**BEFORE THE FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION**

# PETITION TO PROTECT DIAMONDBACK TERRAPINS (*MALACLEMYS TERRAPIN*) FROM MORTALITY IN BLUE CRAB POTS BY REQUIRING BYCATCH REDUCTION DEVICES IN RECREATIONAL AND COMMERCIAL FISHERIES

Credit: George L. Heinrich

**CENTER FOR BIOLOGICAL DIVERSITY**

**FLORIDA TURTLE CONSERVATION TRUST**

**DIAMONDBACK TERRAPIN WORKING GROUP**

**January 28, 2020**

**Notice of Petition**

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Submitted this **January 28, 2020**

Pursuant to Section 120.54(7), Florida Statutes, the Center for Biological Diversity, Florida Turtle Conservation Trust, and Diamondback Terrapin Working Group hereby petition the Florida Fish and Wildlife Conservation Commission to formally adopt a rule requiring bycatch reduction devices in all blue crab pots to protect the diamondback terrapin. Crab pots indiscriminately drown diamondback terrapins, contributing to terrapin declines and intensifying negative effects from additional pressures like habitat loss, poaching, road mortality, and sea-level rise, which already threaten populations range-wide.

The Center for Biological Diversity (Center) authored this petition. The Center is a non-profit, public interest environmental organization dedicated to the protection of native species and their habitats through science, policy, and environmental law. The Center is supported by more than one million members and online activists throughout the United States, including more than 96,500 members and supporters in Florida. The Center and its members are deeply concerned about the conservation of imperiled wildlife—including diamondback terrapins—and their essential habitats.

The Florida Turtle Conservation Trust (FTCT) was formed in 1999 by a group of Florida biologists and conservationists concerned with the conservation outlook for Florida turtles. The FTCT's purpose is to promote the conservation of all Florida turtle species and the preservation of intact, free-ranging populations and their associated ecosystems throughout the state of Florida. The FTCT is committed to and supports education, conservation, research, and management efforts with the above goals in mind.

The Diamondback Terrapin Working Group was formed in 2004 by individuals from academic, scientific, regulatory and private institutions/organizations working to promote the conservation of the diamondback terrapin, the preservation of intact, wild terrapin populations and their associated ecosystems throughout their range. The Diamondback Terrapin Working Group is committed to and supports research, management, conservation, and education efforts with the above goals in mind.

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## I. INTRODUCTION

The diamondback terrapin (*Malaclemys terrapin*) is the only turtle species in the world that lives exclusively in brackish coastal habitats (Wood 1995). It occurs in the United States along the coasts of the Atlantic Ocean and Gulf of Mexico, and in Bermuda. Although the terrapin's ancestors date back as far as the late Pleistocene (Ehret and Atkinson 2018 at 32), the species is now in decline (Roosenburg et al. 2019).

Crab pot mortality—death by drowning in pots set to capture blue crabs (*Callinectes sapidus*)—is one of the greatest threats to the diamondback terrapin's existence (Butler et al. 2006; Grosse et al. 2011; Chambers and Maerz 2018). A fleet of active blue crab pots is capable of steadily removing individual terrapins from a population until it can no longer sustain itself (Roosenburg et al. 1997; Butler and Heinrich 2007), while just one or two inactive or "ghost" pots are capable of killing large numbers of individuals in a population over a single crabbing season (<1 year) (Grosse et al. 2009). Because the terrapin's life history traits prevent it from absorbing chronic increases in adult mortality, crab pots can rapidly cause reduction in population size (Roosenburg 1991 at 231–232; Hoyle and Gibbons 2000 at 736). Roosenburg et al. (1997) estimated that mortality rates caused by the recreational use of crab pots in Maryland alone could increase annual terrapin mortality rates between 15-78%, which can cause decline and rapid extirpation of local populations. Similarly, Hart (1999) modeled the impacts of terrapin bycatch and mortality in crab pots in Massachusetts, finding that even a low harvest rate (15%) could reduce a population by 49% after 15 years. Moderate (30%) and intense (75%) harvest rates produced 77% and 92% population reductions, respectively, over the same time period (Hart 1999 at 46).

Bycatch reduction devices (also known as BRDs or terrapin excluder devices) can prevent the majority of terrapins from drowning in crab pots while having little to no effect on the number or size of crabs captured (reviewed in Chambers and Maerz 2018; Roosenburg 2004; Butler and Heinrich 2007). Recognizing the significant threat crab pot mortality poses to terrapins, several states require blue crab pots to have BRDs, and even more states are considering similar measures. However, the Florida Fish and Wildlife Conservation Commission has failed to adopt or even consider similar conservation action despite clear evidence that crab pot mortality is a threat (Butler and Heinrich 2007; Chambers and Maerz 2018).

Florida's Constitution tasks the Florida Fish and Wildlife Conservation Commission with "exercis[ing] the regulatory and executive powers of the state with respect to wild animal life[,] fresh water aquatic life[,] and . . . marine life" for the purpose of managing, protecting, and conserving them. Fla. Const. art. IV, § 9. To that end, the Commission has implemented many regulations in the interest of conserving and protecting imperiled wildlife. *See, e.g.*, Fla. Admin. Code Ann. r. 68A-1.002 (2012) (stating that "[a]ll wild animal life within the jurisdiction of the State of Florida . . . is subject to the regulation of the Commission"); *e.g. id.* at r. 68A-18.004 (creating wildlife refuges in which it is illegal to take wildlife); *id.* at r. 68A-27.0001–27.007 (establishing rules under the Florida Endangered and Threatened Species Act).

Florida's Administrative Procedure Act provides that "[a]ny person . . . having substantial interest in an agency rule may petition an agency to adopt, amend, or repeal a rule." Fla. Stat. § 120.54(7); *see also* Fla. Stat. § 379.1025 (authorizing the Florida Fish and Wildlife Conservation Commission to adopt rules and regulations pursuant to Chapter 120). Within 30 days of receiving the petition, the agency must either "initiate rulemaking proceedings . . . , otherwise comply with the requested action, or deny the petition with a written statement of its reasons for the denial." Fla. Stat. § 120.54(7). Under this authority and for the reasons explained below, Petitioners respectfully request that the Florida Fish and Wildlife Conservation Commission grant this petition and initiate rulemaking proceedings to amend its current regulations to require BRDs on commercial and recreational blue crab pots to protect diamondback terrapins. While Petitioners assert that requiring BRDs is the most effective measure to protect terrapins, if the Commission declines to adopt a rule requiring BRDs, Petitioners alternatively request that the Commission consider different measures that will effectively address the effect of crab pot mortality on diamondback terrapins.

## II. BACKGROUND

### a. The Diamondback Terrapin

Named for the concentric, diamond-shaped rings on their shells, diamondback terrapins are among the most beautiful and charismatic turtles in the United States. Though their colors may vary between light gray, dark gray, brown, and nearly black, diamondback terrapins are easily identifiable by their diamond-patterned shells and flecked or spotted heads and legs.

Diamondback terrapins are the only turtles that live exclusively in coastal brackish water ecosystems, where freshwater meets the sea. There are seven traditionally recognized subspecies of diamondback terrapin and Florida is home to five of them: the Carolina diamondback terrapin (*M. t. centrata*), eastern Florida diamondback terrapin (*M. t. tequesta*), mangrove diamondback terrapin (*M. t. rhizophorarum*), ornate diamondback terrapin (*M. t. macrospilota*), and Mississippi diamondback terrapin (*M. t. pileata*). Three subspecies—eastern Florida, mangrove, and ornate—occur only in Florida. Experts now recommend recognizing four discrete populations or management units: Northeast Atlantic, Coastal mid-Atlantic, Florida, and Texas/Louisiana (Hart et al. 2014; Lovich and Hart 2018). Of the 16 states within the terrapin's range, Florida has the greatest expanse of coastal habitat (approximately 20% of the species' entire range).

Diamondback terrapins are potentially keystone species in the salt marshes and mangroves they inhabit, which means they help maintain the ecological health of their associated ecosystems. Among the prey of diamondback terrapins are the salt marsh snails (*Littorina spp.*) (Tucker et al. 1985), which in high numbers contribute to loss and erosion of salt marshes by grazing on the epiphytes that live on stems of grasses and thereby killing the grasses (Silliman and Bertness 2002). Because terrapins feed on the snails, it has been suggested that their potential effect on snail populations could reduce salt marsh erosion and loss. The potential top down predation effect suggest that the terrapin may play an important role in salt marsh ecosystem function, particularly when terrapins occur at high densities. (See Brennessel 2007). Terrapins also move substantial quantities of nutrients and calories from the water to land in the form of eggs and adult terrapins, which are then eaten by a variety of terrestrial and avian predators (Seigel 1980a; Clark 1982; Cecala et al. 2008).

### *i. Life History*

Diamondback terrapins spend most of their lives in nearshore habitat (Roosenburg et al. 1999). Their diets include snails, claims, mussels, small crabs, fish, and annelid worms (Tucker et al. 1985; Butler et al. 2012). Male terrapins mature around 2 to 7 years of age, while female terrapins become reproductively mature between 4 and 8 years of age (Seigel 1984; Lovich et al. 2018 at 65–66). In Florida, one study found female terrapins mature at 4 to 5 years, while male terrapins mature at 2 to 3 years (Seigel 1984; Lovich et al. 2018 at 66).

In the spring, terrapins form courtship and mating aggregations for several days to weeks; and beginning in late spring and continuing into the summer, female terrapins come to land to dig nests and lay their eggs (Butler et al. 2018). Wild female terrapins produce one or two clutches of eggs per year, though triple clutches have been reported in Florida (Lovich et al. 2018 at 66–67; Heinrich, pers. comm. 2019). Clutch sizes range from 1 to 23 eggs, though clutch sizes tend to be smaller in Florida based on studies of the Florida east coast diamondback terrapin (6.7 eggs) and the Carolina diamondback terrapin (6.7 eggs) (Seigel 1980b; Butler 2000; Lovich et al. 2018 at 66–67).

As with most turtle species, terrapins appear to have relatively low nesting success and hatchling survival (Lovich et al. 2018 at 69; Butler et al. 2018 at 85). The rate of success varies among sites, from season to season, and depending on threat factors like the presence of predators (Butler et al. 2018 at 85–86). In northeastern Florida, in one year only 22.8% of nests that were discovered intact hatched, and in another year 33.8% hatched (Butler et al. 2018 at 85). Nest predation has ranged from 1-98.9% for northern diamondback terrapins (Burger 1977; Roosenburg 1992; Feinberg and Burke 2003), and 82–87% for Carolina diamondback terrapins in Florida (Butler et al. 2004). Because terrapins exemplify turtle life history traits of delayed reproduction, low nest/juvenile survival, and longevity, increased mortality of adult terrapins results in rapid population decline (Roosenburg and Butler 2018).

### *ii. Status and Threats*

The International Union for the Conservation of Nature (IUCN) Red List ranks the diamondback terrapin's global status as Vulnerable and describes its population trend as decreasing (Roosenburg et al. 2019). Of 54 researchers surveyed across the terrapin's range in 2006, 29.6% said the diamondback terrapin was declining in their state, 14.8% said populations were stable, and 55.6% said the status was unknown (Butler et al. 2006). No one considered populations to be increasing (Butler et al. 2006). Surveys of the 14 researchers from Florida reached mixed results, with some opining terrapin population statuses were unknown, some declining, and some stable (Butler et al. 2006). These mixed responses may have been due to the fact that some researchers had specific areas in mind when they declared populations to be declining or stable, while others assessed statewide populations and ranked their status unknown due to insufficient data (Butler et al. 2006).

Anthropogenic threats to terrapins remain, making the species' future survival tenuous in some locales (Butler and Roosenburg 2018). Threats to the diamondback terrapin include habitat destruction and degradation (Butler et al. 2006; Hart and Lee 2007 at 211); road mortality (Wood and Herlands 1997; Butler et al. 2006; Szerlag and McRobert 2006; Maerz et al. 2018); sea-level rise caused by global climate change (Hunter et al. 2015; Woodland et al. 2017); pollution (Butler et al. 2006; Blanvillain et al. 2007; Drabeck et al. 2014 at 132–133; Roosenburg et al. 2019); boat strikes (Lester et al. 2013); predation (Butler et al. 2004; Draud et al. 2004; Butler et al. 2006); collection for personal and commercial purposes, including the effects of large-scale historic commercial harvesting and current poaching (Hart and Lee 2007 at 207), and inadequate regulatory measures to address these threats (Roosenburg et al. 2019). Terrapin mortality in crab pots has been and continues to be one of the major threats to terrapins, and it has been studied in nearly every state in the species' range (Butler and Roosenburg 2018), as reviewed in the following section. When surveyed in 2006, experts ranked (not in any particular order) predation, habitat loss, and crab pot mortality as the three greatest threats to terrapins in Florida (Butler et al. 2006).

**b. Crab Pot Mortality**

Commercial and recreational crab pots pose a serious threat to diamondback terrapins at the individual, population, and species level (Roosenburg et al. 1997; Crowder et al. 2000 at 1; Roosenburg 2004; Chamber and Maerz 2018). Terrapins enter submerged crab pots and die when they cannot escape to breathe at the water's surface. This can occur in a short period of time—less than five hours (Crowder et al. 2000 at 1). The problem is often compounded when these gregarious turtles follow one another into pots (Bishop 1983 at 428; Butler and Heinrich 2007). Experts posit that terrapins have an innate curiosity to investigate things and that the presence of a terrapin in a crab pot may attract additional turtles, thus increasing the likelihood of large kills in crab pots (Roosenburg 1991 at 231). They also find that crab pots attract terrapins whether or not they are baited (Chambers and Maerz 2018).

Blue crab pots are present throughout the terrapin's range, as commercial and recreational crab fisheries are active to varying degrees in nearly every coastal state along the Atlantic and Gulf coasts (Chambers and Maerz 2018). Even when crabbing potential may be small in a state, it can have a severe effect on a local scale (Roosenburg et al. 1997; Tucker et al. 2001; Grosse et al. 2009; Chambers and Maerz 2018). While commercial crabbing is generally distributed broadly across open water, in many states including Florida it also is allowed in tidal creeks associated with large river systems that intersect with coastal salt marsh habitat (Chambers and Maerz 2018). Commercial harvest of peeler crabs occurs seasonally in small tidal creeks when crabs are molting, which places crab pots in critical terrapin habitat (Chambers and Maerz 2018). Furthermore, a large percentage of recreational crabbing occurs in shallow creeks and other areas that intersect with terrapin habitat (Chambers and Maerz 2018). Both commercial and recreational crab pots can end up as derelict or "ghost" pots in terrapin habitat (Chambers and Maerz 2018). Crab pots fished in deeper waters may be lost and carried into terrapin habitat by tides or storms, thereby affecting terrapins in shallow water (Chambers and Maerz 2018).

Crab pot mortality affects terrapin populations by removing mature adults and hindering the population's reproductive capabilities. While in some places female terrapins may grow too large to enter pots, male terrapins never grow larger than the opening of a crab pot entrance and are susceptible to crab pot mortality throughout their lives (Roosenburg et al. 1997; Chambers and Maerz 2018). In the southeast, female terrapins do not grow as large as more northern populations and therefore do not grow large enough to avoid crab pot mortality (Chambers and

Maerz 2018). For example, in one Alabama population, 85% of female terrapins sampled were susceptible to crab pot mortality (Coleman et al. 2014; Chambers and Maerz 2018).

Diamondback terrapins captured in a crab pot in Indian Bayou, Santa Rosa County, Florida
(Source: University of Florida IFAS/Molly O'Connor)

Crab pot mortality is a long-documented threat to diamondback terrapins across their range, with dozens of studies published over the last 75+ years (Davis 1942; Bishop 1983; Marion 1986; Burger 1989; Mazzarella 1994; Mann 1995; Wood and Herlands 1996; Roosenburg et al. 1997; Wood 1997; Guillory and Prejean 1998; Hoyle and Gibbons 2000; Roosenburg and Green 2000; Cole and Helser 2001; Butler 2002, 2000; Roosenburg 2004; Butler and Heinrich 2007; Grosse et al. 2009). These studies span several states, including Florida (Butler and Heinrich 2007), Georgia, New York, New Jersey, Delaware, Maryland, North Carolina, South Carolina, Louisiana, and Mississippi.

Experts agree that the capture and drowning of terrapins in crab pots is a major threat to terrapin populations throughout their range (Burger 1989; Siegel and Gibbons 1995; Wood 1997; Roosenburg 2004; Butler et al. 2006; Butler and Heinrich 2007). This is because crab pots can eliminate local terrapin populations (Roosenburg et al. 1997 at 1171). Population-level impacts also include rapid, large-scale declines (Roosenburg et al. 1997 at 1170; Cole and Helser 2001; Roosenburg 2004 at 24; Grosse et al. 2009 at 99); skewed sex ratios (Bishop 1983 at 427; Roosenburg 1991 at 231; Roosenburg et al. 1997 at 1170; Hoyle and Gibbons 2000 at 735; Dorcas et al. 2007 at 336–337; Butler and Heinrich 2007 at 183; Grosse et al. 2009 at 99; Grosse et al. 2011 at 765); skewed age distribution (Dorcas et al. 2007 at 338–339); and skewed size distribution (Dorcas et al. 2007 at 3336–337; Grosse et al. 2011 at 763, 766; Lovich et al. 2018 at 71). Because terrapins' life history traits prevent them from absorbing chronic adult mortality, crab pots can cause "significant localized consequences" for local populations (Roosenburg 1991 at 231–232; Hoyle and Gibbons 2000 at 736).

Crab pots essentially cause two "levels" of terrapin mortality: (1) a "constant background mortality" from many crab pots that are regularly fished over a long period of time; and (2) acute mortality events from individual crab pots that have been lost or abandoned ("ghost" or "derelict" pots) (Roosenburg et al. 1997 at 1167; Roosenburg 2004). In other words, regularly fished crab pots have the potential to consistently capture smaller numbers of terrapins over time, while ghost pots can capture more terrapins in one pot over a relatively shorter time (Roosenburg et al. 1997 at 1167).

### *i. Active Pots*

As early as the 1940s, scientists observed the harmful effects of crab fishing gear on terrapins. Through studies in Florida, scientists have found that the same risk exists in Florida's waters (Butler and Heinrich 2007). The following is a survey of published studies documenting terrapin mortality in active crab pots.

Davis (1942) studied crab pot bycatch in Maryland waters and "definitely established that pots will capture terrapin" (Davis 1942 at 16). Although the results were limited, Davis found that three large diamondback terrapins were taken, and two drowned (Davis 1942 at 16–17). The third would have drowned had the pot not been partially protruding from the water so the turtle could obtain air (Davis 1942 at 17).

Bishop (1983) studied crab pot mortality from two South Carolina estuaries over three years and recorded 281 diamondback terrapins (195 male and 86 female) captured in baited and unbaited crab pots.[1] Based on 1982 records that there were 458 licensed crabbers fishing from 50–100 crab pots, and assuming an average number of 60 pots per crabber with 40% of those pots being fished in near-shore shallow waters where terrapins live, Bishop estimated that 2,853 terrapins were captured daily during April and May, with mortality estimated at 285 terrapins (Bishop 1983 at 428). This estimate fails to account for mortalities resulting from ghost pots.

Wood (1997) investigated the effect of crabbing on terrapins in New Jersey, including the extent of terrapin bycatch in commercial crab pots and the mortality levels of terrapins caught in those pots. He found that 19 terrapins (8 male, 11 female) were caught at a capture rate of 15 terrapins per 100 trap-days (Wood 1997 at 23). Although Wood checked pots twice daily to minimize drowning of terrapins, four were drowned, causing a slightly greater than 20% mortality rate (Wood 1997 at 23). Wood observed that commercial crabbers check pots no more than once per day, and that the terrapin mortality may have approached 100% (Wood 1997 at 23).

Roosenburg et al. (1997) studied the rate of capture, size, sex, and age of terrapins captured in crab pots and determined the potential effect of crab pot mortality on local populations in the shallow water areas of Chesapeake Bay, Maryland. They estimated terrapin capture rates of 0.17 terrapins per pot per day (Roosenburg et al. 1997 at 1168). Based on these numbers, the scientists estimated that 15–78% of a local population may be captured in a single year (Roosenburg et al. 1997 at 1169). Thus, they estimated that local terrapin populations could be extirpated in 3 to 4 years (Roosenburg et al. 1997 at 1170).

Hoyle and Gibbons (2000) studied twenty recreational crab pots in South Carolina (Hoyle and Gibbons 2000 at 735). During the 760 days the crab pots were deployed, 21 captures were made of 19 individual terrapins (Hoyle and Gibbons 2000 at 735). Based on an estimated population size of 168 to 299 terrapins, and an estimated annual recruitment of 12 to 17 terrapins, the scientists estimated that 6–11% of the population would potentially be removed from the local

[1] Because the traps were checked daily during the study, less than 10% of captured terrapins died (Bishop 1983 at 427-428).

population[2] (Hoyle and Gibbons 2000 at 735–736). Because terrapins' life history traits prevent them from absorbing chronic adult mortality, the scientists concluded that crab pots could cause "significant localized consequences" for local populations (Hoyle and Gibbons 2000 at 736). Hoyle and Gibbons also found that recreational pots could be a greater threat to terrapins than commercial pots because local crabbers are able to access smaller creeks than commercial crabbers, where terrapins are more populated (Hoyle and Gibbons 2000 at 736). Recreational crabbers are also more likely to leave their pots in the water for a longer period of time without checking them, and even unintentionally abandon them (Hoyle and Gibbons 2000 at 736).

Dorcas et al. (2007) studied 21 years of mark-recapture data (more than 2,800 captures of 1,399 individuals) from a declining diamondback terrapin population in Kiawah Island, South Carolina, to determine whether a population decline there was the result of mortality in crab pots. They found that since the 1980s, the modal size of both male and female terrapins had increased substantially and that the proportion of females was higher than earlier samples (Dorcas et al. 2007 at 336–337). They also noted that the studied population contained more old and fewer young terrapins than before (Dorcas et al. 2007 at 336). This change in the age of the population is also reflected in the size of individual terrapins (Dorcas et al. 2007 at 336). Based on their observations of changes in demography and sex ratio, the scientists suggested that the terrapin population declined as a result of selective mortality of smaller terrapins in crab pots (Dorcas et al. 2007 at 338–339). Another later study in South Carolina showed that in a creek where bycatch mortality was high, terrapins rarely survived to reproduce (Tucker et al. 2001).

Grosse et al. (2011) contemporaneously studied two of the primary conservation concerns for diamondback terrapins: road mortality from coastal traffic and bycatch mortality in crab pots. They captured 1,547 individual terrapins among 29 tidal creeks in Georgia and used mark-recapture estimates of terrapin density and sex ratio to identify crab pot effects (Grosse et al. 2011 at 764–765). They observed that 153 terrapins—approximately 10% of all live terrapins they observed in the study creeks—drowned in 5 crab pots within study creeks, 83% of which were males (Grosse et al. 2011 at 765). Among all sites, terrapin density declined with increasing crabbing activity within the creek, whereas population density was not related to proximity of roads (Grosse et al. 2001 at 765–766). The scientists also found that there was a significantly larger proportion of smaller-sized terrapins in creeks with no crabbing activity (Grosse et al. 2011 at 763, 766). Thus, they concluded that crabbing activities are linked to terrapin population declines in Georgia and recommended that states focus on reducing bycatch risk by regulating fishing times, requiring the use of BRDs, and removing lost or abandoned crab pots from coastal habitats (Grosse et al. 2011 at 766–769).

Hart and Crowder (2011) estimated that if each of the approximately 7,500 crab fishers in North Carolina catches a number of terrapins similar to those observed in their study, and roughly 50% of that catch is removed from terrapin populations due to mortality (consistent with their study), then tens of thousands of terrapins could be removed from populations each year (Hart and Crowder 2011 at 269). Thus, terrapin capture and mortality in actively fished commercial crab pots may represent an extremely large collective effect on local terrapin populations (Hart and Crowder 2011 at 269).

[2] The two recaptures were excluded from the study (Hoyle and Gibbons 2000 at 735).

Coleman et al. (2014) found that although it is generally accepted that male and juvenile female terrapins are more vulnerable to crab pot mortality than adult females, fully mature females in some parts of the terrapin's range may be smaller and equally capable of entering crab pots (Coleman et al. 2014 at 142). Because loss of female terrapins means the loss of greater long-term reproductive potential, crab pot mortality could be more devastating to terrapin populations in some areas than previously considered (Coleman et al. 2014 at 143–144).

### *ii. Ghost and Derelict Pots*

For the purposes of this petition, the term "ghost pot" includes crab pots that are accidentally lost or intentionally abandoned, as well as derelict crab pots that are irresponsibly left in the water for long periods of time without regular supervision. Ghost pots may result from permanent abandonment of fishable pots by crabbers who leave the fishery seasonally or permanently when it is logistically difficult to transport the pots for either temporary storage or permanent disposal, temporary storage sites are not available, or it is difficult or expensive to dispose of them (Guillory et al. 2001 at 2). Crab pots may also be inadvertently lost due to uncontrollable weather or hydrological factors such as tides, currents, and storm surges; deterioration of buoys, lines, or knots; negligent assembly or maintenance of buoys and lines; unintentional clipping of lines by boat propellers; or intentional cutting of buoy lines by vandals (Guillory et al. 2001 at 2). Because commercial crabbers use large numbers of durable pots, ghost pots can persist for long periods of time (Guillory et al. 2001 at 1).

Ghost pots are considered to be even more detrimental to terrapin populations than actively fished pots[3] (Bishop 1983 at 428; Guillory et al. 2001 at 4; Rook et al. 2010 at 172). This is because ghost pots are ongoing threats and have the capacity to capture great numbers of terrapins if they remain abandoned or lost (Rook et al. 2010 at 172). For example, Bishop (1983) found one ghost pot with 28 dead, decomposing terrapins in South Carolina (Bishop 1983 at 429), and Roosenburg (1991) found a ghost pot with 49 terrapin shells, and remains of even more terrapins in Maryland (Roosenburg 1991 at 231). The number of dead terrapins in that single crab pot represented an estimated 1.6–2.8% of the local population (Roosenburg 1991 at 231).

Grosse et al. (2009) reported finding 133 diamondback terrapin carcasses among two abandoned crab pots in one tidal marsh in Georgia, consisting of more than double the remaining estimated population. One abandoned pot contained 94 dead terrapins, and another pot located approximately 100 meters from the first contained 23 dead and one live terrapin (Grosse et al. 2009 at 98). Because the scientists were prohibited by law from removing the pots, they continued to observe it during their 2-month sampling period and observed additional dead terrapins in the derelict crab pots (Grosse et al. 2009 at 98). They estimated that 91% of the total terrapin biomass in the tidal creek was lost as a result of neglected crab pots (Grosse et al. 2009 at 99).

[3] Ghost pots are also known to capture other vertebrates such as river otters (*Lontra canadensis*) and raccoons (*Procyon lotor*) (Guillory et al. 2001 at 4).

Terrapin carcasses found in abandoned crab pot in Georgia
(Source: Grosse et al. 2009)

During Hoyle and Gibbons' (2000) study in South Carolina, the scientists inadvertently created a ghost pot scenario when two of their test pots became entangled during a high spring tide when they were not being monitored (Hoyle and Gibbons 2000 at 735). Four terrapins entered those pots and died (Hoyle and Gibbons 2000 at 735). The scientists estimated that those two lost pots could account for more terrapin captures than all 20 pots set during the study year (Hoyle and Gibbons 2000 at 736).

The number of terrapins lost to ghost pots is exponentially amplified by the number of ghost pots present in terrapin habitat. The commercial fishery generates many ghost pots each year (Chambers and Maerz 2018). These abandoned pots are abundant, and every year more become marine debris in shallow estuaries, sometimes directly in terrapin habitat (Chambers and Maerz 2018; Bishop 1983 at 429). Though the numbers and location of ghost pots are unknown, scientists believe they are frequently abandoned or lost (Roosenburg 1991 at 231). Guillory et al. (2001) estimated that approximately 250,000 derelict crab pots are added to the Gulf of Mexico annually (Guillory et al. 2001 at 2–3).

### *iii. Crab pot mortality in Florida*

Crab pot mortality is a longstanding and ongoing threat to terrapins in Florida, with observed mortality events spanning decades. For instance, between 1979 and 1993, population declines attributed to crab pots were reported in Florida at the Kennedy Space Center (Lovich et al. 2018 at 69). In 1972, 23-27 deceased terrapins were observed in a single crab pot on the Alafia River (Godley, pers. comm. 2019). The terrapins were discovered in a partially submerged crab pot on the south side of the Alafia River, about 1.1 kilometers east of Bird Island (Godley, pers. comm. 2019). The terrapins were taken to a lab at University of South Florida, where they were sorted and examined (Godley, pers. comm. 2019). Most of the deceased terrapins were subadults, with several adult males (Godley, pers. comm. 2019). No adult female terrapins were discovered in the pot (Godley, pers. comm. 2019). The USF catalogues and specimens no longer exist (Godley, pers. comm. 2019).

On May 5, 2008, five deceased terrapins were observed in an abandoned crab pot in Indian Bayou in Santa Rosa County, Florida (O'Connor pers. comm. 2019). Another single dead female terrapin was observed in a crab pot on May 10, 2010 (O'Connor pers. comm. 2019).

Butler and Heinrich (2007) also suggests that terrapins in Florida can drown in significant numbers in crab pots. The results indicated that a mere fifteen pots in Florida waters could lead to the deaths of up to 68 terrapins throughout May (Butler and Heinrich 2007 at 183).

There are also anecdotal reports of crab pots remaining in Florida waters for years at a time, including through seasonal closures of blue crab pots for derelict trap removal (Godley, pers. comm. 2019). These neglected pots represent a significant risk to terrapins because they are not checked frequently and are susceptible to being lost or abandoned during storm events.

### c. Bycatch Reduction Devices

Bycatch Reduction Devices (also called "BRDs" or "terrapin excluder devices") prevent terrapins of a certain size from entering the pot (Roosenburg 2004 at 23). They are designed specifically to prevent terrapin bycatch. Designed in the early 1990s (Wood 1997 at 23), experts now recognize the BRD as the "best and most feasible solution to reducing terrapin mortality in crab pots" (Roosenburg 2004 at 27).

An example of a plastic terrapin excluder device
(Source: South Carolina Department of Natural Resources)

BRDs have been well-studied in several states, and their effectiveness and effect on the crab fishery vary among geographic regions (Roosenburg 2004 at 26). However, there is a general consensus that 4.5 x 12-centimeter (cm) BRD is effective at reducing terrapin entrapment

(Roosenburg 2004 at 26). Likewise, studies have found that both the 4.5 x 12 cm and the 5 x 10 cm BRD have a minimal effect on crab catch (Roosenburg 2004 at 26). These findings have been tested in Florida, with similar results (Butler and Heinrich 2007).

### *i. Effect on Terrapin Mortality*

Experts have studied BRDs of various sizes in several geographic regions within the terrapin's range. All studies found that crab pots with BRDs successfully limited terrapin bycatch to some degree, ranging from 12-100% effectiveness, with smaller BRDs generally being more effective than larger BRDs. The studies widely found that BRDs measuring 4.5 x 12 cm are sufficiently effective at reducing crab pot mortality without significantly affecting the size or number of crabs caught.[4] Table 1 summarizes the findings from studies that evaluated the ability of BRDs to reduce terrapin bycatch in blue crab pots. More detailed summaries of the studies are provided in Appendix A.

**Table 1: Survey of Publications Evaluating the Ability of BRDs to Reduce Diamondback Terrapin Mortality in Blue Crab Pots**

| Article | State | BRD size (cm) | % terrapins excluded |
|---|---|---|---|
| Butler and Heinrich (2007) | FL | 4.5 x 12 | 73.2% |
| Cole and Helser (2001) | DE | 3.8 x 12 | 100% |
| | | 4.5 x 12 | *67% |
| | | 5 x 10 | 59% |
| | | 5 x 12 | 12% |
| Crowder et al. (2000) | NC | 4 x 16 | 100% |
| | | 4.5 x 16 | 100% |
| | | 5 x 16 | 100% |
| Hart and Crowder (2011) | NC | 4.5 x 16 | 77% |
| | | 5 x 16 | 28% |
| Mazzarella (1994) | NJ | 5 x 10 | **90.5% |
| Morris et al. (2011) | VA | 4.5 x 12 | 100% |
| Rook et al. (2010) | VA | 4.5 x 12 | 95.7% |
| Roosenburg and Green (2000) | MD | 4 x 10 | 100% |
| | | 4.5 x 12 | 82% |
| | | 5 x 10 | 47% |
| Wnek (2019) | NJ | 4.5 x 12 | 100% |
| | | 5 x 15 | 100% |
| | | 5.1–6.4 × 7.3 (curved) | 100% |

*averaged percentages for male terrapins and female terrapins

**averaged numbers from two separate seasons

[4] *See* Section II(c)(ii), *Effect on Crab Haul*.

Notably, BRDs have successfully reduced terrapin mortality in crab pots in Florida waters. Butler and Heinrich (2007) evaluated whether 4.5 x 12 cm galvanized steel BRDs reduced bycatch mortality of diamondback terrapins in commercial crab pots in Florida. They fished 15 pots without BRDs and 15 outfitted with BRDs at eight sites along the Atlantic and Gulf coasts (including the Florida panhandle) during the summers of 2002-2005. Thirty-seven terrapins were caught in standard pots and four in those with BRDs. They found that 73.2% of trapped terrapins would have been excluded from pots with BRDs (Butler and Heinrich 2007 at 183–184). Accordingly, Butler and Heinrich (2007) recommended that the Florida Fish and Wildlife Conservation Commission devise and adopt regulations that require the use of 4.5 x 12 cm BRDs on all commercial and recreational crab pots used in Florida waters.

### *ii. Effect on Crab Haul*

Many studies also assess the effect of BRDs on the size and number of crabs captured, with the goal of identifying a BRD design that successfully minimizes terrapin captures while having minimal effect on crab haul. Nearly every study found at least one BRD size that had little to no effect on crab haul, and they generally agree that a 4.5 x 12 cm BRD can successfully prevent terrapin deaths while having insignificant impacts on crab haul (See Table 2, Appendix B).

**Table 2: Survey of Publications Evaluating the Effect of BRDs on Crab Haul**

| Article | State | BRD size (cm) | Finding |
|---|---|---|---|
| Butler and Heinrich (2007) | FL | 4.5 x 12 | no significant effect on sex, size, or number of crabs captured |
| Cole and Helser (2001) | DE | 3.8 x 12 | substantial loss of legal-size blue crabs (26% decrease with BRDs) |
| | | 4.5 x 12 | nominal loss of legal-size blue crabs (12% total decrease, with 6% of most desirable crabs with BRDs) |
| | | 5 x 10 | no statistical difference in blue crab catches (2.4% increase with BRDs) |
| | | 5 x 12 | no substantial change in total blue crab catch rates (0.2% increase with BRDs) |
| Cuevas et al. (2000) | MS | 5 x 10 | similar daily catch rates (mean 19.5 for traps with BRDs and without) and crab size frequency |
| Guillory and Prejean (1998) | LA | 5 x 10 | overall catch per trap day of sublegal, legal, and total crabs was 14.5%, 37.9%, and 25.7% greater, respectively, than in standard pots |
| Hart and Crowder (2011) | NC | 4.5 x 16 | BRD did not have a significant effect on catch of either large male blue crabs or peelers |
| | | 5 x 16 | |

| | | | |
|---|---|---|---|
| Lukacovic et al. (2005) | MD | 4.5 x 12 | all categories of crab catch were significantly lower in crab pots fitted with BRDs; in traps without BRDs, overall crab catch was 35% greater and catch of legal crabs was 28.5% greater |
| Mazzarella (1994) | NJ | 5 x 10 | no significant difference in number of crabs or size of crabs captured |
| Morris et al. (2011) | VA | 4.5 x 12 | no statistical difference between either the number or size of legal-size crabs in crab pots with and without BRDs on the first day after baiting; significant difference in total catch per unit effort and size across all other days after; more legal-size crabs were caught in pots without terrapin bycatch, but the difference was not significant |
| Rook et al. (2010) | VA | 4.5 x 12 | crab catch equivalent between crab pots with and without BRDs; slight increase (marginal) in number, size, and biomass of both legal-size and sublegal-size crabs in pots with BRDs |
| Roosenburg and Green (2000) | MD | 4 x 10 | reduced the size and number of large and mature female crabs |
| | | 4.5 x 12 | no effect on size or number of crabs caught |
| | | 5 x 10 | no effect on size or number of crabs caught |
| Wnek (2019) | NJ | 4.5 x 12 | no significant difference in number of crabs caught; similar mean length, width, height |
| | | 5 x 15 | no significant difference in number of crabs caught; similar mean length; smaller mean width and height |
| | | 5.1–6.4 × 7.3 (curved) | no significant difference in number of crabs caught; similar mean length, width, height |

Butler and Heinrich (2007) tested whether bycatch mortality of diamondback terrapins in commercial crab pots is reduced by using 4.5 x 12 cm galvanized steel BRDs and whether those devices limit blue crab catch. They captured 2,753 legal-sized crabs and found no significant difference between the sex, measurements, or number of crabs captured in standard crab pots versus crab pots with BRDs (Butler and Heinrich 2007 at 182).

Although BRDs have not been studied in large-scale commercial operations that fish more than 100 pots, anecdotal reports from crabbers who use BRDs in large-scale operations claim that they see no effect—or maybe an improvement—in their crab catch (Roosenburg 2004 at 27).

BRDs may offer additional benefits to crabbers as well. For instance, BRDs reduce the rate of entry of many large vertebrate bycatch including fish, turtles, and otters (Guillory and Prejean 1998 at 39). This frees up additional space in pots, which would otherwise be occupied by nontarget species, to capture more crabs. The presence of terrapins in crab pots may cause crabs to avoid crab pots. Morris et al. (2011) found that crab pots with terrapin bycatch in them had, on average, fewer crabs per unit effort (Morris et al. 2011 at 388). Likewise, more legal-size crabs were caught in pots without terrapin bycatch (Morris et al. 2011 at 388). Thus, keeping terrapins out of crab pots may lead to the capture of more and larger crabs. Guillory and Prejean (1998) have also suggested that increased crab catch in traps with BRDs could be due to increased ingress and/or decreased egress through the entrance funnels (Guillory and Prejean 1998 at 39).

Finally, keeping terrapins out of crab pots may help keep crabs in marketable condition. Davenport et al. (1992) studied terrapin feeding behavior on crabs by providing hungry male terrapins crabs of different size classes and observing the terrapins' behavior (Davenport et al. 1992 at 837–846). The size classes for crabs were small (10–25 mm carapace width), medium (30-50 mm), and large (52–75 mm) (Davenport et al. 1992 at 837). They observed that although terrapins are not specialized anatomically for a diet of hard-shelled animals, they will still exploit such food sources if they are hungry and do not have other options (Davenport et al. 1992 at 846). Specifically, they will eat crabs (Davenport et al. 1992 at 846). Small crabs were eaten whole, while medium and large crabs were "cropped"—that is, their walking legs were eaten without killing the crab (Davenport et al. 1992 at 847). Applying their findings to diamondback terrapins in the field, the scientists predicted that terrapins might eat blue crabs through a "cropping" technique (Davenport et al. 1992 at 847). Generally, terrapins will attack smaller crabs before medium crabs, and medium crabs before larger crabs (Davenport et al. 1992 at 847). Because terrapins captured in crab pots are in closed conditions without access to their preferred prey, it is possible that they will shear crabs, thus making them less marketable.

## III. JUSTIFICATION FOR THE REQUESTED RULEMAKING

### a. The Diamondback Terrapin Is Imperiled and Cannot Sustain Effects from Crab Pot Mortality

Wild turtle populations are characterized by a suite of life history characteristics that predispose them to rapid declines when subjected to unnatural levels of adult mortality (Colteaux and Johnson 2017 at 17; Heppell 1998; Galbraith et al. 1997; Congdon et al. 1993, 1994). Among these characters are delayed maturity, low fecundity, high annual survivorship of adults, and high natural levels of nest mortality (Reed and Gibbons 2003). Similarly, terrapins' life history traits prevent them from absorbing chronic adult mortality (Hoyle and Gibbons 2000 at 736). Removing even a few diamondback terrapins from a population can have detrimental effects on the population as a whole (Hoyle and Gibbons 2000). For this reason, experts rank crab pot mortality as the greatest threat to the diamondback terrapin (Butler et. al. 2006 at 332) and have emphasized that modifying pots to reduce terrapin mortality is of utmost importance (Baker et al. 2013 at 676).

Studies and anecdotal evidence demonstrate that blue crab pots can have devastating population-level impacts on diamondback terrapins (Davis 1942; Bishop 1983; Marion 1986; Burger 1989; Mazzarella 1994; Mann 1995; Wood and Herlands 1996; Roosenburg et al. 1997; Wood 1997; Guillory and Prejean 1998; Crowder et al. 2000; Hoyle and Gibbons 2000; Roosenburg and Green 2000; Cole and Helser 2001; Butler 2002, 2000; Roosenburg 2004; Butler and Heinrich 2007; Dorcas et al. 2007; Coleman et al. 2014; Chambers and Maerz 2018). A fleet of active crab pots can significantly reduce a terrapin population over time by periodically removing a few terrapins at a time (Hart and Crowder 2011 at 269). A single ghost pot—which can capture dozens of terrapins at once—can wipe out an entire population in a relatively shorter period of time (Grosse et al. 2009 at 99).

Reports of terrapin deaths in crab pots are so common that they have been documented in numerous recent news stories and social media posts from across the species' range, including hundreds of terrapins in Virginia,[5] 20 terrapins in Maryland,[6] 91 terrapins in New Jersey,[7] 95 terrapins in Louisiana (Butcher et al. 2018 at 30), and 42 terrapins in New York.[8] Most recently in 2019, a Facebook post from Georgia reported more than 20 dead terrapins in a single pot,[9] and a Virginia report documented 30 dead terrapins in a pot.[10]

Florida terrapins are not immune to the effects of crab pot mortality. While the Florida Fish and Wildlife Conservation Commission does not require crabbers to report terrapin mortality in their pots, anecdotal evidence demonstrates that it is occurring (Lovich et al. 2018 at 69, Butler and Heinrich 2007, Godley pers. comm. 2019, O'Connor pers. comm. 2019). Because most commercial crabbers set hundreds of pots, they could cause "significant detrimental effects on local populations" (Butler and Heinrich 2007 at 183). The scientists who conducted the study estimate that "[t]he coastline of Florida represents over 20% of the entire terrapin range, so the effect of crab pot mortality in this state has great significance, not only to Florida terrapins but to the conservation of the entire species" (Butler and Heinrich 2007 at 180).

The potential for crab pot mortality in Florida is high because Florida has a long coastline that allows for a high trapping effort in the crab fishery. Florida is considered one of the top four states for recreational crabbing potential (Chambers and Maerz 2018). Derelict crab pots from commercial and recreational pot fisheries are also a problem in Florida waters. Most recently in July 2019, a team of volunteers collected 176 pots out of Tampa Bay during a derelict trap removal event.[11]

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[5] Karl Blankenship, *Derelict pots killing 3.3 million crabs annually in the Bay*, BAY JOURNAL (Dec. 27, 2016), https://www.bayjournal.com/article/derelict_pots_killing_3.3_million_crabs_annually_in_the_bay; Carol Vaughn, *Virginia bill aimed at protecting turtles passes Senate*, DELMARVA NOW (Feb 10, 2016, 10:48 AM), https://www.delmarvanow.com/story/news/local/virginia/2016/02/09/turtle-bill-passes-senate-house-subcommittee-agenda/80070128/.

[6] *Save the terrapins*, BALTIMORE SUN *(Aug. 17, 2016, 12:15 PM), https://www.baltimoresun.com/opinion/editorial/bs-ed-terrapin-20160817-story.html.*

[7] Dan Radel, *Ghost pots: Abandoned crab traps are sea killers*, ASHBURY PARK PRESS (May 6, 2017, 8:39 AM), https://www.app.com/story/news/local/land-environment/enviroguy/2017/05/05/1379-ghost-crab-pots-marine-killer-water/101246090/; Maxwell Reil, *About 80 turtles found dead on Sea Isle City beach*, PRESS OF ATLANTIC CITY (Jun. 4, 2018), https://www.pressofatlanticcity.com/news/about-turtles-found-dead-on-sea-isle-city-beach/article_fbe05c8e-0c9e-508d-94ec-765c21d6cc5e.html.

[8] Matthew Miller, *Saving Terrapins from Drowning in Crab Traps*, COOL GREEN SCIENCE (Mar. 27, 2018), https://blog.nature.org/science/2018/03/27/saving-terrapins-from-drowning-in-crab-traps/.

[9] Edwin Longwater, FACEBOOK (Apr. 18, 2019), https://www.facebook.com/photo.php?fbid=601987793616969&set=pb.100014172614332.-2207520000.1561385354.&type=3&theater.

[10] SaraRose Martin, *Along marshy edge of York River, you'll find dead turtles, drowned in the lost traps of crabbers*, THE VIRGINIA GAZETTE (Jun. 7, 2019, 7:45 AM), https://www.vagazette.com/news/va-vg-commercial-crabbing-traps-0513-story.html.

[11] Jorja Roman, Volunteers Collect Derelict Crab Traps from Pinellas Co. Waters, (July 13, 2019), https://www.baynews9.com/fl/tampa/news/2019/07/13/volunteers-collect-derelict-crab-traps-from-pinellas-waters?fbclid=IwAR3F3d9joBryHbm31ywvLsnn5roYCrKbDVrobf3qdaVzhoKKAxdc2RPh0YM.

When added to the suite of additional stressors across the species' range, including habitat destruction and degradation, road mortality, nest predation, boat strikes, poaching, climate change, sea-level rise, and subsidized predation (Maerz et al. 2018), diamondback terrapins cannot sustain the harmful impacts of crab pot mortality.

### b. BRDs Protect Diamondback Terrapins While Boosting Marketability of Crabs from Florida's Waters

BRDs provide a simple and inexpensive method to reduce terrapin deaths in crab pots and increase marketability of crabs caught in Florida's waters. A rule requiring BRDs is justified because BRDs protect most mature diamondback terrapins from drowning in pots, BRDs have little to no effect on crab haul, BRDs are inexpensive, and using BRDs increases the marketability of crabs fished from Florida's waters.

Neither the commercial nor recreational blue crab fisheries have adopted these important measures, and research shows that rules simply requiring crabbers to check pots once per day—even if stringently followed—are not enough to combat terrapin mortality (Wood 1997).

#### *i. BRDs Protect Terrapins from Needless Drowning Deaths*

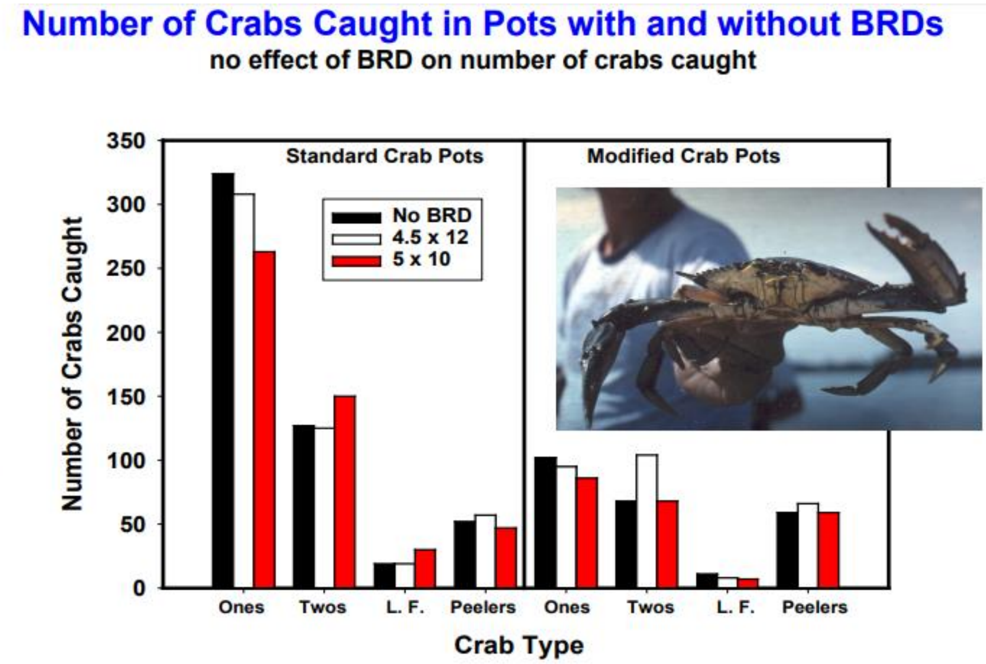
Extensive studies show that BRDs effectively prevent most large, mature terrapins from entering crab pots by restricting the pot entrances to a size that precludes a terrapin's carapace from fitting through (Reviewed in Roosenburg 2004; Chambers and Maerz 2018). Studies demonstrate that on average, 70% of terrapins are unable to enter pots equipped with BRDs while blue crabs can still enter easily (Mazzarella 1994; Crowder 2000; Roosenburg and Green 2000; Cole and Helser 2001; Rook et al. 2010; Hart and Crowder 2011; Morris et al. 2011).

A study in Florida found that BRDs can prevent 73.2% of terrapins from entering crab pots by outfitting them with BRDs (Butler and Heinrich 2007 at 183). This significant reduction in terrapin mortality achieved by BRDs will slow terrapin declines attributed to crab pot mortality and provide Florida's terrapins with a level of resiliency against myriad other threats it currently faces and will face as climate change and sea-level rise continue and accelerate.

#### *ii. BRDs Have Little to No Effect on Crab Haul*

Extensive scientific study also demonstrates that BRDs have little to no effect on the number and size of marketable crabs harvested (Mazzarella 1994; Guillory and Prejean 1998; Cuevas et al. 2000; Roosenburg and Green 2000; Cole and Helser 2001; Butler and Heinrich 2007; Rook et al. 2010; Hart and Crowder 2011; Morris et al. 2011). When Butler and Heinrich (2007) studied BRDs in Florida, they found no significant difference between the sex, measurements, or number of legal-sized crabs captured in standard crab pots versus crab pots with BRDs. Other studies even suggest BRD use can result in an increase in catch of marketable crabs (Rook et al. 2010; Roosenburg and Green 2000; Guillory and Prejean 1998).

The following chart reflecting a survey of all BRD studies demonstrates that crab haul is relatively the same in crab pots with no BRDs and crab pots with 4.5 x 12 cm BRDs (Roosenburg 2017).




(Source: modified from Roosenburg and Green 2000)

### *iii. BRDs Are Inexpensive*

BRDs are small and inexpensive. Some companies in states like Maine sell BRDs for as little as $0.45 each,[12] while other states such as Florida have programs that distribute BRDs for free.[13] There are also free resources that teach fishermen how to build and install their own BRDs.[14]

BRDs will likely become even less expensive over time as they are integrated into the crab pot fishery. As more states adopt rules and regulations requiring the use of BRDs, manufacturers will embrace the opportunity to design pots that already include BRDs. For instance, in Maryland, crab pots with built-in BRDs are already available.[15] As these pot designs become more common, the cost of making them will decrease.

[12] *Purchase Pre-Made BRDs*, VIRGINIA INSTITUTE OF MARINE SCIENCE, https://www.vims.edu/research/units/projects/terrapin_brds/pre-made.php (last visited Jul. 11, 2019).
[13] *BRD Pick-Up Locations*, FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION, https://myfwc.com/conservation/special-initiatives/cwci/education/brds/ (last visited Jun. 24, 2019).
[14] *Recreational Crab Pot Requirements*, MARYLAND DEPARTMENT OF NATURAL RESOURCES, https://dnr.state.md.us/fisheries/Pages/regulations/crabpot.aspx (last visited Jul. 11, 2019).
[15] *Use BRDs. It's the Law*, MARYLAND DEPARTMENT OF NATURAL RESOURCES, https://dnr.maryland.gov/fisheries/documents/flyer_stores.pdf (last visited Jun. 24, 2019).

### *iv. BRDs Make Florida's Crabs More Marketable in an Increasingly Environmentally Conscious Market*

Sustainability is a driving force across markets, and seafood markets are no exception. BRDs would make crabs from Florida's waters more marketable in an increasingly eco-conscious economy. A 2018 global survey by Nielson found that 81% of participants felt strongly that companies should help improve the environment. This sentiment was shared across generations, with Millennials, Generation Z, and Generation X being most supportive, and older generations not far behind.[16] Americans in particular are concerned about environmental issues and recognize that their finances can be used to influence change.[17] They are becoming better informed about of the environmental impact of products they purchase.[18]

These environmental values are driving consumer purchases. A 2017 survey of demographically representative Americans found a steady increase in consumers purchasing products with social benefit, with participants indicating they purposefully use their wallets to drive change by buying products with environmental benefit (Cone Comms. 2017). A majority (79%) indicated they seek out environmentally responsible products (Cone Comms. 2017). Eighty-seven percent of participants said that given the opportunity, they would buy a product with social or environmental benefit (Cone Comms. 2017). These attitudes and actions reflect a growing trend, rising from 83% in 2015.

In a 2015 Global Corporate Sustainability Report by Nielson, 66% of consumers indicated they are willing to spend more on a product if it comes from a sustainable brand.[19] Millennials indicated a similar preference, with 73% willing to pay extra for sustainable products.[20]

This trend toward more sustainable markets is clear in the seafood industry, with several independent organizations recommending consumers purchase only sustainably sourced seafood. For instance, the Monterey Bay Aquarium's Seafood Watch program helps consumers and businesses choose seafood that supports a healthy ocean by recommending which seafood items are "Best Choices" and "Good Alternatives," and which ones to avoid. Currently the Seafood Watch program recommends that consumers only purchase blue crabs from states that have effective regulations to protect diamondback terrapins from drowning in crab pots. Because of Florida's lax regulations to protect terrapins, Seafood Watch recommends that consumers avoid

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[16] Nielsen, Global Consumers Seek Companies that Care about Environmental Issues (Sept. 11, 2018), https://www.nielsen.com/eu/en/insights/article/2018/global-consumers-seek-companies-that-care-about-environmental-issues/.
[17] Adam Butler, Do Customers Really Care About Your Environmental Impact? Forbes.com (Nov. 21, 2018), https://www.forbes.com/sites/forbesnycouncil/2018/11/21/do-customers-really-care-about-your-environmental-impact/#3d6974ee240d.
[18] Adam Butler, Do Customers Really Care About Your Environmental Impact? Forbes.com (Nov. 21, 2018), https://www.forbes.com/sites/forbesnycouncil/2018/11/21/do-customers-really-care-about-your-environmental-impact/#3d6974ee240d.
[19] New Release, Consumer-Goods' Brands That Demonstrate Commitment to Sustainability Outperform Those That Don't (Dec. 10, 2015), https://www.nielsen.com/eu/en/press-releases/2015/consumer-goods-brands-that-demonstrate-commitment-to-sustainability-outperform/.
[20] New Release, Consumer-Goods' Brands That Demonstrate Commitment to Sustainability Outperform Those That Don't (Dec. 10, 2015), https://www.nielsen.com/eu/en/press-releases/2015/consumer-goods-brands-that-demonstrate-commitment-to-sustainability-outperform/.

purchasing blue crabs from Florida. Instead, it recommends purchasing crabs from states like New Jersey, which "requires the commercial fishery to use terrapin bycatch reduction devices."[21]

As more states adopt laws requiring commercial crabbers to use BRDs, Florida will fall behind in the blue crab markets as consumers seek out more sustainable alternatives. For Florida to keep up, it needs to adopt BRD regulations to prevent harming terrapin populations. By being an early adopter of BRD rules, Florida can establish itself as a conservation leader and gain an advantage over crab fisheries in surrounding states that have yet to take this important step.

### c. Other States in the Diamondback Terrapin's Range Require Bycatch Reduction Devices

Several states already require or incentivize crabbers to use BRDs on their pots. New Jersey requires crabbers to use BRDs in waters of less than 150 feet across at mean low water mark,[22] and New York recently implemented regulations requiring crabbers to use BRDs on pots set in creeks, coves, rivers, tributaries, and near-shore harbors of the Marine and Coastal District.[23] In Maryland and Delaware, all recreational crab pots must have BRDs.[24] Virginia encourages crabbers to use BRDs on crab pots by offering a lower cost licensing rate for modified pots.[25]

**Table 3: Survey of State Laws Governing Bycatch**

| State | Terrapin Conservation Status | BRD required on crab pots? |
|---|---|---|
| **MA** | Threatened | no |
| **RI** | Endangered | no |
| **CT** | Species of Special Concern | no |
| **NY** | None | yes |
| **NJ** | Nongame Indigenous Species | yes |
| **DE** | Species of Conservation Concern | yes (recreational only) |
| **MD** | None | yes (recreational only) |
| **VA** | Species of Greatest Conservation Need | no |
| **NC** | Special Concern Species | no* |
| **SC** | High Priority species for conservation | no |
| **GA** | Protected species ("unusual") | no |
| **FL** | Species of Greatest Conservation Need | no |
| **AL** | Highest Conservation Concern/ Nongame species | no |
| **MS** | Species of Greatest Conservation Need | no |
| **LA** | Species of Special Concern | no |
| **TX** | Nongame/ Species of Greatest Conservation Need | no |
| * Wildlife agency empowered to issue rules or orders requiring BRDs | | |

[21] *Crab Recommendations*, MONTEREY BAY AQUARIUM SEAFOOD WATCH, https://www.seafoodwatch.org/seafood-recommendations/groups/crab?q=blue%20crab&type=blue&o=371 (last visited July 11, 2019).
[22] N.J. Admin. Code § 7:25-14.6(c) (Lexis Advance through the New Jersey Register, Vol. 51 No. 13, July 1, 2019)
[23] N.Y. Comp. Codes R. & Regs. tit. 6, § 44.2(d) (Lexis Advance through June 28, 2019).
[24] Md. Code Regs. 08.02.03.07(B)(5); 7-3000-3700 Del. Code Regs. § 1.0.
[25] Va. Code Ann. § 28.2-226.2(B)(1)–(2) (Lexis Advance through the 2019 Regular Session of the General Assembly).

While Florida has a program that offers BRDs to crabbers free of cost from 28 different locations,[26] this program has not generated widespread participation. Without full participation by the crabbing community, the voluntary BRD program has little to no conservation effect for the diamondback terrapin. For this reason, it is imperative that Florida adopt mandatory BRD rules. As the state with the largest area of coastline habitat for diamondback terrapins, Florida is poised to take the lead in the southern states and adopt regulations requiring the use of BRDs on crab pots.

## IV. PROPOSED RULE AMENDMENT

Florida's fishing regulations currently do not require the use of BRDs in blue crab pots. To protect diamondback terrapins from incidental mortality in active and inactive blue crab pots, Petitioners request that the Florida Fish and Wildlife Conservation Commission adopt or amend regulations to require BRDs on all commercial and recreational blue crab pots in state waters. To provide the fishery reasonable time to retrofit crab pots, Petitioners suggest a three-year grace period from the date of adoption or amendment of the regulation. The proposal also includes a provision to allow the use of other gear modifications that demonstrate through peer-reviewed study similar efficacy to 4.5 cm by 12 cm BRDs, as set forth in Butler and Heinrich 2007.

While Petitioners generally request that the Florida Fish and Wildlife Conservation Commission adopt a rule or amendment to require BRDs in blue crab pots, in the interest of specificity and completeness, we suggest the following specific amendments to Chapter 68B-45 of the Florida Administrative Code, rules regulating the blue crab fishery. If the Commission declines to adopt the specific recommended amendments, Petitioners respectfully request that the Commission consider alternative amendments to protect terrapins from bycatch mortality in the blue crab fishery. Petitioners also request the opportunity to participate as stakeholders in any rulemaking process.

In the following proposal, regular typeface denotes the current regulatory language, strikethrough denotes language to be removed, boldface denotes language to be added, and ellipses denote omitted material. Notes are contained in brackets.

68B-45.002 Definitions.

As used in this rule chapter:

(1) "Blue crab" means any crustacean of the species Callinectes sapidus, or any part thereof.

**(2) "Bycatch reduction device" or "BRD" means a rigid rectangular device constructed of wire or plastic that has an opening no larger than 4.5 cm by 12 cm, which is attached to the end of each entrance funnel of a crab trap to minimize bycatch of diamondback terrapins. This definition also includes any**

[26] *BRD Pick-Up Locations*, FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION, https://myfwc.com/conservation/special-initiatives/cwci/education/brds/ (last visited Jun. 24, 2019).

**device or gear modification that results in a ≥70% reduction in terrapin captures compared with unmodified traps, as demonstrated by at least one peer-reviewed study.**

**(3)**~~(2)~~ "Drop net" means a small, usually circular, net with weights attached along the outer edge and a single float in the center.

**(4)**~~(3)~~ "Eggbearing blue crab" means a female blue crab whose eggs are extruded and deposited on the swimmerettes.

**(5)**~~(4)~~ "Escape ring" means a rigid ring forming the boundary of an opening placed flush with the vertical surface of the wire mesh wall of the crab trap.

**(6)**~~(5)~~ "Fold up trap" means a plastic or wire meshed collapsing trap that opens outward to occupy a single plane when placed on the water bottom. It is baited in the center of the base panel and encloses crabs when retrieved by means of a cord drawing together the side panels.

**(7)**~~(6)~~ "Gulf Seasonal Closure Region" means all state waters of the Gulf of Mexico seaward of three nautical miles from shore.

**(78)**~~(7)~~ "Hard shell crab" means any blue crab in intermolt condition that has a shell that is rigid and inflexible.

**(9)**~~(8)~~ "Mesh size" means the size of the opening or space within a polygon formed by the wire of a crab trap, to be measured at the largest dimension across such opening or space in an undistorted condition.

**(10)**~~(9)~~ "Harvest" means the catching or taking of a blue crab by any means whatsoever, followed by a reduction of such blue crab to possession. Blue crabs caught but immediately returned to the water free, alive, and unharmed are not harvested. Temporary possession of a blue crab for the purpose of measuring it to determine compliance with the size requirements of this chapter shall not constitute the harvesting of such blue crab, provided that it is measured on the water immediately after taking, and immediately returned to the water free, alive, and unharmed if undersized.

**(11)**~~(10)~~ "Harvest for commercial purposes" means the taking or harvesting of blue crab for purposes of sale or with intent to sell or in excess of the bag limit.

**(12)**~~(11)~~ "Immediate family" refers to a license holder's mother, father, sister, brother, spouse, son, daughter, step-father, step-mother, step-son, step-daughter, half-sister, half-brother, son-in-law or daughter-in-law.

**(13)**~~(12)~~ "Offshore" means all state waters seaward of the COLREGS Demarcation Line.

**(14)**~~(13)~~ "Peeler crab" means a hard blue crab in pre-molt condition having a new soft shell developed under the hard shell and having a definite white, pink, or red line or rim on the outer edge of the back fin or flipper, and retained specifically for soft crab shedding operations and marketed only after molting and prior to the hardening of the new shell.

**(15)**~~(14)~~ "Push scrape" means a mesh net or bag attached to the outer edges of a triangular or rectangular rigid frame with a handle attached that is fished by being pushed across the bottom by a person wading.

**(16)**~~(15)~~ "Soft shell crab" means any blue crab that has recently molted and has a shell that is tender and flexible.

**(17)**~~(16)~~ "Trotline" means a submerged line with bait at repetitive intervals.

**(18)**~~(17)~~ "Untreated pine" means raw pine wood that has not been treated with any preservative or pine wood that has been pressure treated with no more than 0.40 pounds of chromated copper arsenate (CCA) compounds per cubic foot of wood.

[ . . . ]

<u>68B-45.004 Regulation and Prohibition of Certain Harvesting Gear.</u>

(1) Except as provided in subsections (2), (3), (4), (5) and (6) below, the following types of gear shall be the only types of gear allowed for the harvest of blue crab in or from state waters:

(a) Traps meeting the following specifications:

1. Traps shall be constructed of wire with a minimum mesh size of 1 1/2 inches and have throats or entrances located only on a vertical surface. Beginning on January 1, 1995, traps shall have a maximum dimension of

24 inches by 24 inches by 24 inches or a volume of 8 cubic feet and a degradable panel that meets the specifications of subsection (7) of this rule.

2. All traps shall have a buoy or a time release buoy attached to each trap or at each end of a weighted trotline which buoy shall be constructed of styrofoam, cork, molded polyvinyl chloride, or molded polystyrene, be of sufficient strength and buoyancy to float, and be of such color, hue and brilliancy to be easily distinguished, seen, and located. Buoys shall be either spherical in shape with a diameter no smaller than 6 inches or some other shape so long as it is no shorter than 10 inches in the longest dimension and the width at some point exceeds 5 inches. No more than 5 feet of any buoy line attached to a buoy used to mark a blue crab trap or attached to a trotline shall float on the surface of the water.

3. Each trap used for harvesting blue crab for commercial purposes shall have the harvester’s blue crab endorsement number permanently affixed to it. Each buoy attached to such a trap shall have the number permanently affixed to it in legible figures at least two inches high. The buoy color and license number shall also be permanently and conspicuously displayed on any vessel used for setting the traps and buoys, so as to be readily identifiable from the air and water, in the following manner:

a. From the Air - The buoy design approved by the Commission shall be displayed and be permanently affixed to the uppermost structural portion of the vessel and displayed horizontally with the painted design up. If the vessel is an open design (such as a skiff boat), in lieu of a separate display, one seat shall be painted with buoy assigned color with permit numbers, unobstructed and no smaller than 10 inches in height, painted thereon in contrasting color. Otherwise, the display shall exhibit the harvester's approved buoy design, unobstructed, on a circle 20 inches in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than 10 inches in height.

b. From the Water - The buoy design approved by the Commission shall be displayed and be permanently affixed vertically to both the starboard and port sides of the vessel near amidship. The display shall exhibit the harvester's approved buoy design, unobstructed, on a circle 8 inches in diameter, outlined in a contrasting color, together with the permit numbers permanently affixed beneath the circle in numerals no smaller than 4 inches in height.

4. The buoy attached to each trap used to harvest blue crab, other than those used to harvest for commercial purposes, shall have a legible “R”, at least two inches high, permanently affixed to it. The trap shall have the harvester’s name and address permanently affixed to it in legible letters. The buoy requirements of this subparagraph shall not apply to traps fished from a dock.

5. Each trap with a mesh size of 1 1/2 inches or larger shall have at least three unobstructed escape rings installed, each with a minimum inside diameter of 2 3/8 inches. One such escape ring shall be located on a vertical outer surface adjacent to each crab retaining chamber.

6. Each throat (entrance) in any trap used to harvest blue crabs shall be horizontally oriented, i.e., the width of the opening where the throat meets the vertical wall of the trap and the opening of the throat at its farthest point from the vertical wall, inside the trap, is greater than the height of any such opening. No such throat shall extend farther than 6 inches into the inside of any trap, measured from the opening where the throat meets the vertical wall of the trap to the opening of the throat at its farthest point from the vertical wall, inside the trap.

7. Subparagraphs 1. through 6. shall not apply to any trap used to harvest blue crabs for other than commercial purposes, which trap has a volume of no more than 1 cubic foot and is fished from a vessel, a dock, or from shore.

**8. Beginning [three years from date of amendment], all traps, whether commercial or recreational, must have a bycatch reduction device (BRD) meeting the specifications defined in 68B-45.002(2) attached to each entrance or funnel.**

(b) Dip or landing net.

(c) Drop net.

(d) Fold-up trap.

(e) Hook and line gear.

(f) Push scrape.

(g) Trotline.

(2)

(a) Peeler crabs may be harvested in traps constructed of wire with a minimum mesh size of one inch and with the throats or entrances located only on a vertical surface. Such traps shall have a maximum dimension of 24 inches by 24 inches by 24 inches or a volume of 8 cubic feet and a degradable panel. **Beginning [three years from date of amendment], such traps shall also have a BRD meeting the specifications defined in 68B-45.002(2) attached to each entrance funnel.**

(b) Each trap used to harvest peeler crabs shall have buoys and be identified as described in subparagraph (a)2., and (a)3. or (a)4. of this subsection.

(c) All peeler crabs harvested must be kept in a container separate from other blue crabs.

(d) Each trap used to harvest peeler crabs shall only be baited with live male blue crabs. Male crabs so used as bait to attract female blue crabs into peeler traps may be periodically fed with no more than a single bait fish. Any trap used to harvest blue crabs that is baited with anything other than live male blue crabs shall meet the requirements of paragraph (1)(a) of this rule.

[ . . . ]

## V. CONCLUSION

Petitioners have summarized the harm crab pots inflict on diamondback terrapin populations and the greater estuarine ecosystems in Florida and across their range. Specifically, Petitioners have demonstrated that terrapins cannot withstand continued mortality in crab pots. Petitioners have also demonstrated that BRDs can significantly reduce terrapin mortality in crab pots while having negligible effects on crab haul. For these reasons, several states across the terrapin's range have adopted or are considering rules to require terrapin excluder devices on crab pots. Florida is poised to take the same imperative conservation action for its terrapins, making it a conservation leader in the southeast.

Diamondback terrapins are an essential part of Florida's unique natural heritage, and citizens and visitors alike depend on the Commission to protect them for generations to come. Moreover, they are an important part of healthy estuarine ecosystems. Petitioners therefore request that the Florida Fish and Wildlife Conservation Commission adopt the proposed rule amendment and require BRDs on commercial and recreational crab pots in Florida's waters. In the alternative, Petitioners request that the Florida Fish and Wildlife Conservation Commission adopt any alternative rule or amendment that requires BRDs on crab pots in the commercial and recreational blue crab fisheries.

If the Commission or staff has any questions, please contact Elise Bennett, staff attorney at the Center for Biological Diversity, at ebennett@biologicaldiversity.org or (727) 755-6950. The Center can provide copies of the literature cited in this petition upon request.

## VI. LITERATURE CITED

Baker, P, et al. 2013. Estimating Survival Times for Northern Diamondback Terrapins, *Malaclemys Terrapin Terrapin,* in Submerged Crab Pots. *Herpetological Conservation and Biology* 8: 667-680.

Bishop, J. M. 1983. Incidental capture of diamondback terrapin by crab pots. *Estuaries* 6:426-430.

Blanvillain, G., J.A. Schwenter, R.D. Day, D. Point, S.J. Christopher, W.A. Roumillat, D.W. Owens. 2007. Diamondback terrapins, *Malaclemys terrapin*, as a sentinel species for monitoring mercury pollution of estuarine systems in South Carolina and Georgia, USA. *Environmental Toxicology and Chemistry*. 26(7): 1441–1450.

Brenessel, B. 2007. The Northern Diamondback Terrapin Habitat, Management and Conservation. Prepared for The Northeast Diamondback Terrapin Working Group, Norton, MA.

Burger, J. 1989. Diamondback terrapin protection. *Plastron Papers* 19:35-40.

Burger, J. 2002. Metals in Tissues of Diamondback Terrapin from New Jersey. *Environmental Monitoring and Assessment* 77: 255–263.

Butcher, K. et al. 2018. Derelict Crab Trap Removal in the Pontchartrain Basin: 2018 Update and Recommendations. Lake Pontchartrain Basin Foundation. pp. 30. https://saveourlake.org/?wpdmdl=15095&ind=1538494910701.

Butler, J.A. 2000. Status and distribution of the Carolina diamondback terrapin, *Malaclemys terrapin centrata*, in Duval County. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

Butler, J. A. 2002. Population ecology, home range, and seasonal movements of the Carolina diamondback terrapin, *Malaclemys terrapin centrata* in northeastern Florida. Florida Fish and Wildlife Conservation Commission. Tallahassee, FL. pp.72

Butler, J. A., C. Broadhurst, M. Green and Z. Mullin. 2004. Nesting, nest predation and hatchling emergence of the Carolina diamondback terrapin, *Malaclemys terrapin centrata*, in Northeastern Florida. *American Midland Naturalist*. 152:145-155.

Butler, J.A., R.L Burke, and W.M. Roosenburg. 2018. Reproductive Behavior and Ecology. P. 81–91. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Butler, J.A. and G.L. Heinrich. 2007. The effectiveness of bycatch reduction devices on crab pots at reducing capture and mortality of diamondback terrapins (*Malaclemys terrapin*) in Florida. *Estuaries and Coasts* 30:179-185.

Butler, J.A., G.L. Heinrich, and M.L. Mitchell. 2012. Diet of the Carolina Diamondback Terrapin (*Malaclemys terrapin centrata*) in Northeastern Florida. *Chelonian Conservation and Biology* 11(1): 124–128.

Butler, J.A., G.L. Heinrich, and R.A. Seigel. 2006. Third workshop on the ecology, status, and conservation of diamondback terrapins (*Malaclemys terrapin*): Results and recommendations. *Chelonian Conservation and Biology* 5:331-334.

Cecala, K. K., J. W. Gibbons, and M. E. Dorcas. 2008. Ecological effects of major injuries in diamondback terrapins: implications for conservation and management. *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.

Chambers, R.M. and J.C. Maerz. 2018. Bycatch in Blue Crab Fisheries. P. 231–244. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Clark, W. S. 1982. Turtles as a food source of nesting bald eagles in the Chesapeake Bay region. *Journal of Field Ornithology* 53:49-51.

Cole, R.V. and T.E. Helser. 2001. Effect of three bycatch reduction devices on diamondback terrapin *Malaclemys terrapin* capture and blue crab *Callinectes sapidus* harvest in Delaware Bay. *North American Journal of Fisheries Management* 21:825-833.

Coleman, A. T., T. Roberge, T. Wibbels, K. Marion, D. Nelson, and J. Dindo. 2014. Size-based mortality of adult female Diamond-backed Terrapins (*Malaclemys terrapin*) in Blue Crab Traps in a Gulf of Mexico population. *Chelonian Conservation and Biology* 13:140-145.

Coleman, A. T., T. Wibbels, K. Marion, D. Nelson, and J. Dindo. 2011 Effect of by-catch reduction devices (BRDS) on the capture of diamondback terrapins (*Malaclemys terrapin*) in crab pots in an Alabama salt marsh. *Journal of the Alabama Academy of Sciences* 82:145-157.

Cone Communications. 2015. New Cone Communications Research Confirms Millenials as America's Most Ardent CSR Supporters, but Marked Differences Revealed Among This Diverse Generation, available at http://www.conecomm.com/research-blog/2015-cone-communications-millennial-csr-study.

Cone Communications. 2017. 2017 Cone Communications CSR Study, www.conecomm.com/2017-SCR-Study.

Crowder, L., K. Hart, and M. Hooper. 2000. Trying to solve a bycatch mortality problem: can we exclude diamondback terrapins (*Malaclemys terrapin*) from crab pots without compromising blue crab (*Callinectes sapidus*) catch? Final report 00-FG-23. Fishery Resource Grant. pp.13.

Cuevas, K. J., M. J. Buchanan, W. S. Perry, J. T. Warren. 2000. Preliminary study of Blue Crab catch in traps fitted with and without a Diamondback Terrapin excluder device. *Proceedings of the Annual Southeast Association of Fish and Wildlife Agencies* 54:221-226.

Davenport, J., M. Spikes, S. M. Thornton, and B. O. Kelly. 1992. Crab-eating in the diamondback terrapin Malaclemys terrapin: dealing with dangerous prey. *Journal of the Marine Biology Association* 72:835-848.

Davis, C. C. 1942. A study of the crab pot as a fishing gear. Publication No. 53 Chesapeake Biological Laboratory, Solomons, Maryland.

Dorcas, M. E., J. D. Wilson, and J. W. Gibbons. 2007. Crab trapping causes population decline and demographic changes in diamondback terrapin over two decades. *Biological Conservation* 137:334-340.

Drabeck, D.H., M.W.H. Chatfield, C.L. Richards-Zawacki. 2014. The status of Louisiana's diamondback terrapin (*Malaclemys terrapin*) populations in the wake of the *Deepwater Horizon* oil spill: Insights from population genetic and contaminant analysis. *Journal of Herpetology* 48(1): 125–136.

Draud, M., M. Bossert, and S. Zimnavoda. 2004. Predation on hatchling and juvenile diamondback terrapins (*Malaclemys terrapin*) by the Norway rat (*Rattus norvegicus*). *Journal of Herpetology* 38:467-470.

Ehret, D.J. and B.K. Atkinson. 2018. Evolutionary History and Paleontological Record. P. 27–35. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Feinberg, J.A. and R.L. Burke. 2003. Nesting Ecology and Predation of Diamondback Terrapins, *Malaclemys terrapin*, at Gateway National Recreational Area, New York. *J. of Herpetology* 37(3):517-526.

Garber, S.D. 1990a. Diamondback Terrapin. *Focus* 40(1):33-36.

Garber, S.D. 1990b. The Ups and Downs of the Diamondback Terrapin. The Conservationist NY:DEC 44:44-47.

Gibbons, J.W., J.E. Lovich, A.D. Tucker, N.N. Fitzsimmons and J.L. Greene. 2001. Demographic and Ecological Factors Affecting Conservation and Management of the Diamondback Terrapin (Malaclemys terrapin) in South Carolina. *Chelonian Conservation and Biology* 4(1):66–74.

Grosse, A. M., J. C. Maerz, J. A. Hepinstall-Cymerman, and M. E. Dorcas. 2011. Effects of roads and crabbing pressures on diamondback terrapin populations in coastal Georgia. *Journal of Wildlife Management* 75:762-770.

Grosse, A. M., J. D. van Dijk, K. L. Holcomb, and J. C. Maerz. 2009. Diamondback Terrapin mortality in crab pots in a Georgia tidal marsh. *Chelonian Conservation and Biology* 8:98-100.

Grubbs, S.P. et al. 2018. To BRD or Not to BRD? A Test of Bycatch Reduction Devices for the Blue Crab Fishery. *North American Journal of Fisheries Management*. 3–4,

Guillory, V., A. McMillen-Jackson, L. Hartman, H. Perry, T. Ford, T. Wagner, and G. Graham. 2001. Blue Crab Derelict Traps and Trap Removal Programs. Publication No. 88 Gulf States Marine Fisheries Commission, Ocean Springs, Mississippi.

Guillory, V. and P Prejean. 1998. Effect of a terrapin excluder device on blue crab, *Callinectes sapidus*, trap catches. *Marine Fisheries* 60:38–40.

Harden, L.A. and A. Southwood Williard. 2012. Using spatial and behavioral data to evaluate the seasonal bycatch risk of diamondback terrapins (*Malaclemys terrapin*) in crab pots. *Marine Ecology Progress Series* 467, 207–217.

Hart, K.M. 1999. Declines in diamondbacks: terrapin population modeling and implications for management. MS thesis, Duke University, Durham, NC. 64 pages.

Hart, K. M. and L. B. Crowder. 2011. Mitigating by-catch of Diamondback Terrapins in crab pots. *Journal of Wildlife Management* 75:264–272.

Hart, K. M., M. E. Hunter, and T. L. King. 2014. Regional differentiation among populations of the diamondback terrapin (*Malaclemys terrapin*). *Conservation Genetics* 2014; 15: 593–603.

Hart, K.M. and D.S. Lee. 2007. The Diamondback Terrapin: The Biology, Ecology, Cultural History, and Conservation Status of an Obligate Estuarine Turtle in Studies in Avian Biology

No. 32:206–213, *available at* http://sora.unm.edu/sites/default/files/journals/sab/sab_032.pdf#page=214.

Hoyle, M. E. and J. W. Gibbons. 2000. Use of a marked population of diamondback terrapins (*Malaclemys terrapin*) to determine impacts of recreational crab pots. *Chelonian Conservation and Biology* 3:735–737.

Hunter, E.A., N.P. Nibbelink, C.R. Alexander, K. Barrett, L.F. Mengak, R.K. Guy, C.T. Moore, and R.J. Cooper. 2015. Coastal vertebrate exposure to predicted habitat changes due to sea level rise. *Environmental Management*. DOI 10.1007/s00267-015-0580-3.

Jeyasuria, P. and A.R. Place. 1997. Temperature-dependent Armoatase Expression in Developing Diamondback Terrapin (*Malaclemys terrapin*) Embryos. *J. Steroid Biochem. Molec. Biol.* 61(3–6): 415–425.

Lester, L.A., H.W. Avery, A.S. Harrison, E.A. Standora. 2013. Recreational boats and turtles: Behavioral mismatches result in high rates of injury. *PLOS One* 8(12): e82370. doi:10.1371/journal.pone.0082370.

Lovich, J.E., J.W. Gibbons, and K.M. Greene. 2018. Life History with Emphasis on Geographic Variation. P. 63–80. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Lovich, J.E. and K.M. Hart. 2018. Taxonomy: A History of Controversy and Uncertainty. P. 37–50. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Lukacovic, R, L. S. Baker, and M Luisi. 2005. Diamondback Terrapin and crab pot interactions and effect of turtle excluder devices on crab catch in Maryland's coastal bays. Fisheries Technical Report # 44, Maryland Department of Natural Resources. Annapolis MD USA pp.11

Maerz, J.C., R.A. Seigel, and B.A. Crawford. 2018. Conservation in Terrestrial Habitats: Mitigating Habitat Loss, Road Mortality, and Subsidized Predators. P. 200–220. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Mali I, Vandewege MW, Davis SK, Forstner MRJ. 2014. Magnitude of freshwater turtle exports from the US: long term trends and early effects of newly implemented harvest management regimes. *PLOS One*. 2014; 9(1), *available at* http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3903576/.

Mann, T. M. 1995. Population surveys for diamondback terrapins (*Malaclemys terrapin*) and Gulf salt marsh snakes (*Nerodia clarki clarki*) in Mississippi Museum Technical Report No. 37.

Marion, K. R. 1986. Mississippi diamondback terrapin, p. 52–53. In R. H. Mount (ed.), Vertebrate Animals of Alabama in Need of Special Attention. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Mazzarella, A. D. 1994. Great bay blue claw crab study, diamondback terrapin interaction with crab pots: test of a turtle excluder device in commercial crab pots. New Jersey Division of Fish, Game, and Wildlife. Port Republic, NJ pp. 9.

Mitchell, N.J. and F.J. Janzen. 2010. Temperature-Dependent Sex Determination and Contemporary Climate Change. *Sex. Dev.* 4: 129–140.

Mitro, M.G. 2003. Demography and viability analyses of a diamondback terrapin population. *Can. J. Zool.* 81: 716–726.

Morris, S. A., S. M. Wilson, E. F. Dever, and R. M. Chambers. 2011. A test of bycatch reduction devices on commercial crab pots in a tidal marsh in Virginia. *Estuaries and Coasts* 34:386–390.

Muldoon, K.A. and R.L. Burke. 2012. Movements, overwintering, and mortality of hatchling Diamond-backed Terrapins (*Malaclemys terrapin*) at Jamaica Bay, New York. *Can. J. Zool.* 90: 651–662.

Radzio, T. A. J. A. Smolinsky and W. M. Roosenburg. 2013. Low use of required terrapin bycatch reduction devices in a recreational crab pot fishery. *Herpetological Conservation and Biology* 8:222–227.

Rook, M. A., R. N. Lipcius, B. M. Bronner, R. M. Chambers. 2010. Bycatch reduction devices conserves diamondback terrapins without affecting catch of blue crab. *Marine Ecology progress Series* 409:171–179.

Roosenburg, W.M. 1990. The diamond back terrapin: population dynamics, habitat requirements, and opportunities for conservation. In: Chaney, A., and Mihursky, J.A. (Eds.). *New perspectives in the Chesapeake system: a research and management partnership*. Proceedings of a conference. Maryland: Chesapeake Research Consortium Publication No. 137, pp. 227–234

Roosenburg, W.M. 1991. The Diamondback Terrapin: Population Dynamics, Habitat Requirements, and Opportunities for Conservation in New Perspectives in the Chesapeake System: A Research and Management in Partnership. Proceedings of a Conference. Baltimore, MD. Chesapeake Research Consortium Publication No. 137.

Roosenburg, W.M., K.L. Haley, and S. McGuire. 1999. Habitat selection and movements of diamondback terrapins, *Malaclemys terrapin*, in a Maryland estuary. *Chelonian Conservation and Biology* 3:425–429.

Roosenburg, W. M. 2004. The impact of crab pot fisheries on terrapin (*Malaclemys terrapin*) populations: where are we and where do we need to go? Pages 23–30 *in* C. Swarth, W. M.

Roosenburg, W.M., Baker, P.J., Burke, R., Dorcas, M.E. & Wood, R.C. 2019. *Malaclemys terrapin*. *The IUCN Red List of Threatened Species* 2019: e.T12695A507698. http://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T12695A507698.en. Downloaded on 17 August 2019.

Roosenburg, W. M. and R. L. Burke. 2018. Capture, Measurement, and Field Techniques. P. 8–25. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Roosenburg, W. M. and J. A. Butler. 2018. The Future for Diamond-backed Terrapins. P. 265–268. In W.M. Roosenburg and Victor S. Kennedy (eds.), *Ecology and Conservation of the Diamond-Backed Terrapin*, Johns Hopkins University Press, Baltimore, Maryland.

Roosenburg, W. M., W. Cresko, M. Modesitte, and M. B. Robbins. 1997. Diamondback terrapin (*Malaclemys terrapin*) mortality in crab pots. *Conservation Biology* 5:1166–1172.

Roosenburg, W. M. and J. P. Green. 2000. Impact of a bycatch reduction device on diamondback terrapin and blue crab capture in crab pots. *Ecological Applications* 10:882–889.

Roosenburg, W. M. and E. Kiviat, *editors*. Conservation and Ecology of Turtles of the Mid-Atlantic Region: A Symposium. Biblomania Salt Lake City, Utah. USA.

Seigel, R. A. 1984. Parameters of Two Populations of Diamondback Terrapins (*Malaclemys terrapin*) on the Atlantic Coast of Florida. In *Vertebrate Ecology and Semantics: A Tribute to Henry S. Fitch*, ed. R. A. Seigel, I. E. Hunt, J. L. Knight, L. Malaret, and N. L. Zuschiag, pp. 77–87. Museum of Natural History, Lawrence, Kans.: The University of Kansas.

Seigel, R. A. 1980a. Predation by raccoons on diamondback terrapins, *Malaclemys terrapin tequesta*. *J. of Herpetology* 14(1):87–89.

Seigel, R. A. 1980b. Nesting habits of diamondback terrapins (*Malaclemys terrapin*) on the Atlantic Coast of Florida. *Transactions of the Kansas Academy of Sciences* 83(4):239–246.

Silliman, B. R. and M. D. Bertness. 2002. A trophic cascade regulates salt marsh primary production. *Proceedings of the National Academy of Sciences of the USA* 99:10500–10505.

Simoes J.C. and R.M. Chambers. 1999. The Diamondback Terrapins of Piermont Marsh, Hudson River, New York. *Northeastern Naturalist* 6(3): 214–248.

Suarez, E. 2015. Ecology of Ornate Diamondback Terrapins (Malaclemys terrapin macrospilota) on a small Gulf Coast barrier island and their behavior inside crab traps. Thesis. University of Florida. Gainesville, Florida. USA.

Szerlag, S. and S.P. McRobert. 2006. Road occurrence and mortality of the northern diamondback terrapin. *Applied Herpetology* 3:27–37.

Tucker, D. A., N. N. FitzSimmons, and J. W. Gibbons. 1995. Resource partitioning by the estuarine turtle *Malaclemys terrapin*: tropic, spatial, and temporal foraging constraints. *Herpetologica* 51(2): 167–181.

Tucker, A.D., J.W. Gibbons and J.L. Greene. 2001. Estimates of adult survival and migration for diamondback terrapins: conservation insight from local extirpation within a metapopulation. *Canadian Journal of Zoology* 79:2199–2209.

Wnek, J. 2019. Analysis of bycatch reduction devices (BRDs) on blue crab captures and effectiveness of preventing bycatch: A study conducted at Bernegat Bay, NJ. Report. Ocean County Vocational Technical School, Center for Research and Applied Barnegat Bay Studies.

Wood, R. 1995. Diamondback terrapin. In L.E. Dove and R.M. Nyman, eds., *Living Resources of the Delaware Estuary*. Delaware Estuary Program pp. 299–304.

Wood, R. C. 1997. The impact of commercial crab traps on northern diamondback terrapins, *Malaclemys terrapin terrapin*. Pages 21–27. In J. Van Abbema editor. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference. New York Turtle and Tortoise Society, New York, USA.

Wood, R. C. and R. Herlands. 1995. Terrapins, tires, and traps: conservation of the Northern Diamondback Terrapin (*Malaclemys terrapin)* on the Cape May peninsula, New Jersey USA. Pages 254-256. In J. Van Abbema editor. Proceedings: An International Congress of Chelonian Conservation. Gonfaron, France.

Wood, R.C. and R. Herlands. 1997. Turtles and Tires: The Impact of Roadkills on Northern Diamondback Terrapin, *Malaclemys terrapin*, Populations on Cape May Peninsula, Southern New Jersey, USA. Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles—An International Conference, pp. 46–53.

Woodland, R.J., C.L. Rowe, and P.F.P. Henry. 2017. Changes in habitat availability for multiple life stages of diamondback terrapins (Malaclemys terrapin) in Chesapeake Bay in response to sea level rise. *Estuaries and Coasts* 40(5): 1502–1515.

**Appendix A**
**Survey of Scientific Literature Evaluating the Effect of BRDs on Terrapin Mortality**

Butler and Heinrich (2007) tested whether bycatch mortality of diamondback terrapins in Florida in commercial crab pots is reduced by using 4.5 x 12 cm galvanized steel BRDs. They fished 15 pots without BRDs and 15 outfitted with BRDs at eight sites along the Atlantic and Gulf coasts (including the Florida panhandle) during the summers of 2002-2005. Thirty-seven terrapins were caught in standard pots and four in those with BRDs. They found that 73.2% of trapped terrapins would have been excluded from pots with BRDs (Butler and Heinrich 2007 at 183–184). These researchers recommended that the Florida Fish and Wildlife Conservation Commission devise and adopt regulations that require the use of 4.5 x 12 cm BRDs on all commercial and recreational crab pots used in Florida waters.

Cole and Helser (2001) conducted a 4-year study between 1997 and 2000 in the Delaware Bay estuary to investigate four sizes of wire, rectangular BRDs measuring 5 x 10 cm, 5 x 12 cm, 4.5 x 12 cm, and 3.8 x 12 cm to determine their impacts on terrapin bycatch mortality. During the study, 372 diamondback terrapins were captured (Cole and Helser 2001 at 828–831). Crab pots fitted with 5 x 10 cm BRDs demonstrated statistically significant reduction in terrapin captures (59%) (Cole and Helser 2001 at 828), as did crab pots fitted with 4.5 cm x 12 cm BRDs (38% male and 96% female) (Cole and Helser 2001 at 831). Crab pots fitted with the smallest BRD, 3.8 x 12 cm, prevented all diamondback terrapins from entering the pot (Cole and Helser 2001 at 831). They found that the 5 x 12 cm BRD was the only treatment for which the reduction in overall diamondback terrapin catches was not statistically significant (12%) (Cole and Helser 2001 at 832). Based on the study, Cole and Helser recommended using 4.5 x 12 cm BRDs (Cole and Helser 2001 at 831).

Crowder et al. (2000) studied the extent of terrapin mortality in actively fished crab pots in Jarrett Bay, North Carolina, to evaluate the effect of several different BRDs on both terrapin and crab catch rates (Crowder et al. 2000 at 1). They studied BRD-equipped crab pots for three seasons, testing a 5 x 16 cm BRD the first season (Spring 2000), a 4 x 16 cm BRD the second season (Fall 2000), and a 4.5 x 16 cm BRD the third season (Spring 2001) (Crowder et al. 2000 at 1). All BRDs were made from galvanized fencing (Crowder et al. 2000 at 1). During the course of the three-season study, they captured 12 diamondback terrapins, none of which were captured in pots fitted with excluder devices. (Crowder et al. 2000 at 3).

Hart and Crowder (2011) tested BRDs in North Carolina’s year-round blue crab fishery from 2000 to 2004 and found that BRDs successfully prevent terrapin capture and mortality (Hart and Crowder 268–269). The smaller the BRD was, the fewer terrapins were captured (Hart and Crowder 2011 at 268–269). Specifically, they found that a 4.5 cm tall BRD excluded approximately 77% of terrapins captured, while a 5 cm tall BRD excluded approximately 28% of terrapins (Hart and Crowder 2011 at 269). They also found that longer soak times and closer distances to shore increased the risk of terrapin captures (Hart and Crowder 2011 at 268–269). As a result of the study, Hart and Crowder suggested three complementary and economically feasible tools to prevent terrapin mortality in the blue crab fishery: 1) gear modifications such as BRDs; 2) distance-to-shore restrictions; and 3) time-of-year regulations (Hart and Crowder 2011 at 270–271). They estimated that by using all three measures combined, a reduction in terrapin bycatch of up to 95% could be achieved without significant reduction in target crab catch (Hart and Crowder 2011 at 264).

Mazzarella (1994) studied crab pots with 5 x 10 cm rectangular wire BRDs and crab pots without BRDs in New Jersey's Great Bay estuary for 116 days from July 6 to August 31, 1993, and from May 1 to June 30, 1994 (Mazzarella 1994 at 1, 3-4). In 1993, crab pots with BRDs captured no terrapins, and crab pots without BRDs captured 3 terrapins; and in 1994, crab pots with BRDs captured 3 terrapins, and crab pots without BRDs captured 37 terrapins (Mazzarella 1994 at 1, 3–4).

Morris et al. (2011) studied the effectiveness of BRDs measuring 4.5 x 12 cm on commercial blue-crab pots in the York River, Virginia, by fishing 10 pots with BRDs and 10 pots without BRDs from June 4 to July 31, 2009 (Morris et al. 2011 at 387). All 51 terrapins captured during the study were captured in crab pots without BRDs; no terrapins were captured in crab pots with BRDs (Morris et al. 2011 at 388, 389). Based on local population estimates, Morris and co-workers concluded that the total number of terrapins caught in non-BRD pots during the 46-day study (51 terrapins) represented a potential reduction in population size from 27–50% (Morris et al. 2011 at 389). Given that the crab pots were in the water only 46 days, the terrapin population in the study creek would have experienced significant mortality of juvenile and adult male terrapins over a full, 8-month season of commercial crabbing, likely resulting in skewed population dynamics (Morris et al. 2011 at 389). Thus, the terrapin mortality prevented by the BRDs was significant.

Roosenburg and Green (2000) tested three sizes of wire BRDs in the Chesapeake Bay in Maryland: 4 x 10 cm, 4.5 x 12 cm, and 5 x 10 cm (Roosenburg and Green 2000 at 883-884). They caught no terrapins in crab pots with 4 x 10 cm BRDs, 19 terrapins in crab pots with 4.5 x 12 cm BRD, and 56 terrapins in crab pots with 5 x 10 cm BRDs (Roosenburg and Green 2000 at 884). They caught 126 terrapins in the crab pots without BRDs (Roosenburg and Green 2000 at 884). Thus, the 5 x 10 cm BRDs reduced terrapin bycatch by 47%, the 4.5 x 12 cm BRDs reduced bycatch by 82%, and the 4 x 10 cm BRDs reduced bycatch by 100% (Roosenburg and Green 2000 at 884). This study resulted in the requirement of a 4.5 x 12 cm BRD in the Maryland recreational crab pot fishery.[27]

Rook et al. (2010) tested a 4.5 x 12 cm plastic BRD in the lower Chesapeake Bay during summer 2008. They tested 10 sets of unbaited crab pots, one pot in each set with BRDs and one without (Rook et al. 2010 at 173–174). In a separate experiment they did the same with baited crab pots (Rook et al. 2010 at 173–174). Of 48 terrapin captures in crab pots, only 2 were from pots with BRDs (Rook et al. 2010 at 175). The BRDs diminished terrapin bycatch in crab pots by 95.7% (Rook et al. 2010 at 177). Thus, Rook et al. "recommend[ed] the use of BRDs on all crab traps placed in diamondback terrapin habitat of the North American coastline, particularly for crab traps in the shallow waters fringing coastal marshes, estuaries, and lagoons" (Rook et al. 2010 at 178).

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[27] *See* Md. Code Regs. 08.02.03.07(B)(5); Maryland Department of Natural Resources, Attention Maryland Crabbers: you can help save our state reptile! Publication #03-1282009-430, available at https://dnr.maryland.gov/wildlife/Documents/TerrapinBrochure.pdf.

Wnek (2019) studied the effectiveness of various BRD designs in reducing terrapin bycatch and compared the amounts and sizes of blue crabs captured in crab pots fitted with BRDs in Barnegat Bay, New Jersey. He studied four sizes of BRD (5 x 15 cm, 4.5 x 12 cm, South Carolina prototype in red, South Carolina prototype in white) against control pots without BRDs (Wnek 2019 at 2). No terrapins were trapped in crab pots with BRDs, and two terrapins were captured in control pots without BRDs (Wnek 2019 at 10).

**<u>Appendix B</u>**
**Survey of Scientific Literature Evaluating the Effect of BRDs on Crab Haul**

Butler and Heinrich (2007) tested whether bycatch mortality of diamondback terrapins in commercial crab pots is reduced by using 4.5 x 12 cm galvanized steel BRDs and whether those devices limit blue crab catch. They captured 2,753 legal-sized crabs and found no significant difference between the sex, measurements, or number of crabs captured in standard crab pots versus crab pots with BRDs (Butler and Heinrich 2007 at 182).

Cole and Helser (2001) found that crab pots fitted with 5 x 10 cm BRDs demonstrated statistically significant reduction in terrapin captures (59%) with no statistical difference in blue crab catches (Cole and Helser 2001 at 828). Crab pots fitted with 4.5 x 12 cm BRDs demonstrated statistically significant reduction in terrapin captures (38% male and 96% female) with only a nominal loss of legal-size blue crabs (12% total, 6% of most desirable crabs) (Cole and Helser 2001 at 831). Crab pots fitted with the smallest BRD, 3.8 x 12 cm, prevented all diamondback terrapins from entering the trap, but incurred substantial loss of legal-size blue crabs (-26%) (Cole and Helser 2001 at 831). Based on the study, Cole and Helser recommended using 4.5 x 12 cm BRDs, which effectively protect subadult and reproductively mature female terrapins with minimal loss of legal blue crabs (Cole and Helser 2001 at 831).

Cuevas et al. (2000) studied and compared the catch rate and sizes of blue crab and terrapin bycatch taken in Mississippi Sound with crab pots equipped with and without BRDs. The BRDs were made of welding rods shaped into a 5 x 10 cm rectangle and fitted into the funnel entrances of crab pots (Cuevas et al. 2000 at 223). A total of 740 blue crabs were captured, 370 in pots without BRDs and 370 in pots with BRDs (Cuevas et al. 2000 at 224). Pots with BRDs captured 160 female crabs and 210 male crabs, while control pots caught 125 females and 245 males (Cuevas et al. 2000 at 224). Daily catch rates and crab size frequency were similar for crab pots with and without BRDs (Cuevas et al. 2000 at 224, 225). However, the scientists noted that there was a detectable difference in size distribution, resulting in a slight decrease in numbers of larger crabs observed in pots with BRDs (Cuevas et al. 2000 at 225). This difference could have been attributable to the small sample size in the study (Cuevas et al. 2000 at 225).

Guillory and Prejean (1998) studied the effects of BRDs on blue crab catches in estuarine Louisiana waters. To do this, they fished five standard crab pots and five crab pots with BRDs constructed of stainless-steel wire and measuring 5 x 10 cm (Guillory and Prejean 1998 at 38). They found that overall catch per trap day of sublegal, legal, and total crabs was 14.5%, 37.9%, and 25.7% greater, respectively, than in standard pots (Guillory and Prejean 1998 at 39). The scientists attributed the increased crab catch in pots with BRDs to increased ingress or decreased egress through the entrance funnels (Guillory and Prejean 1998 at 39).

Hart and Crowder (2011) studied various sizes of galvanized steel BRDs in North Carolina. Although they found a positive correlation between the size of the BRD and effect on crab haul (compared with non-BRD crab pots), they concluded that a 5 cm tall BRD did not have a significant effect on catch of either large male blue crabs or peelers (Hart and Crowder 2011 at 269).

Lukacovic et al. (2005) investigated the effect of BRDs on crab catch and terrapin bycatch in crab pots in Maryland's Assawoman Bay. They studied 16 crab pots, 8 with BRDs and 8 without BRDs, which were fished for 24 and 48 hours twice each month from mid-May through October 2004. The BRDs were rectangular and met Maryland's regulatory requirement that they not exceed 1.75 x 4.75 inches (approximately 4.5 x 12 cm) in length (Lukacovic et al. 2005 at *3). The crab pots were set for a total of 1029 pot-days in water depths ranging from 0.6–2.8 meters (2–8 feet), and 3,412 blue crabs and 1 diamondback terrapin were captured (Lukacovic et al. 2005 at *4). The terrapin was captured in a pot without a BRD, making the rate of terrapin bycatch in non-BRD crab pots 0.002 crabs/pot per day (Lukacovic et al. 2005 at *4). They also found that crab catch for unmodified pots was greater than pots modified with BRDs (Lukacovic et al. 2005 at 4). The overall crab catch was 35% greater, the catch of legal crabs was 28.5% greater, the catch of legal male crabs was 25.6% greater, the catch of mature females was 23.7% greater, and the catch of peelers was 104.2% greater (Lukacovic et al. 2005 at *4). Following inferential analyses, Lukacovic et al. concluded that all categories of crab catch were significantly lower in crab pots fitted with BRDs (Lukacovic et al. 2005 at *5).

Mazzarella (1994) observed no significant difference between crabs caught in crab pots with 5 x 10 cm rectangular BRDs and crab pots without BRDs. In the first study year, crab pots with BRDs caught 6,139 crabs (mean size 13.2), while crab pots without BRDs caught 5,288 crabs (mean size 13.3) (Mazzarella 1994 at 1, 3–4). In the second study year, crab pots with BRDs caught 5,703 crabs (mean size 12.3), and crab pots without BRDs caught 5,851 (mean size 12.2) (Mazzarella 1994 at 1, 3–4).

Morris et al. (2011) studied the effectiveness of BRDs on commercial blue-crab pots in the York River, Virginia, by fishing 10 pots with BRDs and 10 pots without BRDs (Morris et al. 2011 at 387). More than 25% of total crabs were caught on the first day after baiting, and on the first day after baiting they found no statistical difference between either the number or size of legal-size crabs in crab pots with and without BRDs (Morris et al. 2011 at 388). Across all other days after baiting, there was a significant difference in total catch per unit effort of legal-size crabs; however, there was no significant difference in size of legal-sized crabs in BRD pots and non-BRD pots (Morris et al. 2011 at 388). These results indicate that in the absence of fresh bait, crabs do not enter crab pots with BRDs as frequently as non-BRD pots (Morris et al. 2011 at 389). Morris et al. also found that crab pots with terrapin bycatch in them had, on average, fewer crabs per unit effort (Morris et al. 2011 at 388). Likewise, more legal-size crabs were caught in pots without terrapin bycatch, but the difference was not significant (Morris et al. 2011 at 388).

Rook et al. (2010) tested a 4.5 x 12 cm BRD in the lower Chesapeake Bay and found that the BRDs had little effect on crab catch (Rook et al. 2010 at 173–178). Crab catch was equivalent between crab pots with and without BRDs (Rook et al. 2010 at 178). In fact, crab pots with BRDs had slight increases in number, size, and biomass of both legal-size and sublegal-size crabs, though the difference was considered marginal (Rook et al. 2010 at 178).

Roosenburg and Green (2000) tested three sizes of wire BRDs in a tributary to the Chesapeake Bay in Maryland: 4 x 10 cm, 4.5 x 12 cm, and 5 x 10 cm (Roosenburg and Green 2000 at 883–884). Neither the 5 x 10 cm BRD nor the 4.5 x 12 cm BRD affected crab size or the number of crabs caught in the crab pots (Roosenburg and Green 2000 at 885). In fact, crab pots with 4.5 x 12 cm BRDs had the highest catch per unit effort (2.69 crabs per pot per day), followed by crab pots without BRDs (2.55 crabs per pot per day), and then crab pots with 5 x 10 cm BRDs (2.39 crabs per pot per day) (Roosenburg and Green 2000 at 885). In the second year of study, the largest crab was caught in a crab pot with a 4.5 x 12 cm BRD (Roosenburg and Green 2000 at 885, 886). The 4 x 10 cm BRD reduced the size and number of large and mature female crabs (Roosenburg and Green 2000 at 884–885). Catch rate for standard crab pots with 4 x 10 cm BRDs was 2 crabs per pot per day lower than standard crab pots fished without BRDs (Roosenburg and Green 2000 at 885). The 4 x 10 cm BRD also had a significant effect on the width and height of crabs caught, excluding larger Number Ones and large females (Roosenburg and Green 2000 at 885). The scientists found that height of the BRD was the limiting factor rather than width (Roosenburg and Green 2000 at 885). Based on their study, Roosenburg and Green stressed the importance of using 4.5 x 12 cm BRDs on commercial and recreational crab pots because they do not affect crab haul but significantly reduce terrapin capture (82% reduction) (Roosenburg and Green 2000 at 886).[28]

Wnek (2019) studied the effectiveness of various BRD designs in reducing terrapin bycatch and compared the amounts and sizes of blue crabs captured in crab pots fitted with BRDs in Barnegat Bay, New Jersey. He studied three sizes of BRD (5 x 15 cm, 4.5 x 12 cm, South Carolina prototype (half white, half red) against control pots without BRDs (Wnek 2019 at 2). There was no significant difference in the number of blue crabs captured in traps with BRDs and traps without BRDs (Wnek 2019 at 4). In terms of measurement, there was no difference in the total mean length of blue crab captures (Wnek 2019 at 4). The control pots had significantly wider blue crabs than the pots with 5 x 15 cm and South Carolina style BRDs; however, the control pots were similar to those fitted with 4.5 x 12 cm BRDs (Wnek 2019 at 4). While mean blue crab height was significantly lower in pots with 5 x 15 cm BRDs, there was no difference in mean blue crab height between control pots and those with 4.5 x 12 cm and South Carolina style BRDs (Wnek 2019 at 4).

[28] Roosenburg and Green (2000) found that the 4 x 10 cm BRDs were not a suitable solution for commercial fisheries because they reduced the number of crabs caught by nearly half (Roosenburg and Green 2000 at 887). However, they could be considered for recreational crabbers, who often place their traps in areas with more terrapins, because the 4 x 10 cm BRDs excluded 100% of terrapins (Roosenburg and Green 2000 at 887).