Conservation Action Plan for

DIAMOND-BACKED TERRAPINS IN THE GULF OF MEXICO

2022

THE NATURE CONSERVANCY

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PROJECT NOTES

This Conservation Action Plan (CAP) was written with the purpose of supporting and increasing Diamond-backed Terrapin conservation activities across the Gulf of Mexico. We hope this plan builds collaboration, enables additional capacity, and elevates the prioritization of terrapin conservation and habitats for the various stakeholder groups whose interest overlap with the species.

In general, we followed the traditional ten step process for CAP development as outlined by the Conservation Measures Partnership. As we began this process, certain activities were adapted due to the COVID-19 pandemic. The original project work plan was to hold several in-person stakeholder meetings across the Gulf of Mexico, utilizing a traditional CAP process. That intention needed to be modified as the early stages of the COVID-19 pandemic overlapped with the beginning of this effort. We switched to a virtual workshop process and engaged stakeholders remotely. Overall, this may have increased accessibility to the project since we had over 100 unique individuals attend at least one of our workshops.

A deliberate choice was made not to include maps or locality information in this plan. Multiple project contributors expressed concerns that presenting specific or even general locality information could potentially harm terrapin populations. These concerns were tied to potential for illegal harvest or collection of terrapins for the pet trade or for consumption. We took a “do no harm” approach and omitted any references that could identify terrapin localities.

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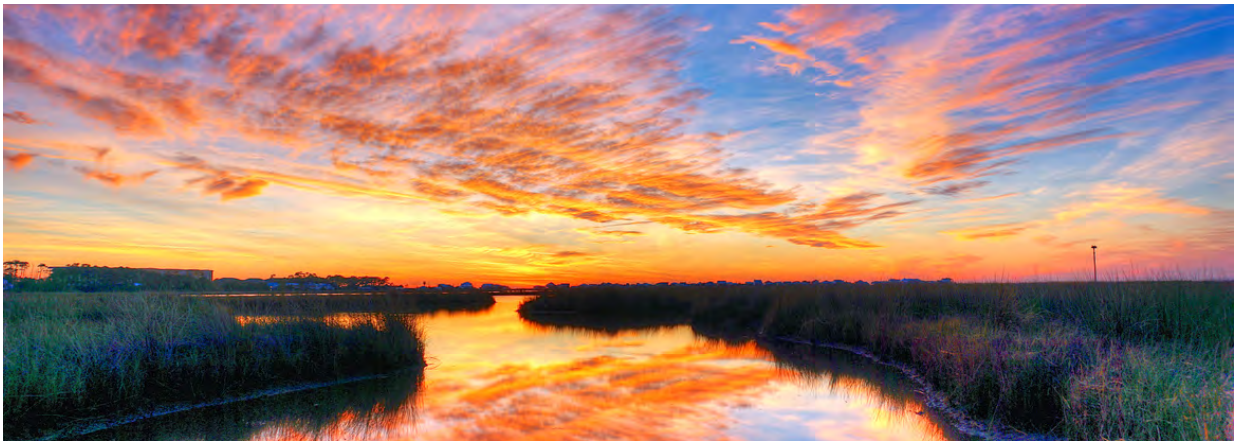
INTRODUCTION

Diamond-backed terrapins (*Malaclemys terrapin*) are a small turtle native to the US Atlantic and Gulf coasts, unique for being the only turtle species that lives exclusively in coastal salt marsh and mangrove habitats. They are vital to the health of these habitats but populations have declined significantly for well over a century due to factors including habitat loss from coastal development, nest predation, and drowning in blue crab traps. Without action, terrapin populations will continue to decline.

Terrapin experts and natural resource managers in the Gulf region have recognized the need to take action that prevents and reverses population decline. However, there have been no previous efforts to create a comprehensive, regional plan to identify and advance terrapin-related research, management, and conservation goals. To address this challenge, the Nature Conservancy's Mississippi Marine Program completed the *Conservation Action Plan for Diamond-backed Terrapins in The Gulf of Mexico* in collaboration with the Diamondback Terrapin Working Group and Gulf of Mexico Alliance Wildlife and Fisheries Team. The conservation plan scope includes all five Gulf states (Texas, Louisiana, Mississippi, Alabama, and Florida) and all four terrapin subspecies found in the Gulf (*M.t. littoralis*, *M.t. pileata*, *M.t. macrospilota*, and *M.t. rhizophorarum*).



Over 95 individuals provided input for this Conservation Action Plan (CAP) including multiple contributors from each of the Gulf states and terrapin experts from the Atlantic coast. Participants included state and federal resource management agencies, non-governmental organizations, academic institutions, and conservation volunteers.

We conducted a series of virtual workshops to complete project activities including five region-wide webinars and five targeted webinars with each Gulf state (10 workshops total). Participants identified and ranked 29 potential threats to terrapin populations, evaluated population viability, and developed strategies for terrapin research, conservation, and management. This conservation plan is intended to be a resource for stakeholders interested in advancing the conservation and management of terrapins and their habitats throughout the Gulf of Mexico.

PROJECT VISION

The vision for this project is to reverse and prevent further declines of Diamond-backed terrapins and their habitats in the Gulf of Mexico by implementing effective, long-term conservation actions, strategies, and research.

GULFWIDE RECOMMENDATIONS FOR TERRAPIN CONSERVATION

Developing effective recommendations to overcome critical threats is an essential part of the conservation planning process. Actions are designed to be directly linked to key CAP objectives such as improving understanding of conservation goals; reducing a critical threat; and/or maintaining or enhancing target viability.

We identified six key actions for terrapin conservation across the Gulf of Mexico based on input from regional experts and recommendations of the project advisory team. They are designed to improve our regional understanding of terrapin population baselines, status, and trends; prevent further declines of terrapin populations and their habitats; and improve long-term species and habitat viability.

Gulfwide Recommendations

- Characterize historic populations
- Understand current status and trends
- Protect, manage, and restore habitat
- Educate the public
- Engage blue crab fishers
- Explore head-starting and captive breeding

HISTORIC POPULATION DATA

The lack of historic, baseline demographic data in most Gulf states is an impediment to understanding population trends and advocating for management actions. We recommend conducting exhaustive studies of historical data, fisheries landings, newspaper articles, and gray literature for terrapins in all of the Gulf states to characterize historic terrapin populations. For example, some historic fisheries landing data includes accounts of terrapin harvest. These data could be used in establishing a historic baseline estimate.

CURRENT STATUS AND TRENDS

Long-term population and demographic data for terrapins is incomplete for much of the Gulf region. There have been a small number of recent publications and long-term studies, but these tend to be limited in scope to a specific bay or estuary system. Statewide assessments need to be initiated or updated where they have been previously conducted to understand if populations are in decline, stable, or increasing. Where statewide assessments are not feasible, dedicated sentinel sites could be used to monitor population trends. We also recommend investigating locations in Texas and Florida with occurrence data gaps.

HABITAT PROTECTION, MANAGEMENT, AND RESTORATION

Identification of remaining unprotected wetland and nesting habitats used by terrapins is essential; protection of these habitats would also benefit numerous other coastal species. Areas modeled to become suitable terrapin habitat as marsh migrates inland should also be identified and considered for protection. We recommend creating guidance for land trusts, resource managers, and other decision-makers to prioritize land protection targets.

We also recommend using habitat management and restoration practices on existing protected lands to benefit terrapins including: removal of invasive species from terrapin nesting beaches, installation of living shorelines and other softening techniques that enhance habitat and increase terrapin access to nesting beaches, and marsh restoration.

PUBLIC EDUCATION AND OUTREACH

Along many parts of the Atlantic coast, terrapins are well-known and used as a charismatic species to raise awareness for coastal conservation. Terrapin-related public education and outreach is under-utilized in the Gulf and provides numerous opportunities to engage stakeholders in stewardship activities, build community-based science programs, and connect people to nature. Stakeholder groups with overlapping interests should consider comprehensive engagement strategies that increase awareness of terrapins as a species of concern and leverage them as ambassador for coastal habitats.

ENGAGEMENT WITH BLUE CRAB FISHERS

Bycatch of terrapins in the blue crab fishery is a complicated resource concern with potential for significant stakeholder conflict. However, there are multiple, non-contentious ways to support and engage recreational and commercial fishers. We recommend the following strategies, which can be implemented as stand-alone actions or as concurrent components of a larger program for a greater impact:

- **Removing derelict traps** Derelict crab trap removal programs are successful in removing lost or abandoned fishing gear that can potentially trap and kill terrapins. Frequency and geographic scope of these events is dependent on available funding. We recommend consistent funding of derelict trap removal programs and improved coordination of these efforts to increase their benefit.
- **Distributing bycatch reduction devices (BRDs)** Several limited, small-scale efforts have occurred to distribute free BRDs to blue crab fishers. We suggest supporting efforts that expand distribution of BRDs and assist fishers in proper installation.
- **Providing fishers with BRD-equipped traps** We recommend providing new, BRD-equipped traps to fishers at a reduced or no cost. Traps may be replaced after the end of their usable life, or after significant gear loss events (e.g. hurricanes, storm events). In addition to increasing the number of BRDs in use, this strategy also provides opportunities to build relationships between stakeholders and engage fishers in BRD testing.
- **Expanding research** Continue research into crab retention and trap selectivity, trap mortality, and the effectiveness of resource management strategies. We encourage expanding research to include a cost-benefit analysis of BRD use, sustainable seafood certification, and marketing.

HEAD STARTING AND CAPTIVE BREEDING

Finally, we suggest considering the potential benefits of head starting and captive breeding. Terrapins have been successfully raised in captivity and released in Alabama and Atlantic coast portions of terrapins' range. This may be a feasible option to increase population viability in some Gulf locations.

Credit: Tom Mohrman

Credit: FWC, Kevin Christman

SPECIES OVERVIEW

The diamond-backed terrapin (*Malaclemys terrapin*) is a medium-sized emydid turtle that lives in coastal estuaries along the Atlantic and Gulf coasts of the United States. They are the only North American turtle species found exclusively in brackish water estuaries; their habitats include salt marshes, tidal creeks, and mangroves.

Diamond-backed terrapins are taxonomically related to other emydid turtles including map turtles (*Graptemys*), river cooters (*Pseudemys*), and sliders (*Trachemys*). They share many similar traits with these aquatic turtle species, including hydrodynamic shells and webbed feet. In addition, they possess lachrymal (salt secreting) glands used for osmoregulation as an adaptation to living in saline/brackish habitats.

Terrapins are named for the diamond-shaped scutes on the back of their shells. The coloration and pattern of both the shell and skin varies among subspecies and individuals within a population. Shell color can include shades of orange, yellow, tan, and brown. Skin patterns include stripes, spots, or speckles in varied combinations. Some terrapins have pale yellow or blue tones on their head and may also have a dark pigmented stripe or “mustache” along the upper beak.

Terrapins are opportunistic predators and their diet includes a wide variety of invertebrates, including periwinkle snails and fiddler crabs, and fish; once they reach maturity, terrapins are a top predator in coastal estuaries. Terrapins play an important role as top-down controllers of marsh productivity, controlling populations of marsh-grazing periwinkle snails.

During the nesting season (April – July), gravid females leave the marsh to find suitable nesting sites above the high tide line. Nesting habitat along the Gulf Coast includes natural sand beaches and shell hash/middens. In areas with extensive coastal development, terrapins may also use man-made beaches, road causeways, yards, and other areas adjacent to marshes if access is not blocked by bulkheads or other obstructions. Terrapin clutch size varies based on multiple factors including geography, climate, and individual maternal variation. Typical clutch size along the Gulf Coast is 6-12 eggs and terrapins may produce up to three clutches in a single nesting season.

Terrapins are a long-lived species with a life span of up to 40 years in the wild. The life history traits of terrapins (and all turtles) include high mortality at the hatchling and juvenile life stages, delayed age to maturity, and long adult life spans. Predation is a natural component of terrapin life history, but these traits combined create exceptionally vulnerable populations that are slow to recover from declines.

REGULATIONS AND CONSERVATION STATUS

Terrapins are protected from illegal trafficking by a variety of laws including state regulations, the Lacey Act, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). All five Gulf states have rules and regulations regarding the general collection of turtles and/or turtle eggs. Texas, Louisiana, and Florida also have rules specifically limiting or prohibiting the collection of diamond-backed terrapins. These statutes are related to the collection of turtles from the wild and not terrapin by-catch.

The state of Florida recently adopted rules set to take effect March 1, 2023, to reduce the mortality of terrapins as bycatch in recreational crab traps. Other states have crab trap regulations designed to reduce bycatch mortality of marine species overall (i.e. fish and crabs) such as requirements for cull rings and visible trap floats. A list of regulations, current as of the publication of this document, are in Appendix I.

Table 1. Diamond-backed Terrapin Conservation Status

Common Name	Location	Designation	Description	Source
Diamond-backed Terrapin	Global	VU	Vulnerable	IUCN 2019
Texas Diamond-backed Terrapin	Texas	S2	Imperiled	SWAP 2020
Mississippi Diamond-backed Terrapin	Louisiana	S3	Rare	SWAP 2015
Mississippi Diamond-backed Terrapin	Mississippi	S2	Imperiled	SWAP 2015
Mississippi Diamond-backed Terrapin	Alabama	S2	Imperiled	SWAP 2017
Mississippi Diamond-backed Terrapin	Florida	SGCN	Vulnerable	SWAP 2019
Ornate Diamond-backed Terrapin	Florida	SGCN	Vulnerable	SWAP 2019
Mangrove Diamond-backed Terrapin	Florida	SGCN	Vulnerable	SWAP 2019

Credit: Aaron Baxter

Subspecies: Texas Diamond-backed Terrapin (*Malaclemys terrapin littoralis*)

Range: Texas to western Louisiana

Status: S2 Imperiled in Texas

Characteristics: Deep carapace is dark; pale plastron; skin is greenish gray with heavy black spotting; light colored head (Ernst et al. 1994)

Credit: Christina Mohrman

Subspecies: Mississippi Diamond-backed Terrapin (*Malaclemys terrapin pileata*)

Range: Western Louisiana to Florida panhandle

Status: S3 Rare in Louisiana; S2 Imperiled in Mississippi and Alabama; SGCN Vulnerable in Florida

Characteristics: Carapace is dark with vertebral knobs and orange or yellow upturned marginal scutes; plastron is yellow and often dusky; skin spotted with is dark brown or black (Ernst et al. 1994)

Credit: FWC, Britt Brown

Subspecies: Ornate Diamond-backed Terrapin (*Malaclemys terrapin macrospilota*)

Range: Florida panhandle to Florida Bay

Status: SGCN Vulnerable in Florida

Characteristics: Carapace scutes have orange or yellow centers; knobbed keel (Ernst et al. 1994)

Credit: FWC, Kevin Christman

Subspecies: Mangrove Diamond-backed Terrapin (*Malaclemys terrapin rhizophorarum*)

Range: Florida Keys

Status: SGCN Vulnerable in Florida

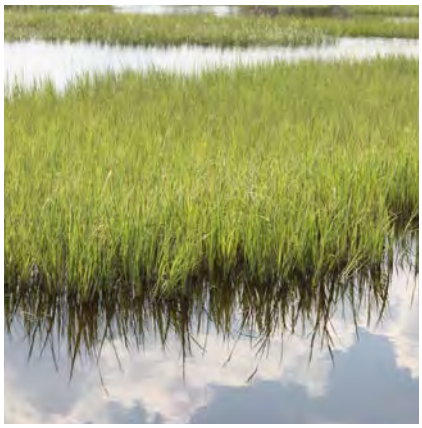
Characteristics: Oblong shell with strong vertebral knobs; gray neck and limbs, spotted with black; brown or black carapace; plastron seams are outlined in black (Ernst et al. 1994)

HABITAT OVERVIEW

Diamond-backed terrapins utilize a variety of coastal and estuarine habitats across the Gulf of Mexico including: salt marsh, mangroves, sand beaches, and shell middens. These habitats are in decline, losing overall area of available habitat from historical benchmarks; however, it is difficult to track recent status and trends in wetland and nesting habitat as that information is not consistently reported across states or with the same habitat classifications.

Terrapins generally occur along the entire Gulf coast from the Florida Keys to south Texas where suitable habitat is present, although their local-scale distribution may be patchy. There are specific localities in Florida and Texas where the presence of terrapins needs to be confirmed.

Experts working on the Conservation Action Plan and other members of the Diamondback Terrapin Working Group strongly expressed their concerns that specific terrapin locality information should not be listed in this plan because of concerns related to the illegal collection of terrapin eggs, hatchlings, and adults.



Emergent Marsh (salt marsh, tidal creeks, etc.)

Salt marsh habitats are defined by their tidal regime, salinity, and emergent vegetation. These are low lying, tidally flooded coastal wetlands often forming a complex of interconnected estuarine water habitats and creeks. Terrapins are associated with a variety of salt marsh classifications such as: salt marsh, brackish marsh, coastal wetlands, coastal marshes, estuarine marsh, tidal streams, tidal creeks, tidal flats, intertidal marshes, flats, and hyper-saline marshes in Texas.

Mangroves

Mangroves are tropical/subtropical trees and shrubs that form complex intertidal coastal wetland habitat. Habitat forms from dense stands or emergent prop roots, which slow water allowing sediments to settle and build substate. Along the Gulf of Mexico, these habitats are largely concentrated in southern Florida, but they are also found in Texas and Louisiana. Mangroves are range limited by their intolerance to freezing and cold temperatures, however northern migration is anticipated due to increased temperatures caused by climate change.

Credit: Tom Mohrman

Sand Beach

Natural and man-made sand beaches are located throughout the northern Gulf of Mexico. Terrapins utilize these areas where they can nest above the high tide line. Beaches are typically long and narrow, extending along tidal creeks and bays. They are low in elevation and vulnerable to overwash and erosion during storm events. Natural beaches include patches of bare, open sand and areas of sparse to dense vegetation.

Credit: TNC, Audra Melton

Shell Hash

Shell hash and shell middens are upland coastal habitats used by terrapins as nesting areas. Made up of oyster shell deposits, these areas can have a unique vegetative community due to soil conditions caused by the breakdown of shell material. "Shell hash" is a term that typically describes these habitats in Texas whereas "shell middens" is used in Mississippi, Alabama, and Florida. Even though the substrate in these habitats appear to be hard to dig in, they are used by terrapins as nesting locations.

CONSERVATION ACTION PLAN PROCESS

The Nature Conservancy has successfully implemented a ten-step CAP process for defining conservation projects, developing and executing strategies and measures, and using the results to adapt and improve conservation outcomes (TNC 2007). The process uses an adaptive management framework to help stakeholders focus natural resource conservation strategies on clearly defined elements of biodiversity and conservation targets (as well as the threats to these targets), and to measure their success in allowing for adaptation over time (TNC 2007). The CAP process is supported by an Excel spreadsheet to input rankings from stakeholders, organize the information for prioritization, and define conservation strategies.

Ten-step CAP Process

1. Identify people involved in the project
2. Define the project scope
3. Assess viability
4. Identify critical stresses and threats
5. Complete a situational analysis
6. Develop strategies for conservation
7. Measure results
8. Develop a work plan
9. Implement actions and measures
10. Analyze and learn from results, adapt, and share findings

Credit: Christina Mohrman

VIABILITY ASSESSMENT

We conducted a viability assessment as a first step to better understand the key factors necessary to evaluate the health and sustainability of terrapin populations and their habitats. Using this process, project contributors define the requirements for a healthy target (key ecological attributes) and rate the current status (viability). This portion of the CAP process is key to knowing where to focus immediate attention and metrics developed from the viability assessment forms the basis of measurement for success over time. The viability assessment is based on specific expert analysis or best assumptions using available data.

During the virtual workshops, we asked project contributors to recommend, and later, evaluate key ecological attributes considered to be important for maintaining a healthy terrapin population. Based on the participant responses, we identified 30 potential key ecological attributes related to terrapin health, wetland habitat, and nesting beach habitat viability. That number was pared down to a final list of seven attributes (Table 2) that could be measured consistently across the Gulf states. The full list of candidate attributes is listed in Appendix II, as they may inform future conservation activities.

Key ecological attributes are the most critical components needed to sustain a terrapin population and habitat viability or ecological integrity over time.

Indicators, or measures, can inform the viability of a conservation target. In a viability assessment, indicators for at least one condition, landscape context, and size are ranked. Project viability indicators and their category for each key ecological attribute are listed below (Table 2). Attributes were selected based on their ability to be consistently measured across all states. A full list of attributes considered by workshop participants is listed in Appendix II.

Table 2. Key Ecological Attributes, Indicators, and Categories

Key Ecological Attribute	Indicator	Category
Terrapin Population	Status of terrapin population based on *State Wildlife Action Plan* rankings	Condition
Terrapin Nesting Success	Terrapin population recruitment	Condition
Wetland Condition	Overall status of wetland habitats suitable for terrapins	Landscape Context
Wetland Loss Rate	Rate of wetland loss or accretion in each state	Landscape Context
Nesting Habitat Condition	Overall status of nesting habitats suitable for terrapins	Landscape Context
Nesting Habitat Loss Rate	Rate of nesting habitat loss or accretion in each state	Landscape Context
Available Wetland Habitat	Acreage of available wetland habitat suitable for terrapins	Size

We evaluated the viability indicators for each state (Table 3) using expert input, published literature, and management plans such as the State Wildlife Action Plans for each state.

The goal for improving long-term viability is to implement conservation strategies that improve rankings (e.g. "Fair" to "Good") over a 10-year period. The viability assessment informs the next iterative steps of the CAP process such as assessing potential threats and developing strategies.

Table 3. Viability Results Summary

	Landscape Context	Condition	Size	Viability Rank
Texas	Fair	Fair	Good	**Fair**
Louisiana	Poor	Poor	Good	**Fair**
Mississippi	Fair	Poor	Fair	**Fair**
Alabama	Fair	Poor	Fair	**Fair**
Florida	Fair	Fair	Good	**Fair**
			Overall Viability Rank	**Fair**

THREAT ASSESSMENT

We conducted a threat assessment based on standard CAP threat taxonomy (TNC 2007). First, we asked workshop participants to review a list of potential threats and to add or remove threats, as applicable. Participants then evaluated and ranked the threats based on severity, scope, and irreversibility. Threats that ranked as “very high” or “high” as part of this Conservation Action Plan are: fisheries interactions, marine debris, severe weather, poaching/pet trade, loss of nesting habitat, loss of wetland habitat, sea level rise, temperature change, and salinity change. We also compared the results of the current threat assessment to previous threat surveys.

The Diamondback Terrapin Working Group conducted these surveys in 1994 (Siegel and Gibbons 1995) and 2004 (Butler et al. 2006) as part of the Working Group’s regular workshops on the ecology, status, and management of terrapins. In 1994, experts listed the top threats to diamondback terrapins in the Gulf states as: crab traps, commercial harvest, predation, habitat loss, pet trade, and pollution. This evaluation was a critical first step in identifying potential threats and impacts to terrapins.

Threats to Gulf Terrapins

- Loss of Nesting Habitat
- Loss of Wetland Habitat
- Fisheries Interactions
- Marine Debris
- Poaching/Pet Trade
- Severe weather
- Sea level rise
- Temperature change
- Salinity change

Ten years later, stakeholders ranked the top threats as: predation, habitat loss, crab traps, nesting habitat alteration, and commercial harvest, with an increased emphasis on habitat loss and alteration.

While the threat assessment methods used in this conservation action plan differ from the Diamondback Terrapin Working Group surveys, there are overall trends worth noting (Table 4). In the initial 1994 survey, threats from crab traps, harvesting, and habitat loss were most common across states. In 2004, crab traps and habitat loss remained as consistent threats across states, with nesting habitat alteration and predation as notable additions. Habitat loss, predation, and crab trap interactions continue to imperil terrapin populations in our current threat assessment, with the addition of climate-related threats including: tropical cyclonic activity, sea level rise, habitat conversion, and changes in temperature and salinity.

The highest ranking threats to terrapins Gulfwide are described in detail on the next four pages.

Severity is the level of damage to conservation targets (terrapin populations or habitats) within the next 10 years under current conditions.

Scope is the geographic area of impact to conservation targets (terrapin populations or habitats) within the next 10 years under current conditions.

Irreversibility is the degree to which the effects of a threat cannot be restored.

Table 4. Threat Results for Gulf Terrapins

	1994	2004	2020
Crab traps	✓	✓	✓
Commercial harvest / Poaching	✓	✓	✓
Predation	✓	✓	✓
Habitat Loss / Alteration	✓	✓	✓
Pet Trade	✓	✓	✓
Pollution	✓		
Marine Debris			✓
Climate-related Impacts			✓

LOSS OF NESTING HABITAT

Natural beaches and shell hash/ midden habitats are environments that are of conservation concern unto themselves, with limited existing area. Unfortunately, these habitats are often located in places that are attractive for coastal development. Cities, towns, and settlements that develop in the coastal zone often include a variety of habitat alterations such as bulkheading, dredging, and beach nourishment. These land cover changes can alter or eliminate an area as potential nesting habitat.

As these habitats are reduced in area, terrapins will have fewer places to nest. Sub-optimal nest sites might be utilized instead, exposing nests to potential drowning, temperature extremes, and increased predation at remaining nest sites with higher nesting density. Additionally, adult females may have to travel greater distances to nest, increasing their exposure to anthropogenic threats including crab traps situated near nesting beaches and traffic when crossing roadways.

Loss of suitable terrapin nesting habitat is largely considered in the context of commercial and residential development in the Conservation Action Plan process. Habitat loss related to erosion, sea level rise, and marsh migration are included separately.

LOSS OF WETLAND HABITAT

Coastal wetlands are generally in decline and affected by changes related to “land improvements” for development. Cities, towns, and settlements, that develop in the coastal zone often include a variety of habitat alterations such as bulkheading, dredging, fill, and channelization.

Loss of coastal wetland habitats is largely considered in the context of commercial and residential development in the Conservation Action Plan process. Habitat loss related to erosion, sea level rise, and marsh migration are included separately.

Credit: Christina Mohrman

FISHERIES INTERACTIONS

We primarily considered terrapin interactions with the blue crab (*Callinectes sapidus*) fishery, which has been ranked as a top threat to terrapin populations in the Gulf states (Butler et. al 2006). Blue crab fishing occurs in the same nearshore wetland habitats used by terrapins. Terrapins are attracted to crab pots because of the bait used to lure blue crabs; the presence of terrapins in a trap may also attract more terrapins to enter (Bishop 1983). If left unchecked for a period of time, terrapins can drown within these traps as there is no way to move to the water's surface to breathe or an available means for escape. The impacts of blue crab fisheries bycatch to terrapins can result in extensive mortality, sometimes leading to extirpation of entire local populations (Wood 1997, Roosenburg 2004, Guillen 2015).

In Texas, Guillen (2015) noted that terrapins have also been captured in the bait shrimp fishery. These fisheries are present in all Gulf states, with various management and regulations. In general, bait shrimp fishing is allowed in near shore waters, but regulations and access may limit potential interactions with terrapins. Reporting of mortality or bycatch associated with nearshore trawls has not been documented but may be occurring in other locations.

MARINE DEBRIS

Marine debris (waste that intentionally or unintentionally enters coastal and marine waters) can harm wildlife in numerous ways including ingestion, entanglement, and entrapment. Impacts to terrapins are most directly associated with drowning in derelict (lost or abandoned) crab traps and this is widely recognized as a significant threat to terrapin populations (Butler et al. 2006, other citations). Crab traps are constructed to be long-lasting and derelict crab traps can continue actively fishing for several years (ghost fishing). At a minimum, 20% of actively fished crab traps become derelict in the Gulf of Mexico each year (Guillory et al. 2001). Nearly 113,000 derelict crab traps have been removed from Gulf waters since 1999 (S. VanderKooy, personal communication, October 21, 2021), yet derelict gear remains a problem because additional traps are lost or intentionally abandoned each year. Guillory et al. (2001) estimated up to 250,000 derelict commercial blue crab traps could enter the Gulf annually, based on the number of fishers, traps, and gear loss rate.

Terrapin populations are sensitive to the impacts of ghost fishing and derelict fishing gear can cause significant, long-lasting population declines. Multiple studies (Dorcas et al. 2007; Grosse et al. 2009; Roosenburg 1991) have reported devastating impacts to local terrapin populations due to incidental mortality in commercial and recreational derelict blue crab traps. Terrapins have small home range and can be extirpated from a local area, which may not be repopulated by other terrapins (Gibbons et al. 2001).

POACHING & PET TRADE

Turtles are often illegally collected for the domestic pet trade and for export to Asian markets for meat and traditional medicine. These activities negatively impact many turtle species, including diamond-backed terrapins. Illegal collection of terrapins and other turtle species has occurred in the Gulf states in recent years (Ellasar 2019, U.S. Attorney's Office 2016). It is difficult to quantify the total number of turtles illegally collected as prosecuted cases often only consider turtles seized or the number of animals poachers admit to collecting.

> *"A sustained rise in the illegal collection of U.S. native turtles has been reported by law enforcement officials across the nation and reflects growing demand for these animals, at home and abroad, as exotic pets, status symbols, traditional medicine, and as food. No turtle species is safe: the trade threatens many species of elevated conservation concern including... diamond-backed terrapins..."* (Turtle Survival Alliance 2021)

We evaluated poaching and pet trade as a Gulf wide threat due to its potential impact on localized populations in any of the Gulf states. This threat ranked "high" in Florida due to recent occurrences of turtle seizures. While it did not receive the same "high" ranking in other Gulf states, we recommend it be considered an important threat region wide for the following reasons: 1) potential negative impacts of removing individuals from small, localized populations, 2) increased demand and value of turtles could encourage greater illegal harvest, and 3) terrapins are potentially at high risk due to ease of collection.

SEVERE WEATHER

Tropical storms and hurricanes can significantly impact terrapin habitats, especially nesting beaches. Storm surge and wind may cause flooding, erosion, habitat alteration, and long-term habitat loss when wetlands are converted to open water. These damaging effects are further amplified by rising sea levels (Knuston et al. 2021).

During the nesting season, incubating eggs can be drowned during prolonged high tide/storm surge flooding events. Terrapin nests are often located just above the high tide line and while embryos can survive periods of brief submergence, prolonged nest inundation is lethal (Roosenburg 2004). Storm surge flooding can last several hours and occur well outside the direct path of a storm event.

Terrapin experts expressed concern that terrapin nests may become more vulnerable to severe weather impacts with changes in the timing and seasonality of hurricane season. The Atlantic hurricane season runs from June 1 to November 30, with the peak storm frequency in August and September. The first named storm of the season has formed before June 1 over the last seven consecutive years (2015-2021; Erdman 2021), overlapping with the Gulf Coast terrapin nesting season which runs from late-April through mid-July. More frequent early-season tropical cyclonic activity could alter nesting beaches and negatively impact nest success/terrapin recruitment.

SEA LEVEL RISE

Sea level rise impacts multiple coastal habitats used by terrapins through inundation and erosion including: nesting beaches, shell hash islands, salt marsh, and mangroves. Loss of critical nesting and marsh habitat used by juvenile and adult terrapins is expected to increase over the next century as habitat is submerged and converted to open water (Carter et al. 2018). Inland marsh migration is limited by coastal development (Donnelly and Bertness 2002, Feagin et al. 2005) and will lead to further habitat loss in some areas.

TEMPERATURE CHANGE

Several environmental factors including air temperature, nesting substrate, vegetative cover, precipitation, and latitude all play a role in determining nest incubation temperature. Because terrapins are among the many species of reptiles that exhibit temperature dependent sex determination, incubation temperature of a nest dictates hatchling sex ratios. Hatchlings incubated at higher temperatures have a greater frequency of shell anomalies and temperatures above 35° C are fatal.

The number of days with higher temperatures and warmer nights is expected to increase with climate change (Carter et al. 2018). In addition, increasing temperatures may change vegetative cover present on nesting beaches. These increasing temperatures and nesting habitat changes will directly impact terrapin nest incubation and could lead to skewed sex ratios, increased frequency of anomalies, and/or greater egg mortality.

SALINITY CHANGE

Climate change is expected to intensify extreme precipitation patterns including both drought and heavy rainfall. Extreme rainfall events in the Southeastern US have increased in both frequency and severity and these trends are expected to continue under future climate scenarios (Carter et al. 2018). These changes to precipitation patterns could alter the salinity of coastal watersheds, either through elevated or reduced salt concentrations.

Impacts to wetland habitats could be acute or chronic, altering overall average salinity or having seasonal effects. Permanent or chronic changes could negatively affect vegetation and cause habitat loss through habitat migration or conversion to open water. Further, availability of terrapin prey items could be affected if vegetation and habitats change over time. Terrapin metabolic processes related to osmoregulation could also be impacted.

Credit: Roger Wood

RESEARCH GAP ANALYSIS

As part of the overall CAP project, we also conducted a gap analysis to identify research and data needs. The gap analysis included input from stakeholders during webinars, a bibliography search, State Wildlife Action Plan reviews, and individual contributions from terrapin experts. We also specifically sought recommendations on research and data needs during each state-specific webinar.

The recommendations presented in this section are directly connected to strategies listed in the CAP under the "Gulfwide Recommendations for Terrapin Conservation." These recommendations were identified as research needs across all Gulf states and enable and support specific strategies.

A complete list of research recommendations for future research proposed by stakeholders is listed in Appendix IV. These recommendations capture all input provided by participants. Recommendations may not be directly connected to CAP strategies or may be limited to a specific geography within the region.

Table 5. Research Recommendations for Gulf Terrapins

Historic Population Data and Trends	• Estimate the historical population in each state • Determine population trends from historical estimates
Current Population Trends	• Estimate population in each state, including demographics such as sex ratio and age classes • Collect vital rates (survivorship, recruitment, population growth)
Nesting Habitat	• Identify current nesting habitats • Estimate area of current available nesting habitat • Estimate rate of change in nesting habitat • Determine potential use and role of artificially created and modified islands and beaches for nesting habitat
Life History	• Document and clarify nesting period • Evaluate how changes in patterns of tropical cyclonic activity may negatively impact nesting success • Determine salinity range • Study influence of terrapins in controlling marsh snails and overall salt marsh health
Hatchling and Juvenile Habitat Usage	• Determine hatchling and juvenile habitat use and if these habitats differ from adults • Evaluate land protection priorities to support hatchling and juvenile habitat needs
Fishing Gear Interactions	• Study economic impact of bycatch reduction devices for blue crab fishers and the fishery • In locations where data is deficient, conduct studies that evaluate bycatch reduction devices • Document interactions with fishing gear from existing, unpublished data • Map areas of overlap between terrapin habitat and blue crab fishing activity for target management approaches
Genetics	• Identify number of individuals contributing to genetic diversity within populations • Determine if genetic bottlenecks are occurring • Evaluate use of eDNA to identify populations in estuarine/brackish water environments
Range	• Fill gaps in geographic range data in Texas and Florida

TEXAS

Subspecies: Texas Diamond-backed Terrapin (*Malaclemys terrapin littoralis*)

State Ranking: S2 Imperiled

State-specific Threats: Texas experts did not identify any additional state specific threats for terrapins. Texas Parks and Wildlife Department lists road mortality as a threat in their species profile and this may be a localized concern in some areas of the state.

Research Recommendations: State experts recommended the following: continued population surveys to monitor trends; assessment of hurricane impacts to terrapin populations and nesting; research on terrapin changes in terrapin nesting habitat; synthesis of historic terrapin population and locality data; and eDNA sampling across the state.

LOUISIANA

Subspecies: Mississippi Diamond-backed Terrapin (*Malaclemys terrapin pileata*)

State Ranking: S3 Rare

State-specific Threats: In addition to the threats listed in the Gulfwide overview, experts expressed concerns related to: 1) loss of wetland habitat and access to nesting beaches from bulkheads and other hardened shoreline structures; 2) changes in sediment transport systems, 3) maintenance dredging of shallow water channels, and 4) habitat damage caused by invasive species (e.g. feral hogs and nutria).

Research Recommendations: State experts expressed the need for: 1) life history data; 2) population trend data; 3) nesting surveys and research on nesting ecology; 4) identification of nest predators; 5) information on the impact of breakwaters and terrapin use of natural and artificial/restored beach habitats; and 6) information on bycatch in actively-fished and ghost blue crab traps. They also recommend investigating methods to reduce terrapin capture in crab traps, including bycatch reduction devices and biodegradable panels, and their impact on the blue crab fishery.

Credit: Christina Mohrman

MISSISSIPPI

Subspecies: Mississippi Diamond-backed Terrapin (*Malaclemys terrapin pileata*)

State Ranking: S2 Imperiled

State-specific Threats: In addition to the threats listed in the Gulfwide overview, experts expressed concerns related to: 1) loss of wetland habitat and access to nesting beaches from bulkheads and other hardened shoreline structures; 2) living shoreline restoration techniques that limit terrapin movement between marsh and nesting habitats; 3) restoration project implementation disrupting the the nesting season; and 4) impacts of exotic, invasive plants and animals (fire ants, feral hogs, and nutria) on nest and hatchling success.

Research Recommendations: State experts expressed that dedicated population surveys to establish current and historic population baselines is the highest priority research need in Mississippi. Unpublished data from research efforts over the past 10 years may contribute additional information to understanding terrapin status and trends, but these data remain largely unavailable.

Credit: John Dindo

ALABAMA

Subspecies: Mississippi Diamond-backed Terrapin (*Malaclemys terrapin pileata*)

State Ranking: S2 Imperiled

State-specific Threats: Experts did not identify any additional state specific threats for terrapins in Alabama.

Research Recommendations: Systematic surveys to assess distribution and population size, basic life history studies, and assessment of the continued impact of blue crab traps should be implemented and continued.

FLORIDA

Subspecies: Mississippi Diamond-backed Terrapin (*Malaclemys terrapin pileata*), Ornate Diamond-backed Terrapin (*Malaclemys terrapin macrospilota*), and Mangrove Diamond-backed Terrapin (*Malaclemys terrapin rhizophorarum*)

State Ranking: Species of Greatest Conservation Need, Vulnerable

State-specific Threats: In addition to the threats listed in the Gulfwide overview, experts expressed concerns related to: 1) modification of nesting beach habitat; 2) non-point source nutrient pollution from residential developments; and 3) illegal collection of terrapins for human consumption and the pet trade.

Research Recommendations: State experts expressed that distribution and demographic information are still incomplete for multiple parts of the state of Florida. Follow-up studies are recommended for areas where populations have been previously documented.

Research to understand the magnitude of terrapin loss due to crab trap mortality, to assess crab exclusion by bycatch reduction devices of different sizes and designs, and to assess potential impacts of bycatch reduction device use on the commercial blue crab fishery are underway and should be continued.

GLOSSARY OF TERMS

Condition A measure of the biological composition, structure, and biotic interactions that characterize the occurrence of a target; a class of Key Ecological Attribute

Contribution The source of stress, used in ranking a threat

Indicator Measures related to a specific informational need (e.g. status of a key ecological attribute, change in a threat, or progress toward an objective)

Key Ecological Attribute Aspects of a target's biology or ecology that, if missing or altered, would lead to the loss of that target over time; defines the target's viability or integrity

Landscape context An assessment of a target's environment including ecological processes and regimes that maintain the target's occurrence; a class of Key Ecological Attribute

Objective Specific and measurable statements of what one hopes to achieve with a project

Project scope or Project area The place where the project is located

Project vision A general summary of the desired state or ultimate condition of the project area or scope that a project is working to achieve

Scope (stress) For ranking a stress, most commonly defined spatially as the geographic scope of impact on a target that can be reasonably expected within 10 years

Size A measure of the area of a target; a class of Key Ecological Attribute

S.M.A.R.T. Specific, measurable, achievable, relevant, and time-limited; related to objectives

Stress Impaired aspect of a target that is directly or indirectly related to human activities (e.g. low population size, habitat loss)

Target A group of species, ecological communities, or ecological systems chosen to represent and encompass the biodiversity found in a project area; they are the basis for setting goals, carrying out conservation actions, and measuring conservation effectiveness

Threat The past, current, or future activities that create a stress leading to the degradation, destruction, or impairment of a target

Viability The status or health of a population, indicating its ability to withstand or recover from natural or human-caused disturbances and persist over time

Viability assessment A method for measuring a target's health over time, including its status and what a "healthy state" should be

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APPENDIX I

Rules and Regulations Related to Diamond-backed Terrapins
in the Gulf of Mexico

Texas

It is unlawful: for any person to knowingly take or possess a diamondback terrapin (*Malaclemys terrapin*) or their eggs unless the person is authorized to do so under a permit.

Source: Texas Administrative Code (state.tx.us)

Louisiana

Diamondback terrapins: Hand collection harvest permitted, 6 inches minimum plastron length (plastron is the underside surface of the shell), season closed April 15 through June 15. It is illegal to take this species by a trap of any kind.

Harvest of turtle eggs is prohibited except for eggs of the red-eared slider.

Source: https://www.wlf.louisiana.gov/page/recreational-reptile-and-amphibian-collecting

Mississippi

A person may possess and harvest from the wild no more than 10 other non-game turtles per license year. No more than FOUR (4) can be of the same species or subspecies.

The harvest, possession, shipment, sale and transport of turtle or tortoise eggs of any species is prohibited.

Non-Game Wildlife or their parts taken from wild Mississippi populations may NOT be bought, possessed, transported, exported, sold, offered for sale, shipped, bartered, or exhibit it for Commercial purposes.

Source: https://www.mdwfp.com/fishing-boating/freshwater-commercial/turtle-information/

Alabama

No person shall take, attempt to take, sell or possess any turtle egg or turtle or parts thereof from the wild in this state, to include public and private waters, for commercial purposes. This is not to prohibit the operations of properly permitted 'Turtle Farmers' or 'Turtle Dealers' as defined in Rule 220-2-.142

Taking for personal use of up to two legal turtles per day by hand, dip net or hook and line however, no person shall take more than two turtles per day from the wild in this state, to include public and private waters.

It shall be unlawful to take, capture, kill, or attempt to take, capture or kill; possess, sell, trade for anything of monetary value, or offer to sell or trade for anything of monetary value, the following nongame wildlife species (or any parts or reproductive products of such species) without a scientific collection permit or written permit from the Commissioner, Department of Conservation and Natural Resources, which shall include terrapin specifically state what the permittee may do with regard to said species:

Source: https://www.outdooralabama.com/reptiles/turtles#:~:text=Turtles%20are%20protected%20by%20regulation,private%20waters%2C%20for%20commercial%20purposes.

Ala. Admin. Code r. 220-2-.92 - Protected Nongame Species, It shall be unlawful to take, capture, kill, or attempt to take, capture or kill; possess, sell, trade for anything of monetary value, or offer to sell or trade for anything of monetary value, the following nongame wildlife species (or any parts or reproductive products of such species) without a scientific collection permit or written permit from the Commissioner, Department of Conservation and Natural Resources, which shall specifically state what the permittee may do with regard to said species:

Source: http://alabamaadministrativecode.state.al.us/JCARR/JCARR-JUN-11/220-2-.92.PDF

Florida

Florida recently revised their rules surrounding diamondback terrapin collection and possession. Individuals were previously allowed to collect up to 1 terrapin per day and could possess a maximum of 2 terrapins at a time. Wild-caught terrapins are not allowed to be sold, purchased, or traded. As of March 1, 2022, collection of terrapins is prohibited, and any terrapin in possession must be permitted. Additionally, Florida will be adopting statewide minimum entrance size requirements for all recreational blue crab traps. This can be achieved through trap construction or use of a bycatch reduction device. This rule will be effective on March 1, 2023.

No person shall take, possess, transport, or sell any diamond-backed terrapins (also referred to as diamondback terrapins, *Malaclemys terrapin*), except by permit. Permits may be issued for personal possession, exhibition and education, and scientific use. Permit issuance is in accordance with the Diamond-backed Terrapin Permit Application Guidance, effective March 1, 2022 and hereby incorporated by reference at https://www.flrules.org/Gateway/reference.asp?No=Ref-13929. Persons in possession of diamond-backed terrapins shall have 90 days from the effective date of this rule to come into compliance with the provisions of this section.

Terrapin bycatch reduction requirements.

Recreational harvesters. Beginning March 1, 2023, each trap used to harvest blue crabs, other than those used to harvest for commercial purposes, must contain a bycatch reduction device that meets the specifications of paragraph (8)(b) installed in each entrance or throat.

A trap shall be considered to meet the requirements of paragraph (8)(a) if each entrance or throat:

1. Contains a bycatch reduction device measuring no larger than 2 inches in height by 6 inches in width; or,

2. Is constructed completely of rigid wire such that the narrowest does not exceed 2 inches in height by 6 inches in width.

Source: Provided by Brad O'Hanlon, Florida Wildlife Conservation Commission

APPENDIX II

Considered Key Ecological Attributes

Appendix II: Considered Key Ecological Attributes

The following tables list recommendations received from participant input of candidate Key Ecological Attributes. Tables list the attribute and the state from which the recommendation was received. Ultimately this list was refined to the final list in the viability section of the Conservation Action Plan.

Viability Assessment Responses (Diamondback Terrapin)

Key Ecological Attribute	TX	LA	MS	AL	FL
Population size and sustainability	X	X	X	X	X
Adult survivorship	X	X	X	X	X
Hatchling and juvenile recruitment	X	X	X	X	X
Successful nest maturation and hatchling survivorship	X	X	X	X	X
Access and availability to nesting habitat	X	X	X	X	
Access to juvenile habitat	X	X	X		
Access to adult and forage habitat	X	X		X	
Prey and forage species availability		X	X	X	X
Predation	X		X	X	
Genetic diversity			X	X	X

Viability Assessment Responses (Wetland Habitat)

Key Ecological Attribute (Wetland)	TX	LA	MS	AL	FL
Area of wetland habitat available	X	X	X	X	X
Marsh migration corridor	X	X	X		X
Barrier island complex		X			
Unfragmented connectivity			X	X	
Hydrology	X	X	X		X
Sediment deposition vs. erosion		X			X
Elevation			X		
Biological productivity (prey species and biomass)			X	X	X
Free of exotic species		X	X	X	
Vegetative composition		X			
Habitat Integrity					X

Viability Assessment Responses (Nesting Habitat)

Key Ecological Attribute (Nesting Beach)	TX	LA	MS	AL	FL
Proximity to wetland habitat	X	X	X	X	X
Available sand beach	X	X	X	X	X
Available shell hash	X	X	X	X	
Barrier Island Complex		X			
Unfragmented connectivity			X		
Elevation i.e. water inundation		X	X	X	X
Sediment erosion	X		X	X	
Vegetation composition -natives vs. exotics		X	X	X	X
Temperature regime - vegetative coverage			X	X	X
Lack of Predators			X	X	X

APPENDIX III

Considered Threats for Threat Assessment

Appendix III: Considered Threats for Threat Assessment

The following table lists all threats that were considered for evaluation as part of the stakeholder Threat Assessment. Threats are defined according to the standardized terminology and taxonomy of the international Conservation Measures Partnership (CMP). Definitions for these threats are from the CMP Direct Threats Classification Version 2.0, and can be found at https://conservationstandards.org/library-item/threats-and-actions-taxonomies/.

CMP Threat Classification	Threat Name
1	**Residential & Commercial Development**
1a	Habitat loss; wetland (saltmarsh and mangrove)
1a	Habitat loss; nesting (sand beach, oyster shell, anthropogenic)
1a	Habitat loss; juvenile
1a	Bulkheading and other hardened shoreline structures
2	**Agriculture & Aquaculture**
2d	Mariculture; oysters, finfish, clams
3	**Energy Production & Mining**
3a	Oil & gas drilling
3a	Pollution-oil spills
4	**Transportation & Service Corridors**
4a	Road mortality
4b	Oil and gas pipelines
4c	Dredging of channels, primarily for navigation
5	**Biological Resource Use**
5a	Illegal markets and pet trade
5a	Legal commercial harvest of terrapins
5d	Fisheries interactions; bycatch, crabpots, nets, seines
6	**Human Intrusions & Disturbance**
6a	Recreational activities; boat impacts
7	**Natural System Modifications**
7c	Bulkheading and other hardened shoreline structures
7c	Living shorelines
7c	Alterations in sediment transport systems
7c	Nesting beach modification; restoration activities, sand re-nourishment, geotubes
8	**Invasive & Other Problematic Species & Genes**
8a	Non-native plants and animals; i.e.exotic vegetation, fire ants
8a	Habitat damage caused by invasive species; wild hogs, nutria, others
8b	Subsidized predators at nest beaches; nest predation, direct predation
8b	Disease
9	**Pollution**
9a	Nutrient pollution; non-point run off from households and development
9d	Marine debris; fisheries gear interactions
11	**Climate Change & Severe Weather**
11a	Sea level rise; habitat conversion to open water or other habitat
11a	Changes in nest thermoregulation, temp dependent sex determination, sex ratios
11a	Changes in salinity
11d	Tropical cyclonic activity; hurricanes, nest drowning habitat alteration, and erosion

APPENDIX IV

Stakeholder Research Recommendations

The following is a list of received research recommendations from participants:

Population data and trends

- Establish a historical baseline population estimate in each of the Gulf states.
- Estimate current population in each state, including demographics (sex ratio, age classes).
- Measure current population trends in each state.
- Collect vital rates (survivorship, recruitment, population growth) of terrapin populations.

Nesting Habitats

- Identify specific nesting localities.
- Identify nesting success rate in each state.
- Document current available nesting habitat area (in size) in each state.
    - What is the area of existing sand beach and shell middens?
    - What is the area of those habitats above the high tide line?
- What is the rate of change in available nesting habitat area?
- What role do artificial habitats play for terrapin nesting?
- To what extent do terrapins utilize artificially created islands or beaches for nesting?
- To what degree do we see nest predation, in each state?
- What is the effectiveness of predator control activities?
- Document best practices for predator control and nest predation.
- Document nesting site specifics such as vegetation cover, slope, soil temperature, etc.
- What is the impact of restation activities, such as beach nourishment, living shoreline, and habitat creation on terrapins? Do these actions provide a positive or negative benefit?
- Document impact of bulkhead on terrapin access to nesting locations.

Wetland Habitat

- What is the rate of wetland habitat loss across the gulf and in each state?
- Quantify role of terrapins in controlling marsh grazing snails.

Life History

- Document nesting period across Gulf populations.
- Evaluate nesting period against tropical cyclonic weather.
- What habitats do juvenile and hatchling terrapin's utilization? Do habitats these differ from adults? Does this redirect land protection priorities?
- Do juvenile terrapins have access to the upper marsh?
- What is the effectiveness of head-starting?

Fishing gear interactions

- What is the economic impact to blue crab fishers and the blue crab fishery of utilizing By-catch Reduction Devices (BRDs) on crab pots?
- Research to understand the magnitude of terrapin loss due to crab trap mortality.

- Assess terrapin and blue crab exclusion by, different sizes and designs of BRDs that could be used in crab traps.
- Assess and identify potential impacts of BRD use on the commercial blue crab fishery.
- Investigate impacts of active and ghost trap by-catch in areas known to have viable terrapin populations.
- What areas do terrapins and the blue crab fishery overlap?
    - Where might having site specific BRD usage have the most benefit?
- What regulatory approaches would have the most benefit vrs impact ?
- Would a limited area excluder devices regulation have benefit in areas with high terrapin populations?
- Where might limiting fishing in small creeks have the most benefit?
- Investigate methods to reduce capture in crab traps (i.e., By-catch Reduction Device (BRD) and/or to develop biodegradable panels to limit by-catch in ghost traps.
- What is needed for Marine Stewardship Council (MSC) certification- what are potential economic benefit to benefit fishers?
- Research non-regulatory methods for BRD use encouragement

Genetic Tools

- Within terrapin populations, identify the number of individuals contributing to genetic diversity.
- Determine if genetic bottlenecks are occurring.
- Can EDNA be used to identify populations in saline environments?
- Are subspecies real? This has implications for regulatory approaches toward populations.

Distribution

- Fill in the geographic range data gaps in Texas, Alabama, and Florida.

Climate

- What is the impact of Sea level rise on terrapin habitats?
- What is the impact of Sea level rise on terrapin nesting success?
- What are the impacts of tropical storms and flood water inundation to terrapin nesting success?
- Can mangroves and salt marsh keep pace with SLR?
- Map out likely wetland habitat migration corridors.