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The Impact of Commercial Crab Traps on Northern Diamondback Terrapins, *Malaclemys terrapin terrapin*

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Abstract: Commercial crab traps are widely used throughout the range of diamondback terrapins (i.e., salt marshes along the Atlantic and Gulf coasts of the United States). Experiments on the Cape May Peninsula in southernmost New Jersey and elsewhere show that crab traps catch significant numbers of terrapins of both sexes, including both juveniles and adults. Unfortunately, a substantial proportion of these terrapins drown before the traps are pulled for the daily crab harvest. Conservative estimates project that tens of thousands are inadvertently killed in this manner annually along the New Jersey coast alone. It is likely that considerably larger numbers of terrapins are killed throughout this species' range every year.

During summer 1992 a rectangular wire excluder device was fitted into the inner (narrow) end of entrance funnels in typical commercial crab traps. This device, known as the "Bycatch Reduction Apparatus" (or BRA), was designed to prohibit the entry of most terrapins, yet not impair the number or size of crabs caught. Preliminary results of this pilot study and of subsequent large-scale experiments have been encouraging. Not only have the excluder rectangles greatly reduced the number of terrapins caught in modified traps, but they have also actually increased the crab catch over unmodified traps of standard design. Results of this research make prospects for the widespread adoption of terrapin excluder devices seem highly favorable.

The high mortality of nesting northern diamondback terrapins, *Malaclemys terrapin terrapin*, on roads adjacent to salt marshes in southern New Jersey is clear evidence that these turtles are affected by human activities (Wood and Herlands, this volume). However, anecdotal information from commercial and recreational crabbers suggests that crab traps are a greater source of mortality than is vehicular traffic.

Bishop's (1983) data (from South Carolina) demonstrates that commercial crab traps catch and drown significant numbers of terrapins. Data collected by the New Jersey Bureau of Marine Fisheries (P. Scarlett, pers. comm., 1991), indicates a recent dramatic increase in the number of crab traps deployed statewide and suggests that lethal bycatch of terrapins is increasing.

In New Jersey, diamondback terrapins are designated "game animals" and may be legally taken from 1 November through 30 March, a season that approximately coincides with their hibernation period. During the remainder of the year terrapins and their eggs are fully protected by New Jersey game regulations.

Commercial crabbers apparently do not sell the terrapins they find as bycatch in their traps, but because possession of terrapins during the closed season is illegal, they are generally reluctant to provide information on incidental captures.

In this paper I assess the impact of crabbing upon terrapin populations in New Jersey and describe measures developed to mitigate this impact.

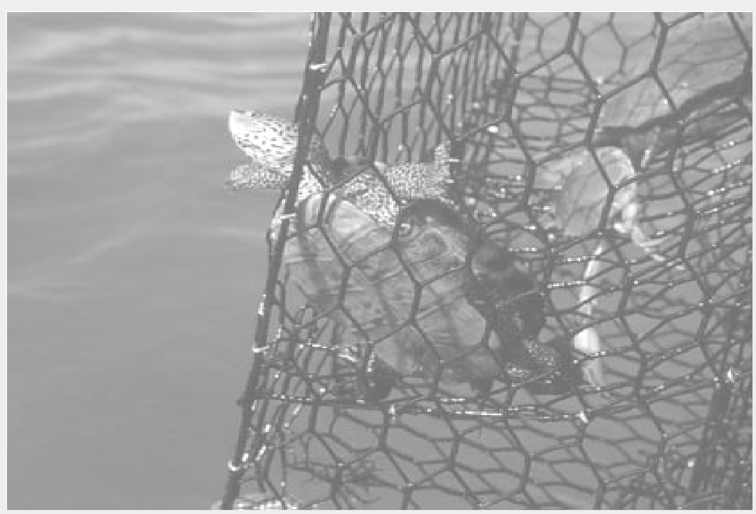

Figure 1. Northern diamondback terrapin in commercial crab trap.

I investigated the following: (1) the extent of terrapin bycatch in commercial crab traps, (2) the mortality levels of terrapins caught in commercial crab traps, (3) trap designs to enable terrapin survival within the traps, and (4) trap designs to exclude terrapins and their effect on the crab catch.

METHODS

Most of our fieldwork was conducted in the vicinity of the Wetlands Institute, a research facility located on the eastern side of the Cape May Peninsula in southern New Jersey (Figure 2). Salt marshes here are situated between a barrier island (Seven Mile Beach) and the mainland, approximately 5 km (≈3 mi) to the west. Although bounded by developed areas on both their western and eastern margins, the marshes are relatively pristine and represent typical diamondback terrapin habitat—a mixture of sinuous creeks and open shallow sounds with thousands of acres of intertidal marsh vegetation (dominated by *Spartina* spp.). Fieldwork concentrated in three areas near the Wetlands Institute: Holmes Cove at the southwestern side of Great Sound, Mulford Creek, and Stone Harbor Creek, which represent, respectively, the marshes' landward, central, and oceanside areas.

A second study area was near the Nacote Creek Research Station (New Jersey Bureau of Marine Fisheries), approximately 65 km (35 mi) north of the Wetlands Institute. Fieldwork here was conducted upstream from the mouth of the Mullica River and along the southwestern edge of Great Bay below the mouth of the Mullica during the summers of 1993 and 1994.

Fieldwork was also conducted in summer 1994 on the Delaware Bay side of the Cape May Peninsula near the mouth of Dias Creek, within the Cape May National Wildlife Refuge. Fieldwork began in summer 1989 and is ongoing.

In summer 1989 we used four Maryland-style crab traps* constructed of rectangular-mesh galvanized wire. The traps measured 24 × 24 in (61 × 61 cm) and were 21 in (53 cm) deep. Four entrance funnels, one at the base of each side, permitted entry from any direction (see Warner, 1976, for detailed description). After 1989 we used more durable traps of vinyl-coated hexagonal mesh wire, but the size and basic design of the trap remained unchanged. The new traps were weighted with bricks or rebar. Elastic cords or wire were used to keep the bait holder closed on the bottom of the trap. Styrofoam floats, painted fluorescent orange and labeled with our scientific collecting permit number, were attached to each trap by a 12–15 ft line.

We attempted to mimic the equipment and the techniques used by commercial crabbers to ensure that our results would be comparable to those of a typical crabbing operation. Traps were checked at least daily, and for our early experiments (before the development of an effective terrapin excluder) we endeavored to check every trap twice daily to minimize drowning of terrapins. When traps were checked, all blue crabs, *Callinectes sapidus*, and other bycatch (spider crabs, conchs, various species of fish, and terrapins) were removed, and the traps were re-baited. A variety of baits were used in early experiments, including bunker (menhaden) as well as heads and filleted carcasses of various market fish (primarily flounder and salmon). Since 1993 we have used only bunker, which is used by virtually all commercial crabbers in southern New Jersey. In some study sites, strong tidal currents and storms occasionally shifted the positions of traps, altering the trap sequence and resulting in the loss of a few traps. Inadvertent and deliberate human activities may also have been responsible for some trap losses. Lost traps were promptly replaced unless the experiment was nearly concluded.

All captured terrapins were removed from the traps and were sexed and measured. With some exceptions (in which only plastron length was recorded), measurements of terrapin shells are straight-line carapace length (SLCL). Incomplete

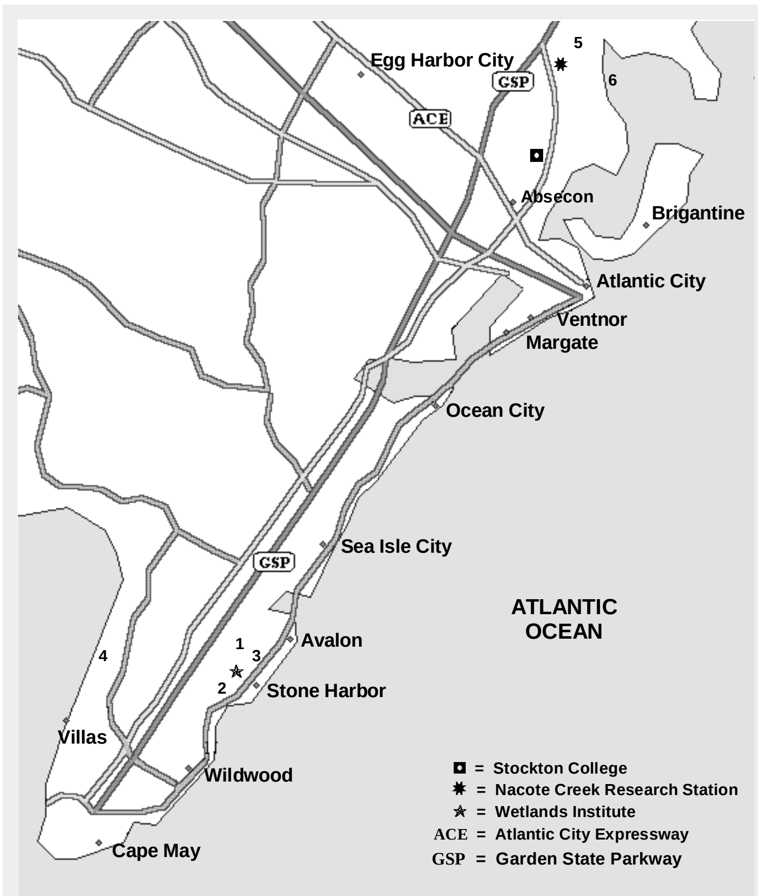

Figure 2. Map of southern New Jersey shore and Cape May Peninsula. Study areas: 1 = Holmes Cove, Great Sound; 2 = Mulford Creek; 3 = Stone Harbor Creek; 4 = Dias Creek; 5 = upstream from mouth of Mullica River; 6 = southwestern edge of Great Bay.

*All traps were purchased from the Maryland Crab Trap Company, Berlin, New Jersey.

processing of some terrapins was due to miscommunication among field personal, and certain adverse field conditions (rain, strong winds, approaching thunderstorms, or nightfall). However, these inconsistencies did not compromise the results of our experiments.

RESULTS

Tests of Unmodified Commercial Traps

A pilot project with commercial crab traps was conducted from 29 May to 29 June 1989 to determine extent of terrapin catch. Four traps were deployed alternately at two small creeks adjacent to the Wetlands Institute, resulting in 124 trap-days of effort. Because commercial crabbers typically move their traps over the course of the summer, shifting our traps between two sites simulated the practice of commercial operations. Traps were checked twice daily to minimize drowning of terrapins.

Nineteen terrapins (8 males, 11 females) were caught, a capture rate of 15 animals per 100 trap-days. Females ranged in size from 7.3 to 13.1 cm. In comparison, the carapace lengths of 16 adult females that nested in close proximity to the sites where the traps were set ranged from 15.5 to 20.0 cm (Figure 3). Males were clustered within a much smaller size range of 10.2–12.6 cm, representing the typical adult size for this sexually dimorphic species. Thus, it appeared that subadult females were being selectively trapped and adult males were routinely caught.

Four terrapins (3 females, 1 male) were drowned, a slightly greater than 20% mortality rate. Under actual operating conditions, commercial crabbers check traps no more than once a day, and New Jersey state regulations require that traps be pulled no less frequently than once every three days. Our terrapin mortality would have increased substantially had we checked our traps only once daily and may have approached 100% had we checked them less than once daily.

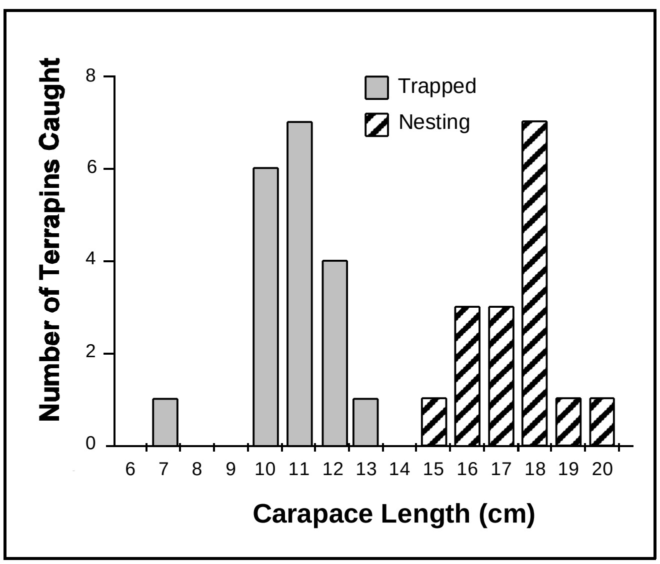

Figure 3. Size distribution of diamondback terrapins caught in unmodified commercial crab traps (dark shading) and terrapins observed nesting nearby (diagonal stripes) during summer of 1989.

Test of Floating Traps

From 27 June through 14 July 1991 we conducted an experiment in Holmes Cove intended to improve terrapin survivorship in crab traps. Nine traps were set in the conventional manner, submerged and resting on the bottom of the cove, and eight traps were equipped with a pair of rectangular Styrofoam floats to keep the trap's upper portion approximately 10–15 cm above water, allowing any captured terrapins access to the surface to avoid drowning. Traps were checked daily. Traps set on the bottom caught 85 terrapins, of which 20 (24%) drowned. Only one terrapin was caught in a floating trap and it was not drowned. The floating traps were also largely ineffective in catching crabs.* In addition, the floating crab traps were considerably more unwieldy than unmodified traps and were subsequently rejected as a mitigation strategy.

In all, bottom traps were deployed for a total of 175 working days, during which 85 terrapins were caught, a rate of 49 terrapins/100 trap-days. The sex of captured terrapins was recorded in all but two instances. The sex ratio of roughly 1:3 (21 males, 54 females) is similar to that previously calculated for this population (Yearicks et al., 1981, based on winter capture of hibernating terrapins).

Additional information on terrapin bycatch in commercial crab traps was gathered during 1991. Six commercial traps checked near our experimental area in July contained three drowned females, a capture rate similar to that in the experiment with bottom traps just described. Two additional unmarked traps adjacent to our experimental area were also checked on 13 and 14 July. One was located close to the banks of the salt marsh, while the other was farther offshore. In four trap-days (minimum), a total of 25 terrapins were captured, of which 17 (nearly 75%) had drowned. Such catches underscore the devastating effect that commercial crab traps can have upon terrapin populations.

Test of the First Excluder Design

In 1992 we attempted to design a simple, inexpensive device that would prevent terrapins from entering traps. Our goal was to reduce the aperture size to prevent access by most terrapins without compromising the crab catch. Two designs of excluder devices were tested in trapping trials from late May to early September at three sites near the Wet-

*This observation is a qualitative impression; the numbers, sexes, and sizes of the individual crabs caught were not recorded, so quantitative crab catch data are unfortunately lacking.

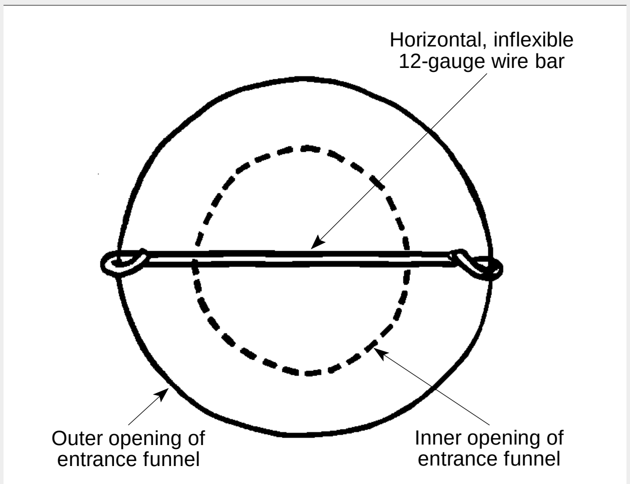

Figure 4. Sketch of the first terrapin excluder design tested (8–17 July 1992). A wire bar (approx. 10 gauge AWG, 2.6 mm) was fastened horizontally across the outer opening of each of the four funnels leading into the trap. This design proved ineffective.

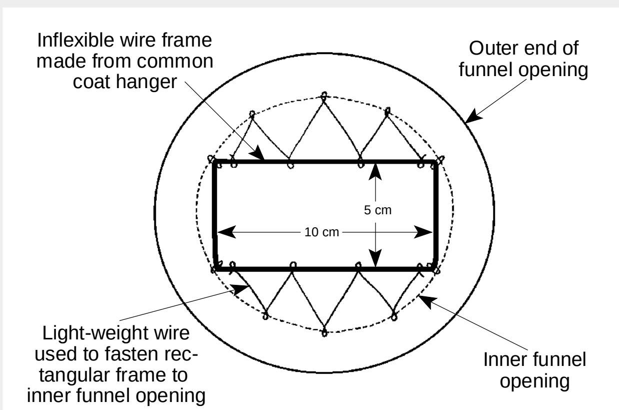

Figure 5. Second terrapin excluder design tested in summer 1992 (14 August–5 September). This was a 5 × 10 cm rectangular wire frame fastened to the inner (narrower) end of each of the four funnels opening into the trap. This device proved to be highly effective in preventing terrapins from entering commercial crab traps.

lands Institute. These were checked at least once and often twice daily during these experiments.

The first excluder device tested was a stiff wire cut from a metal coat hanger (approx. 10 gauge AWG, 2.6 mm) and fastened horizontally across the mouth of each entrance funnel (Figure 4).

To control trap bias associated with subtle differences in location, substrate, etc., traps with modified openings were paired with unmodified traps by wiring them together side by side. Exchange of terrapins between paired traps was prevented by blocking facing entrance funnels with heavy screening. Eight sets of coupled traps were set in Holmes Cove, an area known to support a robust terrapin population. The traps were checked daily over a ten-day period (8–17 July), a total of 160 trap-days of effort.

The results were disappointing. A total of 12 terrapins were caught during this experiment, six in modified traps and six in unmodified traps. Eleven were females ranging in midline plastron length (MPL) from 8.8 to 17.1 cm ($\bar{x}$ = 12.6); one was an adult male with plastron length of 10.6 cm. The six terrapins captured in modified traps were all females ranging from 8.8 to 12.4 cm MPL ($\bar{x}$ = 10.8). Though the six animals (both sexes) in the unmodified traps were on average larger ($\bar{x}$ = 14.0 cm MPL), both juveniles and adults were captured in the modified traps, and it was apparent that this device was ineffective.

First Tests of Second Excluder Design

The second excluder device tested during 1992 was a stiff rectangular frame, again made from coat hanger wire. One of these frames was attached to the inner end of each of the four entrance funnels. Each frame was held in position with light-weight copper or steel wire laced between the rectangular frame and the inner funnel opening, or by hog rings. Both crabs and terrapins would thereby be prevented from entering the trap except through the excluder (Figures 5 and 7). The dimensions of the rectangular wire excluder were 5 × 10 cm (approx. 2 × 4 in). The aperture size was based on shell measurements (maximum height and maximum width) of 68 terrapins caught in crab traps in 1992. Our data showed that 90% of this sample of terrapins would not fit through an opening less than 4 × 8 cm. However, slightly larger dimensions (5 × 10 cm) to accommodate the largest crabs were chosen for our tests. We set out a line of 16 traps, half of which were modified with 5 × 10 cm rectangular excluders. Modified traps were alternated with unmodified ones along the length of the trap line. Traps were checked almost daily (2 days missed) over a period of 23 days (14 August–5 September 1992), a total of 368 trap-days of effort.

The results of this experiment were considerably more encouraging. A total of 15 terrapins were caught, 13 in unmodified traps and only two in traps fitted with excluders. The two terrapins caught in the excluder-modified traps were an adult male (10.4 cm MPL) and a juvenile female (10.5 cm MPL). Moreover, traps modified with 5 × 10 cm rectangular excluders did not adversely affect the crab catch; the catch was actually increased.

Tests of Various Excluder Sizes

In 1993 additional trials of the rectangular terrapin excluder device were conducted to broaden the scope and sample of both terrapins and crabs and to investigate the effects of various excluder sizes.

The first experiment was designed to test the effectiveness of an excluder rectangle smaller than the 5 × 10 cm size originally used in 1992 and to determine how small an opening could be used without adversely affecting the crab catch. For 11 days from late June through early July, 20 traps were placed in Mulford Creek. Ten traps were fitted with 4 × 8 cm rectangular excluders and were alternated with ten identical, unmodified crab traps. This array resulted in 210 trap-days of effort.

Approximately two dozen terrapins were caught in the unmodified traps, whereas only one individual was caught in a trap modified with an excluder device. This single capture occurred because of equipment failure; one of the wire excluders had disassembled, allowing the turtle to enter the trap. However, the crab catch was significantly reduced in the traps equipped with 4 × 8 cm excluders, and the experiment was discontinued.

In a second experiment (conducted 7–28 July), the dimensions of the excluder were increased. Sixteen traps were set in Stone Harbor Creek, of which ten were fitted with 4.5 × 10 cm excluder rectangles (nearly identical in size to the 5 × 10 cm excluders tested in 1992). Again, modified traps were set in the water interspersed with unmodified traps. Traps were checked twice daily, and the experiment comprised 336 trap-days of effort. Twenty-two terrapins were caught, all in unmodified traps. Carapace lengths of these terrapins ranged from 11.1 to 19.8 cm. Seven were caught in one trap on a single day (9 July).

Based on these results, it is apparent that a 4.5 × 10 cm rectangular excluder is effective in preventing terrapins from entering commercial crab traps. In this experiment, modified traps caught approximately eight crabs per day (with the average size of legally harvestable* crabs being 12.5 cm), while unmodified traps caught approximately ten crabs per day (with the average size being 12.8 cm). This suggests that the size of crabs caught in traps with 4.5 × 10 cm excluders is not significantly reduced by these devices, although for reasons not immediately obvious the average numbers of crabs caught by the two types of traps differed slightly.

Subsequently, 20 traps were set (near the Nacote Creek Research Station of the New Jersey Division of Fish, Game and Wildlife) in an alternating pattern, ten modified with 4.5 × 10 cm excluders. Personnel from the Research Station and Stockton College research interns monitored the traps once a day over a 55-day period (7 July–31 August), an effort of 1,110 trap-days. Two additional areas were trapped, one located between the mouths of Motts and Oyster creeks on the southern fringe of Great Bay and the other in the Mullica River, just downstream from the mouth of Nacote Creek. As before, efforts were made to replicate the activities of the commercial crab fishery. Traps were rigged the same, the typical bait fish (bunker) was used, and traps were set in locations concurrently used by commercial crabbers.

Figure 6. An effective excluder device for commercial crab traps is constructed from 12 gauge wire bent into a stiff rectangular frame.

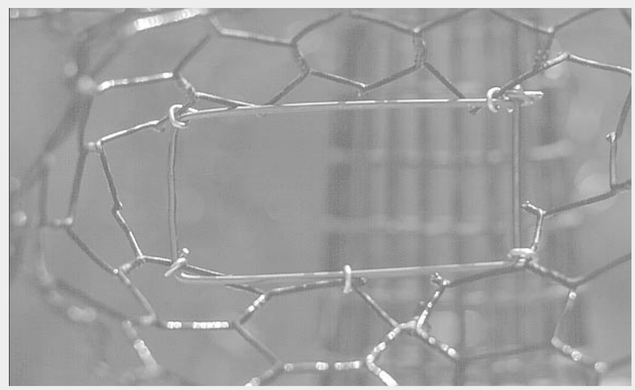

Figure 7. Wire excluder frame is fastened to inner funnel opening with lightweight copper or steel wire, or hog rings as in this photograph.

All data above were pooled for analysis. Only three terrapins were caught, all juveniles and all in unmodified traps. The weekly total crab catch declined, with some intervening fluctuations, from 1,786 in the first week to 1,021 in the final week of trapping. Over the course of this experiment modified traps caught more crabs (6,145 vs. 5,274) of essentially the same average size (13.2 vs. 13.3 cm, not counting sub-legal specimens) than did conventional, unmodified traps. (One of the unmodified traps was lost early in this experiment and not replaced; the total of 5,274 is therefore not directly comparable. The adjusted unmodified trap total would be approximately 5,500 crabs or 9% fewer crabs than in traps fitted with excluders.)

*Through 1993 the minimum legal body width (point-to-point) size for blue crabs in New Jersey, whether caught for commercial or recreational purposes, was 4 in (10.2 cm). In 1994 the minimum legal marketable crab size was increased to 4¾ in (12.06 cm). Recreational crabbers (permitted a maximum of two traps, catch restricted to personal consumption) are permitted to keep crabs of 4½ in (11.4 cm) from point to point.

There are two notable results from this experiment: (1) traps fitted with excluders actually increased the crab catch, and (2) few terrapins were caught despite exhaustive trapping efforts. The low terrapin catch may have been due to the severe depletion of the local population by sustained, heavy commercial trapping in the experimental area that has long been favored by commercial crabbers. Seasonal movement of terrapins within the estuary may also account for their absence from the trapping area.

By the end of 1993 we had established that rectangular excluders with dimensions of 4.5 × 10 cm were effective (nearly 100%) in excluding terrapins. However, we also had evidence indicating that excluders of this size may sometimes (as in our 1993 Stone Harbor Creek experiment) slightly decrease the number of marketable crabs caught in comparison to conventional traps.

1994 Tests

We therefore returned to a further test of 5 × 10 cm excluders in 1994. We set 16 traps in Stone Harbor Creek, again alternating modified and unmodified traps. Traps were deployed for a 34-day period (8 July–10 August, which generated 544 trap-days of effort.

Twenty-nine terrapins were caught. Only four terrapins (2 males and 2 subadult females) were caught in excluder-equipped traps, whereas 25 were removed from unmodified traps. This represents a capture rate of only 1.5 terrapins/100 trap-days for excluder-equipped traps versus a capture rate of 9.2 terrapins/100 trap-days for unmodified traps—a six-fold increase. The size distribution of the trapped terrapins is shown in Figure 8. Specimens ranged in carapace length from 10.0 to 20.0 cm and showed a bimodal distribution, with one peak in the 13 cm range (fully adult males and subadult females) and another at the 18 cm increment (adult females only for this sexually dimorphic species). The four terrapins caught in excluder-equipped traps were all small, ranging from 11 to 13 cm SLCL. Therefore, no large (reproductive) females were caught in traps with 5 × 10 cm excluders.

Additional testing of excluders was conducted for 61 days (1 May–20 June 1994) by the Nacote Creek Research Station. Twenty traps, half of them fitted with 5 × 10 cm rectangular excluders, were deployed in much the same areas as in 1993 (Mazzarella, 1995). Thirty-six terrapins were caught—three in excluder-equipped traps and 33 in unmodified traps. These results are consistent with those obtained from our experiment in Stone Harbor Creek. The capture rate of terrapins/100 trap-days for excluder-equipped traps (0.5) is substantially lower than for unmodified traps (5.4).

Combining the crab catch data for the Mullica River estuary experiments of 1993 and 1994 is of considerable interest and potential economic benefit to commercial crabbers. Only marketable crabs (12.0 cm and larger) are taken into consideration. Gravid females, which may not be legally taken or sold, have been factored out of these statistics. The resultant data are unambiguous and striking. Over the two-year period, excluder-modified traps caught 9,675 marketable crabs while the same number of unmodified traps caught 8,706. The difference of 969 marketable crabs represents an 11% greater catch for the excluder-modified traps.

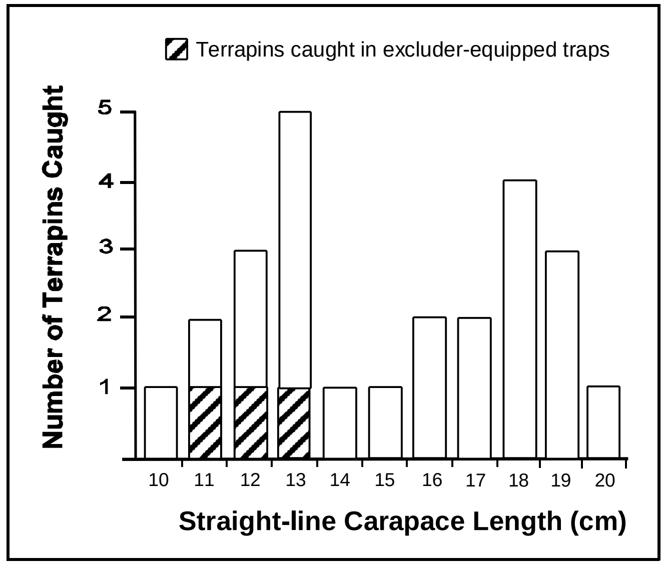

Figure 8. Size range of terrapins (N = 25; carapace lengths of four additional specimens not recorded) caught in 16 commercial crab traps set in Stone Harbor Creek 8 July–10 August 1994. Half the traps were equipped with 5 x 10 cm rectangular excluders; half were unmodified. Each carapace length represents a 1 cm interval, i.e., 10 = 10.0–10.9, etc.

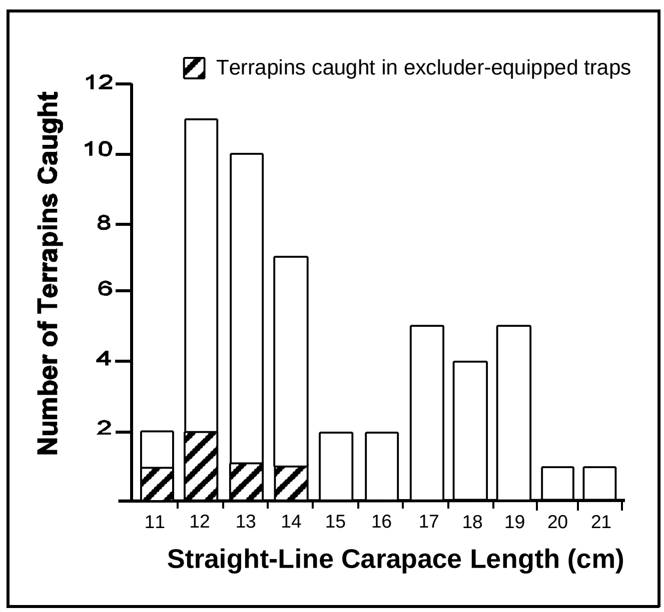

Figure 9. Size range of terrapins (N = 51) caught in commercial crab traps, both conventional and modified, during summer 1995. Each carapace length represents a 1 cm interval, i.e., 11 = 11.0–11.9, etc.

1995 Testing

In 1995 we trapped a single site, Stone Harbor Creek, to continue to build a large data base for an area where commercial crabbing regularly occurs. Twenty traps were set for a period of 61 days (14 June–13 August), a total effort of 1,220 trap-days. As before, traps were deployed linearly, alternating excluder-modified and unmodified traps.

A total of 51 terrapins were caught. Ten were males, 38 were females, and three were of unrecorded sex. Five of the terrapins (ranging from 11.9 cm to 14.9 cm SLCL) were caught in traps equipped with excluders, whereas 46 (ranging from 11.6 cm to 21.6 cm) were caught in conventional commercial crab traps. This disparate capture rate between excluder-equipped traps (0.8 terrapins caught/100 trap-days) and unmodified commercial crab traps (7.5 terrapins/100 trap-days) is comparable to previous results. Nineteen of the 46 terrapins (41%) caught in unmodified traps were larger in size than the largest terrapin caught in a modified trap. Thus, conventional traps not only caught considerably more terrapins, but also a substantial proportion of larger ones.

Figure 9 shows the size range of terrapins caught during summer 1995. All terrapins ≥ 15 cm SLCL were females. Of the seven terrapins measuring between 14.0 and 14.9 cm SLCL, only one was a male at 14.0 cm. Nineteen terrapins (37% of all those trapped) drowned. Neither sex appeared to be disproportionately susceptible to drowning.

The 1995 trapping yielded 5,404 marketable (≥ 12.1 cm) crabs (366 males and 2,743 females). Gravid females of legal size are excluded from these statistics as it is illegal to catch, sell, or consume them. Of the total, 3,237 were taken from excluder-equipped traps, whereas only 2,167 were caught in conventional traps. The difference of 1,070 represents a 49% increase in the marketable crab catch. A daily average of 53.1 marketable crabs was caught by the ten modified traps, whereas a daily average of only 35.5 crabs was caught by the ten unmodified traps.

SUMMARY

• Commercial crab traps kill subadult and adult diamondback terrapins of both sexes. From the most conservative estimates, it is clear that large numbers are drowned annually in New Jersey's coastal waters, during the time of year when terrapins are officially protected by state laws.

• Trap-induced mortality is also common throughout much or all of the rest of the range of diamondback terrapins; the cumulative annual drownings are having a drastic impact upon the species as a whole (Seigel and Gibbons, 1995; Mann, 1995; G. S. Grant, pers. comm.).

• The widespread use of a rectangular wire excluder device (termed the Bycatch Reduction Apparatus, or BRA) can greatly reduce overall terrapin mortality and eliminate mortality of large females almost entirely.

• Installation of excluders in commercial crab traps also seems to increase the numbers of marketable crabs caught. The use of excluders will therefore not only save thousands of terrapins annually, but should also increase the profits of the commercial crabbers who use them.

ACKNOWLEDGMENTS

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