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## **Field Validation of GIS Mapped Hardened Shoreline Structures in the Peconic Estuary**

### **Final Report**

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### **Background:**

Shoreline erosion is an increasingly impactful issue for property owners and environmental planners in coastal towns, including those bordering the Peconic Estuary. Erosion occurs over both short and long-term timescales, and is accelerated by high-impact wave energy, tides, storms, and long-term changes due to sea level rise and increased storm frequency and severity (National Research Council 2007; Nunez et al. 2022; Pang et al. 2023). Due to the potential for property damage caused by beach erosion, shoreline armoring through the use of structures such as bulkheads and rock revetments has become the standard approach to provide a barrier against the impacts of wave energy and high tides (Gittman et al. 2015). Unfortunately, these protective barriers often lead to shoreline destabilization, increased erosion of adjacent beaches, decreased ability for inland marsh migration as an adaptation to rising sea levels, and decreased access to essential intertidal and salt marsh habitats for marine species that rely on these ecosystems (Bilkovic and Roggero 2008; Galbraith et al. 2002; Jackson et al. 2009; Myszewski and Alber 2016; Nunez et al. 2022; Tavares et al. 2020).

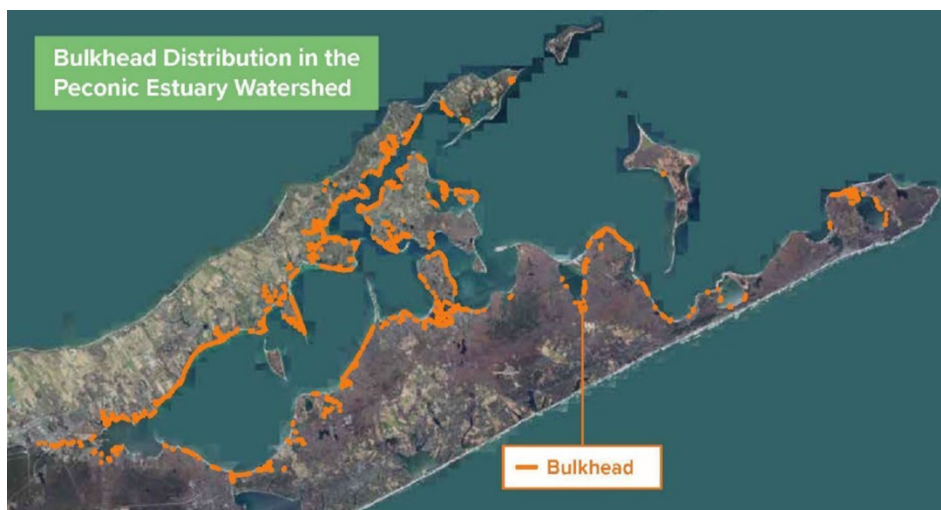
Many of the coastal communities surrounding the Peconic Estuary are vulnerable to these environmental changes, and there has been an increase in shoreline hardening over time as homeowners and coastal planners seek to protect their property and infrastructure from rising sea levels, waves, and storm surge (Peconic Estuary Partnership 2020). Unfortunately, if the current practice of armoring the estuary's shorelines continues, accessible intertidal habitat will decrease over time, salt marshes will be unable to grow inland and vertically to keep up with sea level rise, and the ecological and protective value of our beaches and marshes will be irreparably

reduced. This depletion of coastal habitat not only impacts many of the important species that inhabit them, but also diminishes the essential ecosystem services they provide, such as the filtration of water and removal of contaminants, sequestration of carbon and nitrogen, buffering and absorption of wave energy, and reduction in flooding to nearby communities during storms and high tides (Himes-Cornell et al. 2018; King and Lester 1995; Peconic Estuary Partnership 2020; Shepard et al. 2011).

The Peconic Estuary Partnership (PEP) has been working to protect and restore the Peconic Estuary and its watershed since it was first established as one of the 28 National Estuary Programs in 1992. Towards this end, PEP created, and recently updated in 2020, a Comprehensive Conservation and Management Plan (CCMP) that forms a strategic framework for protecting and restoring the Peconic Estuary of eastern Long Island, New York. PEP's CCMP focuses on four overarching goals: Strong Partnerships and Engagement; Resilient Communities Prepared for Climate Change; Clean Waters for Ecosystem Health and Safe Recreation; and Healthy Ecosystem with Abundant, Diverse Wildlife. PEP's partners have identified a series of objectives and action steps towards the accomplishment of each of these goals.

PEP has been conducting research, monitoring programs, and outreach in alignment with these goals, and is currently focusing efforts on quantifying hardened shorelines and their impacts on intertidal wildlife and climate resilience along the coasts of the Peconic Estuary. Rising sea levels and an increase in storm frequency and severity have resulted in many homeowners on the east end of Long Island installing more bulkheads, sea walls, and other hard shoreline structures to protect their property. Unfortunately, this increase in shoreline hardening conflicts with two of PEP's CCMP 2020 goals: "Resilient Communities Prepared for Climate Change" and "Healthy Ecosystems with Abundant, Diverse Wildlife." The loss of wetlands, submerged aquatic vegetation, and intertidal habitats results in reduced natural buffers from storm surges and also reductions in critical habitats upon which many important species depend for nesting, foraging, and protection, including horseshoe crabs (Bopp et al. 2019; ASMFC 2020), migratory shorebirds (Erwin et al. 2004; Placyk et al. 2004), and diamondback terrapins (Burger and Montevecchi 1975, Feinberg and Burke 2003, Lovich et al. 2001; Roosenburg, et al. 1999).

In 2019, PEP completed a Geographic Information System (GIS)-based survey to document the extent of hardened shoreline coverage along the Peconic Estuary using 2016 digital orthoimagery obtained from the New York State GIS Clearinghouse. This survey manually interpreted the aerial images for shoreline structures and found that there was a large increase in hardened shoreline linear footage from 2000 to 2016, particularly for bulkheads, which show a possible 3-to-4-fold increase during this period (Figure 1) (Larios 2019; Peconic Estuary Partnership 2020). The aim of this analysis was to create a tool for local governments to visualize the extent of shoreline armoring, and to inform decision-making regarding shoreline and land preservation and property development. Another goal of this analysis was to help form the basis of a PEP horseshoe crab (and other wildlife species) strategy for the upcoming shoreline management models of the Peconic Estuary. However, due to the possible limitations of such assessments based on interpretation of aerial imagery, it is important to verify the level of accuracy of these results. Ideally, verification should be performed through the physical groundtruthing of a randomly selected subset of the structures noted in PEP's survey. This groundtruthing would confirm the presence and accurate classification of each structure, as well as to record additional data on the condition, material, and end points of each structure, and any observations related to the surrounding habitat.



**Figure 1.** Map showing the extent of bulkhead coverage in the Peconic Estuary as of PEP's 2019 GIS-based inventory from interpreting the 2016 digital orthoimagery (NYS GIS Clearinghouse). Note this image was created by PEP prior to this project

(Larios 2019; Peconic Estuary Partnership 2020).

**Project Summary and Accomplishments:**

As a quality control measure and expansion upon PEP's 2019 effort, Cornell Cooperative Extension (CCE) has been tasked with the field validation of a subsample of these recorded structures. The goal of this verification was to aid in the elimination of discrepancies between digital mapping and town records, as well as between maps created by different agencies, in different years, or using different survey methods. Field validation occurred via boat in the late summer and early autumn months of 2024. The data from this field verification effort were then used to create a detailed GIS map showing the results of this validation project (Figure 2). The percent accuracy of PEP's 2019 effort was then calculated based on the number of structures verified as being "present" relative to the total number that were sampled.

**Methods:**

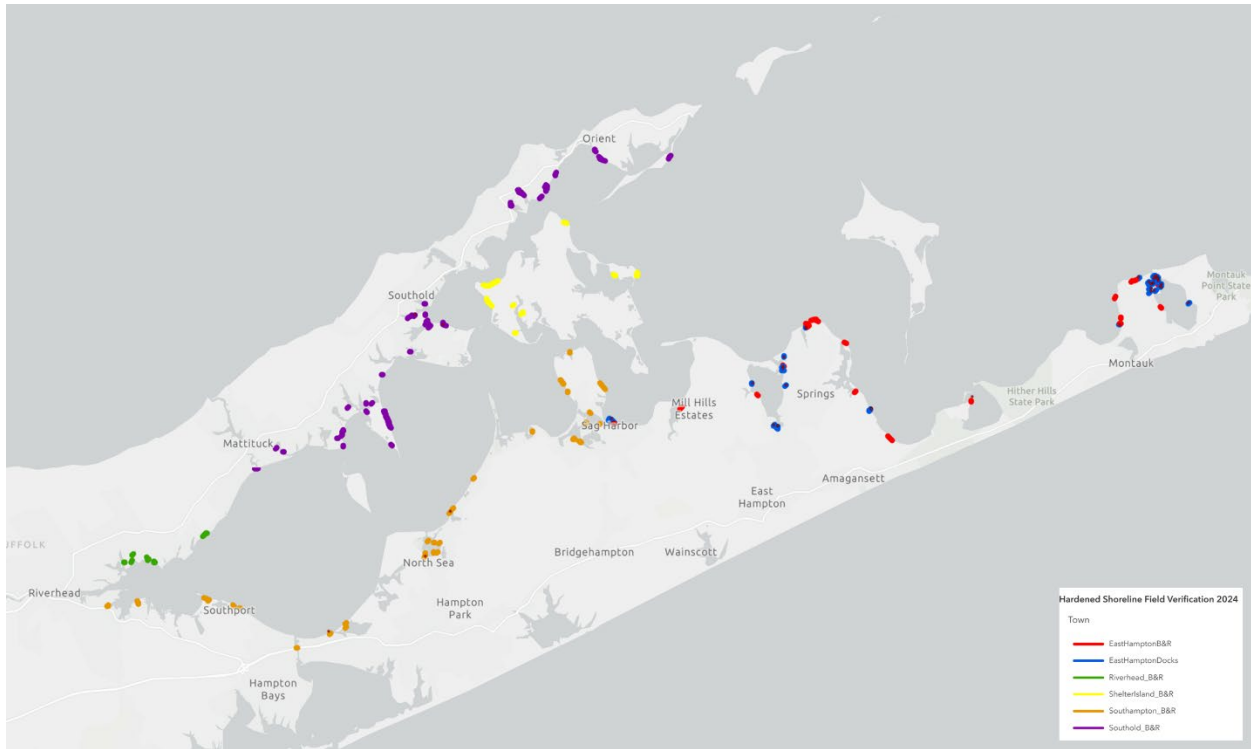
Within the project period, our team completed a review of PEP's 2019 GIS-based hardened shoreline survey by Larios et al. (2019) and relevant literature, purchased supplies, developed a sampling plan and methodology, and created datasheets and data files. PEP's 2019 aerial photo shoreline inventory map was referenced to randomly select GPS coordinates targeting 10% of each of two hardened shoreline types, bulkheads and rock revetments, in each of the five townships (Southold, Riverhead, Shelter Island, East Hampton, and Southampton) evaluated by Larios et al. (2019) for PEP's analysis (Figure 2). Also included in the random selection process were 5% of docks within East Hampton Township (Figure 2). Each hardened shoreline structure was selected from a list of all structures identified in PEP's 2019 GIS-based survey using a random number generator in Microsoft Excel. Once selected, an ID number was assigned to each structure and the corresponding GPS coordinates of that structure were listed in a table for field evaluations. These coordinates were then imported into both a handheld GPS unit and a vessel mounted GPS navigation unit to simplify field navigation. A Google Map of these structures was created to improve portability and accessibility for the ground-truthing field work, and to allow for structure identification based on nearby landmarks while in the field. Additional structures from each township were also randomly selected and used as 'alternates' should any structures on the primary list not be accessible (e.g. obstruction, non-navigable waters, private property, etc.).

Each of the selected shoreline ‘transects’ were validated by three staff members on board a vessel. The vessel utilized was CCE’s 19-foot center console equipped with Simrad GOXSE multifunction display unit. The validation process included the independent recording of data by two of the staff members on the structure’s presence or absence, condition (“good,” “fair,” or “poor”), and any other notable details and surrounding shoreline features (SAV, sediment type, and other observations). Photographs were also taken of each structure to incorporate into data files and a GIS map. Spatial coordinates were recorded by navigating as close as possible to each structure’s end points by vessel, or when feasible, by foot. These coordinates were later added to the GIS map as a separate layer. Field data and notes were entered into an Excel spreadsheet, photos were catalogued, and the data were subsequently incorporated into a GIS database to support PEP and other stakeholders in assessing the extent of shoreline hardening around the Peconic Estuary (Figures 2-4).

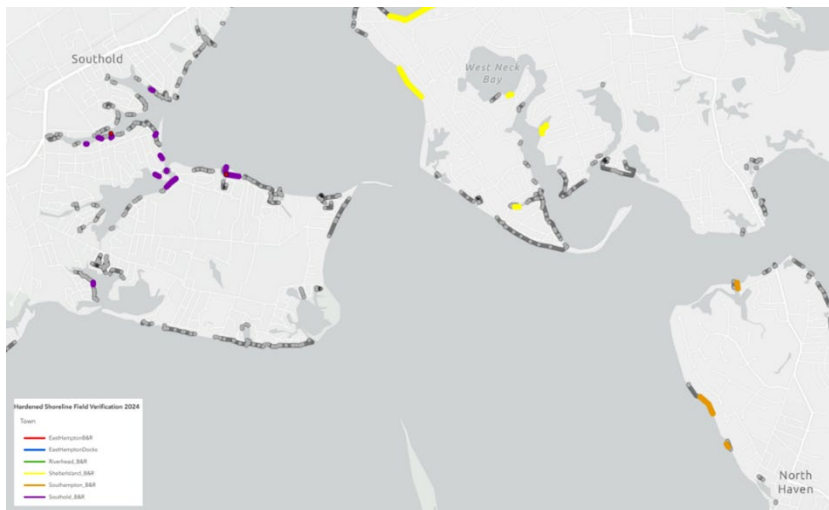
Surveyed structures were considered “present” if they were correctly labeled by PEP’s 2019 survey and found at the specified coordinates. Occasionally, field validation indicated that a structure was only “partially present,” meaning that the structure was still at the specified location, in part, but a portion was missing due to damage or removal. For the purposes of this study, we considered “partially present” structures as “present” since they were found at the indicated location and had likely been fully present at the time the 2016 orthoimagery was created. Structures noted to be “absent” were missing entirely, or the structures may have been present, but incorrectly identified by PEP’s 2019 effort. For example, two staircases on bluffs were marked as docks in PEP’s 2019 survey and the docks were therefore logged as “absent” upon our field validation since they were incorrectly labeled.

The condition of each structure was independently determined by two staff members based on perceived level of wear and age. Structures that were determined to be in “good” condition appeared to be fully intact, relatively new, well-maintained, and without missing or broken pieces. “Fair” condition structures may have had mild to moderate signs of age, such as light wear or discoloration, but with no or very minimal missing or broken pieces. Structures considered in “poor” condition were often degraded, missing pieces or sections, visibly aged, and

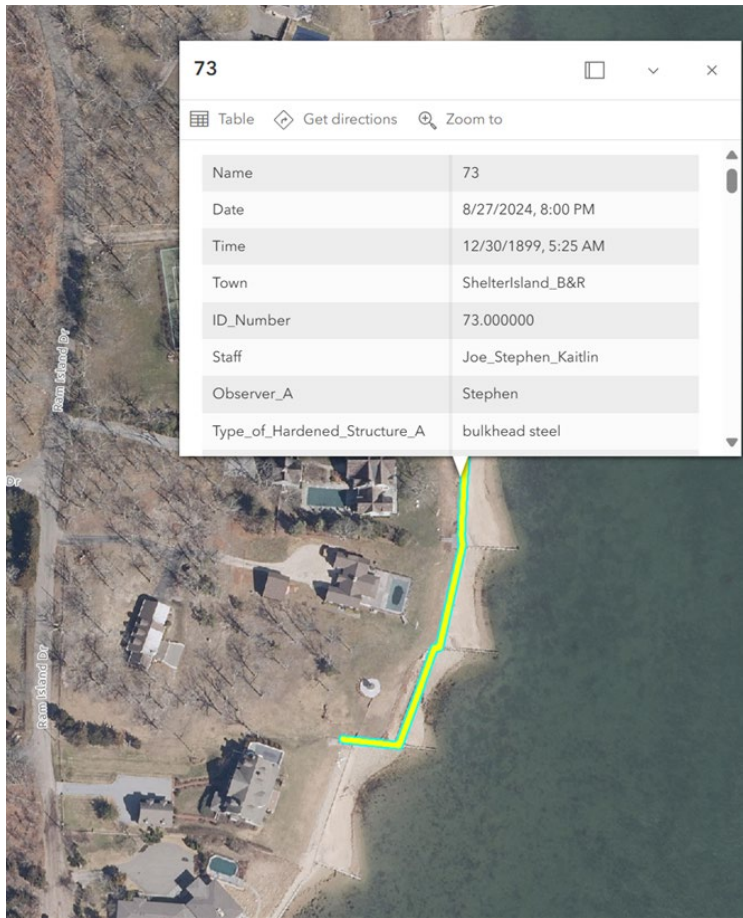
discolored. The poor condition structures typically indicated that these they would require repair, removal, or replacement in the future.



**Figure 2.** Data from this field validation effort were incorporated into a detailed GIS database and map and will be available to all stakeholders (<https://data.gss.stonybrook.edu/>). The color key lists the township and structure type, and corresponding notes and photos can be viewed by clicking on a line segment, and each layer can be toggled “on” and “off” by the user.



**Figure 3.** Zoomed-in portion of verified structures within three townships, Southold, Shelter Island, and Southampton, in addition to PEP’s map of all bulkheads within the estuary (shaded grey). Structures displayed in red, blue, green, yellow, orange, and purple were randomly selected from PEP’s shoreline survey for field validation. The color key identifies the township and type of structure indicated by each color.



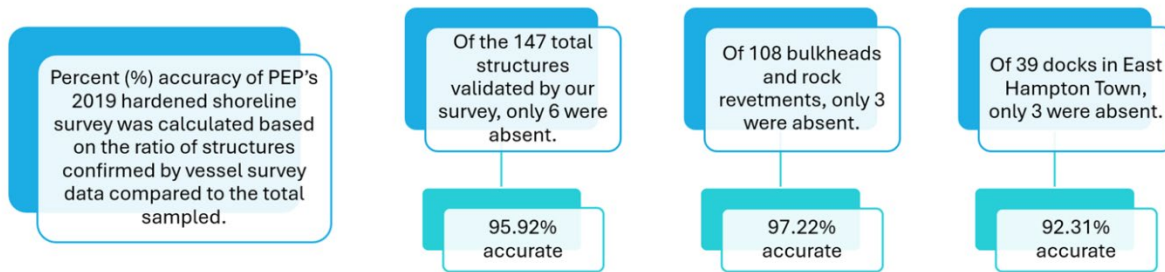
**Figure 4.** This image is an example of the some of the field data (notes) associated with each of the verified shoreline structures, represented by line segments. When a user clicks on any of the segments, all of the associated field data and photos will appear.

## Results:

The accuracy of PEP’s 2019 hardened shoreline survey was determined based on the percent of structures that were verified by the field survey data (Figure 5, Table 1). Of the 147 shoreline hardening structures (bulkheads and rock revetments) sampled by vessel, only 6 were found to be 'absent.'

Therefore, PEP’s 2019 hardened shoreline survey was determined to be 95.92% accurate overall. Of the 108 randomly sampled bulkheads and rock revetments, only 3 were found to be absent, resulting in a 97.22% accuracy rate for PEP’s survey of these structures. The percent accuracy by Township was also calculated (Table 1). Of the 39 docks sampled in East Hampton Town, only 3 were found to be “absent,” therefore PEP’s aerial assessments in 2019 identified these structures accurately 92.31% of the time. Within the Town of Riverhead, 100% of the 8 structures visited were confirmed to be “present”. Within Shelter Island, 100% of the 9 structures visited were found to be “present”. Within the Town of Southold, of the 36 structures visited, only 1 was “absent”, therefore PEP’s survey was 97.22% accurate. Within the Town of Southampton, only 1 of the 35 structures visited were found to be absent, a 97.14% accuracy. Lastly, within the Town of East Hampton, 59 structures were visited and only 4 were found to be “absent”, 3 of which were docks, so PEP’s survey was 93.22% accurate in this area. When docks are removed from the East Hampton samples (i.e. only bulkheads and rock revetments, as were considered in the other

townships), the percent accuracy increased to 95%. All data has been made available to PEP in an Excel spreadsheet format, and all photos and GIS layers produced have also been provided to PEP and the Stony Brook Geospatial Center (<https://data.gss.stonybrook.edu/>).



**Figure 5.** Percent (%) accuracy of PEP's 2019 hardened shoreline survey, as calculated based on the ratio of structures confirmed by field validation compared to the total number sampled. Percent accuracy is shown for all structures as well as by structure type.

Township	Riverhead	Southold	Shelter Island	East Hampton (including docks)	East Hampton (Bulkheads & Revetments)
Number of Structures Visited	8	36	9	59	20
Number of Structures Absent	0	1	0	4	1
% Accuracy	100%	97.22%	97.14%	93.22%	95.00%

**Table 1.** Percent (%) accuracy of PEP's 2019 hardened shoreline survey per Township, as calculated based on the ratio of structures confirmed by field validation compared to the total number sampled within each Town. \*Note: that the percent accuracy for East Hampton includes docks, which tend to be more mobile and less permanent than the other structures. When docks are omitted from the East Hampton assessment, the percent accuracy increases to 95%.

## Discussion:

Based on the results of our field validation effort, it is clear that the use of aerial imagery in identification of hardened shorelines in this region was accurate, especially in the case of bulkheads and rock revetments. The overall accuracy of 95.92% found in this study, suggest that stakeholders can have confidence in the credibility of GIS-based shoreline surveys. However, despite the proven validity of this GIS-based survey method, it is important to consider the potential complications of this type of survey. For example, it is worth noting that some of the

structures marked as “absent” by our ground-truthing effort may have been present at these locations in 2016 when the referenced orthoimagery was captured, then subsequently removed by natural causes or human intervention prior to our field validation. Another important aspect to consider is that the presence of multiple adjoining structures may make it difficult to discern end points from aerial imagery, leading to the frequent representation of several consecutive structures as single line segments on a GIS map, which may appear to be single structures to those reviewing the results of these surveys. This explains why some of the townships assessed during our project may appear to have only had a few structures verified, such as the Town of Riverhead, where several of the line segments actually included several adjoining structures, as was confirmed by field validation and noted in the data affiliated with these line segments in the GIS database developed by our team, which can be viewed through Stony Brook Geospatial Center’s data hub (<https://data.gss.stonybrook.edu/>). To gain a better understanding of the actual length of each structure validated in the field, linear footage of each line segment was also noted in the GIS database, and the number of houses behind each structure was also ascertained using aerial imagery, when applicable, and included in the field notes. Additionally, docks seem to be slightly more difficult to discern using aerial imagery compared to the other shoreline structures, since other man-made objects such as staircases on bluffs tend to look very similar to docks in aerial photos. Because many docks are floating and designed to be installed on a seasonal basis, they tend to be more transient than other shoreline structures due to the ease with which they can be relocated or removed, so outdated aerial imagery may not be truly representative of current circumstances when considering these structures. For these reasons, we advise that ground-truthing be randomly implemented to assess the quality of any future aerial hardened shoreline structure surveys, especially in cases where structures are ambiguous or when the imagery used may be outdated.

As sea levels continue to rise, and storms increase in frequency and magnitude, homeowners and environmental planners within the Peconic Estuary Watershed are facing increased risk of property damage and loss due to shoreline erosion. As a result, shoreline hardening has increased dramatically over the past 20 to 30 years, leading to ecological disruption along the shoreline of this estuary’s coastal ecosystems (Larios et al. 2019). The first step to preventing further shoreline hardening along the Peconic Estuary, and to eventually

restoring ecologically important regions of shoreline to a more natural state, is to assess the current extent of shoreline armoring. This hardened shoreline field verification project helped reduce many uncertainties associated with PEP's previous efforts to quantify and map hardened shoreline structures from interpretations of digital orthoimagery. The results of this effort will aid PEP in better supporting and informing shoreline management, that would include land development and protection decisions, thus aligning with several of the following CCMP 2020 action steps:

- **Action 10:** Incorporating climate change considerations into new and existing projects of PEP and partner organizations
- **Action 11:** Providing tools and assistance to local government to mitigate and adapt to the impacts of climate change
- **Action 12:** Mitigate climate change through coastal ecosystem management
- **Action 23:** Conduct scientific studies to expand understanding of the Peconic Estuary ecosystem and support ecosystem-based management
- **Action 26:** Quantifying the impacts of fishing, aquaculture, boating, navigational dredging, and hardened shoreline structures on habitats and vulnerable species, to foster sustainable recreation and commercial uses of the Peconic Estuary that are compatible with protection of biodiversity.
- **Action 27:** Facilitate spatial planning of the Peconic Estuary to help mitigate resource-use conflicts and ensure the protection of critical habitats.

This project also incorporated the development of a Horseshoe Crab Workgroup in collaboration with PEP and Seatuck Environmental Association in order to develop a protection strategy for horseshoe crabs and other wildlife in the Peconic Estuary. Meetings were held in partnership with Seatuck and PEP in September 2024, November 2024, and September 2025. Many species such as horseshoe crabs, migratory shorebirds, and diamondback terrapins depend upon intertidal and wetland habitats to maintain their populations in the estuary. Data and ideas generated from this ongoing effort will inform PEP's future habitat restoration and protection initiatives for such species, and should also be incorporated into future management policies. By

helping to protect and restore habitats such as intertidal beaches, wetlands, and submerged aquatic vegetation, it not only benefits the marine and wildlife that rely upon these essential habitats, but also increases the coastal resiliency of surrounding communities through natural processes. For example, healthy salt marshes are able to migrate landward as sea level rises, which help to reduce coastal flooding and storm surges (Himes-Cornell et al. 2018; King and Lester 1995; Peconic Estuary Partnership 2020; Shepard et al. 2011).

The results of this hardened shoreline validation project, in combination with the Horseshoe Crab Workgroup and eventual Horseshoe Crab Management Strategy, will aid PEP in the development of a Shoreline Management Model (SMM) to better support and inform decision-making for the agencies and municipalities that manage the shoreline resources (Nunez et al. 2022). The SMM is a novel, geospatial technique used to model existing and potential future conditions along a shoreline and to recommend best management practices for shoreline protection by considering a variety of factors (Nunez et al. 2022). Such factors include wave energy, sediment type and movement patterns, submerged aquatic vegetation, value of the shoreline as wildlife habitat, risk of climate-change related impacts such as flooding, storm surge, and sea level rise (Nunez et al. 2022). By weighing these factors, managers are better equipped to recommend the most appropriate shoreline protection strategy for a specific area. Ideal strategies minimize impact to ecosystems and aid in identification of areas where nature-based solutions may be more suitable than conventional hardened shoreline structures to maintain the ecological and structural integrity of the shoreline, as well as riparian rights for the surrounding community. Additionally, the development of a Horseshoe Crab Management Strategy will enhance this model by allowing PEP and shoreline resource managers to incorporate information on preferred nesting habitats for this important species. This will better protect these ecologically active shorelines from development and to ensure that essential intertidal and salt marsh habitat is prioritized for preservation.

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