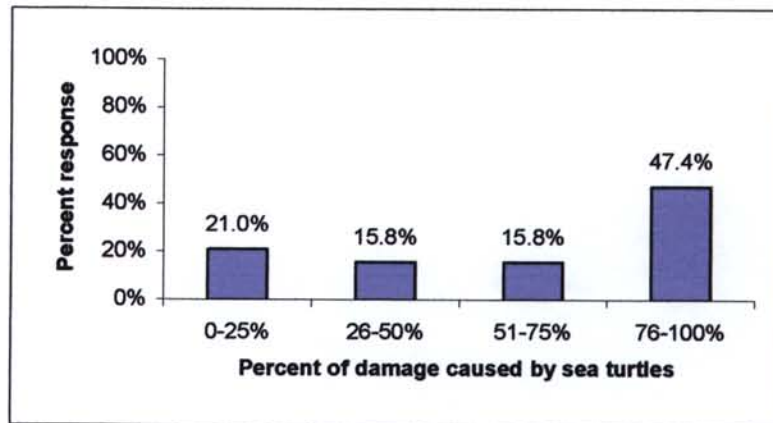
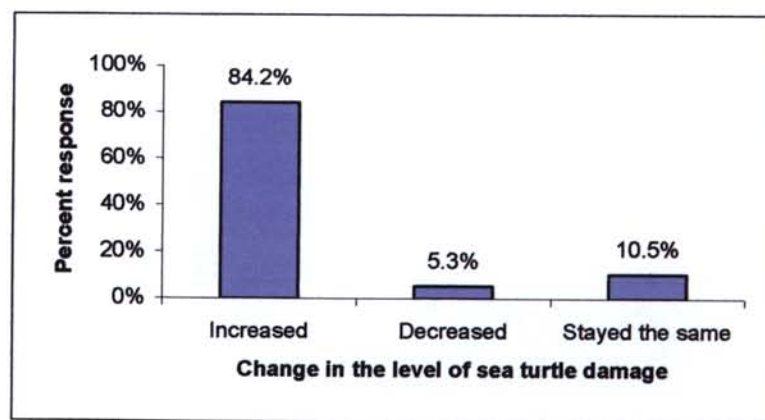


Figure 3.2—“What percentage of damage to your crab pots is caused by sea turtles?” (n=19)

Although all crabbers had seen turtle damage to their pots, I was also interested in their level of concern with this problem. On a scale of 1-5 (1 being not very concerned and 5 being very concerned), the mean level of concern with turtle damage was a 3.8 (n=18, S.D.=1.5). To compare the level of damage caused by sea turtles to other common types of damage, crabbers

were asked to rank several factors from 1 to 5 according to the level of damage caused to crab pots (1 being does not cause a lot of damage, 5 being does cause a lot of damage). The mean responses show that turtles trying to get to the bait (4.05) and turtles trying to get to the crabs (3.69) cause more damage than factors such as storms (2.34) and boats (2.16). Other factors that crabbers listed as causing damage included trawlers and algal growth. To determine if turtle damage was only a seasonal or temporal problem, participants were asked if the level of damage changes throughout the crabbing season, and whether or not turtle damage has changed over the past five years. Sixty-eight percent of respondents indicated that turtle damage is highest in the summer months, and decreases as the water temperature cools down in the fall. According to 84.2% of the respondents, sea turtle damage has increased over the past five years (n=19) (Figure 3.3). Reasons for this increase were attributed to factors such as the protection of sea turtles, including the use of Turtle Excluder Devices (TEDs), and turtles learning to obtain their food from crab pots.



**Figure 3.3**—“How has the level of sea turtle damage changed over the past five years?” (n=19).



### 3.2.3 Extent of sea turtle damage

To determine if turtle damage was localized in Core Sound, participants were asked if they crabbed in other areas, and whether or not they had seen damage in those other areas. Approximately 79% of respondents crabbed in areas other than Core Sound, such as Pamlico and Albemarle Sounds, and the Neuse and North Rivers. Of the crabbers (68%, n=15) who had seen turtle damage in areas other than Core Sound, 36.8% indicated that turtle damage was worse in Core Sound (Figure 3.4). Respondents had heard of sea turtle damage to crab pots in areas other than Core Sound, such as Bogue Sound and West Bay.

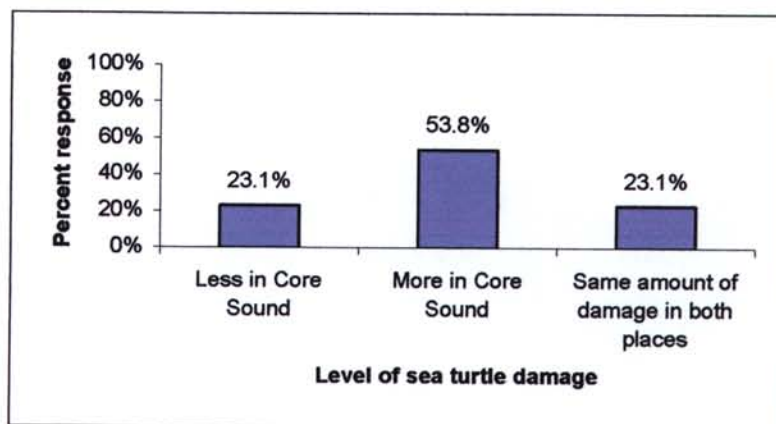


Figure 3.4—"How does the level of damage in Core Sound compare to other areas where you have seen damage?" (n=13)

### 3.2.4 Costs of sea turtle damage

To estimate the costs of sea turtle damage to the blue crab fishery, crabbers were asked whether or not they had seen any changes in crab catch due to turtle damage; the mean crab catch lost due to sea turtle damage, per season, was estimated at 37% (n=14, S.D.=20%). Gear repair and replacement costs due to turtle damage are also an important consideration; these costs were

estimated at \$1,835 per season (n=10, S.D.=\$1,269). At the end of one season, crabbers estimated that sea turtles damaged an average of 54% of their pots (n=17, S.D.=38%). A cost that I was unable to quantify was the amount of time that crabbers spend straightening out pots and re-opening bait wells, which decreases the crabbers' efficiency and productivity. There were large variations in the estimates of damage costs; this is because some crabbers experience more turtle damage, depending on factors such as where they crab, and how many pots they set. Crabbers who fished in lower salinity waters tended to see less turtle damage.

### **3.2.5 Sea turtle and crab fishery interactions**

This section of questions was designed to gain information on sea turtle activity and crab fishery interactions in Core Sound. Crabbers were asked how many turtles, on average, they saw when they went crabbing, and what types of behavior they had observed. On average, crabbers saw at least three turtles each day (n=15), and saw more turtles in the summer months. Sea turtle behavior they had seen included turtles coming up for air, floating near the crab pot buoys, and sitting on top of the crab pots. At least one turtle was observed on 48.3% of the experimental fishing days.

I was also interested in what methods crabbers had previously tried to reduce turtle damage, and whether they had any suggestions for reducing sea turtle and blue crab fishery interactions. Crabbers had tried several methods to reduce turtle damage to their crab pots, such as not using the bait pocket covers, covering the bait well with pieces of plastic or steel, using different kinds of bait, putting the bait well in the middle of the pot, extending rebar out from the sides of the pots, moving pots around more often, and fishing in shallow waters. Only the addition of steel to the bottom of the pot was effective in reducing damage, but was too costly.

Suggestions for reducing interactions included taking loggerheads off the Endangered Species List, or using a type of bait that turtles were not attracted to; many crabbers felt that there was nothing they could do to reduce turtle damage.

### **3.2.6 Perceptions of the low-profile crab pot**

Because the experimental fishing was conducted with one fisherman, I was interested in other crabbers' perceptions of the low-profile pot. After hearing a description of the low-profile pot, crabbers were asked a series of questions relating to the catching effectiveness of the pot, and the likelihood that it would reduce turtle damage. Survey participants expressed varying opinions concerning the low-profile pot's ability to reduce damage. Several survey respondents thought that turtles were such persistent animals that it would be difficult to prevent them from overturning the pots, one crabber saying, "You can't stop a turtle from turning a pot over, but you can stop it from destroying it." Some crabbers felt that the new design would not be as efficient as the current pot design; however, one crabber said he would not mind switching to the low-profile pot if it would reduce turtle damage. Other respondents were concerned with changing the way people fish, even if the low-profile pot was turtle-proof. Crabbers believed that an accurate measure of the catching ability of the low-profile pot could only be obtained if the pots were set in an area where crabs are numerous.

## **4. DISCUSSION**

### **4.1 Implications of the low-profile pot: Is it the best option?**

The low-profile pot caught as well as the square mesh pot in all three locations, and caught as well as the hexagonal mesh pot in lines A and B. Line C was the only location where there was a statistically significant catch difference between the low-profile and hexagonal mesh pots. Because Line C also experienced the least amount of damage, it may be a location where crab catch is high due to decreased turtle damage. Lines A and C had high catch levels compared to line B, yet there was no significant catch difference detected in line A. This suggests that the low-profile pot can compete with the other pot types at both low and high catch levels.

Based on the performance of the low-profile pot during the experimental fishing, the low-profile pot is expected to outlast the traditional hexagonal mesh pot. On average, a typical crab pot will last for one season (Frizzelle 1989); it is likely that, based only on turtle damage, the low-profile pot would not have to be replaced for three to four fishing seasons. Hexagonal mesh pots range in price from \$18-\$25. Although the initial investment of the low-profile pot is approximately twice that of the hexagonal mesh pot, the longer lifetime of the low-profile pot is expected to compensate for its higher cost. The low-profile pots should not be considered turtle-proof; turtles were able to overturn the crab pots, although they overturned fewer of the low-profile than the other pot types. However, the design of the low-profile pot did limit the amount of damage done to the bottom of the pot, as none of the low-profile pots had broken wires or dented pot bottoms. This type of damage causes the pot to sit incorrectly on the bottom of the Sound, and to catch less efficiently.

For crabbers to willingly switch gear types, it is imperative that the new gear can compete with the traditional gear, regardless of the quality of the crab season. However, sea turtle damage adds another dimension to crabbing, and demands that crabbers also consider the issue of turtle damage to their pots. Although the hexagonal mesh pot had the highest catch levels of the three pot types, it also sustained a considerable amount of damage. It was common to see missing bait pocket covers, broken wires on the bottom of the pot, as well as large dents near the bait well. On average, the low-profile pot caught one less crab per pot than the hexagonal mesh pot; a crabber with 300 pots could lose between 60 and 75 pounds of crabs per day by switching to the low-profile pot. There would be virtually no crab catch loss if switching from the square mesh pot; on average the low-profile pot caught 2.97 crabs per pot, and the square mesh pot caught 2.84 crabs per pot. By switching gear types, crabbers also decrease the amount of money spent on gear each season. Although the low-profile pot is larger and heavier than the typical pots used by crabbers, most crabbers have mechanical pot-pullers on their boats, which would decrease the difficulty of handling the new gear. The door on the top of the low-profile pot allows for less vigorous shaking, making it easier to empty.

One concern is that turtles could possibly adapt to the new pot design, and learn how to overturn the low-profile pots as easily as they overturn the hexagonal and square mesh pots. Researchers trying to reduce marine mammal and commercial fishery interactions have raised similar concerns. The gillnet fishery is the primary threat to harbour porpoises (*Phocoena phocoena*) worldwide; however, acoustic alarms (pingers) attached to gillnets have proven to successfully deter porpoises from the nets (Kraus *et al.* 1997). One concern is that porpoises will habituate to the pingers, thereby reducing the alarms' success at reducing bycatch over time. Researchers investigating this possibility used a mooring with a pinger attached, and found that

the displacement of porpoises diminished by 50% within four days (Cox *et al.* 2001). It is possible that loggerheads, like the porpoises, would exhibit behavioral adaptations in response to a change in gear technology.

Gear modifications are only one option to reduce turtle damage; researchers interested in reducing turtle bycatch in the pelagic longline fishery are testing types of bait that turtles may avoid. Behavioral studies indicate that loggerheads, in captivity, avoid food items dyed blue. After four days of experimental trials, the loggerheads continued to have an aversion to the blue-dyed bait. This research indicates that the turtles partially rely on visual cues to distinguish bait that they find attractive. Current research includes testing the responses of loggerheads to food items treated with sea hare (*Aplysia spp.*) ink, which is a known natural feeding deterrent (Yonat Swimmer, Joint Institute for Marine and Atmospheric Research, University of HI, unpub. data). One concern of using this method in the blue crab fishery would be ensuring that blue crabs are also not deterred from the crab pots.

#### **4.2 Addressing protected species and commercial fishery conflicts**

Numerous regulations govern protected species and commercial fishery interactions, providing for the conservation and recovery of the protected species. Interactions of protected species with commercial fishing gear include direct entanglement, capture, disruption of normal behavior, and adverse modification of critical habitats (Allen 2000). Documented interactions of sea turtles occur in several gear types, including trawls, gillnets, longlines, pot gear, and pound nets (Allen 2000; Crowder *et al.* 1995; Anonymous 1992).

Sea turtles interact with several North Carolina inshore water fisheries. Shrimp and summer flounder trawlers are required to have TEDs in their trawl nets, and the large-mesh

gillnet fishery has been seasonally closed in Pamlico Sound due to high turtle bycatch. The trawl and gillnet fisheries are generally thought of as the two fisheries in North Carolina that pose the most serious threats to sea turtles. Pound net fishermen catch turtles on a daily basis in the summer months, and claim that turtles eat the fish caught in their nets, while turtles damage pots in the blue crab fishery. There have been very few reports of sea turtle entanglement in crab pot lines in Core Sound (Joanne Braun-McNeill, NMFS, pers. com. 2002). Sea turtles damaging crab pots deals with a different aspect of the interaction between protected species and commercial fisheries. Typically, gear modifications are made in the interest of the protected species (e.g., TEDs). This research deals with designing new gear in the interest of the fishery.

The development of TEDs is the classic example of a technological solution to address the interaction of a protected species with a commercial fishery. In 1978 all species of sea turtles that occur in the southeastern U.S. were listed as threatened or endangered under the ESA, and several studies were conducted to determine the most imminent threats. The shrimp fishery was found to be the single largest source of sea turtle mortality. Gear technologists developed TEDs working with ideas developed by commercial fishermen to exclude jellyfish from their catch (Watson 2000). The development of TEDs parallels the development of the low-profile crab pot; information and ideas from commercial fishermen may result in a successful method to deal with this problem.

Different approaches can be effective in developing and implementing technologies that are more acceptable to users. Watson (2000) discusses several points to consider: 1) voluntary acceptance of new sustainable technologies may be difficult without financial or other incentives; 2) technologies that result in increased costs or loss of revenue will likely be resisted by users; 3) user groups should be active participants in every aspect of planning, development,

and evaluation of new technologies; 4) mandatory use of new sustainable technologies requires effective enforcement commitment; and 5) successful development and acceptance of sustainable technologies requires effective communication and cooperation between users, fishery researchers, and regulators. To measure the potential success of the low-profile pot within the fishing community, it is useful to look at how the low-profile pot fits these criteria.

Because the low-profile pot reduces turtle damage, there is an incentive to invest in this new gear type. If the building of low-profile pots were subsidized it would be more likely to be accepted as an option to reduce turtle damage. An important consideration is that the low-profile pot will result in short-term increased costs and possible losses in revenue. This may cause crabbers to be skeptical about investing in the low-profile pot; however, the long-term benefits of using the low-profile pot outweigh the costs for those crabbers who experience higher levels of turtle damage. Switching gear types may be beneficial for some crabbers, but not others. Programs such as the NC Sea Grant Fishery Resource Grant Program facilitate involving the user group in the planning, development, and evaluation of new technologies. A local crabber designed the low-profile pot and brought this issue to the attention of researchers at the Duke University Marine Laboratory; collaborative projects that originate from fishermen are more likely to be accepted by the fishing community. It is unlikely that the use of the low-profile pot would be mandatory, as some crabbers experience little or no turtle damage. To date, this project has been successful in effective communication between users and fishery researchers. Regulators have not been involved in this process, although the issue of sea turtle damage to crab pots has been raised at the Blue Crab FMP meetings (Joe Benevides, pers. com. 2002). Promoting sea turtle protection and recovery without threatening commercial fisheries cannot be



achieved without emphasis on technological solutions, fishing method modifications, and outreach and education (Allen 2000).

### **4.3 Innovation diffusion**

Innovation diffusion theory can be helpful in examining the possible acceptance of a new technology such as the low-profile pot. Rogers (1995) defines innovation diffusion as, “the process by which an innovation is communicated through certain channels over time among the members of a social system,” and, “a special type of communication, in which the messages are about a new idea.” There are several characteristics of innovations that help explain their different rate of adoption: 1) relative advantage, which is whether an individual perceives the innovation as advantageous; 2) compatibility, which is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters; 3) complexity, which is the degree to which an innovation is perceived as difficult to understand and use; 4) trialability, which is the degree to which an innovation may be experienced with on a limited basis; and 5) observability, which is the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt it (Rogers 1995).

The examination of these characteristics with respect to the low-profile pot provides some insight into the possible reasons for the success or failure of the modified gear type. For crabbers to willingly adopt a new gear type, they must realize the benefits of the new gear. If switching to the low-profile pot is not perceived as advantageous, it is not likely to happen. In terms of compatibility, the most important consideration will be possible changes in fishing practice. If a new gear causes dramatic changes in the fishing practice, it is less likely to be

adopted. The low-profile pot is neither difficult to understand or use, as it functions the same way as the typical crab pot. Observability is compatible with trialability; through experimental use of the low-profile pot, crabbers can see the results of the innovation for themselves. Any innovations designed to deal with this issue must consider that the status of the blue crab resource and the level of turtle damage are not static. As Dewees and Hawkes (1988) state, “Fishermen’s characteristics, situations, and perceptions change over time. Changes in resource abundance, regulations, and economic conditions affect the ‘climate’ for technological innovation in fisheries.”

#### **4.4 Crabbers’ perceptions of sea turtle damage in Core Sound**

Survey respondents felt that there may be aggregations of turtles in Core Sound, resulting in high levels of sea turtle damage there. However, the damage is certainly not limited to Core Sound. There have been reports of turtle damage in the southeastern part of Pamlico Sound, and as far north as Croatan and Roanoke Sounds. Respondents reported that sea turtle numbers in the Sounds have been increasing, along with the amount of sea turtle damage, over the last five to ten years. Reasons for this increase were attributed to the federal protection of sea turtles under the ESA and the use of TEDs. While some crabbers think that turtles are overpopulated, and are concerned with the government spending money to help protect hatchlings, they do not necessarily dislike sea turtles. One crabber said “[he doesn’t want] to see turtles go extinct, but there has to be a balance,” referring to the concern that if turtles continue to be protected, crabbers will be put out of business. Implementing a policy that deals with sea turtle and crab fishery interactions has the potential to ease the tenuous relationship between crabbers and regulators.

Some crabbers, who also pound net, feel that scientists are underestimating the population of sea turtles in North Carolina inshore waters. Several survey respondents, some of whom had worked with scientists, said that they often caught sea turtles that were too large to have fit through the three-foot square tunnel iron of the pound net. The fishermen hypothesized that the only way the turtles could have gotten in was by swimming over the top of the net at high tide; it is possible that some turtles also swim out before the nets are checked. Crabbers are concerned that these large turtles are not being included in the population estimates for Core and Pamlico Sounds.

Several respondents said that pound net fishermen are catching more turtles now than in the 1970's. The combination of more turtle sightings and the fact that Core Sound is a small water body makes it difficult to avoid turtle damage. Some crabbers expressed interest in receiving government compensation, recognizing that financial compensation wouldn't solve the problem, but "it would help attitudes." Other crabbers felt that the damage is "part of the business," and there is no way to avoid turtles. Although there were no survey questions addressing crab catch, several respondents mentioned there have been less crabs over the last few years due to the 1999 hurricanes. This decrease in crab catch may be affecting the crabbers' perceptions of turtle damage. The lowest catch on record was 2000 and 2001—roughly 70 to 80% lower than the 10-year average (Eggleston 2002). If crabs were abundant in Core Sound, crabbers would not have to be as concerned with turtle damage. The combination of decreased crab catch and increased damage exacerbates the problem, and makes this issue more pressing.

## CONCLUSIONS

The physical characteristics of Core Sound make it especially vulnerable to increased sea turtle abundance, and therefore increased turtle damage. Core Sound is narrow, close to the ocean, and has high salinity waters. This could very well explain the high concentration of sea turtles in this area and the southeastern portion of Pamlico Sound (Anonymous, pers. com. 2001). Increased turtle populations in the Sounds may be leading to an expansion of the turtle damage problem. One crabber described a small area of Core Sound commonly known as “Turtle Lane,” saying it has expanded northward and southward in the past five years. It is important to involve crabbers in the process of working towards a solution to this problem for several reasons. First, their experience on the water, and their intimate knowledge of the ecosystem, make them an excellent resource when addressing fishery-related issues. Second, they will be more likely to accept any changes in gear technology or fishing practices if the idea has come from within the fishing community.

Sea turtles damaging crab pots is a unique issue; a threatened species is adversely affecting a commercially valuable fishery. The low-profile crab pot has the potential to improve this situation. Some crabbers have started using the square mesh pots to reduce turtle damage; however, these results indicate that the low-profile pot is a better option, allowing crabbers to maintain crab catch with a reduction in gear replacement costs. Because the level of sea turtle damage varies for each crabber, investing in the low-profile pot is not a viable option for every crabber; it will primarily depend on the level of damage seen, and the associated costs of that damage.

## **RECOMMENDATIONS**

As human exploitation of the marine environment increases along with efforts to protect threatened and endangered species, the interaction of protected species and commercial fisheries will continue. Sea turtle damage to crab pots is not a localized problem; such damage has also been reported in South Carolina (David Whitaker, SCDNR, pers. com. 2002), and the lower part of the Chesapeake Bay (Mike Oesterling, VIMS, pers. com. 2002). Researchers at the NMFS office in Woods Hole, MA, are developing a project similar to this one to address turtle damage in the Chesapeake Bay (Cheryl Ryder, NMFS, pers. com. 2002). This issue has only recently been brought to the attention of researchers and fishery managers, and merits continued study. A modified pot design or bait type may be the solution to sea turtle damage, and the low-profile pot may prove to be the best alternative.

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## **APPENDIX I: SURVEY INSTRUMENT**

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### **Section I: Demographics**

*The first section of questions is just to get some general information about your involvement in the crab fishery.*

- 1) How long have you been crabbing? \_\_\_\_\_
- 2) How long have you been crabbing in Core Sound? \_\_\_\_\_
- 3) Which months do you crab in? \_\_\_\_\_
- 4) What is your age? \_\_\_\_\_
- 5) How many crab pots do you currently fish in Core Sound? \_\_\_\_\_
- 6) How often do you crab?
  - Every day
  - Several times a week
  - Once a week
  - Less than once a week
  - Other
- 7) What percentage of your fishing income is from crabbing? \_\_\_\_\_
- 8) What is your estimate of the number of commercial crabbers in Core Sound?  
\_\_\_\_\_

### **Section II: Sources and Types of Crab Pot Damage**

*The next section of questions is to find out about sources and types of crab pot damage seen in Core Sound.*

- 9) What kind of crab pot damage have you seen? *(Note: leave open-ended)*
  - Flipped over pots
  - Crushed pots
  - Chewed bait wells
  - Broken wires
  - Holes
  - Broken float lines
  - Dead/eaten crabs
  - Other \_\_\_\_\_

ID # \_\_\_\_\_

10) What do you think is the primary cause of damage to your crab pots?  
\_\_\_\_\_

11) Please indicate the level of damage of these factors on your pots (1 being least damaging and 5 being most damaging)

Storms	1	2	3	4	5
Boats	1	2	3	4	5
Turtles trying to get to the bait	1	2	3	4	5
Turtles trying to get to the crabs	1	2	3	4	5
Other	1	2	3	4	5

12) Have you seen sea turtle damage to your crab pots?

- Yes
- No
- Don't know

13) What percentage of damage to your crab pots is caused by sea turtles? \_\_\_\_\_

14) On a scale of 1 to 5, how concerned are you with crab pot damage due to sea turtles? (1 being least concerned and 5 being most concerned)

1      2      3      4      5

15) How often do you see **new** sea turtle damage to your crab pots (*Note: Probe for seasonal changes*)

- Every time you pull up crab pots
- A couple of times a week
- Other \_\_\_\_\_

16) How does your crabbing behavior change in response to turtle damage?

- Repair damaged pots and leave in same place
- Repair damaged pots and move to new place
- Take pots out of the water completely
- Start fishing for something else
- Other \_\_\_\_\_

ID # \_\_\_\_\_

17) Does the level of crab pot damage due to sea turtles change throughout the season?

- Yes \_\_\_\_\_
- No
- Don't know

18) Have you noticed a change in the amount of sea turtle damage to your crab pots over the past 5 years?

- Increased
- Decreased
- No change (skip to Q20)
- Don't know (skip to Q20)

19) What do you think has caused the amount of damage to change? \_\_\_\_\_

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### **Section III: Extent of Sea Turtle Damage**

*This section of questions is to find out if there is sea turtle damage to crab pots in areas other than Core Sound.*

20) Do you crab in other areas?

- Yes \_\_\_\_\_
- No (skip to Q23)

21) Have you seen crab pot damage due to sea turtles in these other areas?

- Yes
- No (skip to Q23)
- Don't know (skip to Q23)

22) How does the level of sea turtle damage in other areas compare to the level of damage in Core Sound?

- Same
- More in Core Sound
- Less in Core Sound
- Don't know

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23) Have you heard of sea turtle damage to crab pots in other areas?

- Yes \_\_\_\_\_
- No
- Don't know

**Section IV: Costs of Sea Turtle Damage to Crab Pots**

*The next section addresses the costs of sea turtle damage to the crab fishery.*

24) Have you noticed any change in your catch rates due to the amount of sea turtle damage to your crab pots?

- Yes
- No (skip to Q27)
- Don't know (skip to Q27)

25) Approximately how much has your catch rate changed due to this damage? \_\_\_\_\_

26) Approximately how much money do you lose because of decreased catch rates (*Note: Probe for time scale - each day/season*)? \_\_\_\_\_

27) Approximately how much money do you spend repairing crab pots damaged by sea turtles each season? \_\_\_\_\_

28) At the end of the season, how many of your crab pots have been damaged by sea turtles?  
\_\_\_\_\_

**Section V: Sea Turtle and Crab Fishery Interactions**

*This section of questions is to get information on sea turtle activity and crab fishery interactions in Core Sound.*

29) On average, how many sea turtles do you see when you go crabbing? \_\_\_\_\_  
(*Note: Probe for seasonal changes*)

30) What types of sea turtle behavior have you observed? \_\_\_\_\_

31) What methods have you tried to reduce sea turtle damage to crab pots?  
\_\_\_\_\_  
\_\_\_\_\_

32) Do you have any suggestions for reducing sea turtle and crab fishery interactions?  
\_\_\_\_\_  
\_\_\_\_\_

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**Section VI: Low-Profile Crab Pots**

*The last section of questions asks about your opinion of the low-profile crab pots.*

33) Do you think that low-profile crab pots will decrease sea turtle damage to crab pots?  
Why, or why not? \_\_\_\_\_  
\_\_\_\_\_

34) Do you think that using low-profile crab pots will result in decreased crab catch?

- Yes
- No
- Don't know

35) Have you noticed any differences in damage between the low profile and regular crab pots?

- Yes \_\_\_\_\_
- No
- Don't know