Diamondback Terrapin (*Malaclemys terrapin*) Mortality in Crab Pots

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Abstract: *The entrapment of diamondback terrapins (* Malaclemys terrapin*) in crab pots frequently results in drowning and death of the trapped turtles. We determined the rate of capture, size, sex, and age of terrapins captured, and the potential impact crab pot mortality has on local terrapin populations. We estimated terrapin capture rates of 0.17 terrapins/pot/day in shallow water areas of Chesapeake Bay (Maryland, USA). The sex ratio of terrapins caught in crab pots was 3:2 male biased because female terrapins become too large to enter crab pots by the time they reach 8 years of age. Males, however, remain vulnerable to entrapment throughout their life. Our estimates of capture rates and local population size suggest that 15–78% of a local population may be captured in a single year. As a consequence, crab pots may be the major reason terrapins are extirpated in coastal, shallow water areas with heavy crab pot fisheries. Additionally, the selective removal of males may also contribute to female-biased sex ratios observed in this diamondback terrapin population. We developed and tested a modified crab pot that increases terrapin survival and does not reduce the number of crabs caught. Our modified crab pot maintained permanent access to air and prevented the drowning of terrapins. Additionally, our modified crab pot caught more crabs than standard commercial crab pots, suggesting that the modified crab pot could be a viable alternative to standard traps that result in terrapin mortality.*

Mortalidad de la Tortuga *Malaclemis terrapin* en Trampas para Cangrejos

Resumen: *Las tortugas* Malaclemys terrapin *atrapadas en trampas para cangrejos frecuentemente mueren ahogadas. Determinamos la tasa de captura, tamaño, sexo y edad de las tortugas capturadas y el impacto potencial de la mortalidad en trampas para cangrejos en las poblaciones locales de* Malaclemys. *Estimamos que la tasa de captura de tortugas es de 0.17 tortugas/trampa/día en áreas someras de la bahía Chesapeake (Maryland, USA). El sexo de las tortugas atrapadas es de 3:2 sesgado hacia machos puesto que las hembras son demasiado grandes como para entrar a las trampas cuando alcanzan la edad de 8 años. Los machos sin embargo, permanecen vulnerables a ser atrapados a lo largo de toda su vida. Nuestras estimaciones de tasa de captura y tamaño poblacional local sugieren que un 15–78% de la población local puede ser capturada en un solo año. Como consequencia, las trampas para cangrejos pueden ser la mayor causa de la extirpación de* Malaclemys *en áreas de aguas costeras someras con una fuerte pesquería de cangrejos con trampa. Adicionalmente, la remoción selectiva de machos puede también contribuir al sesgo hacia hembras en las proporciones de sexos observadas para esta especie. Desarrollamos y probamos una trampa modificada para cangrejos que incrementa la sobrevivencia de tortugas y no reduce el número de cangrejos atrapados. Nuestra trampa modificada mantiene un acceso permanente al aire y previene que la tortuga se ahogue. Adicionalmente, nuestra trampa modificada captura mas cangrejos que las trampas comerciales estandard, sugiriendo que las trampas modificadas pueden ser una alternativa viable para evitar la mortalidad de* Malaclemys *ocasionada por las trampas estandard.*

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Introduction

By-catch and subsequent death of non-target species in fishing equipment is a problem that confronts many fisheries. The "by-catch problem" gained public attention with the mortality of dolphins due to the Pacific Ocean yellowfin tuna (*Thunnus albacares*) fishery (Allen 1985). Recently, the implementation of turtle excluder devices on shrimp trawlers to reduce sea turtle by-catch along the Atlantic and Gulf of Mexico coasts (Henwood & Stuntz 1987) has encountered considerable opposition from both shrimpers and politicians (Buck 1990). Currently, the ubiquitous problem of by-catch of "less valuable" species or undersized target species by a variety of fishing practices has become a focus of fisheries managers because most fishing methods are lethal to by-catch species (Warren 1996). The impact of by-catch losses to local species assemblages remains undetermined in most cases because it is difficult to estimate populations dynamics of both non-target and fisheries species. We quantify a severe by-catch problem of the diamondback terrapin (*Malaclemys terrapin*), an estuarine turtle, by a recreational fishery permitted to use commercial crab pots in the Patuxent River, a tributary of Chesapeake Bay. Additionally, we developed a modified crab pot that is both terrapin safe and equally efficient at catching crabs as standard crab pots.

The diamondback terrapin is an estuarine turtle in North America that ranges from the Gulf Coast of Texas to Cape Cod of Massachusetts. Terrapins inhabit shallow estuarine, bays, lagoons, creeks, and marshes (Carr 1952). Because terrapins are air breathing reptiles, traps and nets used to capture terrapins must maintain access to air. The terrapin's range and habitat overlaps with that of the blue crab (*Callinectes sapidus*), an important commercial and recreational fishery species. Terrapins and blue crabs are attracted by razor clams, menhaden, and other fish species commonly used as bait in crab pots. Because blue crabs obtain oxygen directly from the water through gills, there is no need for standard crab pots to have access to air. Therefore, turtles caught in crab pots are vulnerable to drowning.

Terrapin biologists at a recent workshop concurred that the major problem confronting terrapin populations throughout their range is drowning in crab pots (Seigel & Gibbons 1995). Drowning of terrapins has been observed in Maryland (Roosenburg 1991*a*), North Carolina (Bishop 1983), New Jersey (Burger 1989; R. Wood personal communication), South Carolina (A. Tucker personal communication), and Louisiana (T. Mann personal communication). Reduced terrapin populations in areas with expanding blue crab fisheries suggest that increasing use of crab pots is substantially decreasing terrapin populations in New Jersey (Burger 1989), Florida (Seigel 1993), South Carolina (Tucker personal communication), Louisiana (Mann personal communication), and throughout the coastal southeast (Seigel & Gibbons 1995).

Commercial use of crab pots in Maryland waters of Chesapeake Bay is restricted to the main branch of the Bay. Here the Bay is typically deep (>4 m), and terrapins, particularly juveniles, are rarely encountered in these open waters. Recreational use of crab pots is allowed in all the tributaries of the Bay in Maryland; landowners are allowed to set two crab pots to catch crabs for personal consumption in the water adjoining their property. Many recreation crab pots can be found in the shallow (<2 m) rivers and creeks inhabited by terrapins. Recreational crab pots are typically attached to a pier and piers shared by several landowners frequently support more than the two crab pots per pier limit.

Terrapin mortality in crab pots occurs at two levels. First, a constant background mortality occurs in crab pots that are fished on a regular basis. In addition to the terrapins caught in crab pots in our study, we have numerous anecdotal accounts of terrapins captured in crab pots by recreational crabbers. Second, occasional large kills occur when abandoned or "ghost" crab pots capture many terrapins over a long period of time. A single ghost crab pot has killed as many as 29 terrapins in North Carolina (Bishop 1983) and 49 terrapins in the location of our study (Roosenburg 1991*a*). The impact of crab pots on terrapin populations in Chesapeake Bay is unknown and probably varies with the extent of shoreline development along the tributaries.

Our study had three objectives. First, we estimated the background level of terrapin mortality in crab pots and its effect on the population. Second, we described the sex, size, and age of terrapins caught in pots. Third, we designed and tested a crab pot that reduced terrapin mortality, yet remained equally effective at catching crabs.

Methods

Since 1987 a mark-recapture study of the diamondback terrapin has been ongoing in the Patuxent River Estuary of Chesapeake Bay (Roosenburg 1991*a*; 1991*b*; 1992; 1994). Terrapins were captured using a variety of methods including bank traps, fyke nets, gill nets, standard and modified crab pots, and by hand. Included in this data set were terrapins found drowned in crab pots. Turtles were marked using a marginal notching technique (Cagle 1939), measured (plastron length, carapace length, and mass) and released as soon as possible. Age was determined by counting annual plastron growth rings; a method confirmed by consistent age determination of recaptured individuals from one year to the next. We compared the size (plastron length) and age of terrapins caught in crab pots with terrapins caught using all other techniques from 1987 through 1994. Statistical analyses were performed using PROC GLM in SAS version

6.03 (SAS Institute 1988). All significance levels were set to reject H_o at $p < 0.05$.

Estimation of Background Level of Terrapin Mortality

During the 1994 field season we used modified crab pots (Fig. 1) to estimate the background level of terrapin mortality in crab pots. We fished crab pots from 25 May until 29 July. We calculated daily catch rate (*m*) as the total number of terrapins caught in crab pots divided by the number of days crab pots were fished. We generated a simple index to calculate the background level of annual terrapin mortality (*M*) in crab pots based on our data of terrapin captures in crab pots, the number of piers in the study area (*P*), the length of the crabbing season in days (*D*), and the number of traps per pier (*T*):

$$M = mPTD.$$

We compared the estimated impact of crab pot mortality to a Jolly-Seber population estimate (Jolly 1965; Krebs 1989) of the terrapin population at our study site.

Development and Test of a Modified Crab Pot

Standard crab pots used by commercial and recreational crabbers in the Chesapeake Bay have dimensions of 0.6 × 0.6 × 0.6 m (standard 2 × 2 × 2 foot crab pot, Fig. 1). Crab pots used in Chesapeake Bay have four openings or funnels where the crabs enter the pot in the lower chamber. The lower chamber is separated from the upper chamber by a wire divider known as the "church" because it resembles the steeple of a church. Two openings in the church allow crabs to move into the upper chamber where they remain until the pots are checked. Standard crab pots remain submerged continuously and are retrieved by a line tied to a buoy or pier.

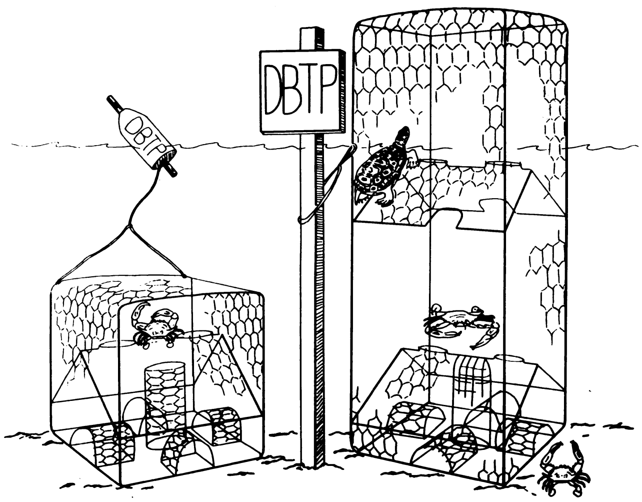

Figure 1. The two crab pot types that were used in the study. The smaller is the standard crab pot used throughout Chesapeake Bay. The larger pot is the modified pot with four major differences between it and the standard pot: (1) height of the trap; (2) second church; (3) opening in the second church that allows terrapins and crabs to move back down into the middle section; and (4) the stake that prevents the tall pot from falling over.

We designed and built crab pots similar to the standard design, but with four differences (Fig. 1). First, we increased the height of the pot to approximately 2 m (0.6 × 0.6 × 2 m) so that the trap's top remained above the water's surface at all times. Second, we added an additional church that added strength; the increased height of our experimental pot made it flexible and weak, but the second church provided the necessary strength for durability. Third, we placed two holes in the lower portion of the second church to allow crabs and turtles to return to the middle chamber; without return holes, animals may have been trapped and died above the water when the tide receded. Fourth, to prevent the trap from being knocked over, we secured the crab pot to a stake set next to the pot. Finally, we tied a marked buoy on each pot in order to locate the pot in case it was knocked over. We used standard crab pot wire (16 gauge, 1.5-inch mesh) to build the modified pots.

We built six tall and purchased six standard crab pots. Modified and standard crab pots were deployed in a systematic 2 by 6 array parallel to shore. The array minimized any effects that proximity to shore or "crab hot spots" might have on crab catching ability. We placed pots approximately 30 m apart in an area where turtles were rarely caught but crabs were common. We fished pots for 11 days from 16 August through 27 August 1992. Daily, we checked and baited all crab pots with fresh fish, white perch (*Morone americanus*) and Norfolk spot (*Leiostomus xanthurus*). We culled and counted crabs in standard commercial grades: number ones (>5.5 inches from point to point), number twos (5–5.5 inches point to point), females, buckrams (recently molted crabs that are low in meat), and peelers (crabs just prior to ecdysis). Turtles caught in the pots were marked, measured, and released as soon as possible. We used a chi-square contingency test (Sokal & Rohlf 1981) to compare the number and types of crabs between the two pots.

Results

Terrapin Capture Rates

We caught 80 terrapins during 470 crab pot days from 26 May until 29 July 1994. Terrapin capture rate was 0.17 terrapins per crab pot day. Additionally, we counted 69 piers on the study site and assumed a 92-day (June, July, and August) fishing season. Using our formula, we estimated that 2161 terrapins were caught annually in crab pots on the study site. A Jolly-Seber population estimate based on all capture techniques ranged from 2778–3730 terrapins on the study site during the 6 years for which the estimate could be made. Based on the population estimate, if there is 100% terrapin mortality in crab pots, 58–78% of the terrapins are killed annually. If we overestimated the terrapin catch rate by a factor of four, then 15–19% of population is killed annually. Both our conservative and liberal estimates of terrapin mortality indicate that crab pots are a major threat to terrapin populations.

Terrapins Caught by Crab Pots

Crab pots catch smaller terrapins resulting in a male biased capture rate (Table 1). Sex ratio of the Patuxent population based on total initial captures using all methods except crab pots was 1:2 female biased (Table 1). However, 60% of the terrapins caught in crab pots were males (Table 1). Terrapins caught in crab pots ranged from 80 to 155 mm plastron length (Fig. 2). The average size of male terrapins caught in crab pots did not differ from the average size of males in the population ($F_{1,1771}$ = 0.38, p = 0.57, Table 1). Female terrapins caught in crab pots were considerably smaller than the average size of female terrapins ($F_{1,3498}$ = 138.04, $p < 0.0001$, Table 1). Because males never reach the maximum size of terrapins caught in crab pots (155 mm plastron length), they remain vulnerable to entrapment in crab pots throughout their life, whereas female terrapins are no longer vulnerable after age 8 (Fig. 3). Juvenile terrapins caught in crab pots were larger than the average size of juveniles ($F_{1,668}$ = 86.51, $p < 0.0001$, Table 1). The difference between juveniles is attributable to the large number of hatchlings, which can easily swim through the 1.5-inch wire mesh of crab pots, caught during this study. Finally, both male and female terrapins were most vulnerable to capture in crab pots at age 5 (Fig. 3). Crab pots may selectively capture young terrapins because pots tend to be set in habitats more frequently used by juveniles (W.M.R., personal observation).

Table 1. Mean (SE) of terrapin plastron length caught in crab pots and caught by all methods used during the 1987–1994 study period.

	Crab pots		All methods		
Sex	n	*$\bar{x}$ length (mm)*	n	*$\bar{x}$ length (mm)*	p
Males	163	110.3 (0.88)	1610	110.9 (0.32)	NS
Females	108	109.1 (1.50)	3392	157.9 (0.74)	<0.0001
Juveniles	23	96.2 (2.61)	647	44.4 (1.07)	<0.0001
Total	294	108.7 (0.82)	5649	131.5 (0.69)	

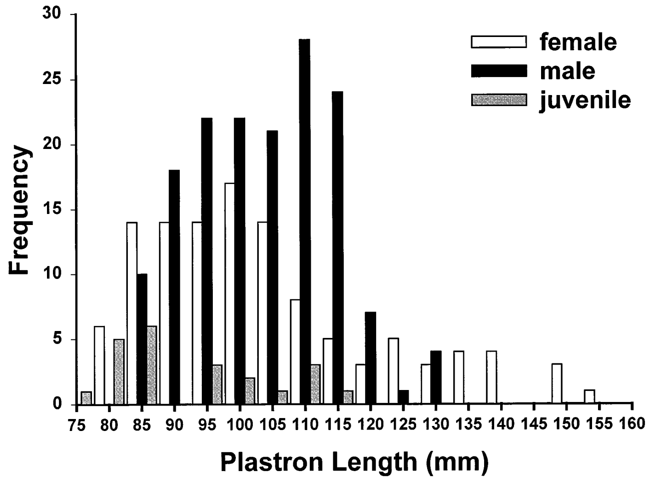

Figure 2. Frequency of male, female, and juvenile terrapins in 5-mm interval size classes caught by crab pots during the 8-year mark-recapture study.

Crabs Caught by Crab Pots

Tall crab pots caught more crabs than standard crab pots (chi-square = 12.27, df = 4, $p < 0.025$, Table 2). Tall crab pots caught more number twos, females, and buckram crabs. We were not able to detect any difference between tall and standard crab pots in their ability to catch high quality crabs (number ones and number twos). When female or female and buckram crabs were removed from the analyses, there was no longer a statistical difference between the two pot types (females removed, chi-square = 4.41, df = 3, $p > 0.05$; female and white crabs removed, chi-square = 2.35, df = 2, $p > 0.05$). Thus, the tall crab pots' greater success catching

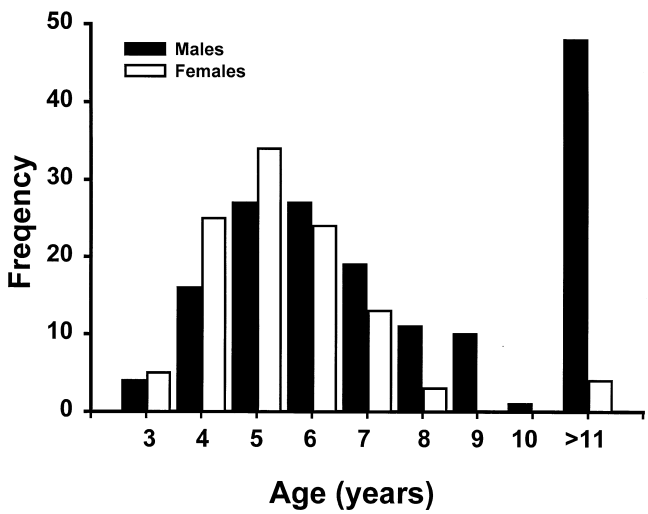

Figure 3. Frequency of male and female terrapins in different age classes caught by crab pots during the 8-year mark-recapture study. Individuals in the >11 column could not be aged; males were greater than 10 years old.

Table 2. Number of crabs caught by the standard and modified crab pots during the 11 days of the study.

Crab grade[a]	*Caught in standard crab pot*	*Caught in tall crab pot*[b]
Number ones	136	132
Number twos	76	78
Females	9	18
Buckram crabs	59	71
Peelers	4	1
Total	284	300

[a] *Crabs were culled into standard commercial grades: number ones (>5 1/2″ from point to point), number twos 5 inches to 5 1/2 inches point to point), females, buckram crabs (recently molted crabs that are low in meat), and peelers (crabs just prior to ecdysis).*

[b] *When all crab types were included in the analysis, tall crab pots caught significantly more crabs (chi-square = 12.27, df = 4,* $p < 0.025$*). Removal of buckram crabs and female crabs from the analysis results in no difference between the two pots.*

female and buckram crabs significantly increased the total number of crabs caught; however, females and buckram crabs are frequently discarded because of the lesser quality of the meat.

Discussion

Our estimates of the capture rates of terrapins by crab pots indicate that crab pot fisheries can have a severe effect on local terrapin populations. We estimated that between 15% and 78% of the patuxent population dies annually as a result of this fishery. Our findings suggest that local terrapin populations can be extirpated in 3 to 4 years, and after an initial 2- to 3-year period of high turtle mortality, the capture of terrapins in crab pots will become relatively rare in a particular area. This could result in the misleading interpretation that terrapins do not occur in those areas. We may have underestimated terrapin mortality because the actual crabbing season in Maryland runs from April through November. Additionally, removing female terrapins too large to be entrapped in crab pots from our population estimate would further increase the mortality rate of vulnerable size classes. Our findings also suggest that the presence of a stable population cannot be determined by the number of nesting females in a particular area.

The problem of terrapin entrapment in crab pots has been known for a long time (Davis 1942). Bishop (1983) estimated terrapin catch rates in crab pots similar to ours (average 0.11 terrapins per crab pot day); however, he did not have the terrapin population estimates to determine the impact on the local population. Our conclusions contrast sharply with his that terrapin mortality due to crab pots does not significantly affect populations. Bishop's (1983) conclusion was based, in part, on low mortality rates of terrapins in crab pots. This may be attributable to the time of year when his study was conducted. His study ran from March through June when water temperatures were still cool and the temperature dependent physiology of terrapins allowed them to remain submerged for longer periods at cooler temperatures. Our use of the tall crab pots in the mark-recapture study has twice resulted in the death of terrapins when our pots were knocked over by severe summer squalls; this suggests that terrapins cannot remain submerged for more than 12 hours during warmer, summer water temperatures. Additionally, researchers in other states now recognize that terrapin populations are declining and that the most likely cause of death is drowning in crab pots (Seigel & Gibbons 1995).

More male terrapins were caught in crab pots because at their maximum size they are still capable of entering crab pots, making male terrapins vulnerable throughout their entire life. Female terrapins, on the other hand, attain body sizes too large to enter crab pots by 8 years. Mature female terrapins did not get caught in crab pots because the size of the funnels leading into the crab pot does not allow turtles greater than 155 mm in plastron length to enter. Female terrapins in the Patuxent population mature above 165 mm plastron length (Roosenburg 1991*a*). Entrapment of females in crab pots may be a greater problem in populations where females mature at smaller body sizes (Seigel 1984).

Disproportionate capture of male terrapins in crab pots may in part explain the female biased sex ratio observed in the Patuxent population. We observed a 3:2 male bias in captures by crab pots; however, a 1:2 female biased sex ratio was estimated for the population. Mortality caused by entrapment in crab pots may contribute to differential survivorship between male and female terrapins and to the female biased sex ratio. How female biased sex ratios affect terrapin and turtle populations is not well understood. In turtles, sex ratios can be complicated by factors such as environmental sex determination (reviewed in Janzen & Paukstis 1991) and sex biases in sampling techniques (Gibbons 1990). Furthermore, sperm storage capabilities of female terrapins (Hildebrand 1929) and the polygamous mating system complicate investigations of operational sex ratios versus apparent sex ratios in turtles. Other studies of terrapin populations have observed sex ratios that are skewed: Merritt Island, Florida 5:1 female biased (Seigel 1984); Kiawah Island, South Carolina, 1:1.78 male biased (Lovich & Gibbons 1990).

Because male terrapins mature at a smaller size than females, a larger proportion of the males that were caught were sexually mature and may have reproduced. The female mortality due to crab pots may be more damaging to the viability of terrapin populations because they are killed when their residual reproductive value is high, they never have reproduced. Thus, removal of female terrapins by crab pots may have a greater impact on the population dynamics than the removal of males, despite the male bias of terrapins captured in crab pots.

Congdon and colleagues (1993, 1994) in studies of banding's turtles (*Emydoidea blandingii*) and snapping turtles (*Chelydra serpentina*) have shown that decreases in juvenile survivorship similar to the levels we have found will lead to collapse of turtle populations.

Use of Modified Crab Pots

No difference was observed between the modified and the standard crab pots in their ability to catch high quality crabs. The tall design maintained a constant air space and only when the traps were knocked over did terrapins drown. Although the use of an escape mechanism would have been the preferred modification, we were unsuccessful in implementing an escape device. Our enlargement of the standard pot was the preferred design because it (1) maintained the maximum availability of air for terrapins; (2) was easiest to construct; and (3) was the most sturdy of the modified pot designs we tested.

The enlarged pots were slightly more cumbersome to handle. We found that the second funnel slightly increased handling time required to check pots. However, increased handling time is trivial considering that recreational crab potters fishing in terrapin habitat are allowed a maximum of two pots in Maryland. Additionally, because extended traps require extra wire, the enlarged pots are more expensive to build. The modification increases cost for crab pots about $15–20 per pot above the present cost of approximately $20 per pot.

We have demonstrated that crab pots can rapidly eliminate local terrapin populations. Our study indicates that the tall crab pots are just as effective at catching crabs as ordinary crab pots and contemporaneously prevent mortality of diamondback terrapins. Although the sheer number of terrapins lost in crab pots is alarming, this mortality is even more staggering considering that females killed by crab pots have high residual reproductive value. The minimal increase in cost and handling time of the tall crab pot is trivial compared to the benefits of these traps for conserving terrapins. These traps also provide the satisfaction of placing a live terrapin back into the water. Mandating the use of tall traps in all the tributaries of Chesapeake Bay by recreational crabbers would greatly enhance conservation efforts for the diamondback terrapin.

There are two broader issues that our study addresses that bear on the apparent conflict between fisheries and conservation. First, the use of "commercial" gear for recreational purposes without thorough consideration of the impact on the fishery and by-catch is a dangerous management strategy. The second issue involves the interaction between the life history of the organism and the most effective conservation or management strategy for that species. Turtles in general are portrayed as the model long-lived organism with relatively low reproductive rates and with population dynamics most effectively maintained by increasing adult and juvenile survivorship (Congdon et al. 1993, 1994). Simple modifications that entail a minimum effort at slightly greater than regular cost, such as our solution, can be an effective management and conservation tool. This would prevent the need for halfway technologies such as hatcheries and headstart programs (Frazer 1992) that have had questionable success in sea turtle conservation (Woody 1990; Eckert et al. 1994; Caillouet et al. 1995). Unfortunately, the use of devices that reduce by-catch frequently are strongly resisted because of the fear of increased equipment costs or loss of revenue. As with our by-catch solution, the successful implementation of management practices relies on the education and recognition of the value of non-commercial species as important and integral components of global biodiversity.

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