Testing a Device to Exclude Ovigerous Blue Crabs, *Callinectes sapidus,* from Commercial Pots

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ABSTRACT—North Carolina fishery managers are considering methods to offer greater protection to the blue crab, Callinectes sapidus, *spawning stock while maintaining a viable commercial fishery for female blue crabs in high salinity estuaries. We tested how effectively wire rectangles, or excluders, of two internal sizes, 45x80 mm and 45x90 mm, would prevent entry of ovigerous female (sponge) crabs into pots relative to control pots (without excluders) while maintaining sizes and catch rates of male and nonsponged female hard crabs. Field sampling among three pot designs (two excluder sizes and control pots) was conducted in Core Sound, N.C., during 2004–06. Median sizes (carapace widths) of mature female crabs were not different among the three pot types. However, median sizes of male crabs and sponge crabs were greater in control pots than pots with either size of excluder. Catch rates of mature female crabs from control pots were greater than from pots with 45x85 mm excluders. Catch rates of legal male and sponge crabs from control pots were greater than from pots with either size of excluder. Results indicate that using excluders involves a tradeoff between reducing catches and sizes of sponge crabs while also reducing sizes and catches of legally harvestable nonsponge crabs; moreover, the reduction in total catch and sizes would be greater for legal male crabs than for legal nonsponged female crabs. In high salinity waters close to North Carolina's existing no-harvest blue crab sanctuaries, where females typically dominate catches of hard crabs, the benefit of using excluders to prevent entry of sponge crabs may outweigh a potentially modest decrease in landings of nonsponged females.*

Introduction

The blue crab, *Callinectes sapidus,* provides the most economically important fishery in North Carolina (NCDMF, 2004) but population trends have raised concerns among fishery managers. Eggleston et al. (2004) documented a significant spawning stock-recruitment relationship, and trends in biomass decline, increasing fishing mortality, and decreasing mean size of mature females during 1987–2001. Because female crabs have a terminal molt and small mature females may continually escape through cull rings, fishing mortality may decrease their average size and subsequent recruitment in North Carolina (Wolcott and Wolcott, 2004). For these reasons, fishery managers have set a goal to maintain the stock at a level that maximizes reproductive potential (NCDMF, 2004).

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Brooding female (sponge) crabs can be legally harvested in North Carolina. Since 1965, North Carolina has used five spawning sanctuaries to protect mature female crabs in the vicinity of inlets between the Atlantic Ocean and Pamlico and Core Sounds (Fig. 1). Owing to seasonal and annual fluctuations in salinity, as well as their small area, sanctuaries appear to offer minimal protection to the North Carolina blue crab spawning stock (Medici, 2004). Fishery managers in North Carolina have recently expressed interest in investigating other methods to protect the sponge crab population short of an outright prohibition against their harvest (NCDMF, 2004).

Effective protection of sponge crabs may increase the reproductive potential for blue crabs in North Carolina; this species currently has a stock status of "concern" in the state (NCDMF[1]). There are several reasons to investigate efficient, inexpensive methods to reduce capture rates of sponge crabs in the North Carolina commercial pot fishery instead of simply prohibiting their harvest. Depending on location and time of year, sponge crabs have relatively little or no market value. As such, they are often discarded at sea or landed at low-value (cull) market grades (Paul J. Rudershausen, personal observ.). The capture and subsequent release of sponge crabs can affect their brood sizes and migrations. Sponge crabs mutilate their broods while held in pots (Rittschof, 2004), but the impact of sponge crab confinement on reproductive potential has not been quantified. Prohibiting the harvest of sponge crabs would affect crab fishermen along the Outer Banks, where these crabs can constitute 25% or more of the harvest (Ballance and Ballance, 2003).

The effectiveness of a device to exclude sponge crabs but permit entry of nonsponged crabs rests on the fact that these two groups have different body proportions. A similar premise has been used to effectively exclude diamondback terrapins, *Malaclemys terrapin*, from crab pots (Guillory and Prejean, 1998). A partially or fully developed egg mass will result in a functionally greater body length (inter-orbital teeth to the back of

[1]NCDMF. 2006. Stock status of important coastal fisheries in North Carolina, 2006. Available online at http://www.ncfisheries.net/stocks/bluecrab.htm.

the apron) and body depth of a sponge crab relative to a male or nonsponged mature female of roughly equal carapace width (Fig. 2). Blue crabs enter pots in a direction parallel to their carapace width such that this dimension is perpendicular to the face of the opening that the crab enters (Guillory and Merrell, 1993). Thus, the body length and depth of a blue crab will determine whether it fits through the opening of a crab pot. The development of the egg mass can prevent entry of a sponge crab into a pot with a restrictive opening, depending on the size of the opening, size of the crab, fullness of the sponge, and motivation of the crab to enter the pot.

Our objective was to identify one or more excluder sizes that would simultaneously reduce sizes and numbers of sponge crabs relative to control pots while maintaining sizes and numbers of nonsponged crabs. If effective at preventing the entry of sponge crabs into pots, excluders would increase reproductive potential of the blue crab population through at least three processes: 1) reduce levels of harvest, 2) reduce stress (such as brood scrubbing) and limb loss to sponge crabs that fishermen elect not to harvest, and 3) eliminate a barrier to sponge crabs migrating to offshore waters to release their broods. In theory, a barrier to entry, such as an excluder, would only need to be applied in the high salinity portions of estuaries where sponge crabs are typically found.

Eldridge et al. (1979) believed that the effectiveness of culling devices affixed to crab pots depended on satisfying three criteria; they are inexpensive and easy to affix, they reduce catches of non-target crabs, and they maintain catches of target crabs. These criteria were considered in assessing the utility of sponge crab excluders as a means to protect blue crab broodstock in North Carolina waters.

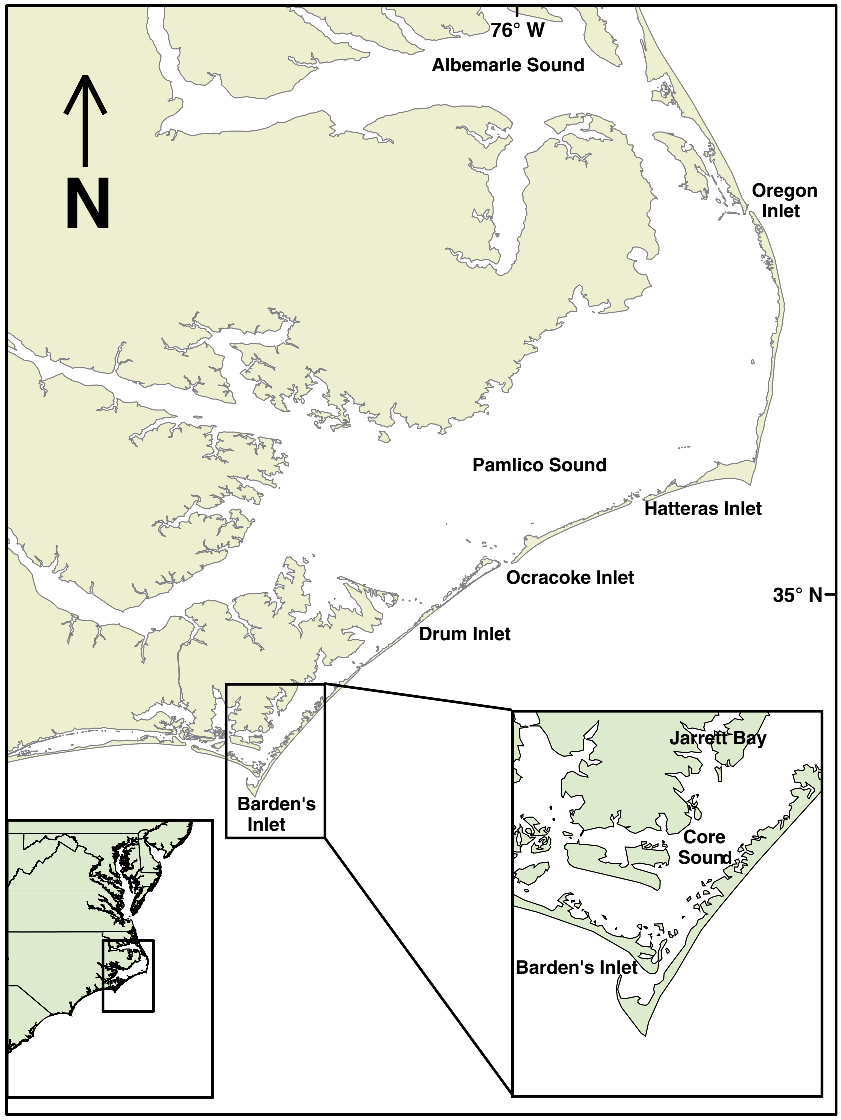

Figure 1.— The field sampling area, Jarrett Bay and lower Core Sound, N.C. Oregon, Hatteras, Ocracoke, Drum, and Barden's Inlets represent the five blue crab spawning sanctuaries in North Carolina.

Methods

Potentially effective excluder sizes were determined from trials conducted in spring, 2004 by holding hard crabs in shedding tanks. Seven sizes of rectangular excluders were tested: 52×105, 50×100, 50×95, 50×90, 45×90, 45×80, and 40×80 mm (internal dimensions). Excluders were constructed from 12-gauge stainless steel, with four of the same size attached with wire hog clips to the four funnel entrances of each of seven pots (Fig. 3). Each pot soaked for tank trials was baited with previously frozen Atlantic menhaden, *Brevoortia tyrannus*.

Pots were submerged into tanks that measured 2 m long, 0.75 m wide, and 0.4 m deep, which covered the funnel entrances of pots. Ten tagged, variably sized crabs of each type (legal male (>127 mm carapace width), mature female, and sponge) were introduced in turn into a tank containing a single pot. The status (entry vs. non-entry) of each crab was recorded every 4 h for 24 h. A second 24 h trial was repeated for each type and excluder size using ten new crabs. From these tank experiments, two excluder sizes were selected for comparisons in field trials: 45×90 and 45×85 mm. Smaller excluders prevented entry of a high percentage of nonsponged crabs while larger excluders allowed entry of a high percentage of sponge crabs.

Pots with excluders were fished alongside control pots (no excluders) from 2004–06. All field trials were conducted in Jarrett Bay and adjacent lower Core Sound, a mesohaline estuary west of North Carolina's Outer Banks (Fig. 1). Lower Core Sound lies close to (~10 km from) Barden's Inlet, one of the five North Carolina blue crab spawning sanctuaries. Salinity in this estuary varies widely as a function of wind and rainfall (Paul J. Rudershausen, personal observ.). In 2004 (May–November), pots were deployed over a range of salinities (10–30‰) (upper Jarrett Bay–lower Core Sound) in order to capture male, female, and sponge crabs in a range of sizes. In 2005 (April–June) and 2006 (May–June), we made an effort to deploy pots in higher salinities (Core Sound) to capture a greater number of sponge crabs. All pots were made of 38.1 mm vinyl-coated square mesh that had two legally mandated 58.7 mm escape (cull) rings affixed to the middle of opposing sides of the upper chamber of each pot.

Pots were baited with fresh or frozen fish, deployed sequentially (varying treatments), and soaked for durations ranging from 24–96 h. Within each sampling period, all pots were soaked for the same duration. The 2004 field sampling consisted of fishing 36 pots (before pot loss) on each of 40 days. The 2005 sampling fished 60 pots on each of 20 days, and the 2006 sampling fished 30 pots in each of 20 days.

Upon retrieval of each pot, each crab was identified (male, mature female, immature female, and sponge) and measured (carapace width, body length, and body depth, mm). Male crabs were separated by size (legal vs. sub-legal). Female crabs were separated by level of maturity (mature vs. immature; North Carolina seasonally prohibits harvest of immature female crabs of certain sizes). Brood color (a proxy for brood stage) and percent fullness (nearest 25%) were recorded for sponge crabs.

Figure 2.—Mature nonsponged female (left) and sponged female crab (right). The brood effectively increases the body length (distance from interorbital teeth to back of the apron) and dorsal-to-ventral body depth.

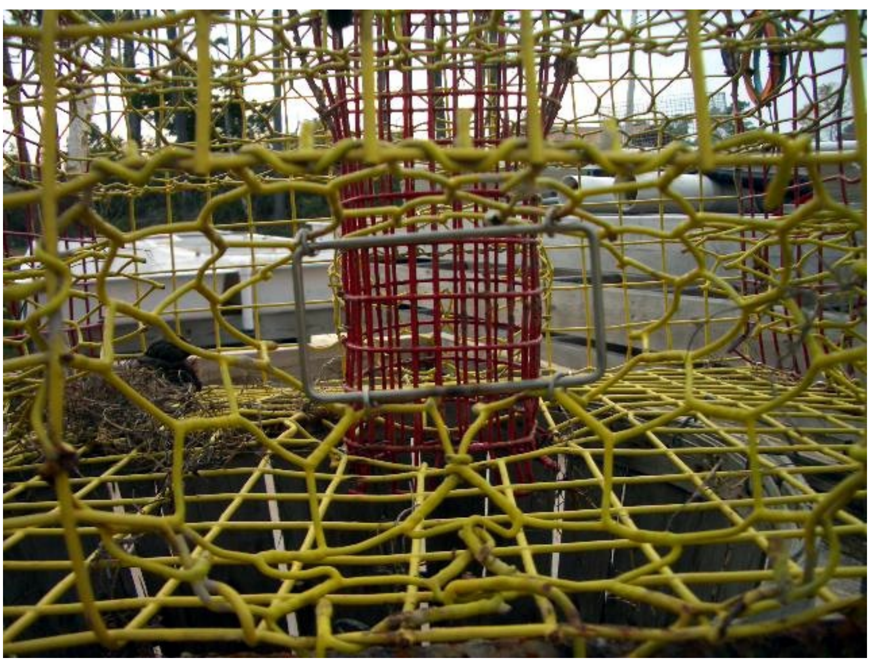

Figure 3.—Excluder attached to a funnel entrance of a pot set for hard crabs. Photograph is taken from the outside the funnel entrance looking inward through the stainless-steel excluder into the bottom chamber of the pot. The small-mesh bait well is in the background.

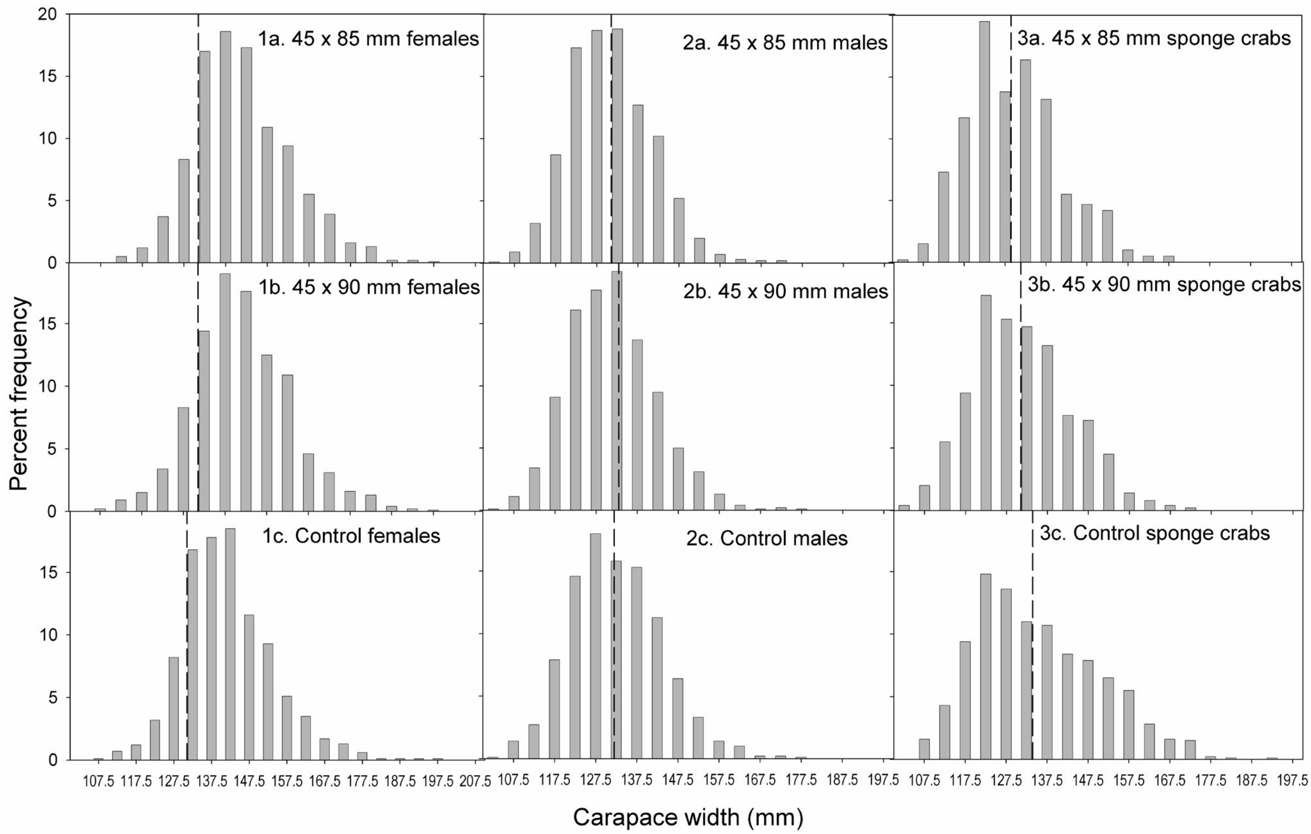

Figure 4.—Carapace width frequency histograms and median carapace widths (vertical dashed lines) of mature female (1), all male (2), and sponge crabs (3) from pots with 45×85 mm excluders (a), 45×90 mm excluders (b), and control pots (c) tested during 2004–06.

Carapace width, body length, and body depth (mm) were measured on each crab ≥ 59 mm body length. Crabs that were less than 59 mm body length (less than the diameter of the cull rings) were not included in the analysis because early in the field work they were often observed escaping through the cull rings as pots were being pulled.

Owing to the high variability on the catches of each category of legally harvestable crabs (mature female, legal male, and sponge), catch-per-pot (catch-per-unit-effort (CPUE)) comparisons among treatments for each crab type were conducted using the nonparametric Kruskal-Wallis test. Post-hoc multiple comparisons were performed in those cases when the Kruskal-Wallis test statistic was significant.

Due to the non-normality of crab size (carapace width) data, widths of mature female, all male (legal and sublegal), and sponge crabs were compared among treatments using a median test, a nonparametric pairwise ranks test that employs a chi-square test statistic.

Body length and depth measurements were used to determine the percentage of crabs in each of three categories (female, legal male, and sponge) that were too large to fit through each of the two excluder sizes tested in field trials.

Results

A total of 1,061 control pots, 1,027 pots with 45×90 mm excluders, and 1,015 pots with 45×85 mm excluders were fished. Median and mean carapace widths of mature female crabs were similar among treatments (Fig. 4; Table1). There were no significant pairwise differences in the median carapace width of mature female crabs between treatments (Table 2). Excluders had a more pronounced effect on widths of male than female crabs (Fig. 4; Table1). Each excluder treatment caught significantly smaller male crabs than the control, although there was no difference among the two excluder treatments (Table 2). Excluders also had a pronounced effect on the widths of sponge crabs (Fig. 4; Table 1). Each excluder treatment caught significantly smaller median sized sponge crabs than the control, although there was no difference among the two excluder treatments (Table 2).

The analysis of catch-per-pot data indicated that larger openings permitted the entry of greater numbers of mature female, legal male, and sponge crabs (Table 3). Pots with 45×90 mm excluders, but not pots with 45×85 mm excluders, maintained mean catch rates of mature females relative to control pots (Krukal-Wallis H=10.19; p=0.070) (Fig. 5a, Table 4). Pots with each size

Table 1.—Median and mean (±S.E.) carapace width (mm) of mature female, all male, and sponge crabs among three pot treatments tested during 2004–06.

Measurement	Treatment	Mature female	Male	Sponge
Median	45×85 mm excluder	141	131	129
	45×90 mm excluder	141	133	131
	Control	141	132	134
Mean	45×85 mm excluder	141.90±0.25	131.52±0.23	130.06±0.59
	45×90 mm excluder	141.91±0.24	131.68±0.22	131.59±0.55
	Control	142.21±0.23	132.86±0.21	135.72±0.53

Table 2.—Chi-square test statistics and significance levels (α= 0.05) of multiple comparisons tests of median carapace width of mature female, all male, and sponge crabs among three pot treatments tested during 2004–06.

Crab type	Treatment ↓ →	45×85 mm excluder	45×90 mm excluder
Mature female	45×85 mm excluder		
	45×90 mm excluder	1.08; 0.299	
	Control	0.71; 0.400	0.04; 0.841
Male	45×85 mm excluder		
	45×90 mm excluder	0.25; 0.614	
	Control	14.18; 0.0001	8.07; 0.005
Sponge	45×85 mm excluder		
	45×90 mm excluder	4.02; 0.045*	
	Control	15.81; <0.0001	9.85; 0.002

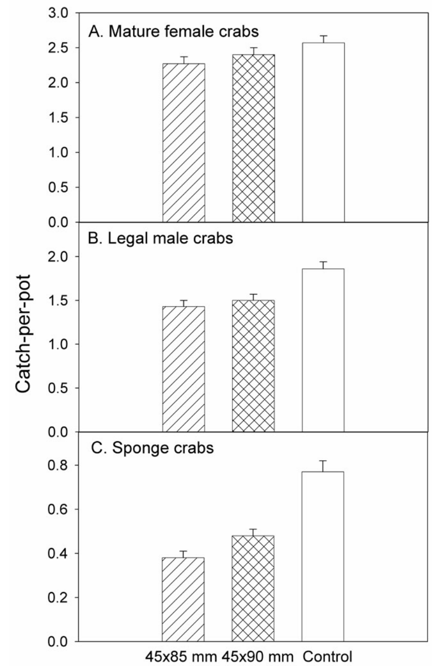

Figure 5.—Mean catch-per-pot (± S.E.) of mature female (a), legal male (b), and sponge crabs (c) among three pot treatments tested during 2004–06.

of excluder caught significantly less legal male crabs than control pots (H =26.05; p=0.001) (Fig. 5b; Table 4). Similar results were observed for the mean number of sponge crabs caught (H =49.09; p<0.001) (Fig. 5c; Table 4).

Crabs from control pots were assumed to represent the sizes of crabs in the Core Sound population (no negative size selectivity). Measurements of mature female crabs from control pots from 2004–06 showed that 0.5% had a body length and/or depth that exceeded the 45×85 and 45×90 mm excluders. Measurements of legal male crabs from control pots show that 0.7% had a body length and/or depth that exceeded the 45×85 and 45×90 mm excluders. Lastly, measurements of sponge crabs from control pots show that 13.4% had a body length and/or depth that exceeded the 45×85 mm excluder while 7.2% had a body length and/or depth that exceeded the 45×90 mm excluder.

Table 3.—Mean catch-per-pot (±S.E.) of mature female, legal male (≥127 mm carapace width), and sponge crabs among three pot treatments tested during 2004–06.

Treatment	Mature female	Legal male	Sponge
45×85 mm excluder	2.27±0.10	1.43±0.07	0.38±0.03
45×90 mm excluder	2.40±0.10	1.50±0.07	0.48±0.03
Control	2.57±0.10	1.86±0.08	0.77±0.05

Discussion

Three years of sampling in Core Sound indicates that, depending on spring salinities and weather, the potential exists for crab pots with excluders to reduce entry of sponge crabs relative to those without excluders (control pots). In this experiment, control pots had a significantly greater catch rate of sponge crabs than pots with either size of excluder. Sampling also demonstrated that pots with excluders could not maintain catch rates of both mature female and legal male crabs while concurrently reducing catch rates of sponge crabs. Further, when using excluders, sizes of both mature female and legal male crabs could not be maintained while also reducing sizes of sponge crabs. While some crabs can pass through an excluder of an equal or smaller size than their body length and/or depth, the field data we collected also indicates that a restrictive opening the same size or slightly (mm) larger than a crab's body length and/or depth will deter some non-sponge crabs trying to enter pots.

Only a small percentage of sponge crabs from control pots had body lengths and/or depths that would theoretically prevent them from entering pots with 45×85 (13.4% prevented entry) and 45×90 mm excluders (7.2% prevented entry) (Fig. 6). (It is assumed that

Table 4.—Significance levels (α= 0.05) of multiple comparisons tests of mean catch-per-pot of mature female, legal male (≥127 mm carapace width), and sponge crabs among three pot treatments tested during 2004–06.

Crab type	Treatment ↓ →	45×85 mm excluder	45×90 mm excluder
Mature female	45×85 mm excluder		
	45×90 mm excluder	0.888	
	Control	0.018	0.268
Legal male	45×85 mm excluder		
	45×90 mm excluder	0.660	
	Control	<0.0001	0.006
Sponge	45×85 mm excluder		
	45×90 mm excluder	0.954	
	Control	<0.0001	0.0002

the funnel opening of a control pot (~150×100 mm) is sufficiently large that it does not bias the size of sponge crabs entering it). While sampling closer to Barden's Inlet or one of the other four inlet blue crab sanctuaries in North Carolina may have yielded different percentages of sponge crabs that would theoretically be prevented entry by using excluders, it is assumed that the size distribution of sponge crabs approximates that of the population from other waters close to spawning sanctuaries. While the percentage of sponge crabs prevented entry from excluder-equipped pots is low, reducing the excluder size to prevent entry of a larger percentage of sponge crabs would (in the minds of commercial fishermen) prevent entry of an unacceptably high percentage of nonsponged legal crabs. Sponge crabs prevented entry by either 45×85 or 45×90 mm excluders would be among the most fecund in the population; a sponge crab 180 mm carapace width, for example, has a brood with roughly three times the number of eggs as a sponge crab 120 mm carapace width (NCDMF, 2004). Since a female crab can produce up to five broods in the same season (Rittschof, 2004), the disproportionately greater egg production by larger females, and protection of these female, have benefits over multiple broods.

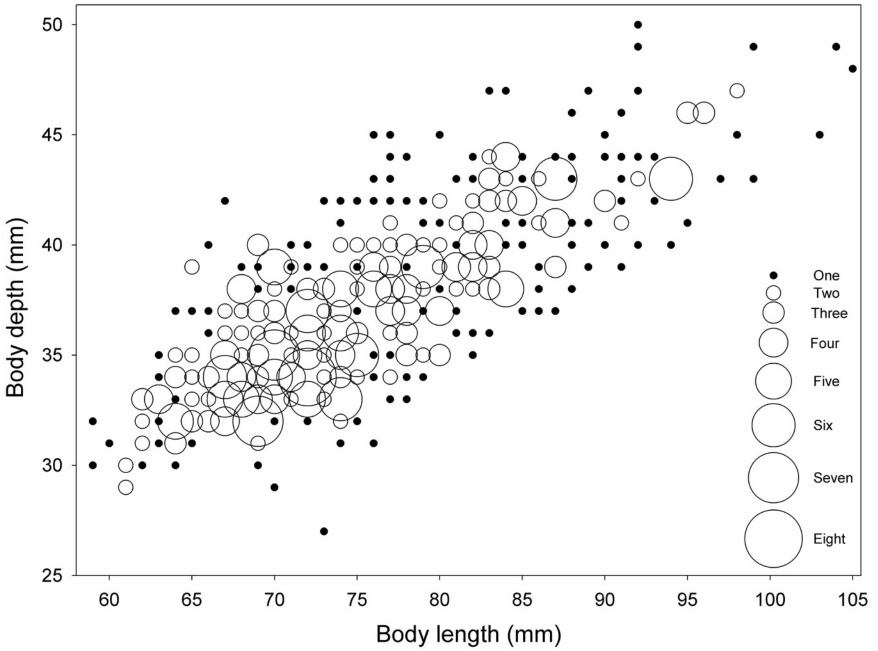

Figure 6.—Body lengths and depths (mm) of sponge crabs with full broods (estimated 100%) from control pots. Color (black or white) and size of each mark denotes the number of sponge crabs that had this body length and depth.

According to a recently developed model of sponge crab emigration from nearby Newport River (NC) estuary (Rittschof, 2002), sponge crabs caught in Core Sound are carrying their first broods. Thus, harvest of sponge crabs in North Carolina estuaries eliminates not only release of the first brood, but production and release of subsequent broods as well. Field work from studying excluders indicates that the reproductive potential of blue crab broodstock may also be impacted by brood scrubbing when sponge crabs become stressed from confinement in pots. Of sponge crabs that had broods in the early stages of development (yellow or orange sponges) when a rounded sponge should be observed, 31.7% had broods with a scrubbed appearance. Rather than naturally releasing some of their brood, many crabs with orange or yellow sponges likely were stressed in pots to the point that they began to scrub (Rittschof, 2004). Additionally, field work for the excluder study revealed that 28% of sponge crabs had brown or black broods. Given that sponge crabs release their broods in coastal (not estuarine) waters (Rittschof, 2002), it appears that sponge crabs are being caught as they emigrate from estuaries. Thus, the reproductive potential of sponge crabs may be impacted through harvest and capture that stresses the crab (brood scrubbing) or delays its migration offshore.

Success of using excluders as a management tool to protect sponge crabs rests on two premises: 1) male and female crabs are variably distributed by salinity, and 2) fishermen would be satisfied that specific areas where excluders are required have sufficiently few male crabs that the sizes and catch rates of nonsponged hard crabs (primarily nonsponged females) could be maintained. In the study area, the composition of the hard crab catch abruptly switched from males to females with increasing distance from land (or marsh) (increasing depth) and also proximity to Barden's Inlet (increasing salinity). While the catch was not examined on an area-by-area basis, these observations indicate that using excluders in high salinity waters close to inlets would have little impact on catches of males, because relatively few are found there. Indeed, the differential salinity preferences between male and female crabs creates a relatively low natural abundance of males in the vicinity of inlet sanctuaries, and a correspondingly low expectation by commercial fishermen that large numbers of males would be found there. The comparative catch data between excluder sizes also shows that using excluders of the largest size we tested (45x90 mm) would have no statistical impact on catch rates of nonsponged females compared to pots without excluders (control).

The seasonal abundance of sponge crabs is sufficiently brief and the area where they are found in abundance sufficiently small that excluders could have a positive effect if used over short periods and in specific locations. Of course, North Carolina already has time and area closures to protect sponge crabs, in the form of its five spawning sanctuaries that prohibit crab potting and trawling during seasons (spring/summer) of greatest sponge crab abundance. The effectiveness of North Carolina's five blue crab sanctuaries remains unclear. In 2005 sampling, sponge crabs represented 29% of our total catch despite our relatively long distance (~12 km) from the nearest sanctuary, Barden's Inlet. Medici (2004) postulated that a spatially and temporally dynamic, rather than static, sanctuary program would allow managers the flexibility to protect sponge crabs during times when, and in areas where, they are most abundant. These areas of highest sponge crab concentration before they leave estuaries would likely shift westward during drought years and seaward during years of high rainfall (Medici, 2004).

Because of their construction from 12-gauge stainless steel, each excluder was relatively expensive ($2.60, 2004 price). The cost of outfitting an entire pot with excluders from stainless would be a likely impediment to their acceptance among commercial fishermen. However, high-density polyethylene (HDPE) (for example) can be molded to form excluders of precise sizes and relatively inexpensive prices (~$0.30 each, 2004 price). HDPE excluders attached externally to funnel entrances, such as done in studies of interactions between diamondback terrapins and crab pots (Cahoon and Hart 2004), can greatly decrease the time required to affix or remove them.

This analysis of excluders as devices to prevent entry of sponge crabs to pots while allowing entry of nonsponged crabs demonstrates that excluders of any one size are not highly effective at preventing entry of sponge crabs. The largest openings tested (control pots) allowed the greatest rates of capture of both sponge and nonsponged crabs. Conversely, the smallest excluder tested prevented entry of a high percentage of sponge crabs (relative to control pots) but also prevented entry of a high number of nonsponged hard crabs. Rather than a physical barrier such as excluders, a yet-to-be-tested chemical device may hold greater promise of preventing entry of sponge crabs in high salinity environments where their protection is sought.

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