## The Diamondback Terrapin Working Group's



On behalf of the Organizing Committee and Diamondback Terrapin Working Group Officers, WELCOME to the 9<sup>th</sup> Symposium on the Ecology, Status, and Conservation of the Diamondback Terrapin! Our community has grown steadily since the inaugural *Workshop* at the Savannah River Ecology Laboratory in 1994. The 1994 *Workshop* was convened in response to growing concern about declining terrapin populations, with the goals of identifying threats to terrapin populations and producing recommendations for management agencies. The major findings and recommendations compiled from the 1994 Workshop (Seigel and Gibbons, 1995) have served as a springboard for scientific research and conservation actions that continue today.

While a great deal of progress has been made in the 25 years since the first *Workshop*, the principal threats to terrapins have not been fully mitigated, additional management strategies must be developed and evaluated, and the adoption and implementation of sound conservation practices are needed. We still have work to do. This 9<sup>th</sup> *Workshop* renews our commitment to improve our knowledge of terrapin ecology and management, build new collaborations, and chart future initiatives toward recovering and sustaining wild terrapin populations and the marshes they inhabit. It is also a time to catch up with old friends and make new ones who share our love and interest for these special animals. Thank you for being here, and we look forward to a great meeting!

John Maerz 9th Workshop Host and DTWG Co-Chair

Local Workshop Organizers: Vanessa Terrell Danielle Bradke Jared Bailey Shelby Bauer Ally Brown Cyndi Carter Kirstine Grab Anuja Mital Corrie Navis Dare Scott

#### DTWG Officers:

Senior Co-Chair: Amanda Williard (outgoing), John Maerz (incoming) Junior Co-Chair and Workshop Host: John Maerz (outgoing), John Wnek (incoming) Treasurer: Joe Butler (outgoing), Randy Chambers (incoming) Secretary: Sarah Finn

#### **DTWG Board Members**

Northeast Regional Representative: Russ Burke Mid-Atlantic Regional Representative: Randy Chambers (outgoing) Southeast Regional Representative: Jordan Gray Florida Regional Representative: Chris Lechowicz Gulf Regional Representative: Tom Mohrman At-Large Member: Jason Alstad At-Large Member: Barbara Brennessel At-Large Member: George Heinrich At-Large Member: Patricia Levasseur At-Large Member: John Wnek, (outgoing)

#### DTWG Board Regional Representative Alternates

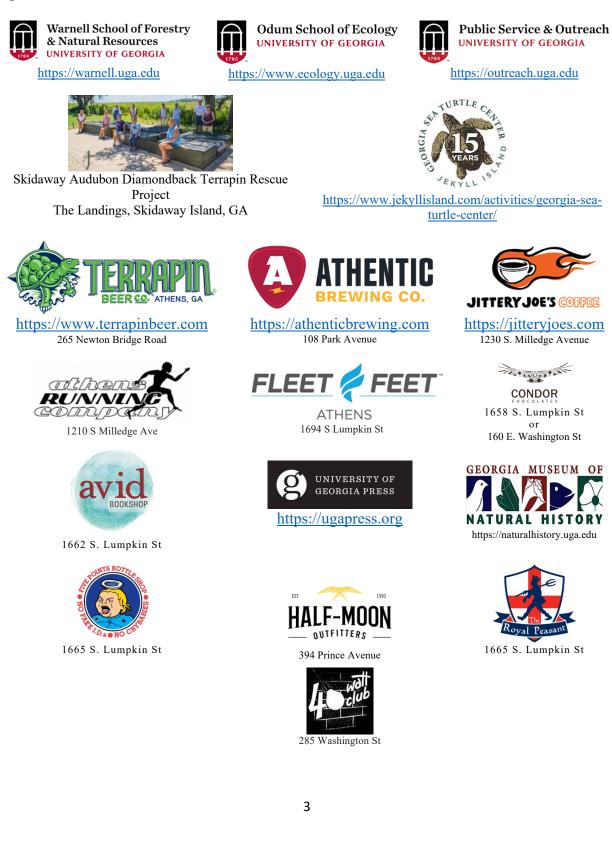
Southeast Region: Kathryn Craven Florida Region: Ben Atkinson Gulf Region: Aaron Baxter Northeast Region: vacant Mid-Atlantic Region: vacant

#### For the 2023-2025 cycle, the DTWG is seeking:

- A new Mid-Atlantic Regional Representative
- A new At-Large Board Member
- A Northeast Region Alternate Representative
- A Mid-Atlantic Alternate Representative
- A new editor for the Terrapin Times newsletter
- A bibliography manager
- Web content developers

### Sponsors and Donors

The Diamondback Terrapin Working Group recognizes and appreciates the generosity of these organizations and businesses.



### About our major sponsors...



Warnell School of Forestry & Natural Resources UNIVERSITY OF GEORGIA The Warnell School of Forestry and Natural Resources prepares leaders in the conservation and sustainable management of forests and other natural resources; to

discover ways to restore and better use the earth's natural resources; and to put into practice forestry and natural resources knowledge. The Warnell School was established in 1906 as the oldest forestry school in the South. Today, the school has 71 faculty and 25 research professionals supporting Ph.D., masters, and undergraduate training in fisheries and wildlife science; forestry; geographic information systems and landscape ecology and management; human dimensions of natural resources; parks, recreation, and tourism management; soil and water ecology and management; and natural resources sustainability.



In support of the 9<sup>th</sup> Workshop, the Warnell School donated the use of Flinchum's Phoenix and provided generous cash support.

You can learn more about the Warnell School of Forestry and Natural Resources at <u>https://warnell.uga.edu</u>.



Odum School of Ecology UNIVERSITY OF GEORGIA Ecological research at the University of Georgia dates back to the early 1950s, when two major programs provided the impetus to form what would become the Odum School of Ecology, the first school of Ecology in the world. Today, the

Odum School has more than 350 members a cross section of faculty, senior scientists, technicians and graduate students who represent several departments and schools on campus including the Savannah River Ecology Laboratory, the Marine Institute (Sapelo Island, Georgia), and the Skidaway Odum School of Oceanography. The school is named after its, Eugene P. Odum, who is widely considered the "father of modern ecology."



The Odum School studies the fundamental ecological processes that shape the world, trains future generations, and creates science-based solutions to environmental problems. They create change by harnessing diverse tools and perspectives in a collaborative community. The Odum School consistently ranks at the top of programs in ecology worldwide. It is a world leader in ecosytems ecology, community ecology, and the ecology of infectious diseases. Most recently, the graduate program ranked tenth in a study by US News and World Report.

In support of the 9<sup>th</sup> Workshop, the Odum School provided generous cash support.

You can learn more about the Odum School of Ecology at <u>https://www.ecology.uga.edu</u>.



As Georgia's only sea turtle education and rehabilitation facility, the Georgia Sea Turtle Center offers the public a chance to learn about sea turtles, diamondback terrapins, and other coastal wildlife, and see rehabilitation in action with a host of interactive exhibits and experiences. Year-round indoor and outdoor programs are available for guests of all ages. In addition, the Georgia Sea Turtle Center runs wildlife monitoring and research programs or collaborates with regional partners to further the conservation and management of sea turtles,

diamondback terrapins, alligators, and various snake species. This includes a long-term monitoring and head-start program for diamondback terrapins. The Georgia Sea Turtle Centers research and management actions to reduce terrapin road mortality and improve nesting success has become a conservation model. As part of its rehabilitation, research, management, and outreach missions, the Georgia Sea Turtle Center provides professional training through an extensive internship program.



In support of the 9<sup>th</sup> Workshop, the Georgia Sea Turtle Center provided generous cash support.

To learn more about the Georgia Sea Turtle Center visit https://www.jekyllisland.com/activities/georgia-sea-turtle-center/.



The Skidaway Audubon Diamondback Terrapin Rescue Project is a citizen group founded in 2002 and currently supported by 15 volunteers. The project started with terrapin nests that were rescued from the local golf course being incubated in flowerpots on a founding member's porch. In 2010, Skidaway Audubon adopted the program.

Over its 13 years of activity, the Skidaway Audubon Diamondback Terrapin Rescue Project has protected and reared ~3,400 terrapin nests to the release of a ~23,000 terrapin hatchlings. They have saved 88% of terrapin eggs that prior to the efforts of these individuals were almost all destroyed by predators or golf course maintenance. In addition, the program has hosted more than 200 events attended by more than 4,000 people, and the program has been embraced so positively by the entire community that in 2020 The Landings Club renamed the "Plantation Golf Course" to "Terrapin Point" in honor of the turtles and the efforts of its residents to conserve these turtles.

Beyond their local efforts within their community, the Skidaway Audubon Diamondback Terrapin Rescue Project has partnered with the Coastal Conservation Group on the island to do numerous presentations to the families who attend their 'kids fishing events', hosted a number of exchange students and their families, conducted special events for the Landings Club employees and their families, participated in UGA's Marine Science Fairs and summer camps, led special programs for special needs children, done presentations to a number of groups on and off the island such as Kiwanis, PEO Groups, and the Rotary, and published articles to inform residents of the status of the project and the dates for the 'Hatchling Happenings'. The group worked with Mary Landers from The Savannah Morning News to publish several articles on the project, they worked with Chris Steigelman, a Landings course superintendent, to write an article about terrapin conservation for the Georgia Golf Course publication. The Skidaway group has also engaged with researchers and conservation biologists around the region to leverage their efforts in support of terrapin science.

In support of the 9<sup>th</sup> Workshop, the Skidaway Audubon Diamondback Terrapin Rescue Project members made a generous cash donation.



In 2022, Terrapin Rye Pale Ale debuted at the Classic City Brew Fest in Athens, GA. Since then, Terrapin Beer Company has become nationally recognized for its creative "hoppy" beers and its support of the Athens community. The Terrapin Beer Company logo was inspired the Grateful Dead's

Terrapin Station. As it has grown and evolved, Terrapin Beer Company has adopted as part of its mission to make its business more sustainable through its Terraprint initiative.

In support of the 9<sup>th</sup> Workshop, Terrapin Beer Company provided the custom beer glasses, t-shirts and other items as gifts, and a discounted tour and tasting to Workshop participants.



Cofounders Paul Skinner and Mark Johnson built the brewery of their dreams: A true microbrewery that is a community meeting spot open to everyone. Their mission is to celebrate their roots, enjoy the present, and cultivate a beer

community based on quality products and neighborhood involvement. Athentic Brewing is in the heart of Normaltown in Athens, GA. They dedicate themselves to being authentic to our city and to working hard to create the types of beers Athens deserves.

In support of the 9<sup>th</sup> Workshop, Athentic Brewing Co. donated the use of their events space for the welcome social and provided some t-shirts and other items as gifts.



Jittery Joe's Coffee was started in 1994 next to the famous 40 Watt Club in Athens, Georgia. The connection with the club helped Jittery Joe's become something larger than anyone would have imagined. Joe's clientele included everyone from the Mayor, teachers, and construction workers coming in during the morning,

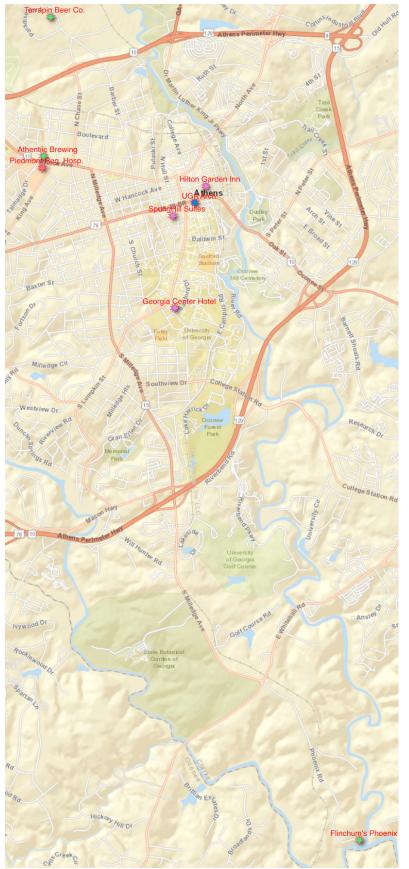
to students, townies, and artists coming in at night. The Jittery Joe's buzz was helped with frequent celebrity guests such as Michael Stipe of R.E.M., the B-52s, comedians Penn and Teller, and many others. The name comes from *The Simpsons* parody of the movie *Thelma and Louise*. In that episode Marge goes to a diner named "Jittery Joe's". The founders did a national name search, discovered that the name was not copyrighted and obtained a federal trademark. At one time Jittery Joe's was the official coffee of Antarctica. According to *Rolling Stone Magazine* the #5 underground album of all time is "Live at Jittery Joe's" and *Rolling Stone Magazine* also named Jittery Joe's one of the top 24 hour coffee houses in America. What makes Jittery Joe's Coffee better than the rest? Jittery Joe's Coffee strives to source the best beans available, and they roast in small batches to allow for greater quality and care.

In support of the 9<sup>th</sup> Workshop, Jittery Joe's Coffee donated the coffee for the event and some gift items for auction.



Avid Bookshop is a fiercely independent, community-focused bookselling business headquartered in Athens, Georgia. They have a bookstore in Athens's Five Points neighborhood, plus they serve readers nationwide with a full-service webstore at avidbookshop.com. Avid has been named by *Flagpole* readers as Athens' Favorite Local Business for nine years in a row! Avid firmly believe that books change readers' lives for the better. Drop by their charming store or browse online.

In support of the 9<sup>th</sup> Workshop, Avid Bookshop donated over \$600 worth of books for the silent auction.



### Getting around Athens

The business meeting and social no Friday, October 28, will take place at Athentic Brewing Company 108 Park Avenue, Athens, GA 30601

All other Workshop events on Saturday and Sunday morning will take place at Flinchum's Phoenix. There is ample parking on site. 650 Phoenix Road, Athens, GA 30605

The optional "field trip" on Sunday afternoon is at the Terrapin Beer Company 265 Newton Bridge Rd, Athens, GA 30607

Free shuttles will run attendees from SpringHill Suites and the Hilton Garden Inn.

Attendees not staying at either of those hotels but who need or wish to use the free van shuttles have several options. If you email us your lodging address and a contact cell phone number (send to jcmaerz@uga.edu), we can arrange to pick you up at a location near your accommodation. Alternatively, both Athens Clarke County and UGA busses are free. You can take a bus to the UGA Arch or the Georgia Center Hotel and we can arrange to pick you up there.

We have a packed agenda for you, but if you are looking to stretch your legs and experience some of Athens, you can consider strolling downtown (the area north of the UGA Arch), there are trails in Oconee Forest Park around Lake Herrick and in the State Botanical Garden not far from Flinchum's Phoenix. You can also visit the tree that owns itself [yes that is a real thing], which is close to the SprinHill Suites.

In case of an emergency, the closest hospital is Piedmont Regional Hospital 1199 Prince Ave, Athens, GA 30606

### Program-at-a-Glance

Friday, October 28 All events at Athentic Brewing Company, 108 Park Avenue, Athens, GA 30601 3:30PM – 5:30PM DTWG Business Meeting (open to all members)		Sunday, October 30 All events at Flinchum's Phoenix 650 Phoenix Road, Athens, GA 30605. Ample free parking on site. Shuttles available.	
6:00PM – 9:00PM	Welcome Social (open to all workshop registrants)	8:00AM – 8:30AM 8:30AM – 9:30AM	Breakfast Presentation Session 5
Saturday, October	29	9:45AM – 11:15AM Discussion Groups Bycatch; Gulf Terrapin Conservation Plan; Education and Outreach; Population Surveys; Website Content Development	
All events at Flinchur Phoenix Road, Athen Ample free parking o Shuttles available.	s, GA 30605.	11:15PM – 11:45PM Presentation of Discussion Group Findings, Concluding Remarks	
7:45AM – 8:40AM breakfast, and welcor	Registration, ne	12:00PM 1:00PM – 3:00PM	Workshop adjourns Optional Field Trip:
8:40AM - 9:30AM	Plenary Talks	1	tour of Terrapin Beer
9:45AM - 10:45AM	Presentation Session 1		265 Newton Bridge Rd Athens, GA
11:00AM - 12:30PM	Presentation Session 2		30607. Ample free parking on site. Shuttles available.
12:15PM – 1:30PM	Lunch		
1:30PM – 2:15PM	Presentation Session 3	Please RSVP: https://forms.gle/i1WHAygGxHFTUcAw9	
2:30PM - 3:15PM	Presentation Session 4		
3:30PM - 5:30PM	Poster Session		
6:00PM – 9:00PM	Social and Reception DTWG Awards Silent Auction to Support DTWG Grants Program		

### **Detailed** Program

\*Student presenter, **\$**Student award nominee

#### Friday, October 28

All events at Athentic Brewing Company, 108 Park Avenue, Athens, GA 30601. Ample free parking on site. Shuttles available.

3:30PM – 5:30PM **DTWG Business Meeting** Meeting of the DTWG officers and board members. Open to all DTWG members.

6:00PM – 9:00PM Welcome Social Open to all Workshop registrants. An opportunity to relax and enjoy some local Athens beverages and food. Food provided by Cali-N-Titos and includes vegetarian options. Beer and seltzers including non-alcoholic options by Athentic Brewing.

#### Saturday, October 29

All events at Flinchum's Phoenix, 650 Phoenix Road, Athens, GA 30605. Ample free parking on site. Shuttles available.

#### 8:40AM – 9:30AM Plenary

8:40 Welcome John Maerz, DTWG Junior Co-Chair
9:00 System-wide change of southeastern US mudflats driven by an invasive ecosystem engineer Jeb Byers
9:30 Break

#### 9:45AM – 10:45AM Presentation Session 1 – Habitat and Movement

Session Chair: John Maerz

- 9:45 Home range and movement patterns of diamondback terrapins at four sites across the northern Gulf of Mexico Daniel Catizone, Melissa Price, Travis Thomas, Margaret Lamont
- 10:00 Use of a Radio Telemetry Receiver Grid to Study Movements and Habitat Use of Female Diamondback Terrapins (*Malaclemys terrapin*) in Southern New Jersey Brian Williamson, Amanda Lyons, Lisa Ferguson

- 10:15 "If You Build It, They Will Come": Nest Site Enhancement and Hatcheries as a Means of Creating More Suitable Nesting Habitat for Diamondback Terrapins in Coastal NJ John Wnek, Michele Budd, Ben Wurst, Kathy Lacey, Tony and Sandi Kosinski, Leslee Ganss, Ray Fisk
- 10:30 Drivers of Spatiotemporal Distribution Patterns of a Range Edge Population of Diamondback Terrapins \*Patricia Levasseur, Chris Sutherland
- 10:45 Break

#### 11:00AM – 12:30PM Presentation Session 2 – Conservation and Management I

Session Chair: Willem Roosenburg

- 11:00 Research and Conservation of Diamondback Terrapins (*Malaclemys terrapin*) in a Northern Gulf of Mexico Retrograding Deltaic System
   Michael J. Archer, Andrew J. Heaton, Jonathan L. Pitchford, Kimberly Cressman, Emmett Carstens, Iwo Gross
- 11:15 Examination of mating system dynamics in Mississippi diamond-backed terrapins (*Malaclemys terrapin pileata*)
   \*Iwo P. Gross, Matthew E. Wolak
- **\***11:30 **Evaluating and Improving Diamondback Terrapin Monitoring in Georgia** \*Danielle R. Bradke, Brian A. Crawford, John C. Maerz
- 11:45 The effects of commercial diets on growth in captive diamondback terrapins (*Malaclemys terrapin terrapin*) for Ideal Growth
   \*Courtney E. Parks, Bethany Holtz, Jonathan Fingerut, Scott McRobert, John Wnek
  - 12:00 **2022 Diamondback Terrapin** (*Malaclemys terrapin*) Conservation Program Season Update on the Downing-Musgrove Causeway Jekyll Island, Georgia Jamie Gamby, Michelle Kaylor, Davide Zalio, George Bancroft, Diana Rodas, Rebecca Fulle, Rachel Overmeyer, Terry Norton, Katie Dixon

#### 12:15PM – 1:30PM Catered Lunch

#### 1:30PM – 2:15PM Presentation Session 3 – Conservation and Management II

Session Chair: John Wnek

 1:30 The Orientation and Behavior of Hatchling Diamondback Terrapins (*Malaclemys terrapin*) in the Presence of Acoustic Cues
 \*Bethany Holtz, TriciaLyn Beamer, Scott McRobert 1:45 Foraging Ecology of the Mississippi Diamondback Terrapin (Malaclemys terrapin pileata) in the Northern Gulf of Mexico: A Technology Application of Stable Isotopes

\*Forrest Collins, Thane Wibbels

- 2:00 Developing Methodologies for Evaluating Sex Ratios in Diamondback Terrapin Populations \*Robby Brannum, Thane Wibbels, Ken Marion
- 2:15PM Break

2:30 – 3:15PM Presentation Session 4 – Conservation and Management III

Session Chair: John Wnek

- 2:30 Mitochondrial repeat haplotypes confirm natal homing in Georgia diamondback terrapin nesting populations
   Brian M. Shamblin, Michelle Kaylor, James Olsen, Kathryn S. Craven, Danielle R. Bradke, Allison Hardman, Jamie Gamby, Chantal Audran, Carissa Adams, Sarah Thompson, Davide Zailo, John C. Maerz
- 2:45 Diamond-backed Terrapin Bycatch Reduction and Management in the North Carolina Blue Crab Fishery
   \*Brett Wilson, Joe Facendola, Amanda Southwood Williard
  - 3:00 Searching for Alternatives to Bycatch Reduction Devices Randy Chambers, Kirk Havens, Madeline Reinsel, David Stanhope, Kory Angstadt, Lindsey Dillard

#### 3:30PM – 5:30 PM Poster Session, Happy Hour, and Silent Auction

 Evaluating the Detection of Diamond-backed Terrapin (*Malaclemys terrapin*) from an Unmanned Aerial System Using 3D Printed Models
 \*Rebecca J. Berzins, Rachel A. Katz, Sean C. Sterrett

**Remotely-sensed terps:** Assessing the accuracy of measuring diamond-backed terrapins (*Malaclemys terrapin*) from drone imagery Rebecca J. Berzins, Sean C. Sterrett

Population demographics of Diamondback Terrapin in Barataria Bay \*Claire Boudreaux, Timothy A. Clay

**Population Study of Diamondback Terrapins in Tidal Creek System in Virginia** \*Lindsey Dillard, Madeline Reinsel and Randy Chambers

**An Investigation of Diamondback Terrapin Eggs** \*Ashleigh Feltman, James Olsen, Kathryn S. Craven

### Conditions Osmotic Status of Diamond-backed Terrapins (*Malaclemys terrapin*) under Natural

\*Jasmine Pierre, Amanda Southwood Williard

Analysis of Nesting Statistics of Diamond-backed Terrapins on Skidaway Island, Georgia

\*C. Dare Scott, Danielle R. Bradke, John C. Maerz

### The mitochondrial repeat array: a revived method improves resolution of diamondback terrapin genetic structure

Brian M. Shamblin, J. Susanne Hauswaldt, Matthew J. Draud, Kristen M. Hart, Travis C. Glenn

Potential Effects of Climate Change on Habitat Use by the Diamondback Terrapin in South Texas

\*Laurynn J. Thompson-Torres, Garrett Guzoski, Aaron S. Baxter, and Loretta L. Battaglia

Effects of Bycatch Reduction Devices on Diamondback Terrapin and Blue Crab Catch in Southeast Louisiana

\*Shelby Truckenbrod, Claire Boudreaux, Timothy A. Clay

# Early results examining effectiveness of two styles of road mortality mitigation fencing: best practices for reducing diamondback terrapin (*Malaclemys terrapin*) mortality on coastal roadways

Brian Williamson, Lisa Ferguson

### Terrapin Town: A Community Effort in Conservation at Stafford Township, New Jersey, USA

John P, Wnek, Gregory Myhre, Matthew von der Haden, Joseph Kosa, Fran Kosa

The use of a wildlife exclusion fence to reduce nesting diamondback terrapin road mortality along a spatially explicit length of the Jekyll Island Downing Musgrove Causeway

David Zailo, Jamie Gamby, Michelle Kaylor, George Bancroft, Diana Rodas, Rebecca Fulle, Terry Norton, and Katie Dixon

#### 6:00PM – 9:00 PM Awards, Dinner Social, and Silent Auction

6:00 Awards

2022 Sornborger Citizen Conservation Award2022 Community Conservation Award2022 Terrapin Conservation AwardBest Student Oral and Poster Presentation Awards

7:00 Catered Dinner

#### Sunday, October 30

*Flinchum's Phoenix, 650 Phoenix Road, Athens, GA 30605. Ample free parking on site. Shuttles available.* 

#### 8:00 – 8:30AM Breakfast

#### 8:30AM – 9:30AM Presentation Session 5 – Head start and Community science

Session Chair: Amanda Williard

- 8:30 **Demographic comparison of Head-start vs. Natural Release Terrapin Hatchlings** Willem M Roosenburg, Julia Joos, David Jenkins, Alayna Tokash, Paul Converse
- 8:45 The First 25 Years: Headstarting Northern Diamondback Terrapin in Southern New Jersey Roger Wood, Lisa Ferguson
- 9:00 Tallying Terrapins Along the North Carolina Coast: Using Community Scientists to Inform Management Sarah A. Finn, Hope Sutton, Elizabeth Pinnix
- 9:15 Assessing the Status of Diamondback Terrapins (*Malaclemys terrapin*) in the Florida Panhandle Rick O'Connor
- 9:30 Break

#### 9:45AM – 11:15AM Presentation Session 5 – Head start and Community science

9:45AM Discussion Groups

Fisheries Bycatch, Moderator: Amanda Williard

Education and Outreach, Moderator: John Wnek

Population Surveys, Moderator: Sarah Finn

11:15AM Presentation of Discussion Group Findings, Concluding Remarks

#### 1:00 PM – 3:00PM Optional Field Trip: tour of Terrapin Beer Co.

265 Newton Bridge Rd Athens, GA 30607. Shuttle available upon request.

### Abstracts

#### Plenary Presentation

System-wide change of southeastern US mudflats driven by an invasive ecosystem engineer James E. Byers (1)

(1) Odum School of Ecology, University of Georgia, 140 East Green Street, Athens, GA 30602.

Invasive ecosystem engineers positively and negatively affect ecosystems by generating novel habitats that alter ecosystem properties and native species diversity and abundance. The Asian red seaweed Gracilaria vermiculophylla is an ecosystem engineer that invaded estuaries of the southeastern USA within the last few decades and now covers intertidal mudflats that were historically devoid of seaweeds. We hypothesized that G. vermiculophylla has been aided in its establishment through positive interactions with the native decorating tube worm, Diopatra cuprea. We further hypothesized that G. vermiculophylla would affect multiple ecosystem properties including secondary production and detrital and trophic food webs. We found that the native tube worms have established a conditional mutualism with G. vermiculophylla which has helped the seaweed to thrive. Furthermore, G. vermiculophylla is affecting many ecosystem level properties including shorebird foraging activity. Surveys of mudflats >1 ha revealed that two times more shorebirds occurred on mudflats with G. vermiculophylla than without it. This increased density was consistent across 7 of 8 bird species. At smaller spatial scales (200 m<sup>2</sup> and < 1 m<sup>2</sup>), experimental removals and additions of G. vermiculophylla and focal observations showed strong variation in behavioral responses to the seaweed among bird species-some preferentially foraged in bare mud, in G. vermiculophylla, or displayed no preference for either habitat. Thus, while the invasive ecosystem engineer on mudflats attracted greater numbers of birds, the bird species differed in behavioral responses at smaller spatial scales that affect their foraging. Our studies underscore that ecosystem engineers can profoundly affect the systems they invade, especially because of the novel structure, function, and environmental alteration they bring to a system.

KEY WORDS: Food web, Gracilaria vermiculophylla, Invasive species, Salt marsh

#### **Oral Presentations**

# Research and Conservation of Diamondback Terrapins (*Malaclemys terrapin*) in a Northern Gulf of Mexico Retrograding Deltaic System

Michael J. Archer (1), Andrew J. Heaton (1), Jonathan L. Pitchford (1), Kimberly Cressman (1), Emmett Carstens (1), and Iwo Gross (2)

- (1) Grand Bay National Estuarine Research Reserve, Mississippi Department of Marine Resources, 6005 Bayou Heron Road, Moss Point, MS 39562, USA;
- (2) Auburn University, Auburn, AL 36849, USA

The Grand Bay estuary is a retrograding deltaic system with rates of shoreline retreat ranging from 0.50 - 1.99 m/yr at Point Aux Chenes and 2.0 - 6.5 m/yr at Grand Battures shorelines, the two primary nesting beaches for diamondback terrapins (*Malaclemys terrapin*) within the Grand Bay National Estuarine Research Reserve. To better understand how terrapins are being impacted, we conducted weekly depredated nest surveys during the summer of 2021 and determined that Grand Battures, a previously high-density nesting area, had undergone extensive change in the past decade. The total number of nests found at Grand Battures decreased from 158 (2014) to 65 (2021) and the total available nesting area decreased from 2.34 km (2014) to 1.45 km (2021) of shoreline. During the summer of 2022, we developed a plan to survey nests once per month at these two locations and added a third site outside the Reserve along Graveline Bay. For these surveys, we collected precise elevation data, vegetation community information, and soil characteristics for each depredated nest encountered and for a randomly selected paired site. These data are being analyzed using logistic regression to determine preferred nest site characteristics. This information can be used to support future restoration initiatives, particularly those aimed at shoreline stabilization and/or beach creation, which is anticipated in several areas in Mississippi in the coming years. Finally, we also support external research that answers questions about terrapin ecology including a recent project that was focused on genetic sampling of hatchlings, nest protection, and a head start program for hatchlings. Collectively, these projects are helping us understand more about terrapin nesting ecology and will hopefully lead to improved conservation of this imperiled species in Mississippi.

KEYWORDS: Salt marsh, Erosion, Distribution, Abundance

#### Evaluating and Improving Diamondback Terrapin Monitoring in Georgia

\*Danielle R. Bradke (1), Brian A. Crawford (2), and John C. Maerz (1)

- (1) Warnell School of Forestry and Natural Resources, University of Georgia, 180 East Green Street, Athens, GA 30602, USA;
- (2) Compass Resource Management, 111 Water Street, Vancouver, BC V6B1A7, Canada

Developing effective monitoring is important for evaluating management and for tracking population changes over time. However, designing monitoring sensitive enough to inform management is challenging for elusive species that occupy difficult to access environments, like the diamondback terrapin. In Georgia, diamondback terrapins inhabit dendritic networks of tidal creeks within expansive salt marshes. Current monitoring in the state includes annual capturerecapture surveys at a small number of creeks. It is unknown if this approach is sensitive enough to detect population changes and, because it is time and labor intensive, this approach is only feasible at a relatively small spatial scale. Thus, our objectives were to 1) assess the ability of the current monitoring approach to detect changes in survival in relationship to proposed management and 2) explore the potential of unmarked count surveys to improve monitoring sensitivity and allow for state-wide monitoring in Georgia. To address objective 1, we used 12 years of capturerecapture data collected from two creeks near Jekyll Island, GA and a Bayesian robust-design model to estimate annual apparent survival, availability, and capture probability. Using this model, we simulated 100 capture-recapture datasets that could result if management actions increased survival by 20% and evaluated whether we could detect simulated survival increases. To address objective 2, we conducted repeated counts of terrapins between April – July 2021 and 2022 in 55 tidal creek sites spanning the Georgia coast. Results indicate that the current monitoring approach has low precision and may yield an inaccurate picture of what is occurring on a large scale (i.e., over many populations) in response to management. Future work will evaluate the ability of an integrated model that uses both count data and capture-recapture data to improve precision and detect population changes resulting from broad-scale conservation actions, such as management implemented by GA DNR.

KEYWORDS: Capture-recapture, Management, Monitoring, Population modeling

#### **Developing Methodologies for Evaluating Sex Ratios in Diamondback Terrapin Populations**

\*Robby Brannum (1), Thane Wibbels (1), and Ken Marion (1)

(1) College of Arts and Sciences, Biology Department, 1300, University Blvd, University of Alabama at Birmingham, Birmingham, AL 35233, USA

A variety of reptiles, including most turtles, possess temperature-dependent sex determination (TSD) in which the incubation temperature of the egg determines the sex of the hatchling. This form of sex determination has the potential to produce biased sex ratios, which can affect the reproductive ecology and conservation status of depleted populations. Therefore, it is advantageous to evaluate naturally occurring sex ratios and their impact in species with TSD. In the case of turtles, secondary sex characteristics are typically used to identify the sex of adults. However, it is often difficult or impossible to identify the sex of immature turtles. The purpose of the current study is to develop and evaluate methodologies for evaluating the sex ratio in the immature portion of diamondback terrapin populations. A variety of body morphometrics were recorded including tail length, head width, shell lengths, etc. from multiple age classes of "headstart" terrapins prior to their release into the wild. Additionally, blood samples were taken from each age class of terrapins and analyzed for testosterone concentrations. The results are providing insight on the chronology of secondary sexual characteristics development, and the use of testosterone levels as potential predictors of sex in immature diamondback terrapins. These findings have the potential of producing methodologies for estimating sex ratios in populations of diamondback terrapins throughout their range in the United States.

KEYWORDS: Sex ratios, Sexing technique, Juvenile, Testosterone

### Home range and movement patterns of diamondback terrapins at four sites across the northern Gulf of Mexico

Daniel Catizone (1), Melissa Price (1), Travis Thomas (2), and Margaret Lamont (1)

- Wetland and Aquatic Research Center, United State Geological Survey, 7920 NW 71<sup>st</sup> St, Gainesville, FL 32653, USA;
- (2) Nature Coast Biological Station, University of Florida, 552 1<sup>st</sup> St, Cedar Key, FL 32625, USA

Satellite telemetry has provided valuable information on sea turtle home ranges and movement patterns, but the relatively large tag size has restricted their use with smaller turtle species. Recent advances in technology however have allowed development of smaller tags which can provide similar movement information for small turtle species such as diamondback terrapins. From 2018 - 2021, 16 adult female diamondback terrapins were captured at 4 sites across the northern Gulf of Mexico ranging from Pensacola to Cedar Key, Florida and tracked using satellite telemetry. Tagged terrapins ranged in weight from 600 to 1200 g (mean 886 g) and straight plastron length of 135 to 173 mm (mean 154 mm). Captured individuals were satellite tagged between April and July each year and the deployed tags transmitted for a mean of 152 d (range of 38 to 268 d). All tags transmitted a total of 23,529 locations. Quality of tag locations varied among individuals with nearly 94% of tag transmissions from some individuals consisting of low-quality locations (classes A and B) whereas others produced fewer than 50% low quality locations. This may be due to individual variation in habitat use or time spent on land. Peaks in location quality surrounding the lowest (A and B) and highest (2 and 3) location classes most likely reflects the estuarine nature of terrapins, as a significant portion of their time is spent on land where tag antennae have direct access to satellites. Home range size and distances traveled of tagged terrapins are currently being calculated and will be included in the final presentation. These data highlight the value of satellite telemetry to diamondback terrapin studies but also illustrate the need for even smaller tags for use on juveniles and males.

KEYWORDS: Movement, Satellite telemetry

#### Searching for Alternatives to Bycatch Reduction Devices

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Commercial and recreational crabbers are resistant to using bycatch reduction devices (BRDs) that significantly reduce terrapin mortality. Despite having scant data to support their stance, crabbers have argued successfully to legislators and regulators that BRDs inhibit the entry of the largest blue crabs into commercial-style pots, and thus BRDs should not be required. Given the hesitancy of policymakers to enact BRD legislation, we sought an alternative to BRDs: rather than narrowing the pot funnels that keep terrapins out and to address the perception of inhibiting entry by large crabs, we considered leaving the funnels fully open, looking for ways to allow terrapins (but not crabs) to exit the pots once entered. Similar to the escape hatch used by sea turtles in the shrimp fishery, our goal was to design a "terrapin release hatch" using materials already used in pot construction. After a series of over 15 release designs built into pots and tested on terrapins in a swimming pool filled with brackish water, we discovered that terrapins were incredibly poor at figuring out how to open any release hatch. We therefore settled on a very simple, single opening in the top of a pot and covered with lengths of parallel elastic cord, forming false prison bars. In a short field trial, too few terrapins were captured to assess breakout potential. Legal crab catch and size from pots fitted with elastic bars, however, were similar to control pots without bars. Sublegal crab catch in pots with elastic bars was much lower than in control pots, suggesting the elastic bars perform similarly to cull rings. Additional field studies will be necessary next year. The elastic bars are simple, inexpensive, and may be a substitute for cull rings, thereby making their use potentially more attractive to crabbers, relative to the use of BRDs.

KEYWORDS: BRD, Alternative, Elastic Cord, Blue Crab Fishery

### Foraging Ecology of the Mississippi Diamondback Terrapin (*Malaclemys terrapin pileata*) in the Northern Gulf of Mexico: A Technology Application of Stable Isotopes

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The Mississippi Diamondback Terrapin, Malaclemys terrapin pileata, is a protected species whose numbers have greatly declined over the past century in the coastal areas of Alabama. One way to track foraging behaviors and habitat between the terrapins was to utilize stable isotope technology. By analyzing the stable isotopes of carbon ( $\delta^{13}$ C) and nitrogen ( $\delta^{15}$ N), we were able to better understand the foraging changes ( $\delta^{13}$ C), and trophic level and pollution changes ( $\delta^{15}$ N) that were exhibited by the terrapins in the Mississippi Sound. Adult female terrapins were obtained from their major nesting beach of Cedar Point Marsh, Alabama. Blood was taken as a way to determine most recent foraging shifts. Throughout the Mississippi Sound, prey items were obtained to create an isoscape. When terrapins were compared to their prey,  $\delta^{13}$ C values suggested that terrapins within the Mississippi Sound favored crustaceans and bivalves. Further, the Marsh Periwinkle has been well-documented as a favored forage item by terrapins. Periwinkles were collected from different marsh systems of the Mississippi Sound, while large samples were collected from two distinctly different locations (north and south ends) of Cedar Point Marsh, to determine isotopic uniqueness. Significant differences were found between  $\delta^{13}C$  and  $\delta^{15}N$  values of the marsh systems. The two different locations of Cedar Point Marsh revealed a significant difference in  $\delta^{15}N$ values. Stable isotopes have provided a revolutionary means to track terrapins foraging ecology to better conserve the species.

KEYWORDS: Terrapin, Foraging, Stable Isotopes, Carbon, Nitrogen

# Tallying Terrapins Along the North Carolina Coast: Using Community Scientists to Inform Management

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The Terrapin Tally, a citizen science project led by the NC Coastal Reserve and NC Wildlife Resources Commission, has collected head-count data around Masonboro Island Reserve since 2014. After a brief hiatus in 2020, the Terrapin Tally was expanded in 2021 to 10 new sites in addition to Masonboro Island, extending the project to 6 counties and a total of 39 mapped kayak routes. Several new partners were added to the project for coordinating terrapin head-count surveys and over 200 volunteers were trained in 2021. The goal of the project is to identify terrapin hot spots that may be important for further study and management. Using head-count surveys has proven to be an effective method of rapid-assessment of terrapin relative abundance. A recent amendment to the Blue Crab Fishery Management Plan allows the NC Division of Marine Fisheries to designate areas of high terrapin abundance as Diamondback Terrapin Management Areas (DTMAs), requiring bycatch reduction devices (BRDs) to be used on blue crab pots within these designated areas. Data from the Terrapin Tally was used to inform one of the first two pilot DTMAs, Masonboro Island DTMA. With continued annual surveys and expanded geographic coverage of the Terrapin Tally, we hope the data will be used to designate future DTMAs in North Carolina.

KEYWORDS: Relative abundance, Management, Community science

### 2022 Diamondback Terrapin (*Malaclemys terrapin*) Conservation Program Season Update on the Downing-Musgrove Causeway Jekyll Island, Georgia

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The Downing Musgrove Causeway (DMC) connects Jekyll Island to mainland Georgia and provides nesting habitat for diamondback terrapins. However, road mortality, nest predation, and to a potential lesser extent crabbing-pressures are contributing to expected population decline. The Jekyll Island Authority Georgia Sea Turtle Center (GSTC) and collaborators have been monitoring the diamondback terrapin population since 2007. The GSTC road surveys are performed primarily around diurnal high tides and begin in mid-April and extend until August. For the 2022 nesting season, we encountered 393 diamondback terrapins, 72% were alive and uninjured. Of those, 384 diamondback terrapins were nesting females, 74% were alive and uninjured at the time of the encounter. In addition to road surveys, the GSTC extracts eggs from deceased gravid terrapins and induces injured female terrapins with oxytocin +/- prostaglandins to lay their eggs. Eggs are then incubated, and a sample of animals are head-started for approximately nine months. From the 2022 season, the GSTC incubated 203 eggs and 155 have hatched as of late August. We encountered five nesting females that were previously incubated, hatched and released as part of our head-start efforts. We continue to use a variety of management tools to protect and promote the longevity of diamondback terrapin populations around Jekyll Island, GA.

KEYWORDS: Road mortality, Diamondback terrapin, Egg incubation

### Examination of mating system dynamics in Mississippi diamond-backed terrapins (*Malaclemys terrapin pileata*)

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In studies of sexually reproducing organisms, the paternal contribution to the population growth rate is often ignored on account of the assumption that males generally do not limit the reproductive success of female conspecifics. However, theoretical and empirical studies have shown how sexual conflict and skewed operational sex-ratios can shape mating systems and ultimately influence population extinction risk. Quantification of mating system dynamics should therefore be a priority when assessing the viability of depleted populations. Here we propose a study design which will produce the first estimates of the rate of multiple paternity-a key characteristic of mating systems—from a diamond-backed terrapin (Malaclemys terrapin pileata) meta-population along the Alabama-Mississippi coastline. Despite the cryptic nature of terrapin mating systems, the predictable nesting habits characteristic of all turtles provides us an opportunity to collect maternal and embryonic genetic material from emerged nests and thus infer parentage. Considering high rates of terrapin nest predation, however, we describe here a method to use depredated terrapin eggshells and their residues as a non-invasively sampled DNA source to acquire a more comprehensive sample of the population. Preliminary attempts have demonstrated our capability of extracting DNA from pond slider (Trachemys scripta) eggshells. Our next step is full implementation of our study procedures—DNA extraction, genotyping at informative SNP loci, and parentage assignment within a Bayesian framework-on depredated terrapin eggshells. We hope that this non-invasive genetic sampling approach will useful information regarding mating system structure at key terrapin nesting beaches along the northern Gulf of Mexico.

KEYWORDS: Multiple paternity, non-invasive genetic sampling, Parentage assignment

## The Orientation and Behavior of Hatchling Diamondback Terrapins (Malaclemys terrapin) in the Presence of Acoustic Cues

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Anthropogenic sounds have been found to be correlated with increased stress levels, threshold shifts in hearing, and behavioral changes in marine mammals and fish. The extent to which these sounds have similar impacts on turtles has not been studied. We examined the orientation behavior of hatchling diamondback terrapins (Malaclemys terrapin) in the presence of environmental acoustic cues normally present in their habitat, and anthropogenic sounds associated with human activity. Environmental sounds included marsh sounds (0-18 kHz) and avian predator (seagull) vocalizations (0-18 kHz). Anthropogenic sounds included vehicle traffic (0-20 kHz), human conversation (0-10 kHz), boat engines (0-10 kHz), music (0- 20 kHz), and airplane noise (0-50 kHz). Some anthropogenic sounds were examined at two volumes to simulate 'crowded' and 'less crowded' scenarios. When presented with two sound pressure levels of human conversation, hatchlings demonstrated a significant negative orientation at lower volumes (p=0.052), but did orient in any given direction at higher volumes (p=0.646). In the pressure of marsh sounds or seagull vocalizations, hatchlings showed no significant orientation pattern (p>0.05). When presented with music, boat engines, airplane noise, or two levels of vehicular traffic, hatchlings exhibited no orientation response (p>0.05). Our results demonstrate that hatchling diamondback terrapins respond to some acoustic cues. Further experiments should build on these findings and explore the physiological significance of hearing in diamondback terrapins.

KEYWORDS: Sound, Bioacoustics, Acoustic cues

# Drivers of Spatiotemporal Distribution Patterns of a Range Edge Population of Diamondback Terrapins

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Strategies implemented to meet conservation and management objectives are based largely on knowing the number and distribution of individuals in a population and how these change over time. However, population assessments, particularly for diamondback terrapins, are financially and logistically intensive, and tend to be limited in geographic scope and often only snapshots in time, which poses uncertainty in how those assessments represent the broader landscape. In this study, we leverage the efficient head count survey methodology of Levasseur et. al (2019) that can be spatially and temporally replicated to explore species-habitat associates and how these relationships change through time within a season to predict spatiotemporal distribution and abundance patterns of diamondback terrapins in Wellfleet Bay. Initial investigations using true abundance models demonstrated lack of fit due to evidence of non-independence in the count data of 5 repeated counts per survey. Reducing the data to counts 1 and 5 only and using an occupancy framework worked well. We found proportion of saltmarsh habitat and sheltered sites to positively influence occurrence. We also found a strong temporal influence, where occupancy probability at any given site within the bay was lowest in May and October and highest in July. Although informative on their own, we took the independent spatial and temporal effects one step further and created a 2-dimensional spatiotemporal predictive surface. From here, occupancy can be predicted at any point in space and in any point in time, which provides a more informative lens on how diamondback terrapin occupancy shifts through space and time in Wellfleet Bay. This work also prompts the need for further investigations on how to address nonindependence of counts in the visual head count survey design to accurately estimate abundance.

KEYWORDS: Diamondback terrapin; Population monitoring; Spatiotemporal variation; Occupancy; Visual head count

# Assessing the Status of Diamondback Terrapins (*Malaclemys terrapin*) in the Florida Panhandle

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Diamondback terrapins (*Malaclemys terrapin*) are the only resident brackish water turtles in the U.S. and live in coastal marshes and mangroves from Massachusetts to Texas. The animal has been studied throughout most of its range but there are large data gaps from the Florida panhandle. To begin to fill some of these, Florida Sea Grant began a citizen science project in 2007. Each year trained volunteers monitor nesting activity by visiting known nesting locations once a week. Tracks, depredated nests, and active nests are logged and grouped into 16-day periods to help determine relative abundance. Thirty-minute head counts are also conducted to determine relative abundance. Throughout the season there are efforts to capture individuals either by nets or incidental take by hand. Standard metrics are collected from captured individuals including carapace length and width, plastron length, sex and mass of the individuals. They are marked using the marginal scute notching method as well as given PIT tags. Tissue samples are collected for genetic analysis to determine the range of the two subspecies found within the region. This presentation will give an update on the work and information obtained by these volunteers.

KEYWORDS: Citizen science, Florida panhandle

### The effects of commercial diets on growth of captive diamondback terrapins (*Malaclemys terrapin terrapin*) for ideal growth

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In their natural, coastal estuary habitat, northern diamondback terrapins (Malaclemys terrapin terrapin) are exposed to many harsh environmental conditions. These include both natural and human-influenced threats, including sea level rise, salinity fluctuations, predators, crab pot drownings, boat and road mortalities, loss of nesting habitat and exploitation for the meat and pet trade. In response to these threats to terrapin populations, conservation efforts ranging from the creation of new nesting grounds, mark- recapture studies, boating regulations, and head-start programs have been initiated. In the head-start initiatives, hatchlings are raised in captivity for 9to-10 months, during which they are maintained in optimum conditions in hopes of growing them large enough to be successful when they are released into the wild. During the fall of 2021, thirty head-start hatchlings were used in a diet study to examine the effects of two commercial turtle foods, Reptomin (39% protein content) and Mazuri Balls (41% protein content), on health and growth. The hatchlings were divided into groups and measured amounts of food were provided ad libidum, Monday-Friday. Weight and carapace length were measured biweekly. At the end of the twelve-week study, turtles in the Mazuri Balls group were significantly larger than turtles in the Reptomin group, in terms of weight (Mazuri: 88.31 +/- 6.073 g.; Reptomin: 64.75 +/- 2.135 g., p = 0.008, two-tailed t-test), but not in terms of carapace length (Mazuri: 38.88 + 3.009 mm.; Reptomin:  $43.19 \pm -1.333$  mm., p = 0.192, two-tailed t-test). These results suggest that the Mazuri diet may have advantages in producing larger turtles for release in head-start programs, although longer-term studies still need to be completed.

#### Demographic comparison of Head-start vs. Natural Release Terrapin Hatchlings

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We conducted a multi-year demographic study to evaluate the life history difference that may occur by head-starting. We released more than 3000 head-starts over 17 years and more than 16,000 natural release hatchlings over 20 years on the Poplar Island Ecosystem Restoration Project. All hatchlings were marked with coded wire tags prior to release and the head-starts were marked with PIT tags. Additionally, all wild hatchlings were cohort notched to determine age upon recapture. All head-starts were reared in K-12 classrooms throughout Maryland, USA. Trapping using fyke nets, crab pots, and other non-lethal techniques was done from mid-May through early August every field season since 2008. We compare demographic parameters of these two groups including age of first reproduction, effect of size at release on survival, and stage specific survival. Head-starting accelerates age of first reproduction by 2-3 years initiated by accelerated growth during their first winter. However, size of head-starts at release does not influence recapture probability. Finally, we will analyze survivorship differences between the head-start and natural release hatchling groups. We will interpret our results analyzing the effectiveness of head-starting as a management tool to restore and supplement terrapin populations that have declined.

### Mitochondrial repeat haplotypes confirm natal homing in Georgia diamondback terrapin nesting populations

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Diamondback terrapin mark-recapture studies have documented strong fidelity to nesting and foraging sites. However, previous genetic analyses have typically failed to detect structure at local scales, possibly due to cryptic dispersal or male-mediated gene flow. Georgia terrapins have not been genetically analyzed, but foraging aggregations spanning 100 km of the South Carolina coast were not differentiated based on nuclear microsatellite allele frequencies. We tested for structure among Georgia populations by comparing maternally inherited mitochondrial repeat haplotype frequencies for females that nested in 2021 on the Tybee Island Causeway (n = 66), on Terrapin Point golf course on Skidaway Island (n = 99), and on the Jekyll Island Causeway (n = 237). These sites are separated by approximately 20 to 115 km. We collected scute drill shavings or cloacal swabs from living females and salvaged tail snips from road mortalities. We sequenced a microsatellite repeat array in the mitochondrial control region. Variation in 'AT' and 'ATTAT' repeats yielded 156 haplotypes. Haplotype diversity was high at all sites, ranging from 0.87 to 0.98. The three nesting aggregations shared few haplotypes and were strongly differentiated with respect to pairwise FST values and exact tests. We tested for hierarchical structure at Terrapin Point golf course by comparing haplotype frequencies for females nesting at hole three (n = 27) and those nesting on the southern tip of the island (n = 72), approximately 2 km distant. Haplotype frequencies were significantly different at this scale ( $F_{ST} = 0.0817$ , p < 0.00001), with only seven of 33 haplotypes shared, confirming fine-scale natal homing by most females. Future work will add complimentary nuclear markers to characterize relatedness and quantify natal homing versus dispersal within and among sites. This mitochondrial repeat marker holds promise for resolving structure and connectivity between nesting and foraging sites at local scales.

KEYWORDS: Mitochondrial Microsatellite, Population structure, Genetic structure

## Use of a Radio Telemetry Receiver Grid to Study Movements and Habitat Use of Female Diamondback Terrapins (*Malaclemys terrapin*) in Southern New Jersey

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Movements and habitat use of Northern Diamondback Terrapins (Malaclemys terrapin terrapin) can be difficult to examine due to limitations of standard telemetry technology in a salt marsh environment. In 2021, we tested a new approach to track terrapin locations using Cellular Tracking Technologies' Powertag radio transmitters to better understand terrapin movements and habitat use in a tidal salt marsh in southern New Jersey. We captured and attached radio transmitters to 60 nesting terrapins. Terrapins were divided into two groups based on capture location to assess differential risk of road mortality to the population. We detected radio signals using a grid of 33 stationary receiver nodes spaced 100 meters apart throughout the study site. We triangulated terrapin locations based on the relationship between strength of the radio signal received by each node and distance. We then used these triangulated locations to generate Kernel Density Estimates (KDEs) of terrapin activity areas using the AdehabitatHR package in R with likelihood cross validation and least-squares cross validation to derive smoothing factors. Preliminary results suggest female terrapins spend more time in salt pannes during the nesting period than previously understood, and seasonally inhabit tidal creeks close to nesting areas between subsequent nesting attempts, sometimes remaining near the nesting area for several weeks. In addition, terrapins captured in closer proximity to the road may experience elevated risk; however, terrapins from both groups occasionally interacted with the road. Results of this work will improve our understanding of terrapin habitat use and movements and help inform conservation efforts focused on the species locally and range wide.

KEYWORDS: Radio Telemetry, Movements, Home Range, Habitat Use

# Diamond-backed Terrapin Bycatch Reduction and Management in the North Carolina Blue Crab Fishery

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The Diamond-backed terrapin (Malaclemys terrapin) is listed as a species of "special concern" by the North Carolina Wildlife Resources Commission (NCWRC), and a report submitted by the Scientific Council on Amphibians and Reptiles concluded that incidental bycatch in crab pots is the most serious threat to terrapins in North Carolina and throughout their range. Efforts to reduce terrapin bycatch by installing bycatch reduction devices (BRDs) to funnel openings on crab pots have typically been met with strong resistance by crabbers due to perceived reductions in blue crab (Callinectes sapidus) catch rates and sizes. In May 2020, The North Carolina Division of Marine Fisheries (NCDMF) and Marine Fisheries Commission (NCMFC) designated Diamond-backed Terrapin Management Areas (DTMAs) at Masonboro Island and Bald Head Island. The use of NCDMF-approved BRDs is required for crab pots fished within these DTMAs. While this regulatory measure has been taken, NCDMF acknowledged the need to explore alternative gear modifications that effectively exclude terrapins while minimizing impacts to target species catch. North Carolina crabbers have proposed new gear modifications, referred to as reinforced funnel designs (RFD) and narrow funnel designs (NFD) that narrow the funnel entry without the need for a BRD fitted over the funnel opening. Fisheries-independent trials were conducted assess the efficacy of these novel industry sourced gear modifications at excluding terrapins and examine the impacts of these proposed technologies on crab catch rates and sizes. Pots were deployed in a triplicate design at sites of high terrapin and blue crab spatial overlap across southeastern North Carolina. A total of 65 terrapins were captured from May to September 2021. Preliminary data suggests that the NFD (74% bycatch reduction) effectively excludes terrapins without statistically significant reductions in catch rate or size of legal blue crabs. Additional field trials and statistical analyses will be conducted in Spring 2022.

KEYWORDS: Bycatch reduction device, Gear modification, Fisheries management

#### "If You Build It, They Will Come": Nest Site Enhancement and Hatcheries as a Means of Creating More Suitable Nesting Habitat for Diamondback Terrapins in Coastal NJ

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Anthropogenic impacts to adult female turtles have significant negative impacts for future populations. Along coastal New Jersey, diamondback terrapins (Malaclemys terrapin), an estuarine species, nest in upland shoreline areas. Some of these areas include roadways that bisect terrapin habitat. As a result, nesting female terrapins are prone to road mortality caused by motor vehicles. In some areas, increasing sea level rise coupled with coastal flooding can negatively impact terrapin nesting areas. In response to these threats, terrapin nest site enhancement projects have been implemented to provide safer, suitable nesting areas. The key aspect to the success of nest site enhancement is the strategic placement of nesting substrate and subsequent monitoring efforts. In some locations, such as along the Barnegat Bay shoreline – "Turtle Gardens" have been installed on both public and private properties providing alternate nesting areas for female terrapins in locations with high population densities. Many of these nest site enhancement projects in NJ have been conducted over the past five years, and their effectiveness is still being monitored. We established a raised bed hatchery in 2022 that is a new concept in hatcheries to reduce the risk of flooded ground nesting areas, reduce predation and can amend location. We've demonstrated higher hatch success in the raised bed hatchery than in ground hatchery at Long Beach Island, NJ. Most projects along coastal NJ have demonstrated some initial success resulting from the increase of nesting female terrapins selecting these sites, and reduction of road encounters. We feel that nest site enhancement projects can be applied to other turtle species in other areas that may have similar problems with road mortality and loss of nesting habitat.

KEYWORDS: Nest site enhancement, Road mortality, Sea level rise

## The First 25 Years: Headstarting Northern Diamondback Terrapin in Southern New Jersey

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A novel program to headstart diamondback terrapins (*Malaclemys terrapin terrapin*) formed in 1997 in Cape May County, New Jersey, where a large number of nesting terrapins are killed on roads each year. Several early advancements resulted in a program and marked population of terrapins that continues to contribute to terrapin conservation in southern New Jersey. Among these are regular patrols of the roads, removal of undamaged eggs from the carcasses, and the implementation of methods to consistently headstart terrapins to over 6.3 cm straight carapace length. Eggs are incubated at 30° C to produce female hatchlings that are headstarted for 10 months and microchipped before release to the marsh. Over 3,000 headstarted terrapins have been released through the program. Community members, visitors, and schoolchildren participate in the terrapin releases, creating opportunity for active engagement in conservation. Hundreds of undergraduate student interns and early career professionals have participated the program, from monitoring roads, collecting eggs, and caring for hatchlings, offering valuable hands-on learning opportunities.

KEYWORDS: Headstart, Conservation

#### Poster Presentations

## Evaluating the Detection of Diamond-backed Terrapin (*Malaclemys terrapin*) from an Unmanned Aerial System Using 3D Printed Models

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Diamond-backed Terrapin (Malaclemys terrapin; DT) is a brackish-adapted turtle species in North America and a concern of state biologists for potential population declines. The specific habitat needs of DT presents challenges for traditional monitoring approaches, yet their biology and behavior, including seasonal aggregations and time spent at the water surface, presents an opportunity for using novel approaches for estimation. Unlike traditional approaches, drones offer a non-invasive and potentially unbiased sampling method with the added advantage of committing data to virtual memory. However, we know little about how drones detect DT or influence behavior; therefore, a sampling approach should determine a height detectability threshold while also maximizing distance from DT to decrease disturbance. In this study, we experimentally evaluate DT detection by drones according to drone height, DT size, independent observers, and habitat complexity. We used 3D printed DT shells in three biologically realistic sizes; small (juvenile), medium (male), and large (female). We randomly selected numbers of different DT sizes into trial sets. For each experimental trial, we set 3D printed DT in a standardized sampling arena and flew the drone from 18 to 60m above the arena, taking standardized images at 5m intervals. Then, images were presented randomly to independent observers, who identified and marked DT of various sizes from randomly drawn images using the program iTag. Unsurprisingly, we found that drone height and DT size were important factors for accurately counting DT in trials sets. We also expected that habitat complexity would influence the ability of observers to accurately count DT but, surprisingly, the presence of glare appeared to be a confounding variable, which influenced observer accuracy.

KEYWORDS: Herpetofauna sampling, Remote sensing, Unmanned aerial system, Wildlife monitoring

### Remotely-sensed terps: Assessing the accuracy of measuring diamond-backed terrapins (*Malaclemys terrapin*) from drone imagery

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Diamond-backed terrapin (Malaclemys terrapin; DT) is the only brackish-adapted turtle in North America and a species of greatest conservation need throughout its range. The biology of DT, including seasonal breeding aggregations, presents a temporally- and geographically-constrained opportunity for transforming the way terrapins are monitored with novel methods, which may be attractive to wildlife managers, who often are resource limited. However, measuring organisms accurately from drone imagery is a novel method, so our goal of this study was to assess accuracy of measurements taken from experimental 3D-printed and real DT in drone imagery. Using the ground sampling distance (GSD; e.g. size of each pixel in the image), we first independently tested our method on 3D-printed DT of known size. Then, we tested this method on a known population of DT. We flew a drone (27m height) over a large breeding aggregation of DT in Wellfleet Bay, Wellfleet, MA in May 2019. Individual images were combined into an orthomosaic image. We used the program ImageJ to measure DT by standardizing a scale of measurement using the GSD. Measurements of maximum carapace length were restricted to DT laying flat at the surface of the water. All measurements of 3D-printed DT were within 10mm of actual size (average error = large (9mm), medium (3.5mm), small (5mm)). We were able to measure 53% of the total DT in images (N = 97). DT ranged in length from 96.7mm to 195.9mm. 25.5% of DT were in a medium size class (121.5mm - 133.9mm). We compared size class distributions of those measured from drone imagery to long-term capture mark recapture data from Wellfleet Bay. Our results are encouraging; we were able to measure DT from drone images with high accuracy which overlapped with measurements taken using traditional methods.

KEYWORDS: Drones, Sampling, Unmanned Aerial Systems, Wildlife monitoring

#### Population demographics of Diamondback Terrapin in Barataria Bay

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Long-term Diamondback Terrapin studies have been implemented in many coastal Atlantic states to assess the size and stability of terrapin populations, but much is still unknown in under-studied areas. Louisiana potentially holds the largest percentage of available terrapin habitat within the species' range, but no long-term population surveys have been conducted in the state. To begin to assess the population status of terrapin in Louisiana, we are conducting a mark-recapture study within the Barataria Estuary of Southeast Louisiana. Sampling for our study has relied on the use of un-baited fyke nets within small tidal channels. For each terrapin captured, the age, sex, shell dimensions, head width, and weight were recorded. Prior to release, each was given a unique shell notch ID and passive integrated transponder tag. Along with our sampling data from 2021 and 2022, we used LDWF data from 2012-2014 to estimate the key population parameters of survival and abundance. We used linear models in the statistical program R to compare CPUE amongst months. Survival from 2014-2021 slightly decreased compared to 2012-2013 estimates, and abundance estimates for 2021 increased from 2013 estimates. CPUE varied throughout the year, with peaks occurring during the months of March, June, and July. Survey's will continue in 2023 and future work will begin to evaluate morphological measurements in respect to crab trapping pressure and latitudinal clines. The results of this study will add to our knowledge of Diamondback Terrapin populations in the state of Louisiana and provide robust, long-term data to support future conservation.

KEYWORDS: Survival, Abundance, CPUE, Salt marsh, Tidal channels

#### Population Study of Diamondback Terrapins in Tidal Creek System in Virginia

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We completed a mark and recapture study to estimate the population and distribution of Diamondback Terrapins (Malaclemys terrapin) in Felgates Creek, a tributary of the York River sub-estuary of Chesapeake Bay in southeastern Virginia. We set 15 unbaited blue crab traps, five each at three locations separated by a total distance of ~1350m along the main creek channel. These traps were standard 60 cm by 60 cm by 60 cm commercial-style traps without bycatch reduction devices (BRD), but fitted with 150-cm "chimneys" of coated poultry netting to allow trapped terrapins access to air. The traps were checked four days a week 15 June through 29 July 2022. Each terrapin captured was notched along their right scutes with a unique number using a base two system and notched along left scutes to denote capture site location. We had188 total captures (CPUE = 0.52 terrapins/trap/day), of which 34 were recaptures (most at the same site of capture); there was no terrapin mortality. The sex ratio was 3:1 male to female and sizes ranged from 5.2-16.8 cm in carapace width, 9.1-22.6 cm in carapace length, and 2.5-9.7 cm in shell height. We then used the Schnabel mark and recapture method to estimate the population at 431 terrapins with a 95% confidence interval between 312 and 617. A prior study from 2009 used similar sampling and calculation methods and estimated the Felgates Creek population between 102 and 186 terrapins. Relative to 2009, the current population appears to have tripled in the last 13 years. Felgates Creek is located on federal naval base property where recreational and commercial crabbing are forbidden. Coastal Dept of Defense installations with terrapin habitat could be home to important source populations of terrapins for estuaries that otherwise are under intense crabbing pressure with the associated bycatch mortality of terrapins.

KEYWORDS: Virginia, Population, Tidal Creek, Mark and Recapture

### An Investigation of Diamondback Terrapin Eggs

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The goal of this study is to investigate the embryonic development of fully incubated unhatched diamondback terrapin eggs. A population of diamondback terrapins on Skidaway Island, GA lay their eggs in the sandtraps of the Terrapin Point golf course. Volunteers collect the eggs and move them to outdoor nest boxes to complete the 60 days of incubation. When hatching season has ended, the volunteers dug up the nests and collected the unhatched eggs. These eggs were preserved in 70% ethanol and brought to the lab at Georgia Southern University. The eggs in this study are from the 2021 and 2022 nesting seasons. The individual eggs were dissected and investigated for any evidence of embryonic development. For each egg, the stage of development was determined and any possible deformities were noted. After all the data is collected, the rate of deformities and the average stage of development will be determined.

KEYWORDS: Embryos, Development, Unhatched eggs

### Osmotic Status of Diamond-backed Terrapins (*Malaclemys terrapin*) under Natural Conditions

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Diamond-backed terrapins are exposed to a broad range of salinities within their estuarine habitats, ranging from brackish water to full strength sea water. Terrapins must regulate water loss and salt ingestion if they are to maintain osmotic homeostasis under highly variable salinity conditions. The majority of experiments to understand how this species osmoregulates have taken place under controlled laboratory conditions or semi-natural conditions. The goal of my research is to investigate the osmotic status of wild-caught terrapins from multiple sites in the lower Cape Fear River and Intracoastal Waterway of southeastern North Carolina to better understand the osmoregulatory strategies of this species under natural conditions. Blood samples were collected from 150 terrapins that were captured in salinities ranging from 9-39 psu. To date, a subset of 40 samples from across the broad range of salinities have been analyzed for blood osmolality, organic osmolytes (urea, glucose) and inorganic ions (Na+, Cl-). Statistical models will be used evaluate the effects of environmental salinity, temperature, precipitation, and body size on terrapin osmotic status. Adjustments to maintain body fluid homeostasis or locate suitable habitat under variable salinity conditions may affect terrapin energy budgets, with potential implications for terrapin growth rates, body size, and reproduction rates. The results from this experiment will contribute to assessments of terrapin resilience when exposed to altered salinity profiles due to changes in coastal land use (i.e. urbanization, channel dredging) and rising sea level and salt intrusion associated with climate change.

KEYWORDS: Salinity, Osmotic Status, Blood Biochemistry

#### Analysis of Nesting Statistics of Diamond-backed Terrapins on Skidaway Island, Georgia

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One of the primary mechanisms to evaluate the status of terrapin populations and determine the effectiveness of management actions is the use of population viability models. Such models depend on the quality of demographic data such as survival and fecundity, which are often not known for some populations and therefore "borrowed" from other studies or estimated by expert opinion. For example, recent population viability analyses to estimate the status and management effects on terrapins in Georgia assume based on the literature that terrapins nest - on average twice per year and lay approximately 7 eggs per clutch. However, there are anecdotal reports that nesting frequency may be higher which suggests that current population viability estimates are pessimistic. We used 7 years of citizen science data from the Skidaway Audubon Diamondback Terrapin Project including 5 years of individual nesting histories of diamond-backed terrapins nesting on Skidaway Island, to describe the naïve frequency of nesting event per female per year. While the mean number of observed nesting crawls per year per female was 2.10, 31.95% of females were observed nesting 3 or more times in a single year with a maximum of 6 nesting events in a single season. The distribution of days between nesting events showed a peak interval between nesting events of 16 days but a strong right skew that indicates a high likelihood that many nesting events are not observed and therefore the true mean number of nesting events per female per year is significantly greater than the naïve estimate. These observations indicate that current fecundity estimates for diamond-backed terrapins in Georgia are likely too low and models are underestimating population growth and persistence. The next phase of this project will develop a model of the likely number of nesting events per female per year to better inform population models.

KEYWORDS: Citizen Science, Fecundity, Nesting, Population Viability Models

### The mitochondrial repeat array: a revived method improves resolution of diamondback terrapin genetic structure

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Genetic analyses of diamondback terrapins have detected weaker structure than expected given strong site fidelity identified via mark-recapture. Cryptic dispersal, historical translocations, and male-biased gene flow may contribute to this pattern. Maternally inherited mitochondrial DNA markers could improve resolution of population processes, but nucleotide diversity is low, offering limited variation. A mitochondrial array consisting of alternating 'AT' and 'ATTAT' repeats offers promise of a highly variable marker for characterizing genetic structure and tracking dispersal. However, heteroplasmy, the presence of multiple repeat variants (haplotypes) within some individuals, presents potential challenges for its application. We compared repeat haplotypes between 26 mothers and 439 offspring from Oyster Bay, New York using Sanger sequencing to characterize heteroplasmy and inheritance. We further tested the utility of the mitochondrial repeat marker for resolving fine-scale structure by comparing two North Carolina foraging aggregations not differentiated with respect to nuclear microsatellites: North River (n = 22) and Davis (n = 46), approximately 25 marsh km distant. For heteroplasmic sequences, we called the most common haplotype based on relative peak heights. Heteroplasmy was visually detected in 53 of 465 (11%) Oyster Bay individuals. Haplotype comparisons within maternal families yielded 19 (4%) offspring haplotype calls that mismatched their mother's predominant haplotype. In all cases, the mismatch arose via inheritance of a minor maternal haplotype as the predominant offspring haplotype. Heteroplasmy was apparent in 13 of 68 (19%) North Carolina individuals. North Carolina samples yielded 37 haplotypes, only 4 of which were shared between sites. Haplotype frequencies for North Carolina sites were significantly different (F<sub>ST</sub> = 0.0228, p = 0.018; exact test p < 0.0001), suggesting constrained connectivity. Despite challenges posed by heteroplasmy, the mitochondrial repeat appears robust as a population marker (with appropriate caveats) for testing hypotheses of natal homing and dispersal.

KEYWORDS: Inheritance, Haplotype diversity, Mitochondrial bottleneck, Genetic structure, Dispersal

### Potential Effects of Climate Change on Habitat Use by the Diamondback Terrapin in South Texas

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Diamondback terrapin (*Malaclemys terrapin*) is the only turtle species in North America that lives in brackish ecosystems, but it also requires other habitats, such as beaches for successful nesting above mean high tide, to meet all of its life stage requirements. Based on climate change models, coastal habitats are expected to shrink or to shift landward with sea level rise (SLR). Terrapins, considered an excellent sentinel of climate change, must keep pace or face major population declines. At the southwestern edge of its distribution in coastal south Texas, terrapin ecology has been little studied and no work has been conducted to predict effects of climate warming and SLR on habitat availability and usage. Data from other parts of the turtle's range cannot be substituted because this region is warmer and drier, and hypersaline conditions are common. With SLR, we expect that gravid females will find fewer suitable nesting sites, nest inundation rates will increase, hatchlings will be increasingly exposed to elevated salinity conditions detrimental to their growth and survival, and less area of brackish habitat will be available. Focused research is planned to identify the most vulnerable habitat locations in this part of the terrapin's range and to inform conservation efforts that will support south Texas terrapin populations into the future.

KEYWORDS: Climate change, Nesting, Salinity, Sea level rise

### Effects of Bycatch Reduction Devices on Diamondback Terrapin and Blue Crab Catch in Southeast Louisiana

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Mortality in Blue Crab traps poses a significant threat to Diamondback Terrapins throughout their range. Bycatch reduction devices (BRDs) can effectively reduce terrapin bycatch without affecting crab catch and are required for crabbing industries in many states. Louisiana, the state with the largest commercial Blue Crab industry, however, has no BRD requirements. Our objectives for this study were to (1) determine how crab traps fitted with BRDs affect both Diamondback Terrapin capture and legal Blue Crab catch and (2) identify locations where terrapin capture in crab traps is more likely to occur in commercially fished habitats of Louisiana. We set crab traps fitted with wooden, plastic, or no BRDs in open water and tidal channel locations for 48 hours monthly from May to September 2022. Morphometric data for all captured Blue Crabs and Diamondback Terrapin were recorded. Using linear models, we found that open water locations and plastic BRDs have a negative effect on legal crab catch. Terrapin capture only occurred in tidal channels. Furthermore, only crab traps without BRDs captured terrapin. Both plastic and wooden BRDs equally prevented Diamondback Terrapin capture. We plan to continue sampling during the 2023 season. Our findings can inform management decisions regarding BRD regulations and terrapin conservation in the state.

KEYWORDS: Crab trap, Fisheries, Trap mortality, Management

# Early results examining effectiveness of two styles of road mortality mitigation fencing: best practices for reducing diamondback terrapin (*Malaclemys terrapin*) mortality on coastal roadways

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Road mortality is a major conservation issue, particularly for slower moving wildlife such as turtles. Female Diamondback Terrapins (Malaclemys terrapin) travel overland in search of nesting habitat, and in more developed areas, such as southern New Jersey, this behavior puts them at risk to vehicles. In some areas, an average of over 500 adult female terrapins are killed on roads annually. Due to a suite of life history characteristics including delayed sexual maturity and naturally low juvenile survival rates, loss of adult females on roadways likely contributes to population declines of terrapins in these locations. Currently, in southern New Jersey, mitigation of terrapin road mortality frequently involves the use of corrugated tubing barriers laid near the roadside. While these are effective, they are not very durable in the long term and require annual maintenance of the fence material and surrounding vegetation to properly exclude turtles from the roadway. Along a section of road in Cape May County, New Jersey, we replaced a 150 m section of corrugated tubing with Animex semi-permanent fencing in Spring 2022. Fencing was only possible on one side of the road and so was installed with four one-way ramps (jumpouts) to prevent terrapins from being trapped in the roadway. We are currently monitoring the roadway to compare terrapin behavior, mortality, and crossing activity in this area and examining differences in effectiveness and durability of the material over time compared to corrugated tubing. Our preliminary results suggest a lower probability of encountering terrapins in the study area in 2022 than in 2019, prior to installation, and indicate that jumpouts are being used by terrapins. Currently, the fence appears to be durable and resilient to impacts of vegetation overgrowth. We will continue monitoring in 2023 to inform best practices to reduce terrapin mortality along coastal roadways.

KEYWORDS: Road Mortality, Road Mitigation

### Terrapin Town: A Community Effort and Conservation at Stafford Township, New Jersey, USA

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Diamondback terrapin nesting occurs in coastal estuarine upland areas across their range. Some of the nesting sites include developed properties as a result of increased housing communities along the East and Gulf coasts. Stafford Township, NJ, is one of the fastest growing communities along coastal New Jersey. In order to promote "terrapin awareness", the Stafford Township Green Team, Township Officials, Project Terrapin and a local school, the Marine Academy of Technology and Environmental Science (MATES) formed a partnership to help conserve terrapins and increase community involvement. Terrapin awareness was increased through road signs, lawn signs, and a citizen science terrapin sighting project in Mill Creek, Cedar Run, Mud City and Newell Avenue locations. A township podcast and a sign distribution program were conducted by Stafford Township to make the residents more aware of terrapin activity. A factsheet was also developed by MATES and distributed through the Green Team's outreach channels, which include the Township's Facebook account, tabling at events throughout the year in the Township and for distribution in the Township municipal buildings. Residents and schools participated in a lawn sign design contest over the winter months to promote "terrapin awareness". Stafford named the diamondback terrapin as their town animal in April 2022. Through these efforts, over 100 lawn signs were distributed and the citizen science sighting program galvanized communities throughout the town. We feel that similar efforts could employed by joining governing body officials, residents, conservationists, schools and scientists in other areas with terrapin activity to promote better awareness and enhance stewardship.

KEYWORDS: Terrapin conservation, Citizen science, Community involvement, Terrapin awareness

#### The use of a wildlife exclusion fence to reduce nesting diamondback terrapin road mortality along a spatially explicit length of the Jekyll Island Downing Musgrove Causeway

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Prior to the commencement of the 2022 diamondback terrapin nesting season on the Jekyll Island Causeway, the Georgia Sea Turtle Center (GSTC) partnered with ANIMEX and the Jekyll Island Foundation to install 1,000-feet of wildlife exclusion fencing to mitigate road mortality of nesting diamondback terrapins. During the first year of implementation, the fence dramatically reduced road crossing, road mortality, and negative human-wildlife interactions within the 1,000-foot road footprint it protected. During the 2022 season, encounters along the fence (n=132) comprised ~1/3 of all encounters along the Downing-Musgrove Causeway. Expected road mortality was reduced by over 80%. Nest predation by racoon was an issue but at comparable levels to adjacent areas of the causeway. This poster seeks to illustrate the design considerations, installation process, effectiveness, goals for future management, and solicit feedback from interested parties in diamondback terrapin conservation and management.

KEYWORDS: Wildlife exclusion, fencing, diamondback terrapin, road mortality

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