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NOTE

A Test of Bycatch Reduction Devices on Commercial Crab Pots in a Tidal Marsh Creek in Virginia

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Abstract The effectiveness of bycatch reduction devices (BRDs) on commercial pots designed to capture blue crabs *Callinectes sapidus* was tested in the York River on Felgates Creek (37.2667 N, −76.5850 W) over the period 4 June through 31 July 2009. For each of 10 pairs of pots, one had BRDs affixed to all four entrance gapes and the other had none. Pots were baited approximately once each week but were sampled for blue crabs and bycatch 6 of 7 days each week for the duration of the study. More than one fourth of 1,643 total crabs were caught on the first day after baiting, and for these 7 days, no statistical difference was detected between either the number or size of legal-size crabs caught in BRD versus non-BRD pots. Of 51 *Malaclemys terrapin* and 44 fish caught as bycatch throughout the study, all but three fish were captured in non-BRD pots. BRDs exclude bycatch and may reduce incidental mortality of crabs in pots that are not tended regularly.

Keywords Diamondback terrapin · Excluder · Recreational crabbing

Introduction

The diamondback terrapin *Malaclemys terrapin* is the only fully estuarine turtle in the Western Hemisphere, occurring in coastal habitats from Massachusetts to the Gulf Coast of Texas (Ernst and Lovich 2009). Low numbers or measured declines in population sizes from various threats throughout their range have prompted many states to list terrapins as endangered, threatened, or a species of special concern (Butler et al. 2006). Because the economies of many of these same states are bolstered by the harvest of the blue crab *Callinectes sapidus*, extensive use of commercial pots to catch crabs has led to bycatch mortality of terrapins (Wood 1997; Roosenburg and Green 2000; Hoyle and Gibbons 2000; Butler and Heinrich 2007; Dorcas et al. 2007; Grosse et al. 2009; Rook et al. 2010). New York, New Jersey, Maryland, and Delaware now require a version of a terrapin excluder device on certain commercial pots to reduce that source of mortality, but enforcement is difficult (Roosenburg 2004).

Terrapins typically spend most of their lives in shallow water adjacent to tidal wetlands, so during the summer, only a small portion of the crab fishery spatially intersects with turtle habitat (but see Roosenburg 2004). Within that shallow-water habitat, however, we recognize at least four possible sources of commercial pots. First, some commercial hard-shell crabbers may run lines of pots along the mainstem of small tidal creeks, with daily baiting and harvesting. Second, commercial crabbers during a short period may run "peeler pots" baited with male crabs to attract female crabs ready to shed their shells prior to mating. Crabbers focus their effort in the relatively protected habitat of small tidal creeks where peelers concentrate. Third, many recreational crabbers place one or two commercial-type pots in shallow tidal waters near their waterfront property homes. Baiting and checking of recreational pots may be infrequent. Finally, when hard-shell crab pots placed in deeper water break free from their moorings or are abandoned, they may be carried by storms or tidal currents into shallow-water habitat. Though they are never baited, these ghost or derelict pots are potential,

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chronic causes of bycatch mortality (Roosenburg 1991; Guillory and Prejean 1998; Havens et al. 2008).

In most states where required, regulations to install bycatch reduction devices (BRDs) on crab pots have targeted recreational crabbers, but clearly crab pots from other users are either fished or end up in shallow-water habitat where terrapins are most abundant. For the present study, we designed an experiment to test BRD function in a brackish marsh complex. Our objective was to complete the first test of BRDs in Virginia shallow subtidal waters where recreational, peeler, and derelict crab pots are located. By baiting pots at infrequent intervals, we were also able to assess the potential influence of some recreational pots (that are rebaited infrequently) and derelict pots (that are never rebaited) on crab catch and terrapin bycatch.

Materials and Methods

Study Area

The experiment was conducted over the period beginning 4 June 2009 and ending 31 July 2009, with all sampling completed in the upper reaches of Felgates Creek, a mesohaline tidal marsh creek connected to the York River, on the Yorktown Naval Weapons Station (37.2667 N, −76.5850 W). The surrounding wetland complex is dominated by the marsh grass *Spartina alterniflora*. Commercial and recreational crabbings have not been allowed in Felgates Creek for over 40 years (Rook et al. 2010).

Bycatch Experiment

We placed ten pairs of commercial crab pots (galvanized steel; commercial and recreational pots require cull rings but these were not used in this study) in the subtidal portions of Felgates Creek, to an approximate depth of 60 cm at mean low water so that the pots were submerged at all times. This shallow subtidal zone is where many recreational crab pots are placed and where some derelict and abandoned pots get carried by wave and current action. To ensure that terrapins did not drown when captured, all pots were fitted with sealed poultry wire "chimneys" that extended 120 cm above the top of the pot. During high tide, captured terrapins swam up the chimney to the water surface to breathe.

For each pair of commercial pots, one pot was fitted with 12×4.5 cm BRDs (TopME© Products) attached near the interior end of the funnel of all four gapes; the other pot was not fitted with BRDs. Our sampling strategy was designed to test the effect of BRDs and the impact of infrequent pot baiting on crab catch and bycatch. Although sampling of pots was completed 6 days/week, we baited the pots with fresh gizzard shad (*Dorosoma cepedianum*) on average once each week for 7 weeks during summer 2009. We chose this experimental design because many recreational crabbers bait and/or check their pots infrequently; further, abandoned pots are not tended at all, so the catch obtained after many days without fresh baiting also is a potential proxy for pots that have been lost. The effects of self-baiting on crab capture by abandoned pots, however, were not tested in this study.

When sampling, every organism caught in a pot was identified and recorded. Crabs were sexed, and point-to-point carapace width was measured using a sliding caliper. Legal-size crabs were those with carapace widths exceeding 12.5 cm. Each captured turtle was sexed and measured for carapace width and shell depth. Finally, every newly captured turtle was marked by filing a unique series of notches in the marginal scutes (Cagle 1939); recaptures were noted. The number of fish in each pot was recorded and all live bycatch was set free. Any dead fish remaining in pots were removed, and no bait remained in pots after the second day.

Terrapin Population Estimate

In addition to pots placed in the subtidal creeks, we placed ten commercial pots fitted with 60-cm chimneys in small intertidal channels of the vegetated marsh. These pots remained unbaited throughout the same study period as the BRD experiment and were sampled approximately 6 days each week of the study. All newly captured terrapins were sexed and measured for carapace width and shell depth, marked with a unique code using the notching technique, and then released at the point of capture. Recaptures were noted, and population size was estimated using the Schnabel mark–recapture method (Krebs 1989).

Data Analysis

All capture data were tested for normality using Shapiro–Wilk tests and found to be nonnormally distributed. Because no transformation led to normalization of the data, nonparametric tests comparing crab catch and crab sizes in BRD versus non-BRD pots were completed using Mann–Whitney *U* tests. Bycatch differences as a function of bait day were tested using Kruskal–Wallis analysis of variance. For all tests, the significance criterion was $p<0.05$.

Results

Bycatch Experiment

Throughout the 46 pot sampling days, we caught 1,634 total crabs, of which 679 were of legal size; male crabs comprised 93% of the total catch and 96% of the legal-size catch (Table 1). We caught a mean of 1.78±1.79 SD crabs per pot per day, with a minimum of zero crabs and a maximum of 11 crabs. Catch per unit effort (CPUE) for total and legal-size crabs was highest on the first sampling date following pot baiting (Fig. 1). Over 25% of total crabs were caught on the first day after baiting (Table 1). For these seven sampling days immediately after pot baiting, neither the difference in average ± SD CPUE (2.86±2.02 versus 3.33±2.26 crabs) nor legal-size CPUE (1.19±1.35 versus 1.43±1.40) was significant between BRD and non-BRD pots, respectively (Mann–Whitney U=2,213.5, p=0.318 and U=2,186.5, p=0.254).

Across all other days since baiting (N=39), both the difference in total CPUE (1.07±1.16 versus 2.01±1.80) and legal-size CPUE (0.44±0.70 versus 0.83±1.08) were significant between BRD and non-BRD pots, respectively (Mann–Whitney U=76,434.5, p<0.001 and U=86,733, p<0.001). The difference in mean ± SD size of legal-size crabs in BRD pots (13.30±0.46 cm) and non-BRD pots (13.42±0.68 cm), however, was not significant (U=51,155, p=0.184).

Although crab catch varied by the number of days since pot baiting, the bycatch of terrapins was similar among sampling days irrespective of baiting (Kruskal–Wallis test, X^2=11.71, df=12, p=0.514). All of the 51 terrapins caught as bycatch were in non-BRD pots, with 27 pots containing one terrapin, nine pots containing two terrapins, and two pots containing three terrapins. Further, we caught a total of 44 spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogonias undulates*), and summer flounder (*Paralichthys dentatus*), 41 of which were in non-BRD pots, and all but one of which were caught beyond the first day after baiting. Similar to terrapin bycatch, fish bycatch did not vary significantly among bait days (Kruskal–Wallis test, X^2=19.46, df=12, p=0.078). No other species comprised the bycatch.

We compared the impact of terrapin bycatch on the associated crab catch in non-BRD pots on the first day after baiting. For pots without terrapin bycatch (N=63), the total crab CPUE was 3.52±2.49 crabs; for pots in which one or more terrapins were caught (N=7), the total crab CPUE was only 1.57±1.27 crabs (Mann–Whitney U=112, p<0.05). Likewise, more legal-size crabs were caught on average in pots without terrapin bycatch (1.49±1.46 versus 0.86±0.90 crabs), but the difference was not significant (Mann–Whitney U=170, p=0.306).

Terrapin Population Estimate

From the unbaited commercial pots placed and sampled in the intertidal channels of small marsh creeks, we caught 143 terrapins, of which 98 were original captures and 45 were recaptures. The ratio of male to female terrapins was 2:1. Based on these data, we used the Schnabel mark–recapture method to estimate a total population size of 133 terrapins with a 95% confidence interval between 102 and 186 terrapins. Finally, we plotted terrapin shell depth and carapace width from all captures to show that based on size, 92% of all female and 70% of all male terrapins caught in non-BRD pots would have been excluded from pots fitted with 12×4.5 cm BRDs (Fig. 2). That we caught no terrapins in BRD-fitted pots despite some being small enough suggests possible avoidance behavior of terrapins to BRDs.

Discussion

The use of BRDs on commercial crab pots placed in subtidal sections of marsh creeks had no statistically significant influence on crab catch the day after baiting. This result is similar to the only other BRD study in Virginia waters (Rook et al. 2010), although for that study the pots were placed in more shallow, intertidal locations. With other BRD studies completed in New Jersey (Wood 1997), Maryland (Roosenburg and Green 2000), Florida (Butler and Heinrich 2007), and Louisiana (Guillory and Prejean 1998), the existing consensus is that crab catch is not dramatically compromised by BRDs.

Beyond the first day after baiting, however, crab catch dropped, demonstrating that crabs enter pots in search of food and are responding to the fresh bait. More importantly, when pots are not freshly baited, crabs do not enter BRD-

Table 1 Summary catch data for crab pots fitted with BRDs (ten pots) and those without BRDs (ten pots), splitting catch from first day after baiting (N=70 pot days) versus catch from all other days (N=380 pot days)

	First day after baiting		All other bait days		Totals
Catch	BRD	Non-BRD	BRD	Non-BRD	
Total crabs	200	233	419	782	1,634
Legal-size crabs	83	100	172	324	679
Males	189	210	396	720	1,515
Females	11	23	23	62	119
Terrapins	0	9	0	42	51
Fish	1	0	4	39	44

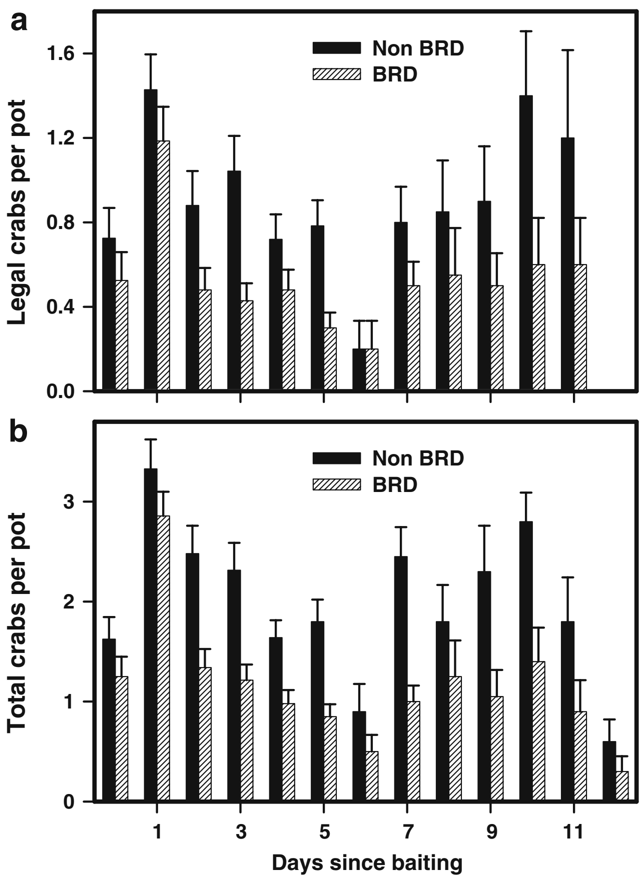

Fig. 1 **a** Mean number of legal-size crabs (+SE) as a function of days since baiting pots with and without BRDs in June–July 2009 in Felgates Creek, Virginia; **b** mean total number of crabs (+SE) in pots with and without BRDs over the same period

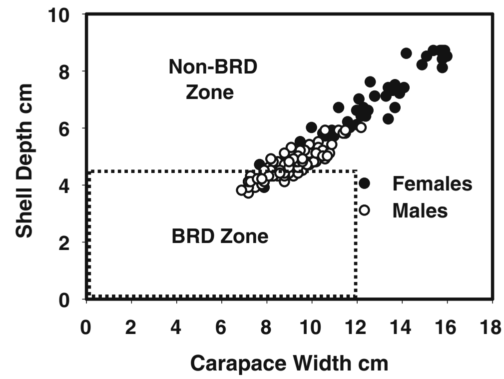

Fig. 2 Plot of carapace width and shell depth for male and female terrapins caught in non-BRD pots. No terrapins were captured in BRD-fitted pots. Dimensions of BRDs used are also plotted to show BRD zone, outside of which any terrapins captured in a non-BRD pot would have been excluded based on size

fitted pots as frequently as non-BRD pots. Irregular tending of pots might happen, for example, when some recreational pots are visited only on weekends; derelict and abandoned pots are not tended at all and are a potential long-term sink for legal-size crabs (Havens et al. 2008). Although untended pots may self-bait over time, unbaited pots fitted with BRDs did not attract as many crabs or bycatch in the present study, suggesting that BRDs may reduce incidental capture and mortality of crabs when pots are not tended regularly.

BRDs were highly effective at excluding both turtles and fish as bycatch. For male and female diamondback terrapins in Felgates Creek, the total number caught (N=51) in the ten non-BRD pots represents a potential reduction in population size from 27% to 50%. Given that pots were sampled only 46 days, the terrapin population in this creek would have experienced significant mortality of adult males and juvenile and young adult females over a single full season of commercial crabbing (8 months). Because the sex ratio of our bycatch of terrapins was male-biased (2:1), we would anticipate a shift in population demographics, as has been noted elsewhere (Roosenburg et al. 1997; Dorcas et al. 2007; Grosse et al. 2009). Interestingly, we found that terrapin and fish bycatch did not vary among bait days, i.e., terrapins and fish entered pots irrespective of whether bait was fresh. On days that bait was fresh, however, the total crab catch was significantly lower in pots containing a terrapin. These results highlight two important concerns: (1) unbaited pots pose an ongoing mortality threat to terrapins and fish and are at least as attractive as freshly baited pots and (2) the presence of live terrapins in pots reduces crab catch. Both of these concerns are addressed by BRDs that exclude terrapins, thereby reducing turtle mortality and improving overall crab catch.

The general impact of commercial crab pots on terrapin bycatch is fairly well-established (i.e., crab pots also capture turtles), but the relative contribution of different crabbing groups (e.g., recreational versus commercial crabber) to terrapin population dynamics is not as clear. We do not know to what extent the current distribution of all diamondback terrapin populations has been influenced by crabbing pressures, nor do we know about population recovery when those crabbing pressures are reduced through use of BRDs. Recent studies by Dorcas et al. (2007) and Grosse et al. (2009) have documented long-term changes in population demographics and short-term decimation of population sizes, respectively, directly related to terrapin mortality in commercial crab pots. The benefits of BRDs should be realized anywhere commercial-type crab pots are set or eventually settle into diamondback terrapin habitat.

Because pots that are placed or are transported to tidal marsh creeks and other shallow subtidal areas (e.g., seagrass beds) may be owned by recreational crabbers, commercial hard-shell crabbers, or peeler crabbers, regulations should not necessarily target a specific crabbing group. Rather, we suggest that regulations should target the terrapin habitat, i.e., BRDs should be mandated for all crabbers in areas of potentially high terrapin density. Similar to current regulations in New Jersey, metrics such as size of tidal creek or adjacency to wetlands can be used to delineate potential terrapin habitat in other states. New Jersey requires that both commercial and recreational pots within 150 ft (45.7 m) of the shoreline be fitted with BRDs (Roosenburg 2004). Based on these metrics, maps of critical habitat areas where BRDs are required could be posted, for example, on a relevant agency website. Unfortunately, the current distribution and sizes of terrapin populations relative to potential habitat is an unknown and probably complex mosaic owing to slow, long-term recovery from species decimation occurring a century ago (Schaffer et al. 2008), more recent threats to successful nesting and juvenile survivorship (Burger 1977; Feinberg and Burke 2003), and periodic pulses of adult mortality, primarily from drowning in commercial crab pots (Seigel and Gibbons 1995).

Conservation of terrapins by either protecting existing populations or facilitating the recovery of others would be best served by minimizing the potential impact from the blue crab fishery in those areas where terrapins might live. Although the BRD requirement is difficult to enforce, the potential benefits of reducing terrapin and fish bycatch and reducing the capture of crabs in infrequently checked pots make a compelling case for enacting legislation to require BRDs on crab pots in terrapin habitat.

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