North American Journal of Fisheries Management 29:170–175, 2009

DOI: 10.1577/M07-208.1

[Management Brief]

Will It Float? Testing a New Technique for Reducing Loggerhead Sea Turtle Damage to Crab Pots

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Abstract.—Loggerhead sea turtles *Caretta caretta* have been found to damage crab pots and reduce catch of blue crabs *Callinectes sapidus* in North Carolina sounds. In response, crabbers have avoided fishing at locations and times of peak loggerhead sea turtle activity and have experimented with modifications to make their gear more robust. We field tested a new, lightweight, and inexpensive modification: self-righting floats tethered to the inside of the crab pots. Thirty pairs of regular and modified pots were fished between 16 June and 31 July 2006. Damage by loggerhead sea turtles was found in 38% of all replicates, and blue crab catch was 57% lower in crab pots that had been discovered by loggerhead sea turtles. The float modification effectively reduced damage, but stronger effects were found when using plastic bait-well covers that the crabbers had introduced. The modified pots were significantly less damaged (average damage index [ADI] = 1.38 with plastic covers and 2.01 with cardboard covers) than regular pots (ADI = 1.78 with plastic covers and 2.38 with cardboard covers). Average blue crab catch was significantly higher in pots with plastic bait-well covers (15 crabs/modified pot, 18 crabs/regular pot) than in pots with cardboard covers (13 crabs/modified pot, 11 crabs/regular pot). However, there was a significant interaction of pot type with bait-well cover type. When plastic covers were used, average blue crab catch was higher in regular pots (18 crabs/pot) than in modified pots (15 crabs/pot). The opposite case was observed when cardboard covers were used: catch was higher in modified pots (13 crabs/pot) than in regular pots (11 crabs/pot). A drawback to the float modification was a qualitative increase in pot drift and loss in high winds, resulting in the need for costly retrieval measures; crab pot loss may also jeopardize estuarine species that become trapped in derelict gear. Adopting these techniques, however, may help crabbers reduce gear damage, catch loss, and negative interactions with loggerhead sea turtles in this fishery.

Loggerhead sea turtles *Caretta caretta* pose a serious problem for crab fishermen (hereafter, crabbers) that target the blue crab *Callinectes sapidus* in North Carolina's Core Sound; loggerhead sea turtles account for a 37–40% loss in crab catch and damage to 67–82% of crab pots (Marsh 2002; Avissar and Crowder 2006). Sea turtles damage crab pots by tipping them over, chewing and breaking wires, perforating the pots, and displacing the bait wells (bait pockets) as they attempt to access the bait or crabs. The most recent North Carolina Blue Crab Fishery Management Plan stresses the need for development of new technologies and gear to minimize conflicts between sea turtles and crabbers (NCDENR 2004). Marsh (2002) examined this issue and tested low-profile, lower-gauge (thicker) wire crab pots for resistance to loggerhead sea turtle damage. This crab pot design minimized sea turtle damage, but this design has not been propagated in the blue crab fishery because of higher manufacturing costs and heavier weight.

Other researchers have developed crab pot modifications designed to deter similar gear damage caused by marine mammals. These include inverted bait wells (Lewis 2007) and different bait-well securing methods, which seem effective at reducing damage and bait theft by marine mammals but which add to fishing time (NOAA Fisheries 2001; Noke and Odell 2002). More importantly, neither of these methods may be effective against loggerhead sea turtles; the turtles are more likely (and better able) to bite through and break the wires of the crab pot when easy access to the bait well is denied.

We have developed a new crab pot modification that may reduce pot vulnerability to loggerhead sea turtle damage, without substantially increasing gear weight, cost, or processing time. This modification involved tethering floats (buoys) to the inside top panel of a regular crab pot so that the pot would remain upright even if a turtle attempted to flip the pot to access the bait well and remove the bait inside (Figure 1). Preliminary testing of this design in August 2005 yielded promising results. In that informal pilot study, we noticed that crab pots in which floats had been installed were more likely to be found upright and to contain bait than nearby pots that had not been modified. The crabbers were satisfied with these initial results and continued installing floats in additional pots as they fished through the fall. We decided to test this design more rigorously by expanding the pilot study into a full-season project in summer 2006, coinciding with the predicted peak in loggerhead sea turtle damage.

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Received November 16, 2007; accepted April 21, 2008
Published online February 23, 2009

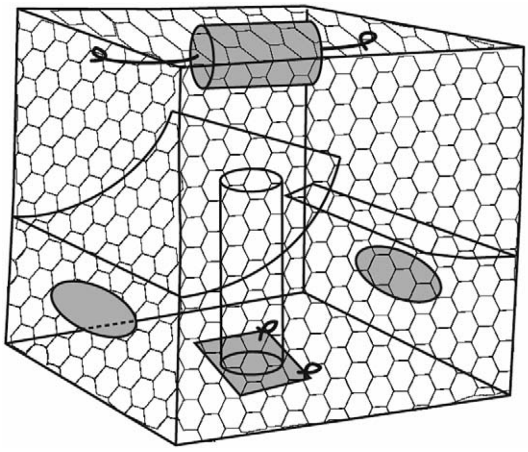

FIGURE 1.—Illustration of a commercial, wire-mesh crab pot, showing float modification design (buoy shown in gray, tethered to top of crab pot) and plastic bait-well cover (square cover shown in gray at bottom). After bait is inserted into the bait-well from the bottom, the bait-well cover is shut behind it and secured with a bungee cord and hook (not shown). The bait-well is closed at the top. The gray ovals on the sides of the pot represent funnel openings through which blue crabs can enter but cannot escape.

Our main objective was to test whether damage by loggerhead sea turtles is effectively reduced by this gear modification in comparison with regular (unmodified) crab pots. Our study builds on previous work in the area (Marsh 2002; Avissar and Crowder 2006) by providing additional data on loggerhead sea turtle damage to crab pots in regular fishing locations while field testing a new damage avoidance technique. We also assessed pot movement and the loss of modified versus regular pots to determine whether the greater buoyancy of the modified pots made them more likely to drift. Our findings should thus indicate whether this modification could help the industry based on its effectiveness at minimizing loggerhead sea turtle damage without encountering additional problems.

Study Area

The experimental fishing area included the Core Sound region, North River, Jarrett Bay, and various creeks and embayments of the Pamlico–Albemarle estuarine complex near Beaufort, North Carolina. The sound is connected to the Atlantic Ocean through Barden and Drum inlets, and limited freshwater input creates a brackish system of 18–30‰ salinity (Epperly and Ross 1986). The tidal range in this area is roughly 1 m, and water height is largely determined by wind. Surface water temperature in Core Sound (measured daily at approximately 0800 hours during summer 2006) ranged from 26°C to 32.1°C and averaged 27.9 ± 1.2°C (SD). Smooth cordgrass *Spartina alterniflora* and black needlerush *Juncus roemerianus* are the dominant vegetation surrounding the sound (Epperly and Ross 1986).

Methods

We conducted a fishing experiment with a pair of crabbers operating one commercial blue crab boat between mid-June and the end of July in 2006. A total of 60 crab pots were tracked over the season for blue crab catch and damage by loggerhead sea turtles. We purchased new crab pots so that new damage would be traceable, and modified half of them with floats so that we had 30 pairs of pots for comparison.

After inserting bait into the bait well, crabbers usually plug the bait well with water-resistant waxed cardboard to deter loggerhead sea turtles from accessing the bait. Though not part of the original study design, the cooperating crabbers adapted 18 of the crab pots by fastening a piece of hard plastic (approximately 15 × 21 cm) to the bottom of the pot with zip ties and tying a short bungee cord with a hook to the plastic to create a latched bait-well cover that would be more durable than the cardboard alternative. Plastic covers were attached as available and were unevenly distributed between modified and regular pots (19 individual trapping events [replicates] in regular pots; 711 replicates in modified pots). The crabbers used cardboard to cover the bait well when they ran out of plastic covers, providing 1,141 replicates for regular pots and 446 replicates for modified pots. The bait wells also came from the manufacturer in three different colors (yellow, red, and black). Because these unexpected factors (bait-well cover type and bait-well color) may have introduced variability to our study, we kept track of them and analyzed our results with multivariate statistics.

We set lines of crab pots in separate, regularly fished locations, alternating modified pots with regular pots within each line so that every other pot was a modified one. The crabbers used two configurations: (1) two lines of 30 pots or (2) two lines of 20 pots plus two lines of 10 pots. Two lines of the same length were set next to each other, one inshore and one offshore; in the case of the second configuration, the set of longer lines was placed in a different location than the set of shorter lines. The crabbers decided where the lines were set based on their usual fishing patterns and locations and were free to move the pots as they saw fit.

The crabbers fished each pot (emptied and newly baited) daily and set them to soak overnight (Figure 2 maps fishing effort, defined as the number of replicates in each location over the entire study period). Daily for each pot, we recorded location using a hand-held Global Positioning System (GPS) unit, signs of damage by loggerhead sea turtles, and number of live blue crabs contained in the pot (crab catch). We characterized damage severity by using a standard damage index (DI) employed in previous studies (Marsh 2002; Avissar and Crowder 2006), assigning a value to the damage level as follows: an index value of 1 indicated no damage to the crab pot; 2 indicated minimal damage (e.g., bite marks on vinyl coating); 3 indicated bent wires and denting on the bottom of the pot; 4 indicated broken wires; and 5 indicated maximum or irreparable damage (e.g., loose bait wells). Average DI (ADI) was used to compare damage severity between the different crab pot treatments. We noted the bait-well cover type (cardboard or plastic) and color (yellow, red, or black). Opportunistically, we also noted locations of encounters with loggerhead sea turtles in our study area.

Because adding internal floats to the crab pots makes them more buoyant, we expected modified pots to move more with the currents and to become lost more frequently than regular pots. Although a simple spatial analysis would not permit differentiation between naturally occurring pot drift and the crabbers' repositioning of their pots, we used a hand-held GPS unit to record the daily position of each crab pot as it was picked up and we recorded whether a pot had notably drifted from where it had been set the previous day. We also noted when a pot was missing. We expected this information to provide us with a qualitative assessment of whether the modified pots are more likely to drift than unmodified pots.

Damaged crab pots were repaired to the best of the crabbers' ability at the time the pots were pulled. When a pot had been previously damaged and repaired, it was not considered damaged on subsequent sampling days unless new damage had occurred. This provided an indication of how much damage occurred with respect to the number of replicates and enabled direct comparison of our results with previous years (Marsh 2002; Avissar and Crowder 2006). Damage frequency (percentage of pots damaged) was calculated as the sum of crab pots found with a DI greater than 1.0 throughout the entire season (each day provided a new number of damaged pots for the seasonal total) divided by the total number of pots fished throughout the season (60 pots $\times$ 39 d $=$ 2,340 replicates). We also used seasonal totals to calculate percent catch loss from the simple difference between total blue crab catch in damaged pots (DI $>$ 1.0) and the total catch in pots that were undiscovered by loggerhead sea turtles (DI $=$ 1.0). To assess spatial patterns in crab catch and pot damage, we used ArcGIS version 9.2 (Environmental Systems Research Institute, Inc., Redlands, California).

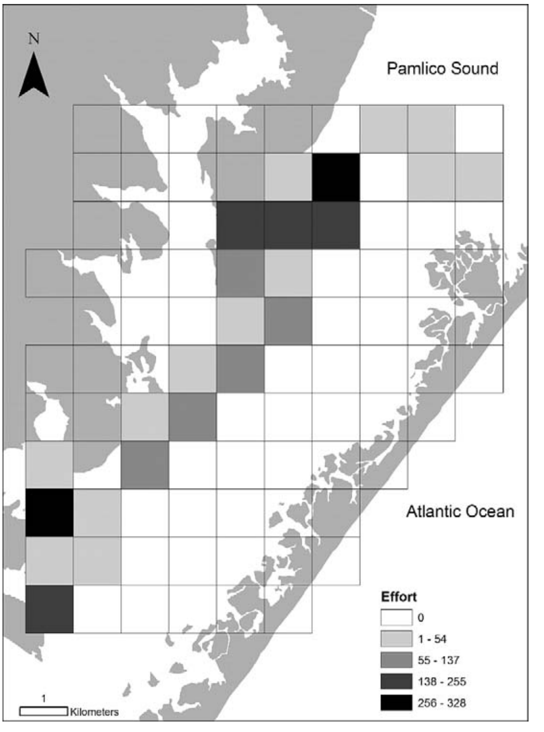

FIGURE 2.—Map of experimental fishing effort with blue crab pots (number of replicates per location) in the Core Sound region, North Carolina, during summer 2006.

We ran two analysis of variance (ANOVA) tests in S-Plus 7.0 (Insightful Corp. 2004) to analyze the potential effects of pot type (modified or regular), bait-well cover material (plastic or cardboard), and bait-well color (yellow, red, or black) on the severity of damage to the pot and on blue crab catch. In addition to individual effects of each variable, we examined two-way interactions to look for more-complex relationships. The data were analyzed using the Type III sum of squares to ensure that the effect of each variable took into account the effects of the other variables. Before analysis, data were tested for normality and variance homogeneity using residual and *q–q* plots. A *q–q* (quartile–quartile) plot places one dataset on the *x*-axis against a second on the *y*-axis, with each point corresponding to an equivalent percent of the data's cumulative distribution function. We plotted our data against a normal distribution to ensure that the data were normally distributed (i.e., followed a 1:1 straight line).

Results

From 16 June to 31 July 2006, 39 d of experimental fishing were completed in Core Sound. Fishing effort

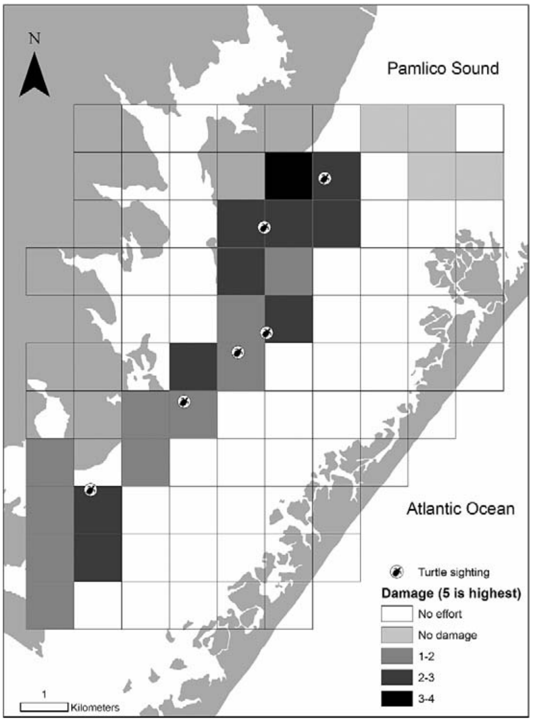

FIGURE 3.—Map of loggerhead sea turtle damage to crab pots at blue crab fishing locations in the Core Sound region, North Carolina, summer 2006, and locations of loggerhead sea turtle sightings. Damage severity is characterized by a standard damage index, where 1 = no damage to the crab pot, 2 = minimal damage (e.g., bite marks on vinyl coating), 3 = bent wires and pot dented on bottom, 4 = broken wires, and 5 = maximum or irreparable damage (e.g., loose bait wells). Most of the loggerhead sea turtle sightings occurred in areas of severe damage to crab pots.

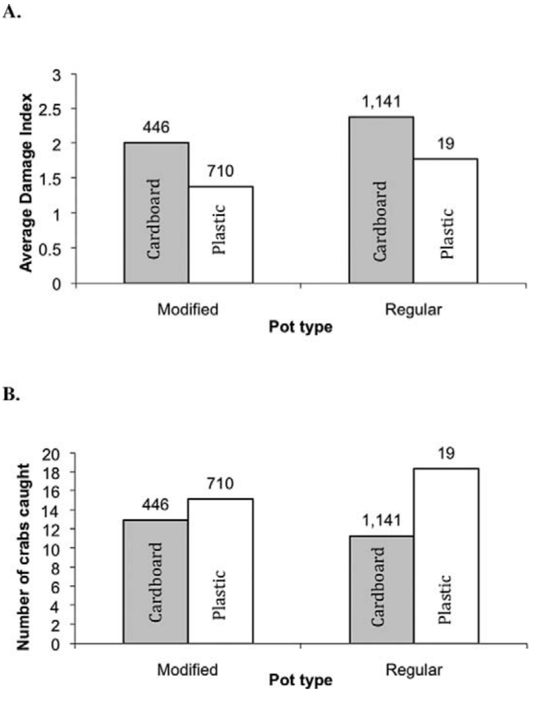

FIGURE 4.—**(A)** Average damage index, describing the severity of loggerhead sea turtle damage to blue crab pots, and **(B)** average blue crab catch (number of live crabs per pot) compared between regular and modified (see Figure 1) pots and between plastic and cardboard bait-well cover types used in the Core Sound region, North Carolina, during summer 2006.

was concentrated: 77% of the replicates were within 1 km from shore (Figure 2). Crab pot damage was pervasive throughout the study and affected nearly all of the areas fished (Figure 3). Blue crab catch ranged from 0 to 26 crabs/pot. Loggerhead sea turtles were observed on six occasions between 14 and 28 July 2006, when water temperature was above average (27.2–32.1°C). Of the six loggerhead sea turtle sightings, four corresponded to areas of high gear damage (Figure 3).

In our initial analysis, we ran a three-way ANOVA (pot type, bait-well cover type, and bait-well color) with interaction effects included. Because we failed to detect significant differences in response variables attributable to bait-well color, we pooled the data that had been previously separated by color and reanalyzed for effects of pot type and bait-well cover type.

Damage to Crab Pots

Damage to crab pots by loggerhead sea turtles occurred at a frequency of 38% throughout the season (all crab pots with new damage [DI $>$ 1.0] over the 39 d of sampling). The first ANOVA examined whether the damage to crab pots was a function of pot type (modified or regular) and bait-well cover type (plastic or cardboard). The float modification significantly reduced damage severity (ANOVA: $F = 5.51$, $P = 0.019$), but the effect was stronger when the plastic bait-well covers were used (ANOVA: $F = 18.41$, $P = 0$; Figure 4A).

Blue Crab Catch

Blue crab catch was 57% lower in pots that had been damaged than in pots that had not been discovered by loggerhead sea turtles (no signs of damage). We tested whether crab catch varied as a function of pot type and bait-well cover type and found a significant effect of cover type (ANOVA: $F = 21.31$, $P = 0$) and a significant interaction effect of cover type and pot type

(ANOVA: $F = 4.53$, $P = 0.0033$); however, the main effect of pot type on crab catch was not significant (ANOVA: $F = 0.59$, $P = 0.44$). Pots with plastic bait-well covers caught more crabs on average (15 crabs/modified pot; 18 crabs/regular pot) than did pots with cardboard covers (13 crabs/modified pot and 11 crabs/regular pot; Figure 4B). Looking at the interaction between the variables, we found mixed results. When cardboard bait-well covers were used, modified pots caught more blue crabs (13 crabs/pot) than did regular pots (11 crabs/pot). However, when plastic bait-well covers were used, regular pots caught more crabs (18 crabs/pot) than did modified pots (15 crabs/pot; Figure 4B). The type of bait-well cover had a greater effect on crab catch in regular pots than in modified pots.

Crab Pot Drift

The crabbers had the freedom to move the crab pots as they saw fit, allowing us to assess realistic levels of damage and blue crab catch that occur in regular fishing locations. Consequently, the crabbers did not always reset the crab pots in the same locations where they had been picked up the previous day, and we were unable to differentiate naturally occurring pot drift from the crabbers' repositioning of their pots. Nevertheless, we can qualitatively report that in general, pot drift from the site of placement was not greater for modified pots than for regular pots. However, during strong, sustained wind events, the pots scattered (pairs were not found next to each other); during such events, the modified pots moved more frequently than the regular pots. During the entire season, eight modified pots were lost during strong wind events but only five regular pots were lost.

Discussion

Damage to commercial crab pots by loggerhead sea turtles has worsened over the past few years. We found a higher frequency of loggerhead sea turtle damage to crab pots in 2006 (38% of all replicates) than in previous years. Sea turtle damage occurred to 34% of all replicates of regular pots in 2001 (Marsh 2002) and to 14% of all replicates in 2005 (Avissar and Crowder 2006). The ADI also worsened in 2006 (2.10 for all regular pots) relative to the 2005 level (1.37). When comparing blue crab catch in damaged pots versus pots that were undiscovered by loggerhead sea turtles, we found that the turtles were responsible for a 57% reduction in crab catch during this study, which translates into substantial economic losses for crabbers. This level of blue crab catch loss is more severe than the 37% catch loss described by Marsh (2002) and the 40% catch loss reported by Avissar and Crowder (2006).

The float modification effectively reduced damage by loggerhead sea turtles but did not increase blue crab catch. We were surprised that pot type was not the primary factor in reducing damage to crab pots or increasing blue crab catch. Apparently, the bait-well cover type variable, which the crabbers had introduced randomly based on availability, explained more of the variation in damage and crab catch than did the pot type variable. Crab pots with plastic bait-well covers were damaged less severely than those with cardboard covers, and average blue crab catch was also significantly higher in pots with plastic bait-well covers.

The number of replicates for regular pots with plastic covers (19) was much lower than that for regular pots with cardboard covers (1,141). For modified pots, the number of replicates was more evenly distributed between plastic covers (711) and cardboard covers (446). Because we were concerned about the low sample size of regular pots with plastic covers, we ran a *t*-test of data from modified and regular pots with cardboard covers only and found similar results. However, an additional controlled experiment testing bait-well covers on regular pots alone is necessary for a better analysis of these effects.

We spoke with the crabbers to gather their impressions of the operation, ease of use, and other characteristics of modified pots in comparison with regular pots. Their assessment of the float modification is that it appeared to deter loggerhead sea turtle damage but caused the pots to move more, especially during windy conditions. Pot drift may create serious problems if it results in pot loss; substantial effort is required to find the pots, and pots that become derelict gear can drown estuarine species, such as diamondback terrapins *Malaclemys terrapin*. The crabbers also worry that even on calmer days, the more-buoyant modified pots will sway, potentially scaring blue crabs away and reducing catch. According to the crabbers, the modified pots did not seem to fish as well as unmodified pots when pot damage was not an issue and suggested using easily detachable floats (e.g., with snaps) that can be removed when loggerhead sea turtles are less active. However, the crabbers are likely to continue using the float modification during the summer fishing season, when sea turtle damage is at its peak.

Management Recommendations

Damage by loggerhead sea turtles to the blue crab fishery has worsened over the years, posing a serious problem for managers and crabbers interested in efficient harvest of this resource. Research over the last few years indicates that damage can be minimized through timing shifts (avoidance of turtles' peak season; i.e., July), gear modifications such as the ones described here, or both. The float modification tested in this study reduced damage by loggerhead sea turtles, but the pots with plastic bait-well covers, regardless of whether they were modified with floats, were damaged less severely and captured more blue crabs than did those with cardboard bait-well covers. The float modification may be a worthwhile investment for crabbers operating in the sounds of North Carolina. However, additional and even greater gains in catch and reductions in damage could be obtained by using plastic bait-well covers instead of cardboard. The data suggest that these modifications could counteract increasing interactions between loggerhead sea turtles and the blue crab fishery, allowing crabbers to continue fishing through the summer months. These modifications may also help crabbers in other areas who are experiencing similar gear damage by marine mammals (NOAA Fisheries 2001; Noke and Odell 2002).

Acknowledgments

This research was funded by North Carolina Sea Grant (06-ECON-04). We thank our grant monitor, Marc Turano, and the three anonymous reviewers of this manuscript. We also gratefully acknowledge our collaborators, Ellen and Ronnie Cahoon and their family, who assisted us on the water. We thank Lisa Valvo for providing the beautiful illustration for Figure 1. The administrative staff at Duke Marine Laboratory, particularly Lindsey Renner, was especially helpful in getting this project off the ground.

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