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A pilot-test of satellite telemetry tags to evaluate habitat use by horseshoe crab and diamondback terrapin in the Peconic Estuary

Final Report

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Background:

Horseshoe crabs (*Limulus polyphemus*) and diamondback terrapins (*Malaclemys terrapin*) are important species that utilize the intertidal and subtidal habitats within the Peconic Estuary (ASMFC, 2020; Bopp et al., 2019, Roosenburg, et al. 1999). Both of these species are affected by similar ecosystem stressors and are particularly vulnerable to the loss of these coastal habitats, which are essential for deposition of their eggs (ASMFC, 2020; Burger and Montevecchi, 1975; Feinberg and Burke, 2003; Lovich et al., 2001). Shoreline hardening, sea level rise, and dredging all present increasing challenges to species reliant on adequate access to beach habitat within the intertidal range or at higher elevations.

Both horseshoe crab and diamondback terrapin abundances within the Peconic Estuary are at low levels. In the latest review of horseshoe crab population status, the Atlantic States Marine Fisheries Commission (ASMFC) listed the status of horseshoe crabs in New York State as "poor," and data generated by the New York State Department of Conservation's (NYSDEC) annual juvenile finfish trawl survey has shown a dramatic decline in abundance of horseshoe crabs in the Peconic Estuary from 1987 to 2012 (Abruzzo, 2015; ASMFC, 2020). Additionally, Cornell Cooperative Extension (CCE) and NYSDEC's annual horseshoe crab survey indices of spawning activity indicate that spawning levels in the Peconic Estuary are the lowest of all estuaries in New York State (Sclafani et al., 2020). Both horseshoe crabs and diamondback terrapins are currently listed as "vulnerable" on the International Union for Conservation of Nature (IUCN) Redlist of Threatened Species, and diamondback terrapins are also considered a species of "special concern" in New York State. Furthermore, salt marsh habitats; a required habitat of diamondback terrapins, are also declining in New York State, and as a result local terrapin populations are also on the decline (R. Burke, Pers. Comm., Hofstra University).

Despite some annual spawning surveys, very little is known of the habitats that are used by horseshoe crabs and diamondback terrapins for nesting throughout the Peconic Estuary watershed, nor of the home ranges they require or their movement patterns. Having such information could help guide conservation policy for intertidal and beach habitats with respect to anthropogenic impacts, shoreline hardening and development, sea level rise, and other factors. Data showing where these species forage and overwinter within the estuary would also help inform protection efforts for these critical habitats (Lamont et al., 2023; Peconic Estuary Partnership 2020).

Although both horseshoe crabs and diamondback terrapins have previously been monitored using mark-recapture methods, VHF radio telemetry, and acoustic telemetry; each of these methods has its limitations (Feinberg and Burke, 2003; Roe et al., 2022; Butler, 2002). Argos satellite and GPS tags offer several advantages over other telemetry methodologies, including immediate transfer of data remotely, more frequent location fixes, and reliable location data once data-filtering techniques are applied, especially in the case of GPS satellite tags. Despite these advantages and until recently, the use of satellite telemetry in marine environments has been limited to larger-bodied wildlife such as cetaceans, sharks, and large sea turtles, as the tags have been too large and heavy for smaller marine animals (Roosenburg et al., 2019; Lamont et al. 2023). However, Argos satellite and GPS tags have improved greatly in recent years with respect to their size, weight, battery life, spatial accuracy, speed of data acquisition, and even the inclusion of additional environmental sensors in certain models (e.g. temperature, depth, etc.) that are capable of recording these measures while simultaneously tracking an animal's location. Hence, these modern tags are now suitable to apply to smaller-bodied aquatic species such as horseshoe crabs and diamondback terrapins, which were previously difficult, if not impossible, to study using these methodologies (Lamont et al., 2023). In addition, the FastGPS technologies offered by several telemetry companies not only offer increased spatial accuracy of typically less than 30 meters resolution (Argos tag readings are usually > 150 m), but also rapidly capture positions for animals that 'surface' very quickly. The FastGPS technology, however, can increase the weight of the tag and cost considerably more than an Argos-only satellite tag, so it is important to consider such tradeoffs with respect to the species of interest and their anticipated movements. These forms of satellite telemetry may be a useful approach to provide critical data about habitat use by both diamondback terrapins and horseshoe crabs, and may also have potential to extend to other species of concern in the future (Brousseau et al., 2004; Bopp et al., 2021).

The main goal of this pilot-study was to test the feasibility of using contemporary Argos based satellite telemetry tags on horseshoe crabs and diamondback terrapins to estimate their spatial habitat use in the Peconic Estuary. A secondary goal was to determine if the FastGPS marine tags could provide increased spatial resolution for horseshoe crab spawning. Due to the budget limitations of this mini-grant, we were only able to test 3 of the Lotek FastGPS tags. Since the tags only collect and transmit signals to the satellites when 'wet/dry' sensors are dry (e.g. 'surfacing' of an animal), we would expect the diamondback terrapins to have a more consistent transmission pattern since they routinely surface for beathing air. In contrast, horseshoe crabs will likely yield more limited data since they would potentially be exposed to air only when they spawn on the intertidal beaches, which is limited to the full and new moon periods from late April through June. While horseshoe crabs are expected to transmit less frequent data, it is anticipated that this reduced frequency of transmission will also conserve battery life (as discussed with Lotek and Wildlife Computers Inc. technical staff) so that we may be able to get data for up to 5 years (or more) when they return annually to spawn on beaches.

The tags used on diamondback terrapins, on the other hand, will have considerably shorter battery life (~160 days), given the higher frequency of satellite transmissions. In both cases, this pilot-scale test of satellite telemetry technology will determine the utility of Argos satellite and FastGPS tags to monitor the movement of these species within the Peconic Estuary. The results of this pilot-study supported the use of modern telemetry methods to provide a better understanding of these species' habitat use for nesting, foraging, and overwintering, as well as home range sizes and movement patterns.

Methods:

Various types of marine-based satellite and GPS tags with a wide range of technological capabilities were explored, and consultations with representatives from the manufacturers of these tags, including Lotek and Wildlife Computers Inc. (WCI), occurred in January and February 2024. These consultations included discussions of which types of tags would be most suitable for each of the species based on their size, morphology, physiology, and behavior; as well as discussions regarding the coordination of each company's online databases and interface with the Argos satellite platform. CCE staff also consulted Dr. Russell Burke of Hofstra University, who has had recent success with tagging diamondback terrapins in Jamaica Bay earlier in 2023 and 2024, and who partnered with us on this project. Dr. Burke's graduate student, Karissa Hough, also utilized and incorporated the data from this pep mini-grant project into her master's thesis research project. She has also agreed to allow us to include some of her maps of the diamondback terrapin spatial distributions and the interpretations of her analyses in this report. Meetings with Seatuck Environmental Association (Seatuck) were also conducted to establish a partnership for this project where Seatuck assisted with funding Argos satellite fees as matching funds.

In this study we elected to use the following two tags: 1) Wildlife Computer Spot 387 Argos based satellite tag (59 x 29 x 23 mm, 59 g) and 2) Lotek FastGPS F6G-276F (101 x 74 x 32 mm, 148 g). Due to budget limitations, the Lotek FastGPS tags were utilized only on the horseshoe crabs in this study, since they were anticipated to have a very low frequency of 'surfacing' to activate the dry sensor, and spend a shorter duration exposed to air, to receive and transmit data to the satellites (thus enabling rapid and accurate spatial estimates from the GPS satellites). In addition, they were also small enough in size and weight for placing on larger female horseshoe crabs.

Adult female horseshoe crabs (n=5, average prosomal width = 30.36 cm ± 1.15 cm) were collected by hand from beaches located at various points along the Peconic Estuary's coastline where the NY Horseshoe Crab Monitoring Network has established monitoring sites, including: South Harbor Road Park (SHR)- Southold, West Creek (WC)- Southold, Squires Pond (SQP)- Hampton Bays, and Northwest Harbor County Park (NWH)- East Hampton (Table 1, Figure 1). Satellite tags were attached to each animal's carapace using the methods and protocol established by WCI for attachment of satellite tags to sea turtles with marine epoxy, which experts at both companies agreed would also be applicable to horseshoe crabs (Wildlife Computers, 2024, Figure 2). After tag attachment, the horseshoe crabs were held overnight in tanks with flow through water (Peconic Estuary seawater) at CCE's Southold marine facility, the Suffolk County Marine Environmental Learning Center, and were released the following day (May 10, 2024) at the same locations from which they were collected (Table 1, Figure 1). Three horseshoe crabs were tagged with Lotek F6G-276F FastGPS tags and each released at Northwest Harbor County Park (NWH), West Creek (WC), and South Harbor Rd. Beaches (Table 1, Figure 1). Two additional crabs were tagged with the WCI SPOT-387 tags and were released at Squires Pond (SQP) and South Harbor Rd. beaches (Table 1, Figure 1).

Adult female diamondback terrapins (n=4, average carapace length 188 mm ± 19.5) were collected by hand in early June from Orient Beach State Park (OBSP), located on the eastern end of Long Island's North Fork, which borders the Peconic Estuary (Figures 1, 3). The Hofstra University and CCE teams attached the WCI SPOT-387 tags (n=4) using methods developed and tested by Dr. Burke, and the animals were released on the same day (June 11, 2024) at OBSP (Figures 1, 3, 4, Table 1). Due to budget constraints and potential size limitations of turtles (i.e. tag weight might have become an issue), we were unable to test Lotek FastGPS tags on terrapins at this time. Additionally, we elected to use the WCI SPOT tags for this pilot-study, based on the

Hofstra University team's previous successes with them in Jamaica Bay. They demonstrated that the SPOT-387 Argos tags were suitable for tagging large female terrapins, and had previously produced reliable data in an urban estuary. We also elected to use these tags in 2024 at Orient Beach State Park for data consistency and to potentially contrast these two locations for diamondback terrapin behaviors and spatial habitat use.

Once tagged, each animal's location and signal quality (i.e. location classes described below) was relayed via the Argos satellite system when the tag came into contact with air (i.e. the dry sensor was activated), which occurred when the animal either exited the water to nest in the intertidal zone beaches or further inland, or surfaced to breathe (in the case of diamondback terrapins). These tags also had the potential to indicate if a horseshoe crab animal was captured offshore by trawl nets, which did not occur during the duration of this project, but this may be an important consideration for future telemetry studies focused on these species.

Argos satellite data are automatically retrieved by a secure web server and stored in a cloud database for viewing, downloading, and processing at any time. The temporal and spatial data can be used to map habitat use as well as to provide a greater understanding of behavioral metrics such as activity, home range, and site fidelity. Data collected from the animals tagged during this project have been downloaded as a CSV file and processed in Excel for incorporation into R (R Core Team, 2023) and ArcGIS (Esri) for analysis.

Data Processing and Analysis:

The estimated error of each Argos location is broken down into seven location classes "LCs" (0, 1, 2, 3, A, B, Z). These depend on how many messages are received per satellite pass and, consequently, how accurately each location is estimated. LC3 is the most accurate, in which the actual location is estimated within a radius of typically < 250m. LC2 is between 250-500m, LC1 500-1500m, and LC0 >1500m. LCs A and B provide no accuracy estimation, however, they may still be useful in certain situations (Witt et al., 2010). LC Z is an invalid location and removed from all analyses. These class designations are ubiquitous across all tags that utilize the Argos satellite systems. Lotek FastGPS tags are equipped with a FastGPS technology that is capable of GPS quality accuracy (typically < 30 m), where they rapidly receive GPS transmissions to estimate the position, which is then relayed through the Argos system for access by the research team (Lotek, 2024).

Although Argos satellite tags sometimes have large error estimates, there are established techniques available to reliably identify and filter out unrealistic locations and to estimate the most probable locations with high confidence levels. Hough (2025) recently reviewed and tested several of these for diamondback terrapins including: using only the highest quality location class 3, boundary filters, state space models, and a combination of them (Hough 2025). If enough high-quality locations are acquired (LC 3 or FastGPS), these can be used independent of all other location estimates for analysis as well. Boundary filters can be applied using ArcGIS to identify physical boundaries or obstructions where it would be unrealistic for a tagged animal to cross or use as nesting or spawning habitat, including hardened shorelines, roads, buildings, etc. (Hough, 2025). Statistical methods such as state space models (SSMs) can also be used to reduce the uncertainty of observed locations and movements with large error estimates by calculating daily mean locations, which are a more reliable estimate of the animal's true location and movement patterns (Patterson et al., 2008). Hough (2025) used a combination of these techniques to calculate home range estimates for terrapins at OBSP. For instance, Hough (2025) applied the following three different analytical methods to determine the Home Ranges for terrapins at OBSP: 1) apply a SSM to unfiltered raw data, 2) apply a SSM to data filtered with a boundary filter, and 3) used only the LC 3 locations.

The SSM technique was applied only to diamondback terrapin location data in this project, as there were enough data points to apply this method due to the more frequent surfacing of the animals to breathe air. Horseshoe crabs, which do not surface to breathe, and had less data points available, so location data for this species was processed using a boundary filter method to remove unrealistic locations and qualitatively describe their positions. Home range estimates for the diamondback terrapins were calculated by Hough (2025) using AdeHabitatHR (Calenge, 2024) for minimum convex polygons (MCP) and kernel density estimators (KDE) that incorporate the 95% home range (where the animal spends 95% of its time) and 50% core use areas (where the animal spends 50% of its time feeding, resting, etc.).

Results:

Horseshoe Crabs:

Of the five horseshoe crabs tagged and released in 2024, only one received an additional location estimate again in 2024 (Squires Pond, WCI SPOT-837, Tag# 263465) following its release (Table 2, Figures 5 and 6). However, three of the five tagged horseshoe crabs received at least one additional location the following year during the 2025 spawning season (West Creek- Lotek Tag #263460), (Northwest harbor- Lotek Tag #263459) and (South Harbor Rd- WCI Tag #263464) (Table 2, Figures 5 and 7-9). One horseshoe crab (South Harbor Road- Lotek Tag #263458) did not receive any locations following release (Table 2). The crab released at Squires Pond (WCI Tag # 263465) only had one location class A position received, and if boundary filters were to be utilized, it would have been excluded as this location was not physically possible for a Horseshoe crab to access (Figures 5 and 6). The horseshoe crab that was captured and released at South Harbor Rd. (WCI, Tag # 263464) received 5 locations estimates in 2025, one each of LC A, B, 0, 2, 3 (Figure 7). These 5 locations were in relative close proximity of one another (<1500m radius), would not have been removed by a boundary filter, and were close to a sand spit coming off of Orient Beach State Park, which is plausible habitat for depositing eggs (Figure 5). Lotek tags (WC Tag # 263460 and NWH Tag # 263459) received locations with FastGPS technology and yielded high quality position estimates (Table 2, Figures 8 and 9).

Diamondback Terrapins:

All Diamondback terrapins received locations for several months following release (WCI Tag #s 263461-63, 263466), with one turtle being located again in 2025 (Tables 1, 3). The four terrapins received an average of 20.2 Argos position fixes per day over the summer of 2024 prior to filtering and was 16.7 fixes per day after applying a boundary filter (Hough, 2025). The location classes, however, varied considerably (Table 2), with many of them falling on land or in unrealistic locations, requiring additional filtering and modelling methods to estimate home ranges. The three location reduction techniques were then applied to the terrapin data prior to the home range analysis (Hough 2025). When using only LC 3 location fixes, 94% of positions were excluded due to LC 3 making up a small proportion (6%) of the dataset. This was, unfortunately, too restrictive of a method to use for estimating home ranges. In contrast, applying a boundary filter to OBSP removed 17.3% of the locations and was more suitable to use in combination with the SSM. Mean total distance traveled for three OBSP terrapins (June 20 - August 30, 2024) for unfiltered data was 69.6 km, and 64.8 km for data using a boundary filter. Average straight-line distance was 1.1 km for unfiltered and .98 km for boundary filtered data (Hough, 2025). Mean home range sizes from boundary filtered SSM locations were 6.7 km^2 (95% MCP), 14.6 km^2 (95% KDE-href), 8.7 km^2 (95% KDE-Least Squares Cross Validation (LSCV)), 3.7 km^2 (50% KDE-href), and 1.9 km^2 for 50% KDE-LSCV (Figures10-13) (Hough, 2025).

Discussion:

The results of this pilot study demonstrate that Argos satellite and GPS tags are suitable for tracking diamondback terrapins and horseshoe crabs, and that these methods may be useful for further research on these species and other important estuarine animals in the Peconic Estuary and regionally. Argos satellite and GPS tags offer significant advantages over other telemetry methods, since data is transmitted immediately via satellite and typically includes more location fixes than alternative methods that were favored in the past, such as VHF and acoustic telemetry (Lamont et al., 2023; Butler et al. 2002; Roosenburg et al., 1999). An increased number of location fixes allows for a more accurate estimation of home range size and displays occasional short-term movements, such as exploratory or nesting excursions, that other methods may not detect (Fujisaki et al., 2014; Christensen and Chow-Fraser, 2014). Other advantages of satellite tags include large datasets, the ability to monitor an animal through multiple seasons, the ability to monitor an animal's location even if it is not within its anticipated range, simultaneous environmental data collection (e.g. optional temperature and depth sensors), and immediate access to data without the need to expend time and resources retrieving the animal or downloading data from a receiver. Alternative telemetry methods that require physical retrieval of data or recapture of an animal also come with the risk of losing the data if the receiver, or tagged animal (e.g. archival), is lost or removed; a potentially costly problem that is avoided with satellite and FastGPS satellite tag technologies. Although Argos satellite tags do sometimes have large error estimates, there are established techniques available to reliably identify and filter out unrealistic locations and to estimate the most probable locations with high confidence levels, and such techniques were applied in this project to ensure the reliability of the data.

The horseshoe crab tagging location data, while much lower in frequency compared to the diamondback terrapin data (as expected), provided useful information on an interannual basis. Three of the five tags (2 FastGPS and 1 SPOT tag) that were released in May 2024 yielded additional locations in April and May 2025, as we hoped they would. Interestingly, all three of these interannual tag "recaptures" were observed to have estuary-level fidelity the following year when they emerged to spawn again. This is consistent with other acoustic telemetry studies in Moriches Bay, NY (Bopp et al. 2021) and in Deleware Bay (Smith et al. 2010) where a proportion of individuals displayed evidence of estuary-level site fidelity on an interannual basis and also partial-migration. The crab that was tagged and released in Northwest Harbor in 2024 was detected again in April 2025 just to the east and near Wood Tick Island, East Hampton. This individual showed nearby utilization of the beach from which it was initially captured and spawned in 2024 (~6 miles east). The horseshoe crab that was tagged and released in West Creek, Southold in 2024, was observed across the estuary near Little Sebonac Creek in Southampton in 2025 (~5 miles south), and the crab that was released at South Harbor Road in 2024 was relocated again in 2025 at Orient Beach State Park. Both of the higher location classes of the Argos-only SPOT tag (Wildlife Computers) and the FastGPS (Lotek), revealed the potential locations of where they were spawning in the Peconic Estuary. The FastGPS positions were particularly informative since they were associated with the highest level of accuracy (< 30 m). It will be interesting to see if any of these tags show relocations in future years, as one of the significant advantages of satellite tags over other telemetry methods (acoustic and radio tracking) is that they have the potential to be located anywhere when they come out of the water to spawn because they are not limited by the size of the receiver array. The animal's position could therefore be located in the same or different estuaries, and even if captured by the offshore commercial fishery (in the case of horseshoe crabs). Such important spatial ecology data could prove useful for both researchers and resource managers, as gaining an enhanced understanding of geographically and temporally widespread movement patterns would better inform conservation management decisions. GPS tags also have the added benefit of increased spatial resolution that allows for improved estimates of the actual spawning locations. The main limiting factor to a larger scale deployment of these advanced tags is their monetary cost. However, depending on the questions of interest and the labor associated with monitoring using these technologies, once capture and tagging is completed, costs may be lower over the long term compared to those of acoustic and radio telemetry methods. These require additional manual downloading from the receivers on a periodic basis, while Argos data is readily available for download from the desktop computer with an active Argos Satellite subscription.

All diamondback terrapins tagged in 2024 received location fixes for several months after release, with an average of 20.2 location fixes per day, and one terrapin was also located again in 2025 (Tables 1, 3). Despite the high frequency of location fixes, the SPOT satellite tags used on the terrapins in this study are often associated with a large measurement error radius, which often renders lower spatial resolution making it difficult to determine location specific behaviors in small geographic areas (Figure 14). This would explain the difference observed between data collected in OBSP (smaller bay) due to most locations falling within the small area of Long Beach Bay (~5km^2), compared to those in Jamaica Bay (~25km^2). Therefore, to determine fine-scale movement information in areas where animals are moving within a smaller geographical range, such as OBSP, tags with GPS specific capabilities may be necessary.

After examining the 2024 Argos data along with Hough's (2025) analyses on the performance of Argos based tags on diamondback terrapins, Cornell Cooperative Extension and Seatuck decided to combine additional outside resources in 2025 to purchase a smaller Lotek FastGPS tag (F6G-173A, 105x21x18mm, 51g) as a pilot-test of this technology. The FG6-173A could potentially be suitable for use on larger sized female diamondback terrapins as well. CCE's team attached the FastGPS tag to a female diamondback terrapin (1,000 grams) that was collected by hand and subsequently deployed on July 1, 2025 at Orient Beach State Park (OBSP, Figures 1, 3, 4). Preliminary data (July 2-August 4, 2025) from this tag showed 26% (164/620) of the locations having high quality GPS positions (<30 m) and 37% (229/620) receiving a location fix with an accuracy estimation (location class 0, 1, 2, 3 or GPS), demonstrating the utility and improved accuracy of novel GPS technologies when used in tandem with Argos satellite positioning (Figures 15-18). The use of FastGPS tags also clearly demonstrated the swimming movements of the terrapin after spending a few days in Orient Park and Narrow River Creek, to move over to Coecles Harbor in Shelter Island, where it has remained for about another month. The fine-scale movements between the different habitats can be clearly seen in Coecles Harbor as well, where the terrapin seems to switch between salt marsh creeks, open water habitats and eelgrass beds. The FastGPS technology deployed here could be very useful in examining the fine-scale movements of turtles utilizing the OBSP area, possibly showing preferences for very specific foraging habitats, such as eelgrass beds (Figures 19 and 20), which are a habitat of concern in the Peconic Estuary waters surrounding OBSP and worthy of future research.

As telemetry technologies continue to improve, lighter, smaller, and more geospatially accurate tags are continually being developed that may prove to be even more useful for marine species that only surface briefly to breathe or come ashore occasionally to nest. These advanced telemetry methods may be especially useful for studying aspects of spatial ecology such as the use of specific habitats for foraging, protection from predators, nesting, and overwintering. Such high resolution spatial data increases the precision of determining an animal’s home range, nesting site fidelity, the distances traveled between different habitats, and their relationships with environmental covariates (e.g. tides, temperature, season, etc.). Such information will be extremely important for conservation management planning and policies in the estuary including the presence of shoreline hardening, coastal development that can alter an animal’s behavior or habitat use preferences or patterns and physical or auditory anthropogenic disturbances. It is worth exploring these modern technologies further to advance understanding and conservation of these and other important estuarine species and their habitats.

This pilot telemetry project has expanded upon Peconic Estuary Partnership's (PEP) previous wildlife monitoring efforts through the Long Island Wildlife Monitoring Network by testing whether satellite and GPS telemetry technologies are viable methods for tracking the movements of these key species when they come ashore to nest, or when they surface to breathe within offshore habitats, in the case of diamondback terrapins. Argos satellite and GPS telemetry monitoring methodologies have the potential to provide important information on the use of specific offshore habitats such as eelgrass beds for foraging and protection, which could, in turn, lead to enhanced protections for these ecologically important areas (Lamont 2025). The preliminary data acquired from this project will form the platform for future telemetry tagging studies that may yield high resolution data on habitat use by these important species across many temporal and spatial scales, improving assessment and prioritization of unknown and preferred habitats for further monitoring, restoration, and protection. In particular, by focusing future efforts with FastGPS tags on a species such as diamondback terrapin, PEP and partnering organizations will have the potential to use a charismatic keystone species that is a year-round estuarine resident to promote an estuary-wide habitat protection and restoration campaign around.

Appendix

Tables and Figures

Table 1. Summary of the horseshoe crab (HSC) and Diamondback terrapin (DBT)), Argos tag ID, brand of tag, location of release (and capture), size measurements (carapace and plastron length for DBT, prosomal width for HSC), date of release, and date of last location collected.

Species	Tag ID	Brand	Release Location	Carapace Length DBT Prosomal Width HSC (cm)	Plastron Length DBT (cm)	Release Date	Date of Last Location
HSC	263464	WLC	South Harbor Rd., Southold	32.5	N/A	5/10/24	5/31/25
HSC	263465	WLC	Squires Pond, Hampton Bays	30	N/A	5/10/24	5/24/24
HSC	263458	Lotek	South Harbor Rd., Southold	28.5	N/A	5/10/24	-
HSC	263459	Lotek	Northwest Harbor, East Hampton	29.7	N/A	5/10/24	5/8/25
HSC	263460	Lotek	West Creek, Southold	31.1	N/A	5/10/24	5/9/25
DBT	263461	WLC	OBSP, Orient Point	20.5	19	6/11/24	10/18/24
DBT	263462	WLC	OBSP, Orient Point	16.3	15.8	6/11/24	4/27/25
DBT	263463	WLC	OBSP, Orient Point	18.2	17.1	6/11/24	8/28/24
DBT	263466	WLC	OBSP, Orient Point	20.2	17.8	6/11/24	12/18/24

Table 2. Number of locations collected for each location class. WLC tags were not equipped with GPS technology. Location classes go in increasing quality from ,0,1,2,3, and GPS. Location classes A and B have no accuracy radius.

Species	Brand	Release Location	Tag ID	Location Classes							
				A	B	0	1	2	3	GPS	Total
HSC	WLC	South Harbor Rd., Southold	263464	1	1	1	0	1	1	N/A	5
HSC	WLC	Squires Pond, Hampton Bays	263465	1	0	0	0	0	0	N/A	1
HSC	Lotek	South Harbor Rd., Southold	263458	0	0	0	0	0	0	0	0
HSC	Lotek	Northwest Harbor, East Hampton	263459	0	0	0	0	0	0	2	2
HSC	Lotek	West Creek, Southold	263460	0	0	0	0	0	0	2	2
DBT	WLC	OBSP, Orient Point	263461	304	1283	143	197	72	140	N/A	2139
DBT	WLC	OBSP, Orient Point	263462	261	1202	142	133	94	115	N/A	1947
DBT	WLC	OBSP, Orient Point	263463	250	1003	104	142	65	102	N/A	1666
DBT	WLC	OBSP, Orient Point	263466	343	1479	175	180	93	139	N/A	2409

Species	Brand	Release Location	Tag ID	2024 Location	2025 Location
HSC	WLC	South Harbor Rd., Southold	263464	No	Yes
HSC	WLC	Squires Pond, Hampton Bays	263465	Yes	No
HSC	Lotek	South Harbor Rd., Southold	263458	No	No
HSC	Lotek	Northwest Harbor, East Hampton	263459	No	Yes
HSC	Lotek	West Creek, Southold	263460	No	Yes
DBT	WLC	OBSP, Orient Point	263461	Yes	No
DBT	WLC	OBSP, Orient Point	263462	Yes	Yes
DBT	WLC	OBSP, Orient Point	263463	Yes	No
DBT	WLC	OBSP, Orient Point	263466	Yes	No

Table 3. Interannual tag detections showing whether each tag had at least one successful location in 2024 or 2025.

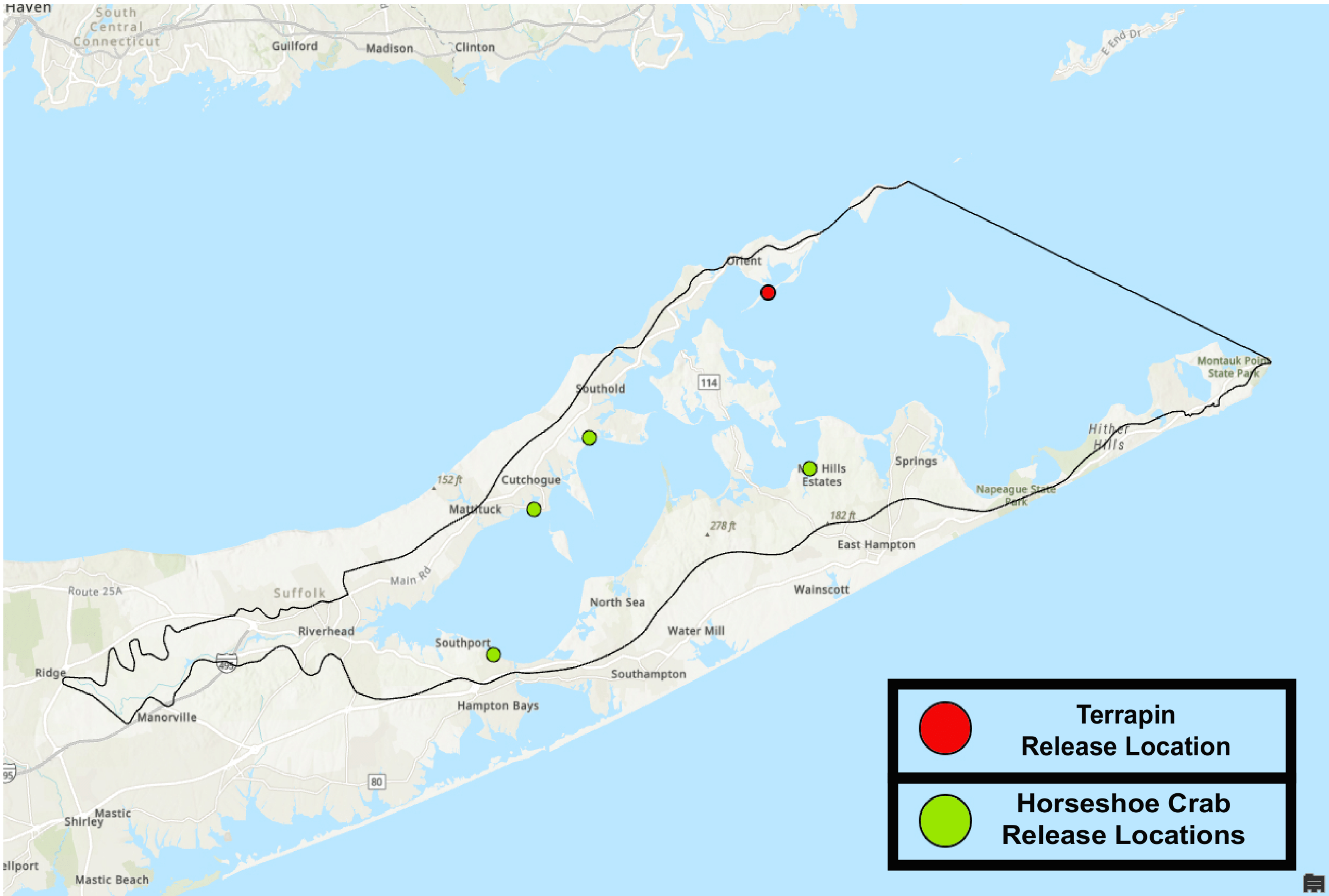


Figure 1. Map showing release locations for Horseshoe crabs (green) and Diamondback terrapins (red) within the Peconic Estuary. Terrapins were captured and release from the same location in 2024 and 2025.

Figure 2. Photos showing Horseshoe Crabs with satellite tags: Wildlife Computers Inc. SPOT-387 tag (left) and Lotek FastGPS tag (right).

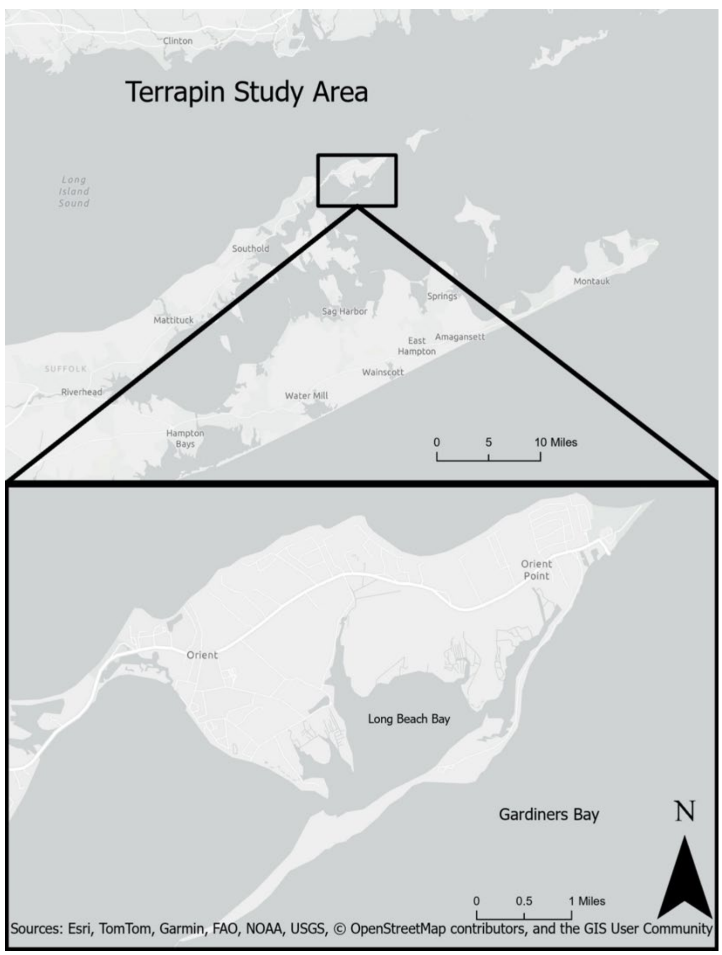


Figure 3. Map showing the area of study for Diamondback terrapins released in 2024.

Figure 4. Photos showing satellite tags on Diamondback terrapins: WCI SPOT-387 tags used on all terrapins in 2024 (left) and Lotek FastGPS tag used on one turtle in 2025.

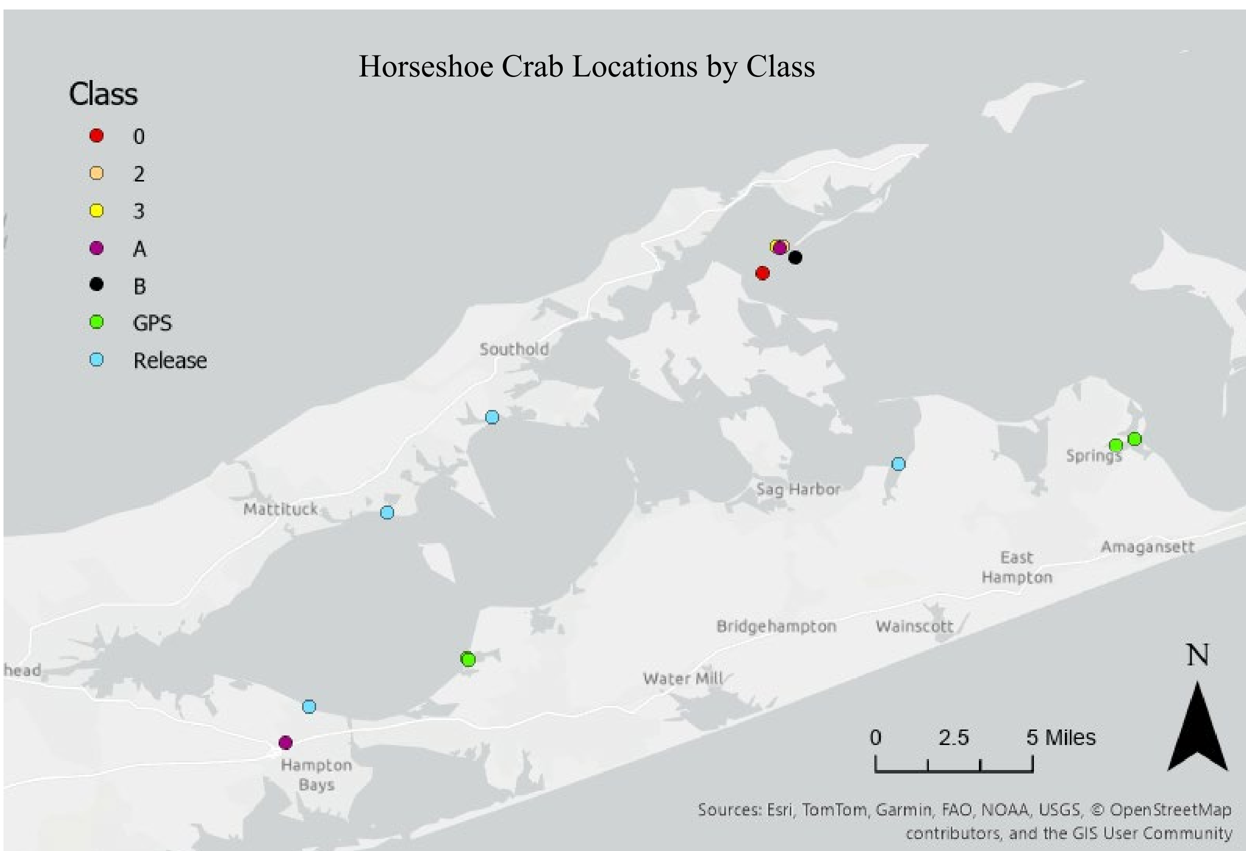


Figure 5. Map showing all locations collected from Horseshoe Crabs in 2024 and 2025, designated by location class. Initial release locations are marked in blue. Note: GPS locations (green) are from Lotek FastGPS series tags only.

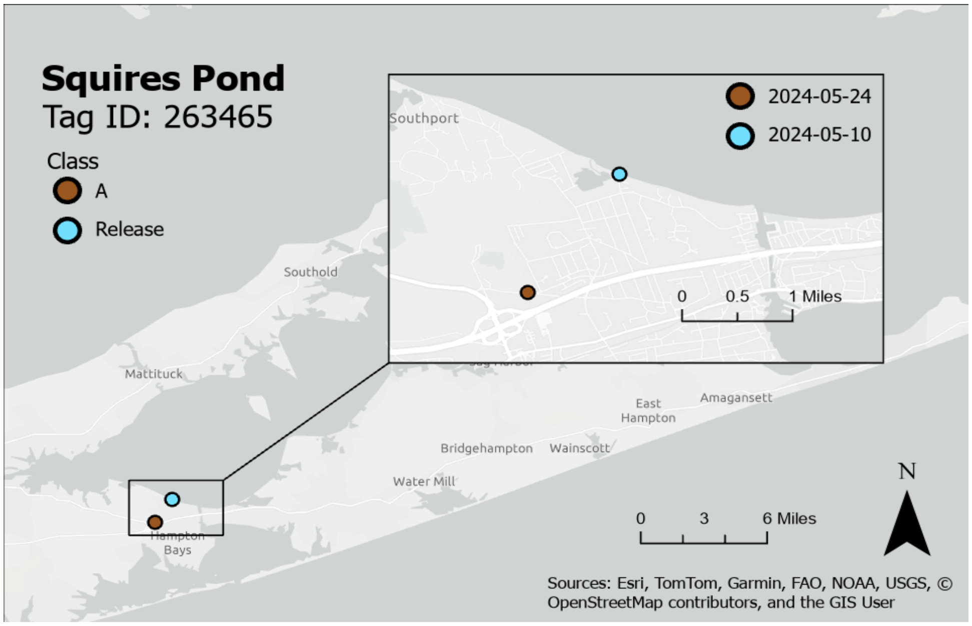


Figure 6. Map showing location received for the horseshoe crab captured and released at Squires Pond, Hampton Bays. This was a WLC Spot-387 tag. This was a Class A location and would have failed a boundary filter as an unrealistic location.

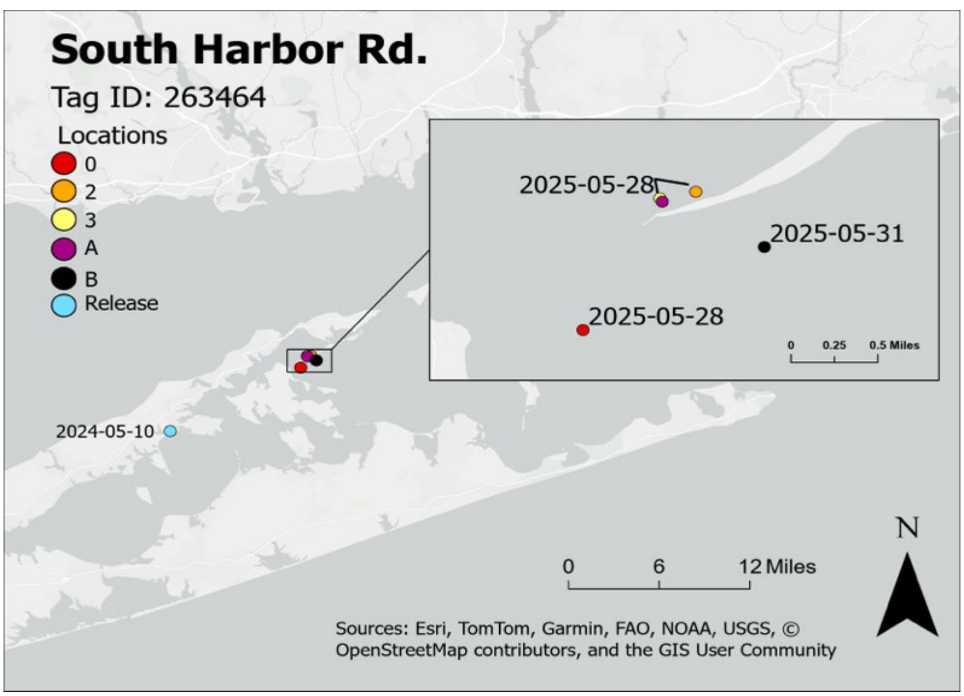


Figure 7. Map of locations received from the horseshoe crab captured and released at South Harbor Rd., Southold. This was a WLC SPOT-387 tag

Figure 8. Map of locations received for the horseshoe crab captured and released at Northwest Harbor, East Hampton. This was a Lotek FG6-276F FastGPS tag.

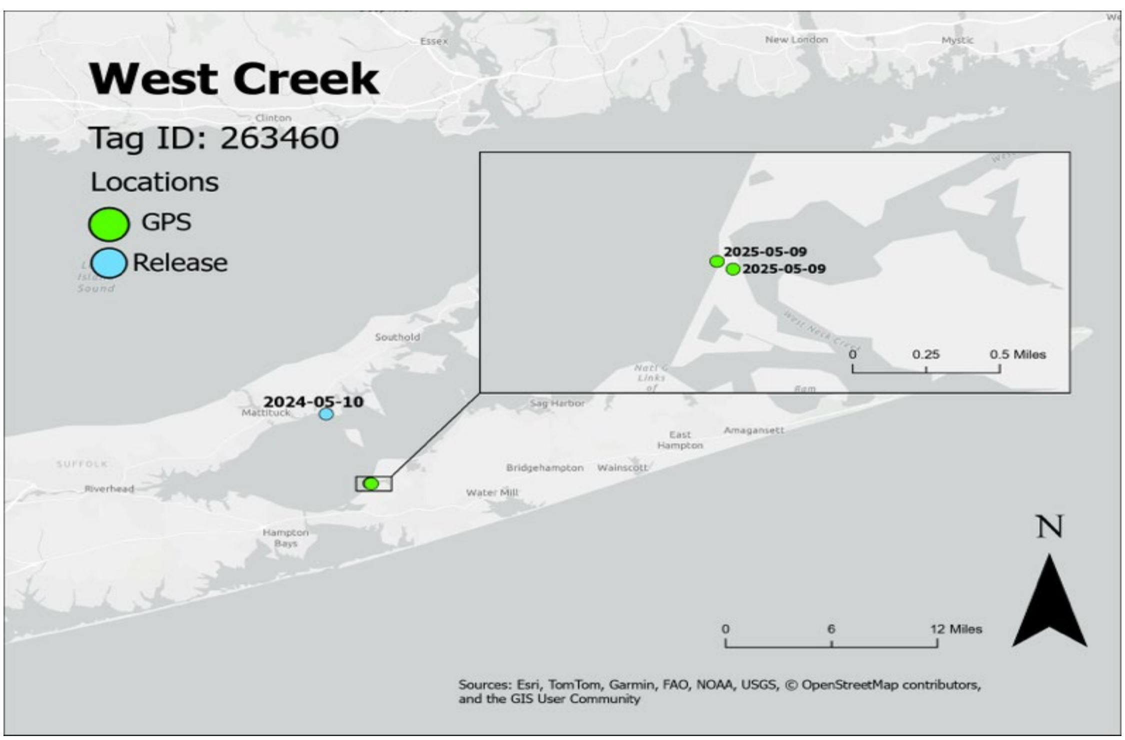
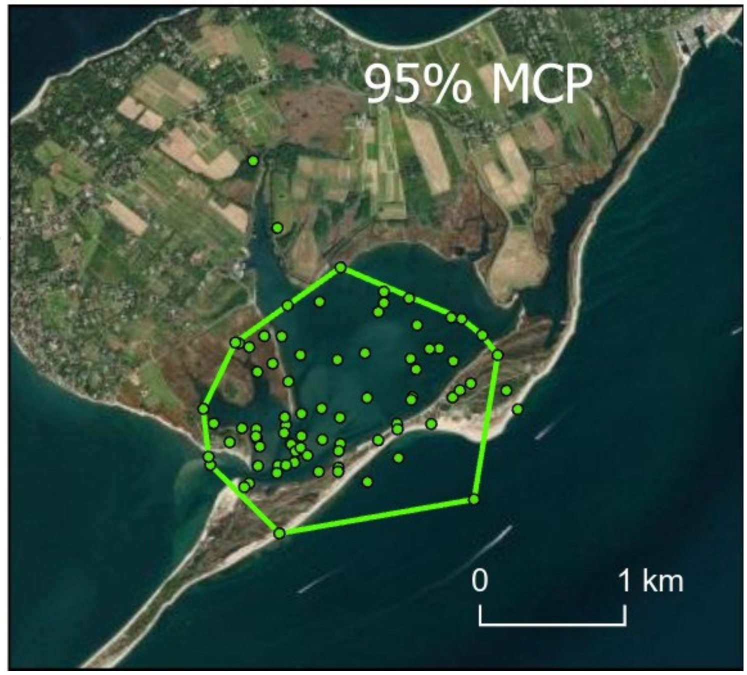
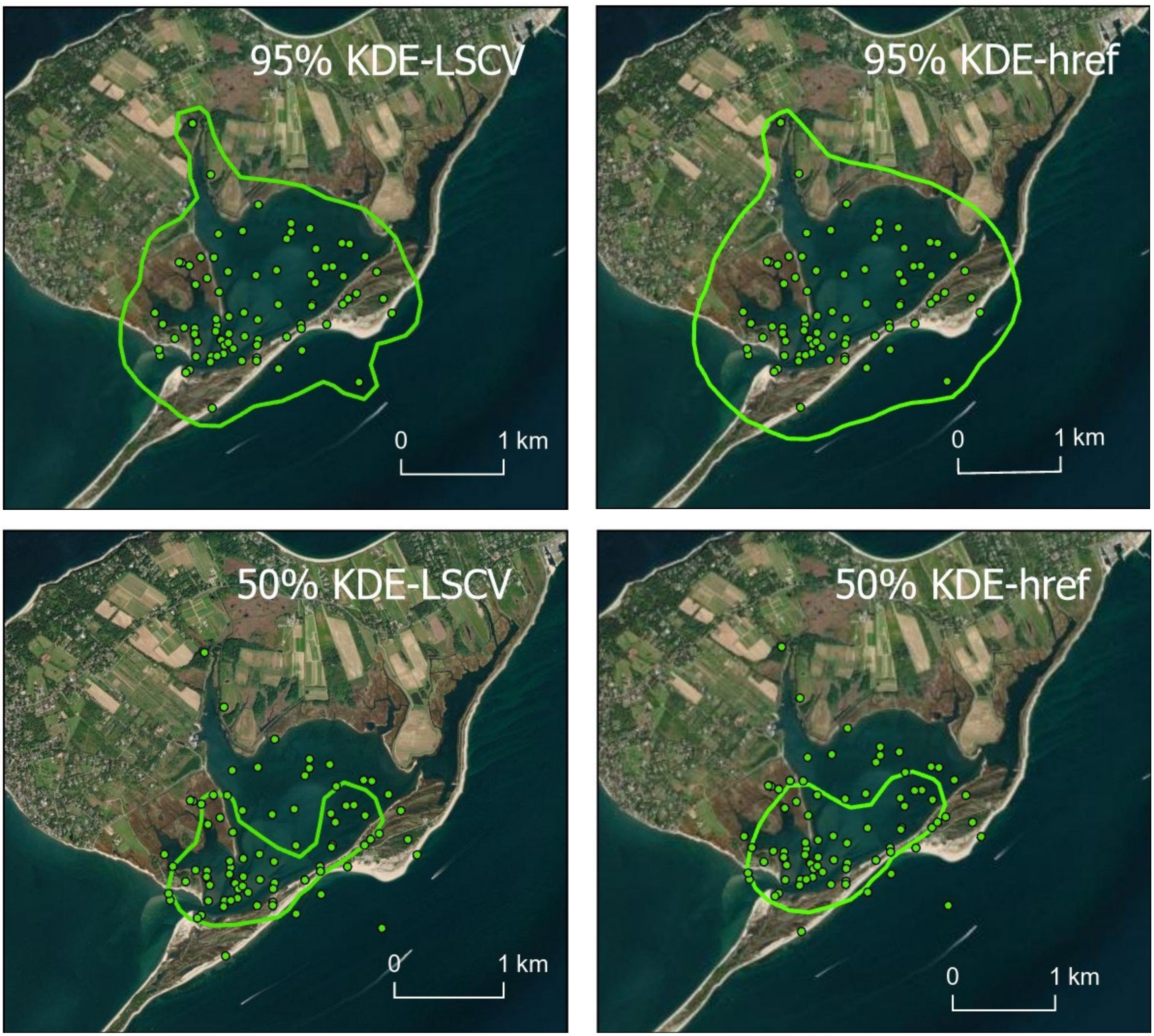


Figure 9. Map of locations received for the horseshoe Crab captured and released at West Creek, Southold. This was a Lotek FG6-276F FastGPS tag.

Figure 10. Home Range maps for terrapin tag ID 263461. Boundary Filtered SSM Daily Mean Locations for 95% MCP, 95% KDE-LSCV, 95% KDE-HREF, 50% KDE-LSCV, 50% KDE-href.





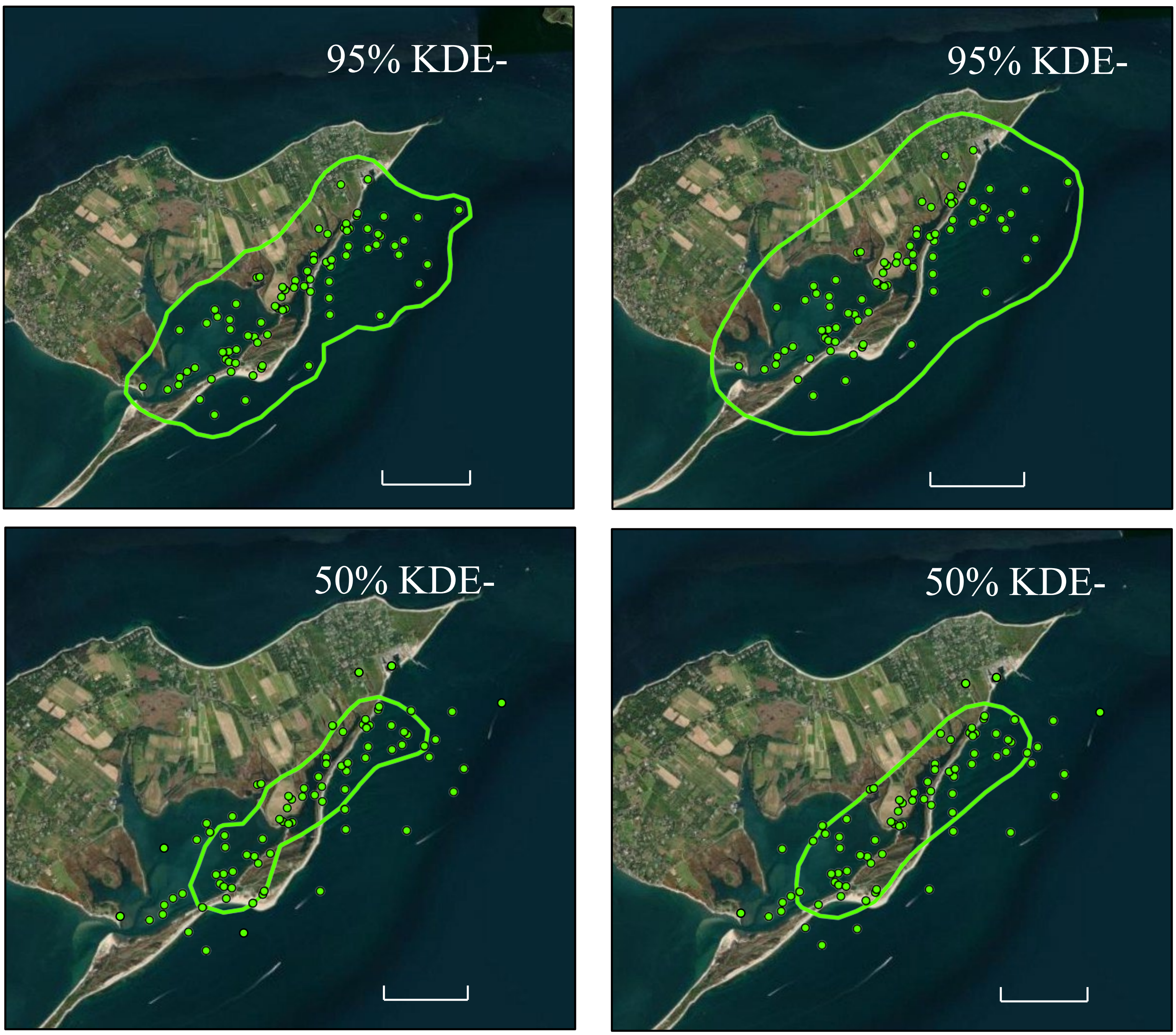
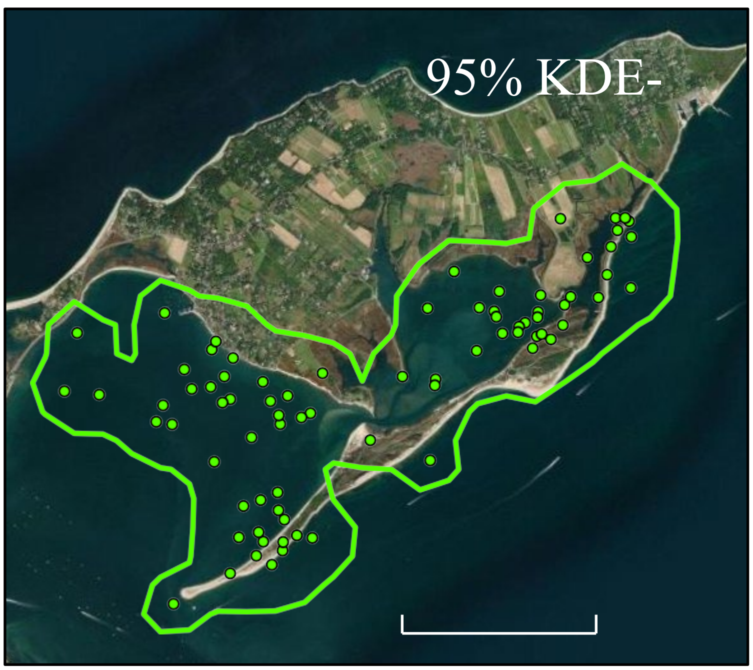
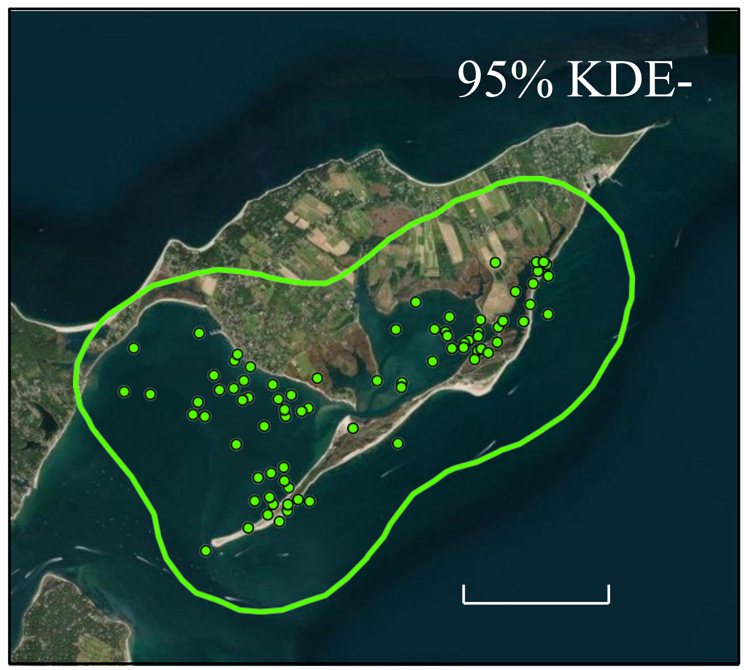


Figure 11. Home Range maps for terrapin tag ID 263462. Boundary Filtered SSM Daily Mean Locations for 95% MCP, 95% KDE-LSCV, 95% KDE-HREF, 50% KDE-LSCV, 50% KDE-href.

Figure 12. Home Range maps for terrapin tag ID 2634623. Boundary Filtered SSM Daily Mean Locations for 95% MCP, 95% KDE-LSCV, 95% KDE-HREF, 50% KDE-LSCV, 50% KDE-href.





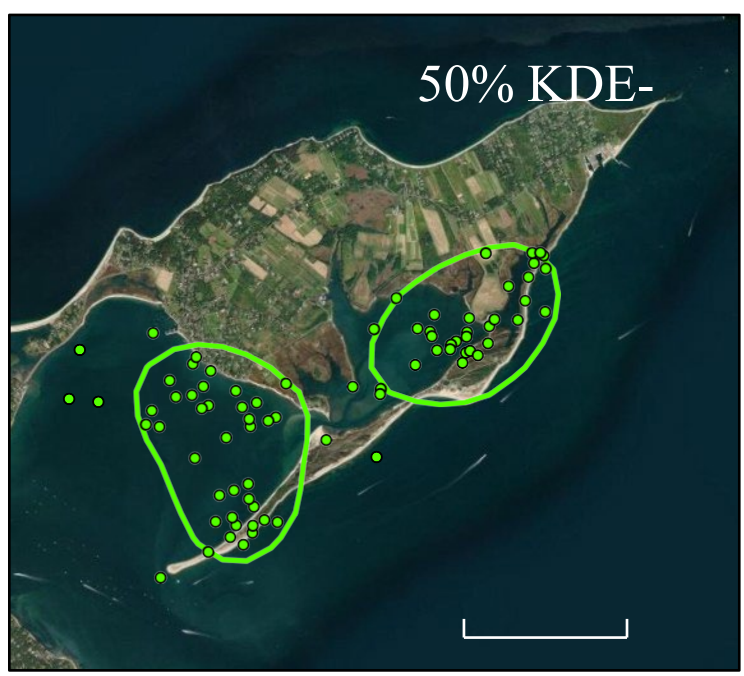


Figure 13. Home Range maps for terrapin tag ID 263462. Boundary Filtered SSM Daily Mean Locations for 95% MCP, 95% KDE-LSCV, 95% KDE-HREF, 50% KDE-LSCV, 50% KDE-href

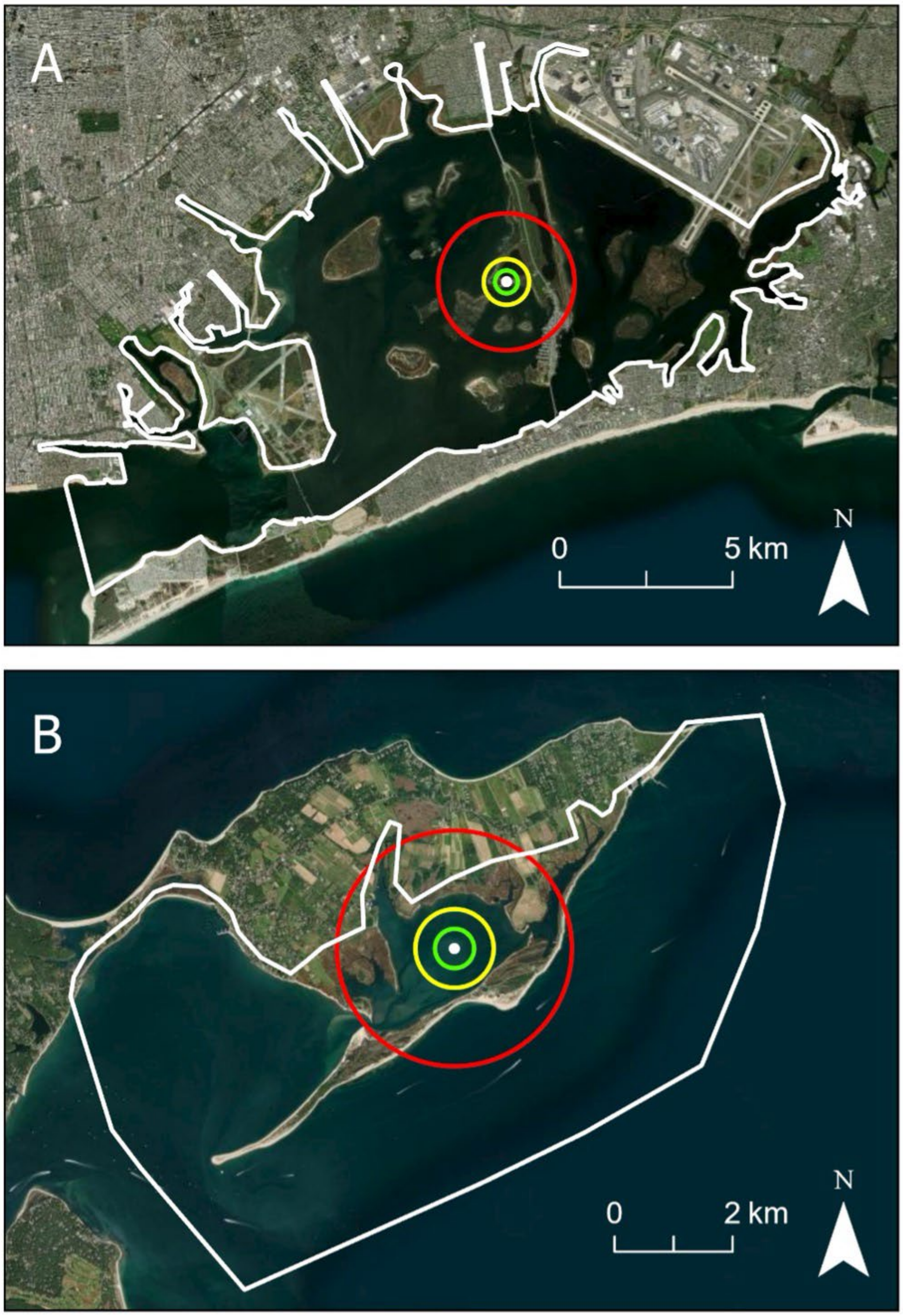


Figure 14. Map showing the error radius of Argos locations in each of the two bays, OBSP and Jamaica Bay. The green circle indicates LC 3 with a radius of 250m. Yellow circle indicates LC2 with a radius of 500m. Red circle indicates LC 1 with an error radius of 1500m. Figure taken from Hough 2025.

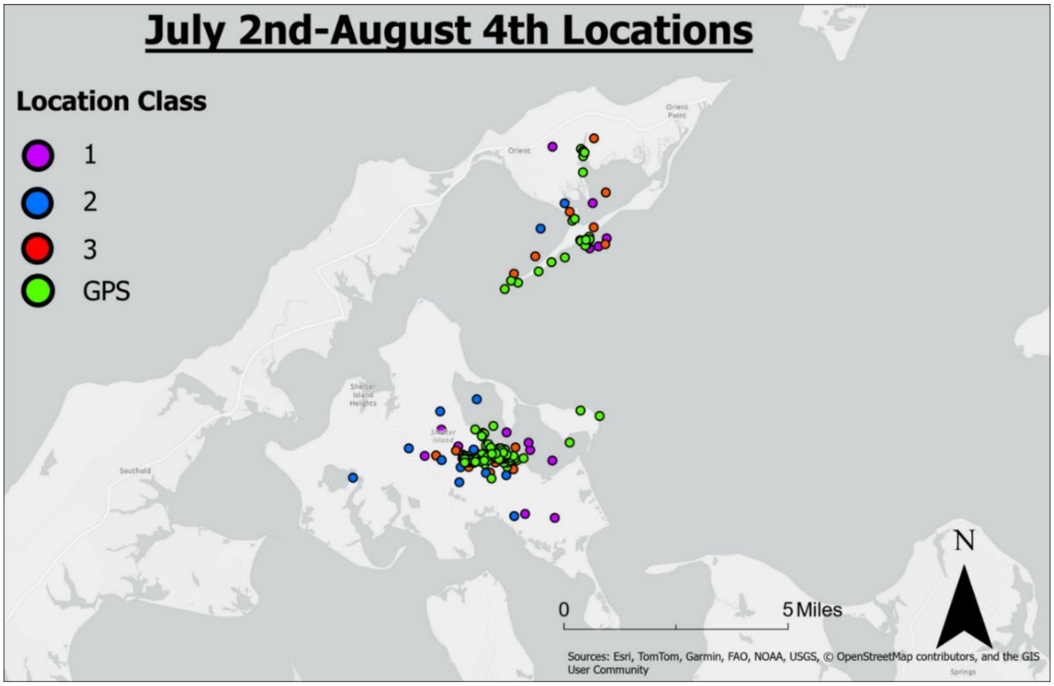


Figure 15. Diamondback terrapin locations with the Lotek FastGPS tag (July 2 – August 4, 2025) showing both GPS positions (green circles) and the Argos-only with different location classes. Note: The GPS enabled tags also yield separate Argos positions as well, but the GPS positions are much finer-resolution (typically < 10 m) and most accurate.

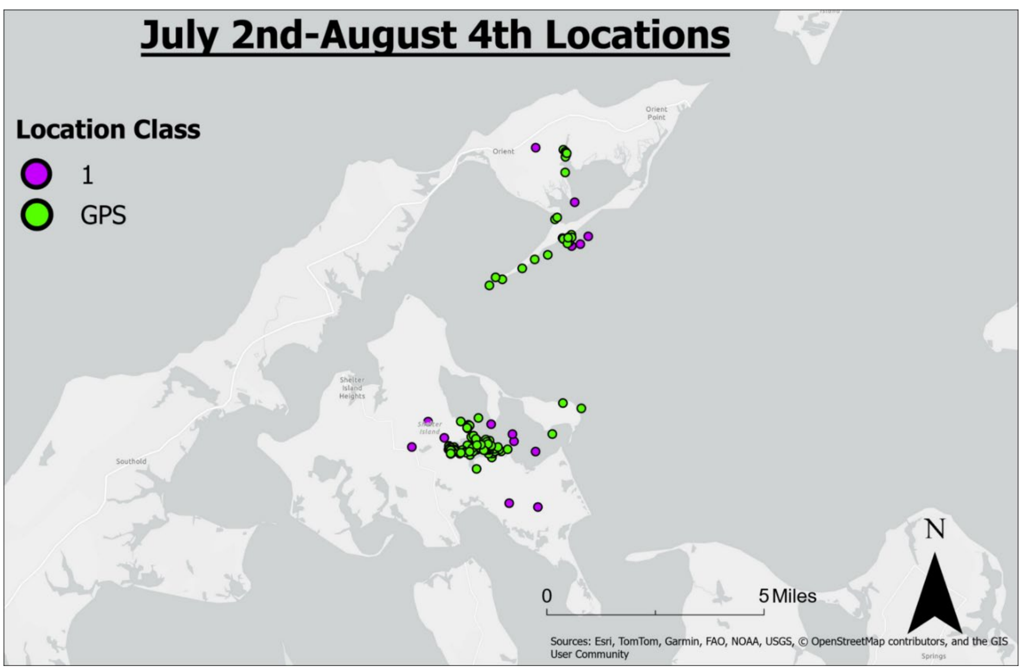


Figure 16. Plot of Diamondback terrapin locations with the Lotek FastGPS tag (July 2 – August 4, 2025) comparing GPS positions (green circles) and the Argos-only location class 1 (purple circles). The GPS positions are much finer-resolution (typically < 10 m) and more accurate than the Argos-only LC1 position estimates(500-1500m).

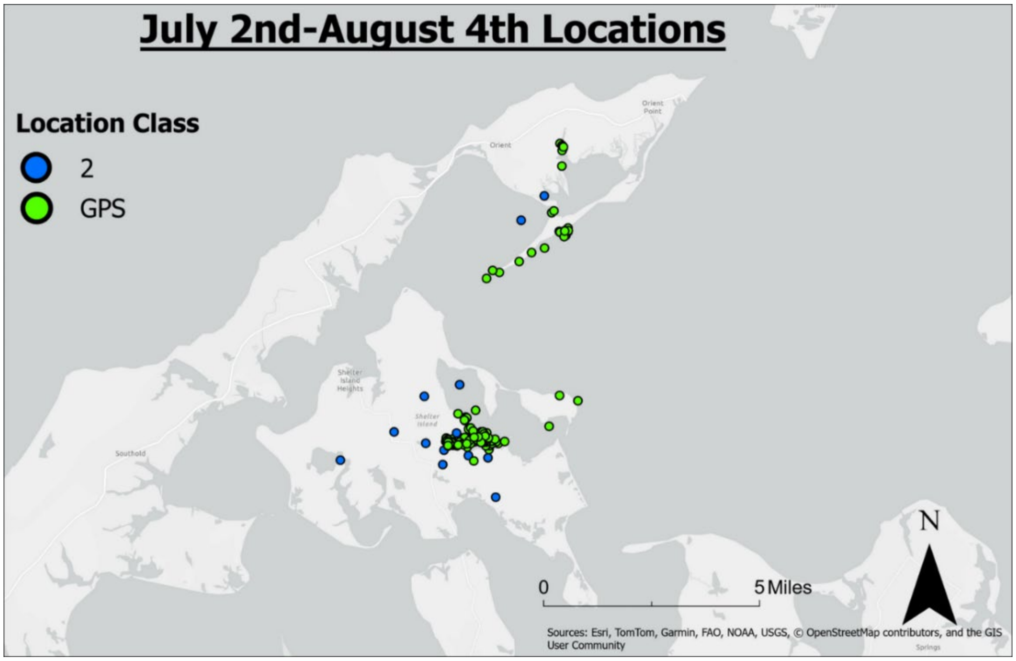


Figure 17. Plot of Diamondback terrapin locations with the Lotek FastGPS tag (July 2 – August 4, 2025) comparing GPS positions (green circles) and the Argos-only location class 2 (blue circles). The GPS positions are much finer-resolution (typically < 10 m) and more accurate than the Argos-only LC2 position estimates. (250-500m)

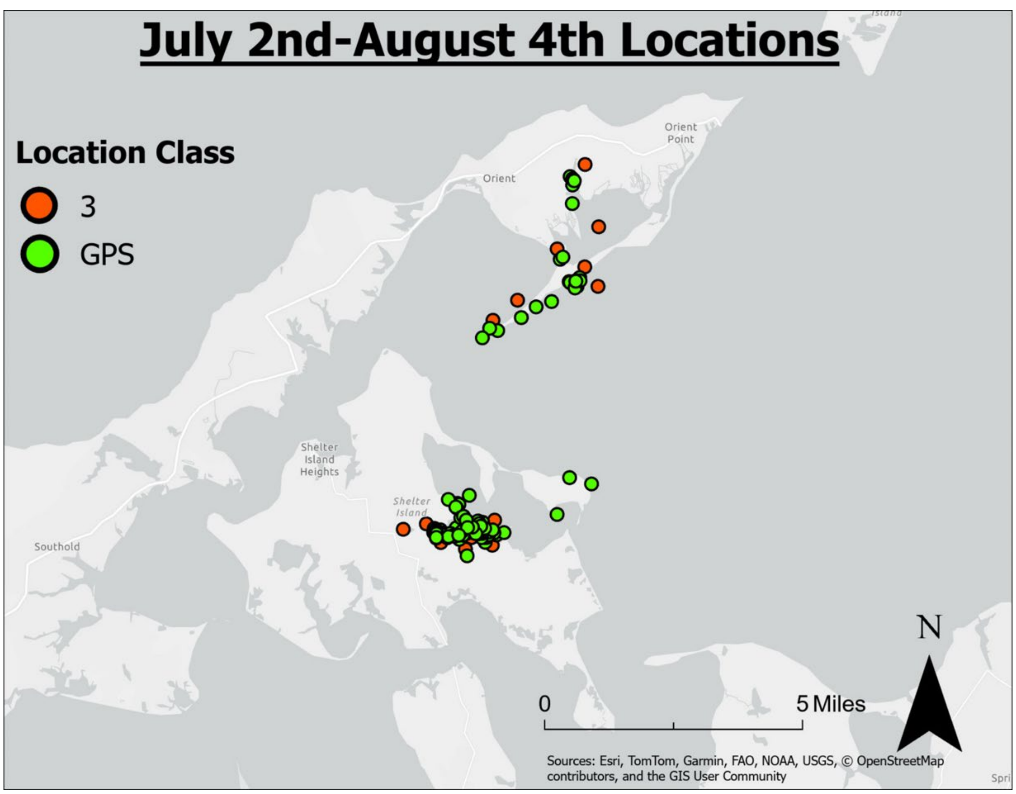


Figure 18. Plot of Diamondback terrapin locations with the Lotek FastGPS tag (July 2 – August 4, 2025) comparing GPS positions (green circles) and the Argos-only location class 3 (red circles). The GPS positions are much finer-resolution (typically < 10 m) and more accurate than the Argos-only LC3 position estimates, but when compared with LC2 and LC1 estimates, they tend to have lower spatial error(<250m).

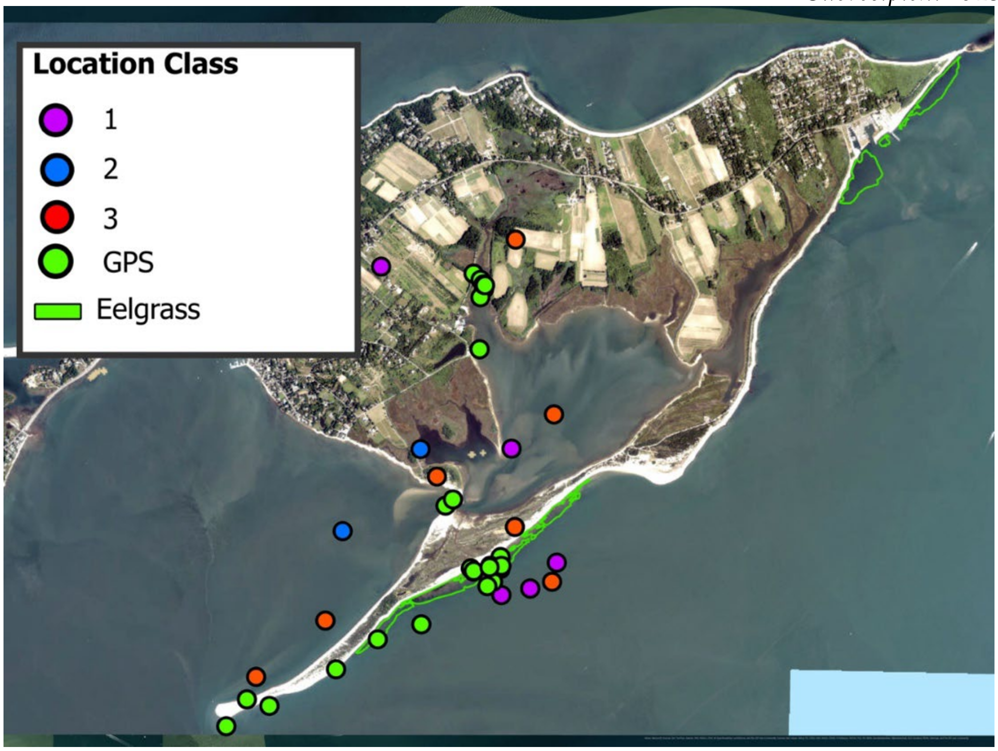


Figure 19. Plot of Diamondback terrapin locations with the Lotek FastGPS tag (July 2nd-July 7th, 2025) that shows the spatial overlap with extant eelgrass beds near Orient Beach State Park. This data suggests that diamondback terrapins may be utilizing the eelgrass habitat in this area to forage or for other purposes

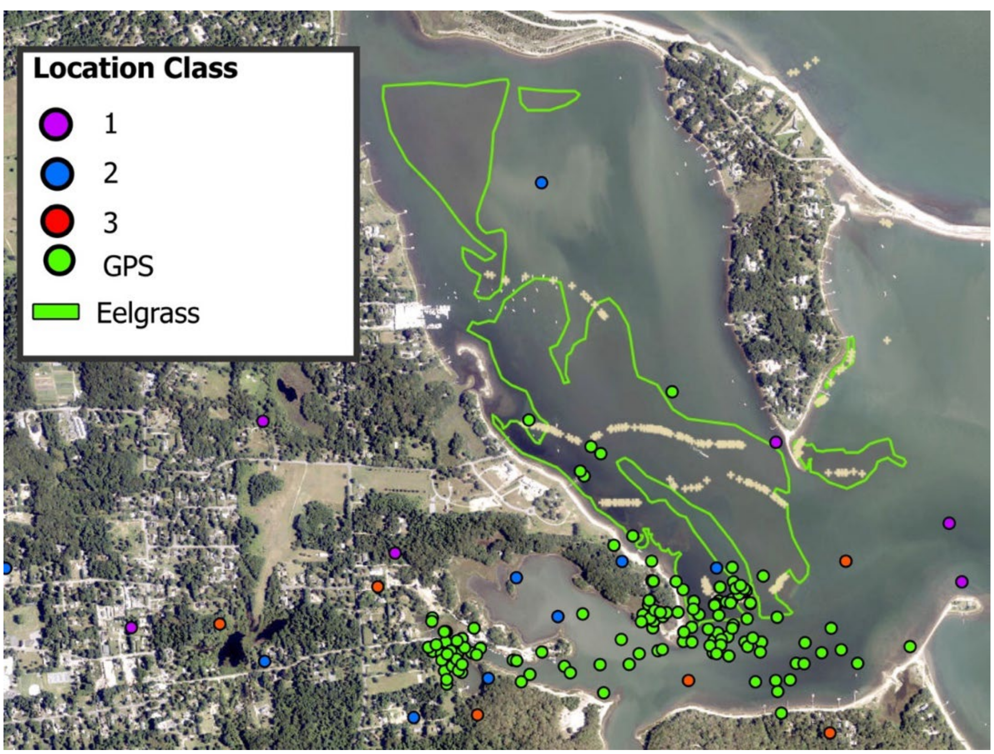


Figure 20. Plot of Diamondback terrapin positions from Lotek FastGPS tag after swimming from Orient Beach State Park on July 7, 2025 and residing through August 4, 2025 into Coecles Harbor, Shelter Island. There also appears to be spatial -overlap with the extant eelgrass beds near Coecles Harbor, Shelter Island (green polygons). This data suggests that diamondback terrapins are likely utilizing the eelgrass habitat in this area to forage or for other purposes.

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