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Eelgrass Distribution in the Great Bay Estuary and Piscataqua River for 2025: Final Project Report submitted to the Piscataqua Region Estuaries Partnership

Michael Routhier
University of New Hampshire, Durham

Raymond Grizzle
University of New Hampshire, Durham

Taylor Goddard
University of New Hampshire, Durham

Krystin Ward
University of New Hampshire, Durham

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Eelgrass Distribution in the Great Bay Estuary and Piscataqua River for 2025

Final Project Report submitted to the Piscataqua Region Estuaries Partnership

Michael Routhier
Earth Systems Research Center
Morse Hall, 8 College Road
Durham, NH 03824

Raymond Grizzle
Jackson Estuarine Laboratory
85 Adams Point Road
Durham, NH 03824

Taylor Goddard
Earth Systems Research Center
Morse Hall, 8 College Road
Durham, NH 03824

Krystin Ward
Jackson Estuarine Laboratory
85 Adams Point Road
Durham, NH 03824

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Abstract

Eelgrass (*Zostera marina*) distribution in Great Bay, Little Bay, and the Piscataqua River was mapped using 10m spatial resolution European Space Agency (ESA) Sentinel satellite imagery and high-spatial resolution low-altitude drone (UAV – Unoccupied Aerial Vehicle) imagery supported by non-geo-rectified aerial digital still photos taken from a mounted GoPro camera. Field verification and ground-truthing consisted of field visits to 177 sites with a 6000 Sea-Drop HD Seaviewer video camera and 39 site inspections by divers. Polygons were coded by Assessment Zones defined in previous eelgrass mappings for archiving in the state of New Hampshire [GRANIT Geographic Information System \(GIS\) Geodata Portal](#). The total area of eelgrass beds with 10% or greater cover and a polygon area equal to or greater than 100 square meters was 85 hectares (211 acres). In previous years this calculation included areas of mixed eelgrass/widgeon grass (*Ruppia maritima*), of which both individually had 10% or greater cover, but no mixed eelgrass/widgeon grass areas were detected within the system this year. The largest concentration of eelgrass was within Portsmouth Harbor, Little Harbor/Back Channel, and by Gerrish Island. Great Bay, with the largest areas of eelgrass in previous years, saw a 98% drop this year. In addition to eelgrass areas, 4 hectares (10 acres) of widgeon grass area was also mapped within the study area and found only at the head of Spinney Creek. No dense widgeon grass was found in Great Bay, unlike in previous years. Since the last mapping of eelgrass, completed within the study area in 2024, the total eelgrass acreage has decreased by approximately 80%. Due to this large loss of eelgrass this year, locations of eelgrass (> 0% and < 10% coverage) were also mapped to show further potential of future recovery. In Great Bay, 15 hectares (36 acres) of sparse eelgrass were detected and mapped for this purpose, though these areas were not included in the annual total sum of eelgrass coverage because they did not meet the > 10% coverage threshold specified in the [Quality Assurance Project Plan](#) (QAPP). Furthermore, to better understand the dynamics that aquatic vegetation plays in the larger ecosystem, we also detected and mapped 136 hectares (335 acres) of sub-tidal algae in select locations of the study area surveyed by the project's low-altitude drone.

Introduction

The overall extent of eelgrass beds is a major factor in the assessment of the condition of the Great Bay Estuary. Thus, changes in eelgrass distribution over time reflect potential changes in the health of the estuary. The present report provides details on the mapping of eelgrass distribution in Great Bay, Little Bay, the Piscataqua River, Portsmouth Harbor, and a small portion of the Atlantic Coast, including areas near Fort Foster in Kittery, ME, New Castle, NH, and Odiorne Point in Rye, NH, for 2025. In addition to eelgrass, widgeon grass, mixed widgeon grass and eelgrass, and subtidal macro algae were mapped. Upon the distribution of this report, the data herein are the latest regional mapping of eelgrass beds in the study area.

Methods

Guidelines in the [Quality Assurance Project Plan](#) (QAPP) were followed for all fieldwork and map production. The overall process consisted of acquiring digital imagery, producing preliminary maps, field verifying the preliminary maps, and producing final maps (*Figures 6, A1-A3*) for the study area (*Figure 1*).

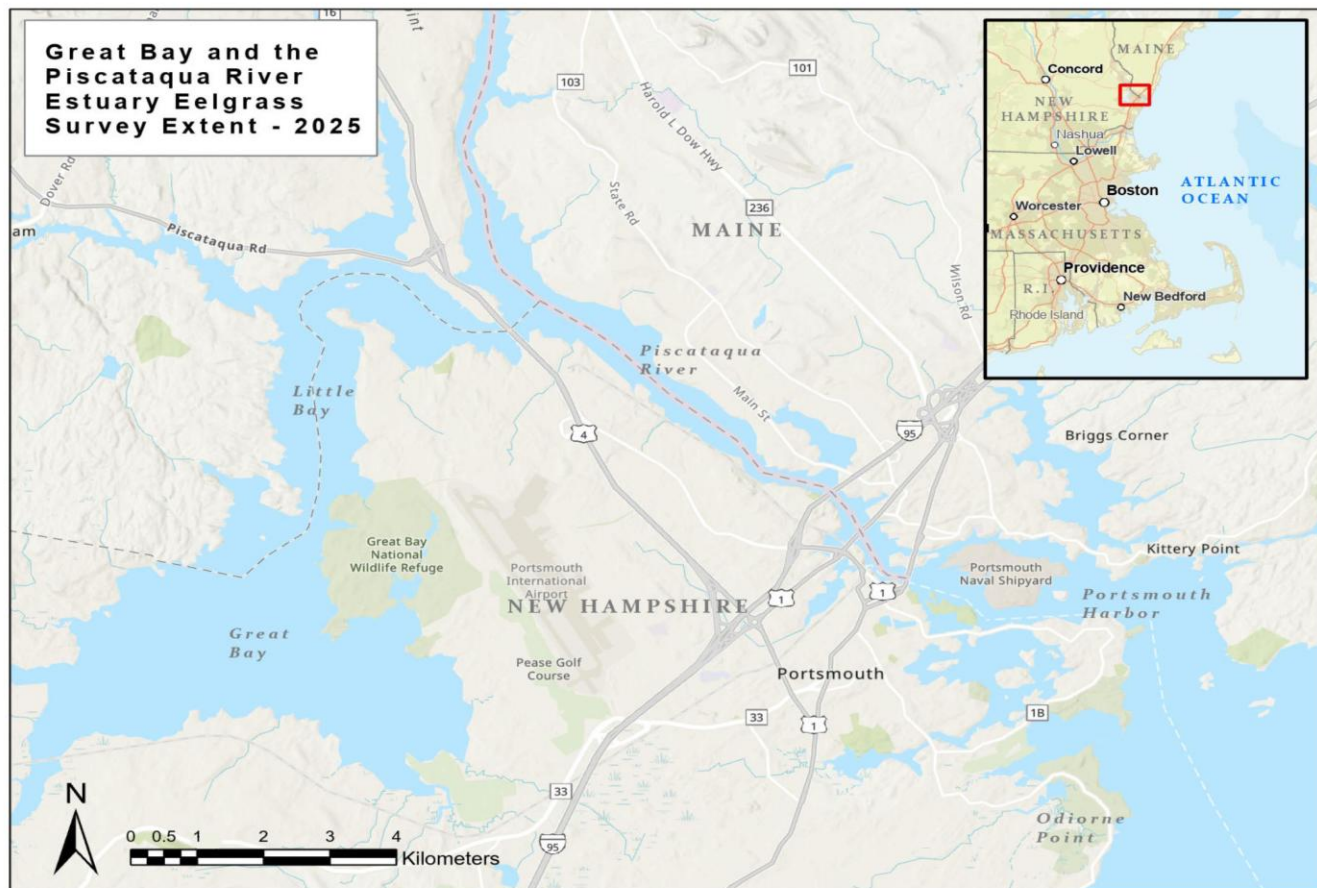


Figure 1 – 2025 Great Bay Estuary - Eelgrass Survey Study Area Map. Digital imagery obtained by satellites, an airplane, and a low-altitude drone (UAV – Unoccupied Aerial Vehicle) (*Figure 2*) were used to produce a preliminary map of eelgrass in the study area consisting of polygons constructed by photointerpretation and processing of four mapped classes: (1) eelgrass (defined as >10% cover), (2) widgeon grass (>10% cover), (3)

eelgrass/widgeon grass (each >10% cover), and “unknown” where interpretation was questionable.

A European Space Agency (ESA) 10m spatial resolution Sentinel-2 multispectral satellite image, dating from July 29th, 2025, was also acquired for 100% of the study area. Both Red, Green, Blue, and Near Infrared, Red, Green band combinations were used for interpretation purposes.

2-6 cm varying spatial resolution drone imagery were acquired with a DJI Matrice 300 drone carrying a six-lens multispectral camera from late June through October 2025 (*Figure 2*).

Non-geo-rectified, aerial, digital photos were captured primarily over Great Bay on October 9th, 2025, with a downward-pointing GoPro camera mounted to the underside of a light airplane.



Figure 2 – Photo of the DJI Matrice 300 Drone in flight on its way to survey the southeastern section of Great Bay. (Photo by Michael R. Routhier).

Since pixel sizes of the imagery vary based on the altitude from which they are acquired, the spatial resolution of the drone imagery used within this study varied between 2 and 6 cm based on FAA maximum altitude ceiling rules around the Pease International Airport. These very high spatial resolutions allowed for better use of texture and density characteristics during the interpretation and processing of the imagery. (*Figure 3*).



Figure 3 – Underwater eelgrass (green) as imaged from above with a DJI Matrice 300 drone carrying a six-lens multispectral camera in flight at the mouth of the Piscataqua River, July 27th, 2025.

In total, approximately 186,000 multi-band drone images were acquired over the study area during the 2025 field season. Only about 80% of the area on the far eastern side of Great Bay was imaged with the drone because FAA airport proximity flight restrictions prevented legal flight access to some of the area. Acquisition flights in areas where the UAV could fly were completed when environmental conditions best exhibited good weather, low tides, low sun angles to reduce water surface sun glare, and little to no wind to prevent excessive water surface turbulence. These specifications were used in order to maximize unobstructed lines of sight between the drone camera and the targeted submerged vegetation. Acquired adjacent UAV images were mosaicked into per-flight-day super-set orthomosaics to aid in image interpretation when possible. Both Red, Green, Blue, and Near Infrared, Red, Green band combinations were used for processing and interpretation purposes.

Digitizing of submerged vegetation was completed by adding and interpreting all available imagery into a geographic information system database using ArcGIS Pro software. In locations around the study area where more than one imagery source existed, interpretation preference was assigned based on image spatial resolution, clarity, and positional accuracy, with first preference usually given to the UAV-acquired imagery, then the GoPro imagery, then the satellite image (Figure 4). The projection used to map the study area was New Hampshire State Plane, NAD83. Database file attributes for the 2025 survey are as follows: “id,” a unique consecutive number; “Hectares,” the area of the polygon in hectares; “Acres,” the area of the polygon in acres; “Year,” equal to 2025, the year of the imagery used, “Name” and “Type” to distinguish between polygons mapped as sparse eelgrass (0) eelgrass (1), inclusive of both eelgrass and widgeon grass (2) or widgeon grass (3), “Label” for the assessment zone, “Confidence,” a measure of cartographer confidence (H = Higher, M = Medium, L = Lower) of the existence and/or cover type of vegetation per polygon. “Notes,” a text field listing the types of imagery used and/or mapping limitations per polygon as observed by the cartographer. The items “Confidence” and “Notes” were included to help record varying vegetation mapping confidence levels caused by turbidity, depth, and image quality clarity issues within this year’s imagery.

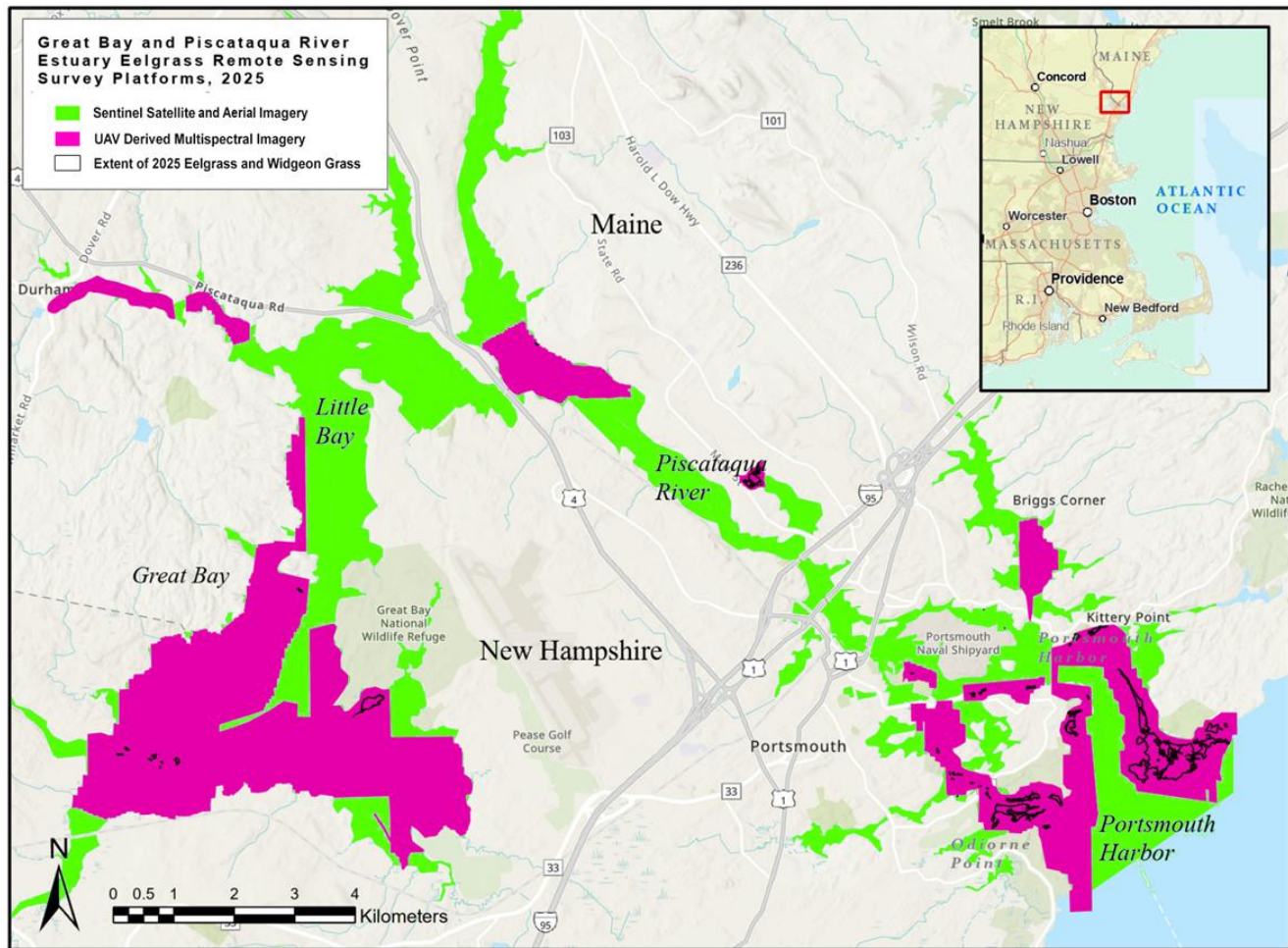


Figure 4 – 2025 Great Bay Estuary – Map of Eelgrass Survey Remote Sensing Platforms Used.

Field verification of the initial maps consisted of inspections at 177 “[Tier 1](#)” sites and 29 “[Tier 2](#)” and other sites as see in *Figure 5*.

- Tier 1 site inspections were conducted July 24th through August 28th, 2025, with a towed underwater video and still Seaviewer HD camera system (Example camera still images in *Appendix C*).
- Tier 2 site inspections were completed June 10th to October 7th, 2025, via diver surveys.

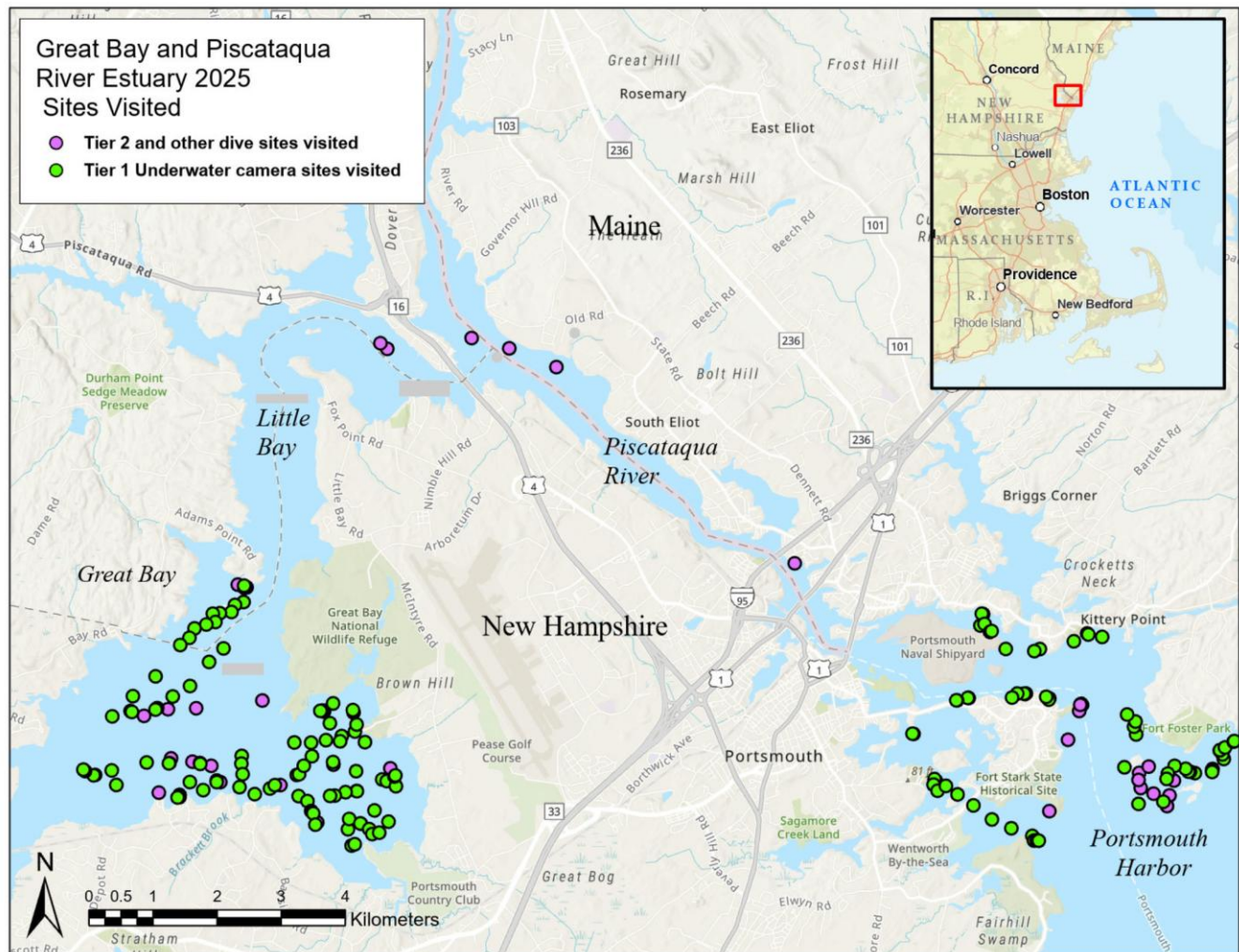


Figure 5 - 2025 Great Bay Estuary – Map of Ground Truthing Survey – Sites Visited.

Results and Discussion

Species Distributions

The distribution of eelgrass for 2025 within the whole study area is shown in *Figure 6* and within finer-scale maps shown in *Figures A1-A3*. The total area of sea grasses within the project area was 221 acres. Of these seagrasses, eelgrass (eelgrass and eelgrass/widgeon mix) mapped in the project area totaled 211 acres. This distribution, broken down by Assessment Zone, is shown in *Table 1*. **From 2024 to 2025, the full estuary experienced an approximate 81% decrease in eelgrass areas, with most losses occurring in Great Bay, which experienced a 98% decrease in eelgrass coverage** (See Appendix B, Figures B1 – B4 for aerial image examples of 2024 vs. 2025 eelgrass distributions in Great Bay). In 2025, only small patches of eelgrass occurred north of Sandy Point and to the east of Woodman Point, as shown in *Figure 6*.

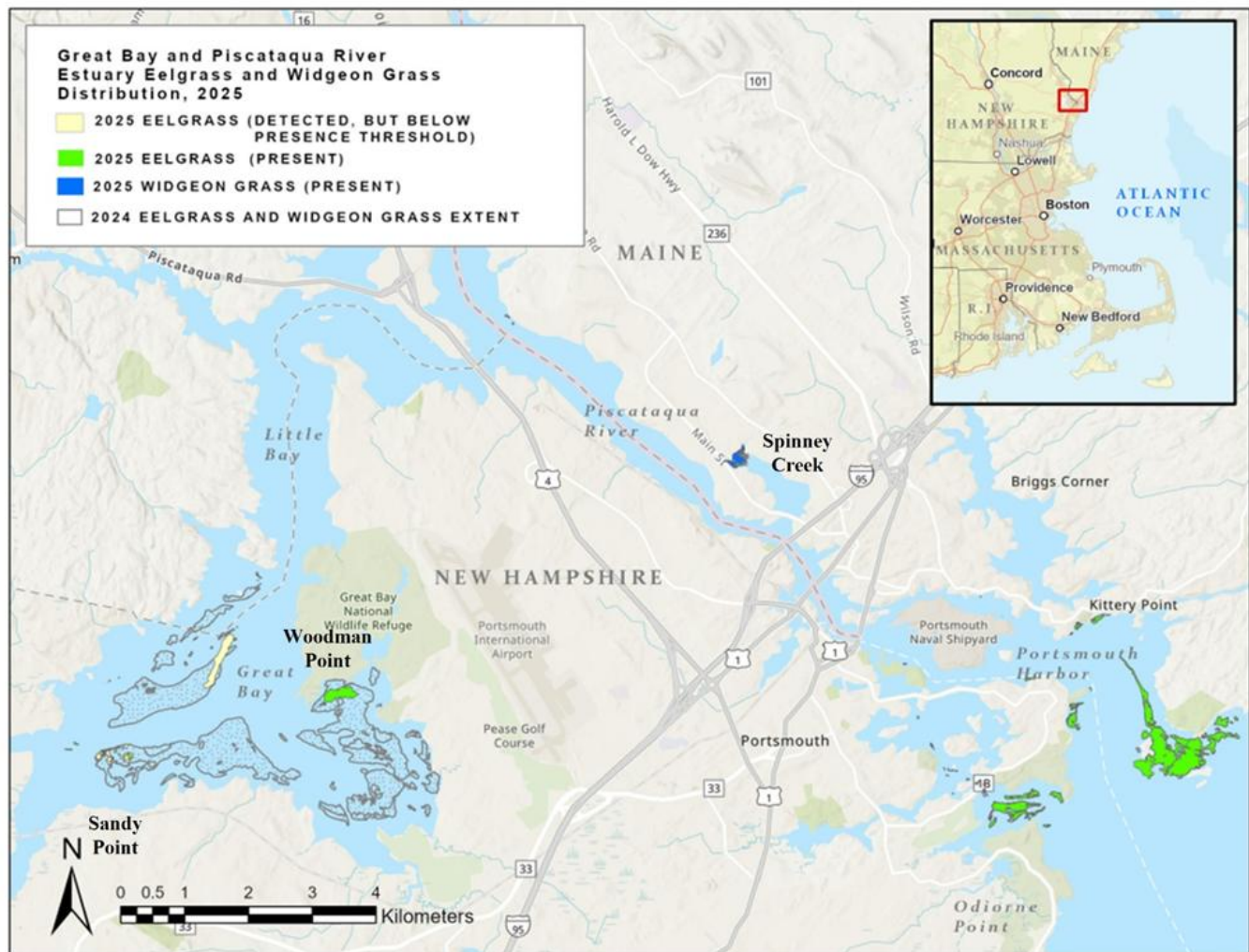


Figure 6 – 2025 Great Bay Estuary Survey – Map of Distribution of 2024 and 2025 Eelgrass and Widgeon Grass – Great Bay, Little Bay, and the Piscataqua River.

Though not included in the total of eelgrass cover within this year's survey, areas of eelgrass ($> 0\%$ and $< 10\%$) were detected and mapped to identify potential areas of future recovery. These areas, in Great Bay, totaled 36 acres (down from 95 acres in 2024) and can be seen in *Figure 6*.

Although mixed eelgrass/widgeon grass (where both species had 10% or greater cover) existed within the system in previous years, no mixed dense eelgrass/widgeon grass areas were detected within the system this year. (*Figure 6 and Figures A1-A2*). Areas of Widgeon grass at or above the presence threshold of 10% cover were observed to have increased slightly at the head of Spinney Creek but were reduced to zero acres in Great Bay (*Figure A2*).

Table 1 – Summary of Eelgrass, Combined Eelgrass and Widgeon Grass, and Widgeon Grass Area Totals – 2025

Area in Acres – 2025	Vegetation Type Totals By Assessment Zone					
Assessment Zone	Eelgrass	Eelgrass & Widgeon Grass	Widgeon Grass	Total Eelgrass *	Total Widgeon Grass	Total **
Atlantic Coast	2.02	0.00	0.00	2.02	0.00	2.02
Gerrish Island Beds	59.96	0.00	0.00	59.96	0.00	59.96
Great Bay	21.53	0.00	0.00	21.53	0.00	21.53
Little Bay	0.00	0.00	0.00	0.00	0.00	0.00
Little Harbor/Back Channel	32.50	0.00	0.00	32.50	0.00	32.50
Lower Piscataqua River North	0.17	0.00	0.00	0.17	0.00	0.17
Lower Piscataqua River South	0.15	0.00	0.00	0.15	0.00	0.15
Odiorne Point Beds	0.96	0.00	0.00	0.96	0.00	0.96
Portsmouth Harbor	93.76	0.00	0.52	93.76	0.52	94.28
Sagamore Creek	0.21	0.00	0.00	0.21	0.00	0.21
Spinney Creek	0.00	0.00	9.19	0.00	9.19	9.19
Upper Piscataqua River	0.00	0.00	0.00	0.00	0.00	0.00
Winnicut River	0.00	0.00	0.00	0.00	0.00	0.00
2025 Totals	211.25	0.00	9.72	211.25	9.72	220.97
2024 Totals	1063.34	23.24	41.59	1086.59	64.83	1128.17
Difference	-852.09	-23.24	-31.87	-875.34	-55.11	-907.20
% Difference	-80.13%	-100.00%	-76.63%	-80.56%	-85.01%	-80.41%

* Total Eelgrass = Eelgrass + Eelgrass and Widgeon Grass

** Total = Eelgrass + Eelgrass and Widgeon Grass + Widgeon Grass

Presence of Seaweeds

This year, besides eelgrass and widgeon grass, the project ground verification crew observed many areas of both floating and submerged algae/kelp locations around the study area (*Figure 7a and 7b*) and recorded their coordinates (*Figure 8*).

Figure 7 – Photos of several types of attached Algae observed via UAV from above Little Bay (7a) *Fucus vesiculosus* observed from above the southeast section of Great Bay (7b) (photos by Taylor Goddard and Michael Routhier)



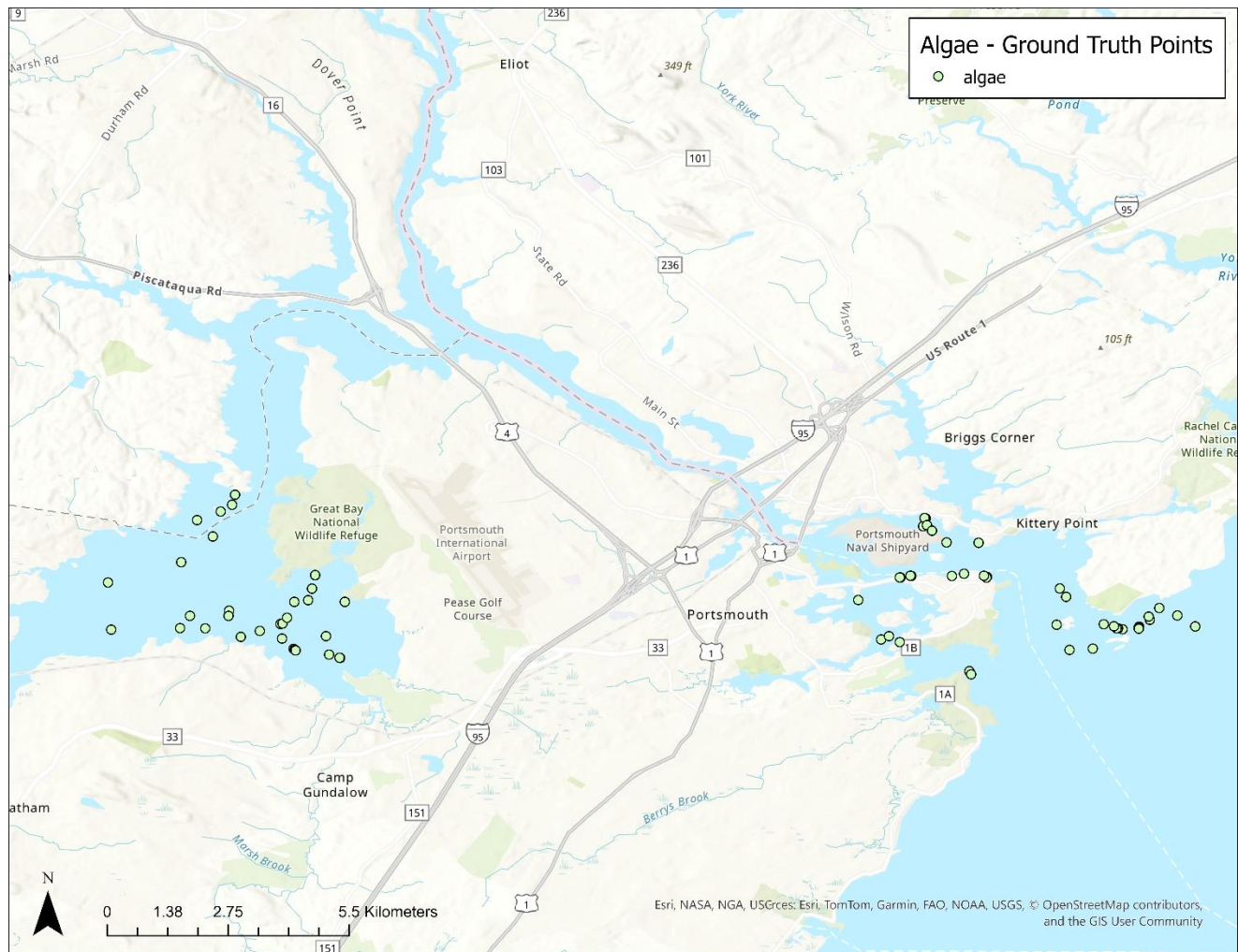


Figure 8 – Map of Project Field Verification Crew Observed Algae or Kelp Locations around the Study Area

Furthermore, the remote sensing team of this year's survey quantified the sum of areas of sub-tidal algae within a subset of the study area determined by the extent of the project's collected UAV-derived imagery (*Figure 9*). Initial findings have shown 335 acres of sub-tidal algae distributed through the estuary. However, the southern section of Great Bay showed prominent distributions of *Gracilaria* and large patches of *Fucus vesiculosus* just north and west of the Portsmouth Golf Course. The Atlantic coast showed prominent distributions of *Ulva*, kelp, and numerous other species, and the Western section of Little Bay showed a prominent distribution of mixed species, including *Gracilaria*, *Ulva*, and *Porphyra*. These and other species were sometimes found in homogeneous patches but were also found mixed with eelgrass along the Atlantic coast (*Figure 7a and 12*). Furthermore, it was not uncommon to find algae species in co-presence with the locations of oyster reef restoration areas and natural oyster reefs.

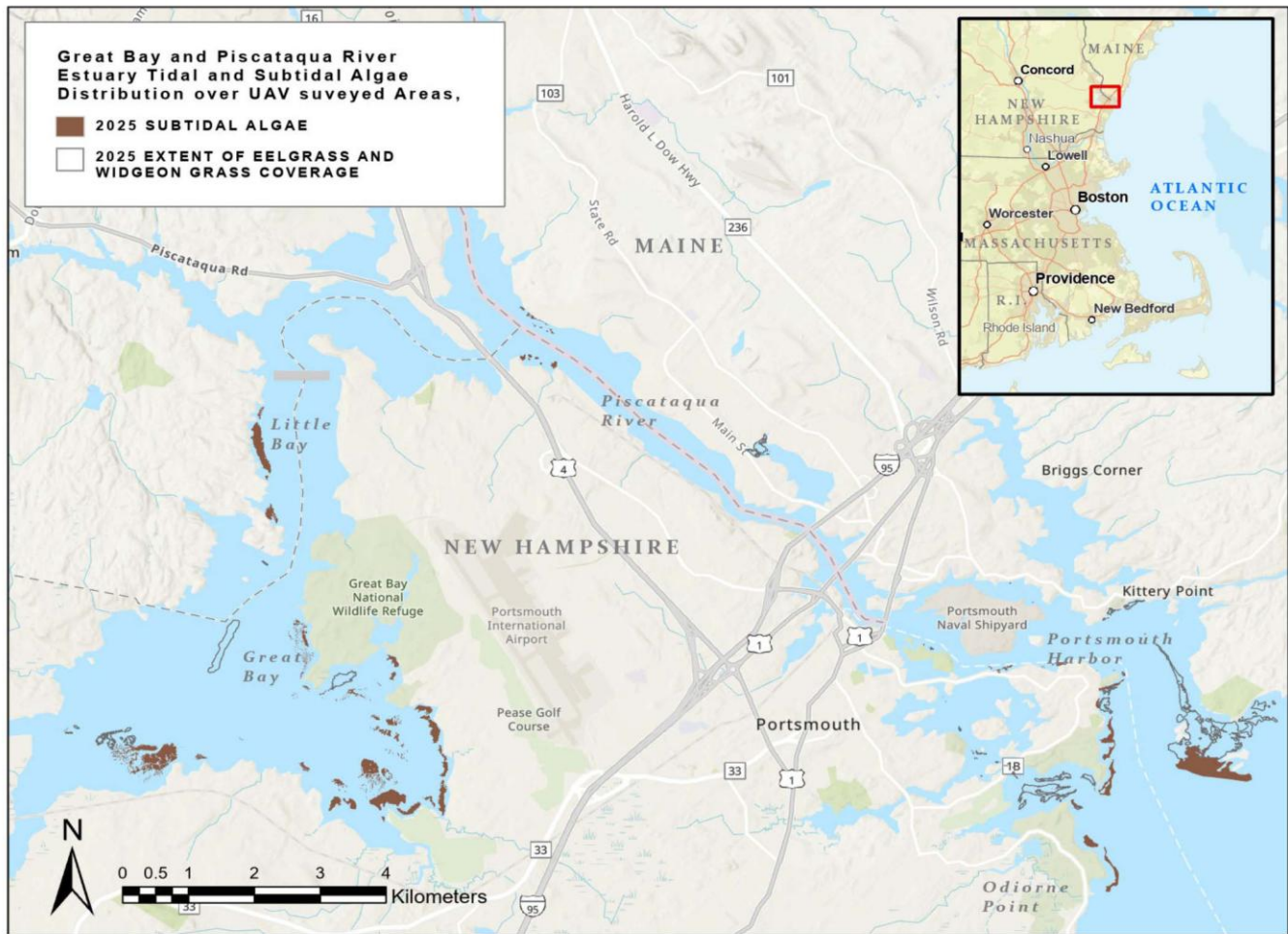


Figure 9 – Great Bay Estuary Survey – Map of the Distribution of 2025 Algae (Subtidal) in Areas only Overflowed by the Project UAV – Great Bay, Little Bay, and the Piscataqua River.

Although this preliminary mapping in 2025 provides some insights into the distribution of algae within the Great Bay and Piscataqua River Estuary, no formal spatial analysis was completed on the seaweed data this year for this report. Currently, there are ongoing studies on the temporal dynamics of seaweed and eelgrass at a few sites in the estuary that may be complemented by this year or future years' algae mapping work. This is clearly a topic that should be considered in the design of future eelgrass mapping efforts. For example, even if quantitative changes are detected in algal abundances at a few sites, data will be needed on overall spatial distribution patterns to validly infer estuary-wide changes and how those changes may interact with and change the distribution of light and other resources to seagrasses.

Presence of Oysters

Previous reports on eelgrass surveys in the estuary have also discussed the presence of oyster reefs in some areas. In 2025, oysters were clearly detected in several locations during the ground verification efforts (Figure 10).

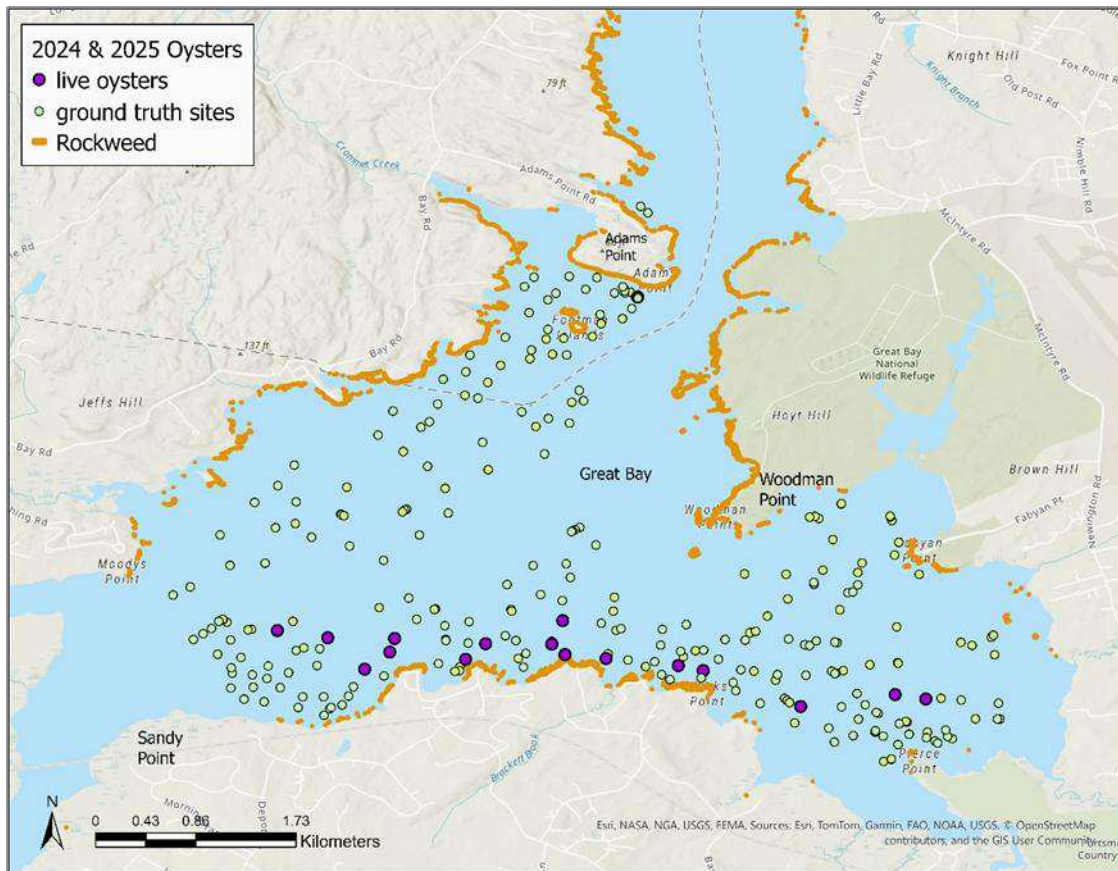


Figure 10 – Map of observed oyster locations in 2024 and 2025 within the project study area (only found in Great Bay).

As in past years, oysters provided areal image signatures that were detected in some locations. If many oysters were present on the surface of a mud bottom, the signature was detectable. If found in the presence of eelgrass but not seaweed, the eelgrass signature was clear, and to a lesser extent, oysters could be detected. However, if oysters were present along with seaweed and eelgrass, the signature was confounded such that only the predominant feature could be discerned.

There is clearly a need to make better use of all data collected on the various benthic habitats of interest by management agencies and others in the Great Bay Estuary system, in part because there are important (but in most cases poorly understood) ecological relationships among the different habitats. For example, oysters in the Great Bay Estuary occur mainly in the subtidal zone, but they have also been found to occur intertidally under the canopy of rockweed. It has been hypothesized that the expansion of oysters into the intertidal zone in northern New England estuaries is due to climate change (Capone et al. 2008). McKown et al. (2025) recently characterized the rockweed/oyster habitat in the system, but much remains to be learned about its importance, particularly with respect to the oyster/macrophyte communities (Figure 10) found in the present study.

Accuracy Assessment

The positional accuracy of mapped polygons within this study varies by the image platform used in their creation. Sentinel satellite imagery is reported to have a positional accuracy of $\pm 20\text{m}$. The UAV imagery used within this survey is reported to have a positional accuracy of $\pm 0.33\text{m}$. The captured aerial GoPro imagery was not rectified to real-world coordinates and thus was used within this study to help inform the other data sources.

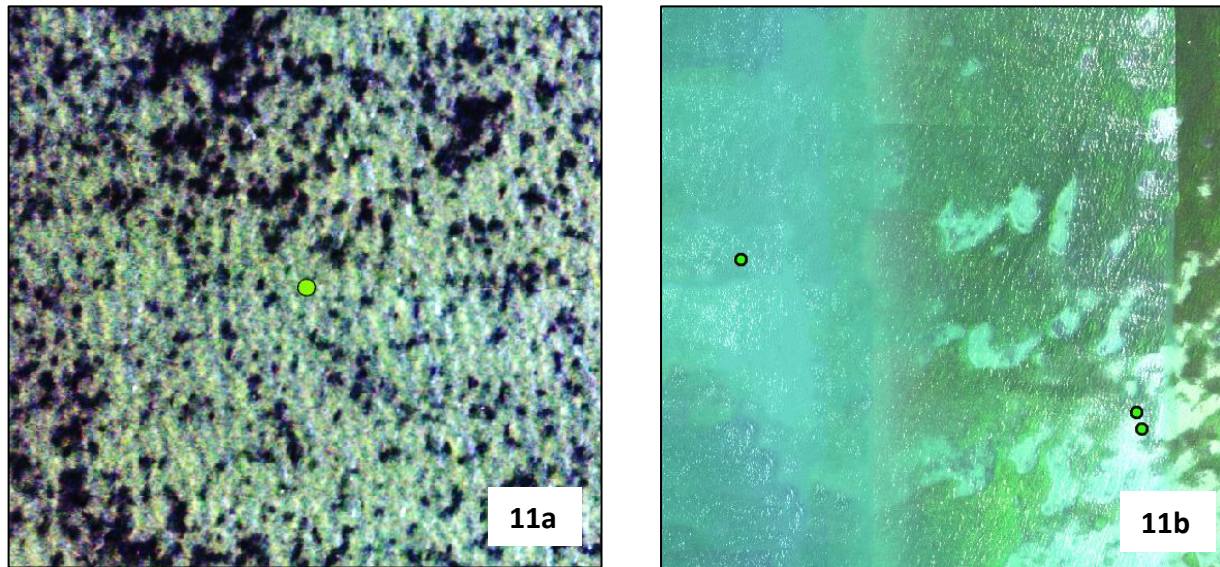
The positional accuracy of the on-water ground control points was dependent on the 2cm to 14cm RTK unit and a $\pm 3\text{m}$ GPS unit positional accuracies used for collecting coordinates and relative to the location where vegetation was observed. Variations in true position were caused by the drift of the boat due to constantly changing tidal and wind conditions, and inconsistent distances between the position of the video feed camera and the onboard GPS antenna. It is estimated that positional variations caused by drift could be as much as $\pm 10\text{m}$, thus making the total estimated positional accuracy of on-water ground control points $\pm 13\text{m}$.

Thematic accuracy, in this study, was defined by correspondence between ground truth point observations and what could be observed within the project's imagery. Imagery observations were compared to 177 Tier #1 video survey site observations sampled from July 24th through August 28th, 2025, and 39 Tier #2 and other diver survey site observations sampled from June 6th to October 10th, 2025, yielding a 97% total accuracy, as seen in *Table 2*. This accuracy is similar to last year's 2024 assessment accuracy of 95% and better than or similar to prior studies, where accuracies were judged to be 87% (imagery and field verification from Fred Short) and 94% (imagery from Cornerstone, Inc., field verification by Seth Barker). (See [UNH Scholars Repository](#) QAPP 4 website and [UNH Scholars Repository](#) QAPP 3 website for details, respectively.) Future year surveys will include a similar number and diversity of class sampling sites as collected in both Tier 1 and Tier 2 of the project.

Table 2 - Thematic Accuracy Table (based on Tier 1 dive, Tier 2 underwater camera survey, and on-the-water kayak visited sites). Total count of ground control points = 216. Total accuracy between ground control points and classified polygons = 97%

Ground Control Points	Remotely Sensed Classified Polygons				
	Vegetation Type	Eelgrass	Eelgrass & Widgeon Grass	Widgeon Grass	Other or Un-Classified
					Producer Accuracy
	Eelgrass	31	0	0	3
	Eelgrass + Widgeon Grass	0	0	0	0
	Widgeon Grass	0	0	0	0
	Other	3	0	0	179
	User Accuracy	88%	N/A	N/A	98%
					97%

It can be noted that mismatches between ground truth point observations and image interpretations of eelgrass locations tend to occur for two reasons. First, ground truth points may happen to fall in small patches of bare or sparse eelgrass surrounded by just-out-of-sight dense eelgrass areas (*Figure 11a*). Second, depth obscures the ready processing and interpretation of deep eelgrass areas, despite the fact that the ground verification crew is able to detect it with their underwater drop camera (*Figure 11b*).



Figures 11 – Two images that show common reasons for inaccuracies between ground truthing and interpretation of vegetation cover imagery. Figure 11a shows the mismatch of a less than 10% eelgrass coverage ground truth point surrounded by areas that can be interpreted as greater than 10% eelgrass coverage. Figure 11b shows the locations of eelgrass coverage ground truth points, two easily interpreted in shallow areas on the right side of the image, and one obscured by depth on the left side of the image.

Additionally, we believe that variations in the geographic distribution of turbid waters within Great Bay may influence interpretation errors more than the regularly less turbid waters of Portsmouth Harbor and the Atlantic Coast (*Figure 12*).

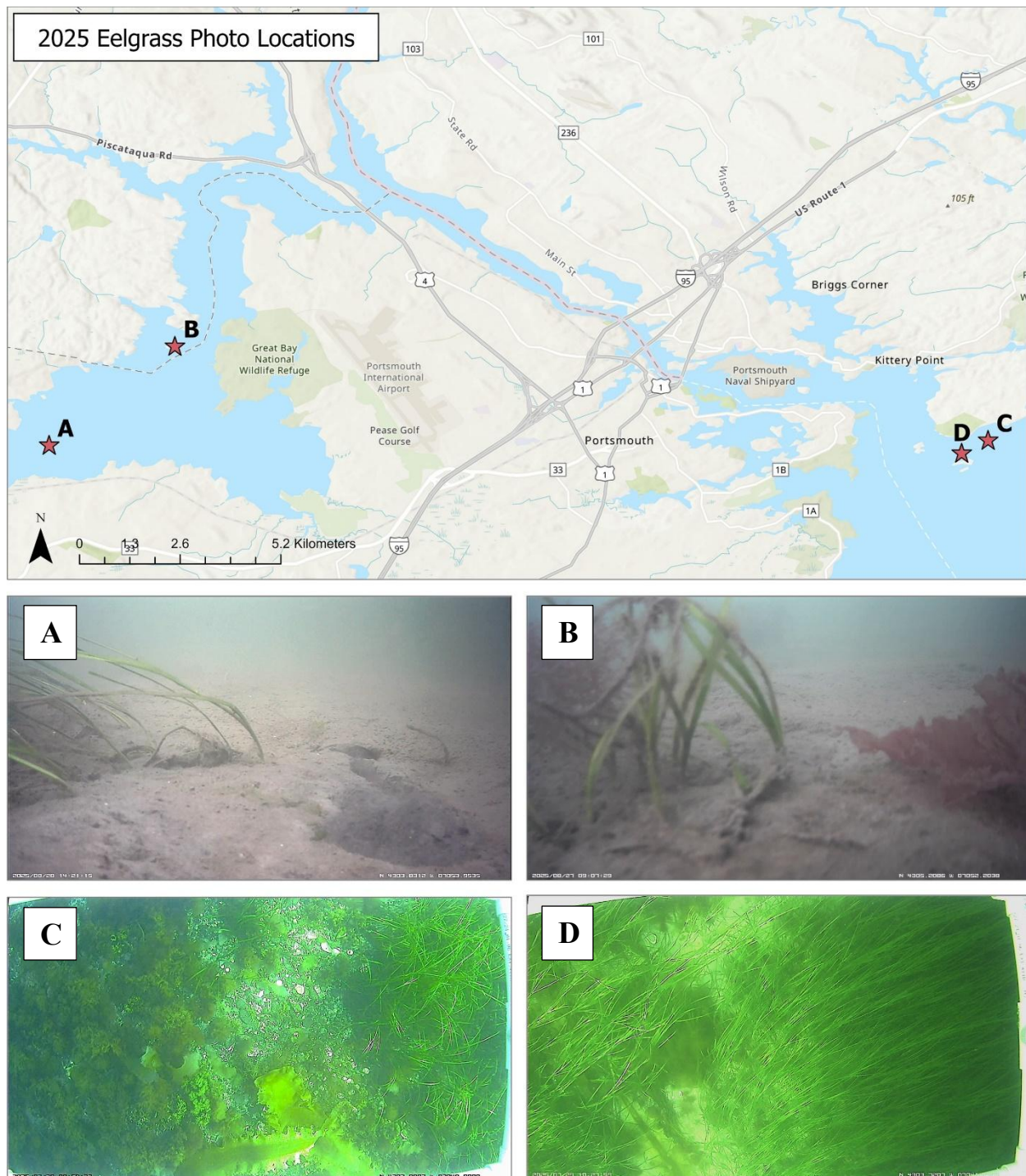


Figure 12 – 2025 Map and Video Still Images of Four Video Survey Locations, Two in Great Bay (A and B) and Two at the Mouth of the Piscataqua River (C and D).

Conclusion

This report lists and maps the inventories of seagrasses within the Great Bay and Piscataqua River Estuary using a series of remote sensing and ground verification methods. The results listed herein are the latest full mapping of this inventory as of the date of this publication. The mapping of seagrasses is a complex endeavor within this study area due to its highly dynamic nature, with varying tidal, weather, and biological influences at play. For instance, rainy spring conditions, such as those during the 2025 growing season can influence watershed runoff and the turbidity of the waters in Great Bay. This in turn may influence the amount of solar radiation that can penetrate the water column thus affecting potential eelgrass growth. Furthermore, this year's eelgrass mapping project identified several topics beyond the historical focus on eelgrass that are related to the health of the Great Bay Estuary. There is no question that eelgrass health is related to overall estuary health, but there are other species, such as seaweed and oysters, that are ecologically and otherwise connected to eelgrass that should be considered for future monitoring efforts. In order to help this effort, a concurrent study in 2025 included an assessment of oysters living within the sediments and associated with seaweeds and eelgrass.

Acknowledgements

The authors of this report would like to thank David Burdick, Nate Gruen, Lara Martin, Kalle Matso, and Trevor Mattera for providing additional on-water and dive site observations that helped to inform portions of this report.

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Appendix A – (Eelgrass Subsection Maps)

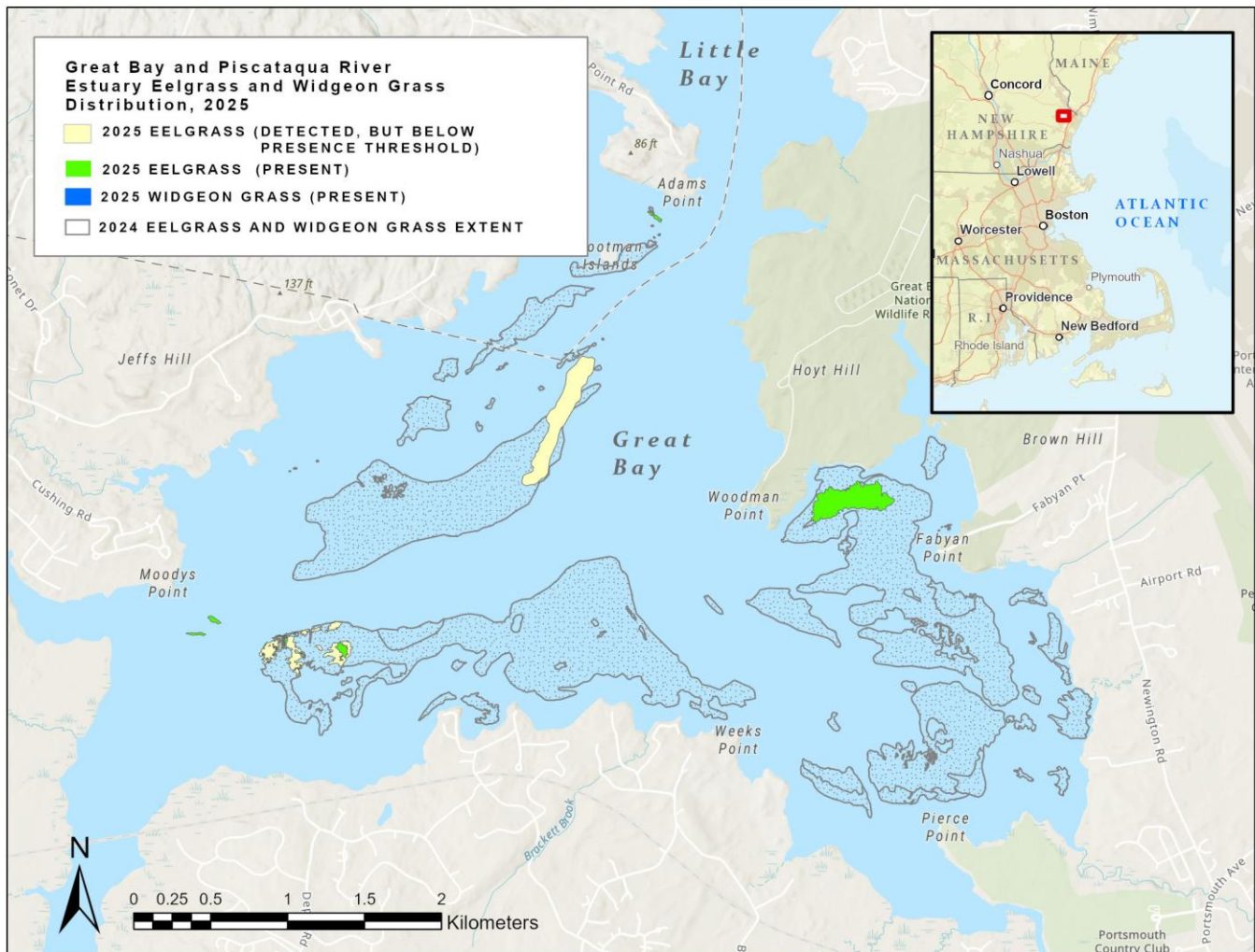


Figure A1 – 2025 Great Bay Estuary Survey – Map of the Distribution of 2024 and 2025 Eelgrass and Widgeon Grass – Great Bay.

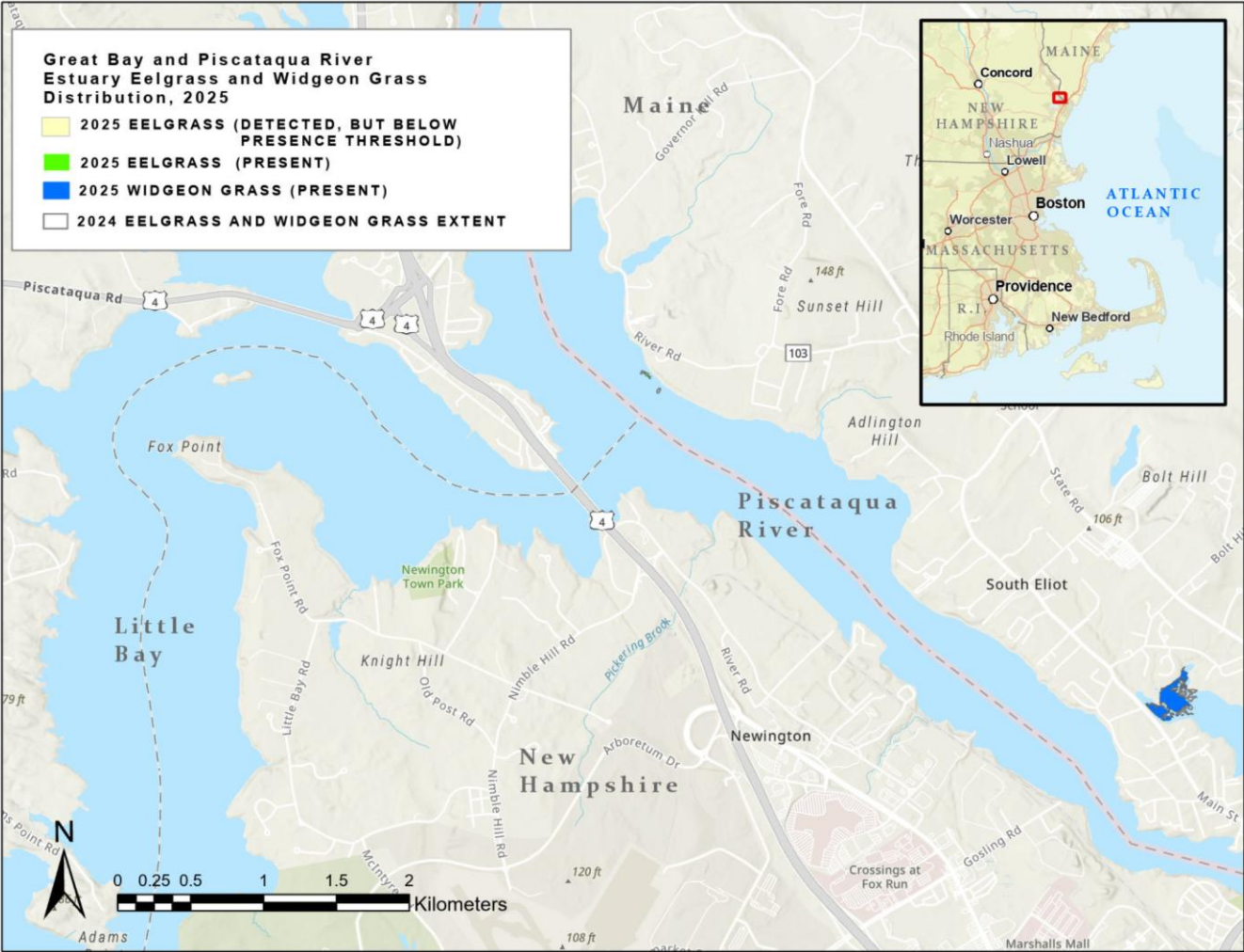


Figure A2 - 2025 Great Bay Estuary Survey – Map of the Distribution of 2024 and 2025 Eelgrass and Widgeon Grass – Little Bay and the Piscataqua River.

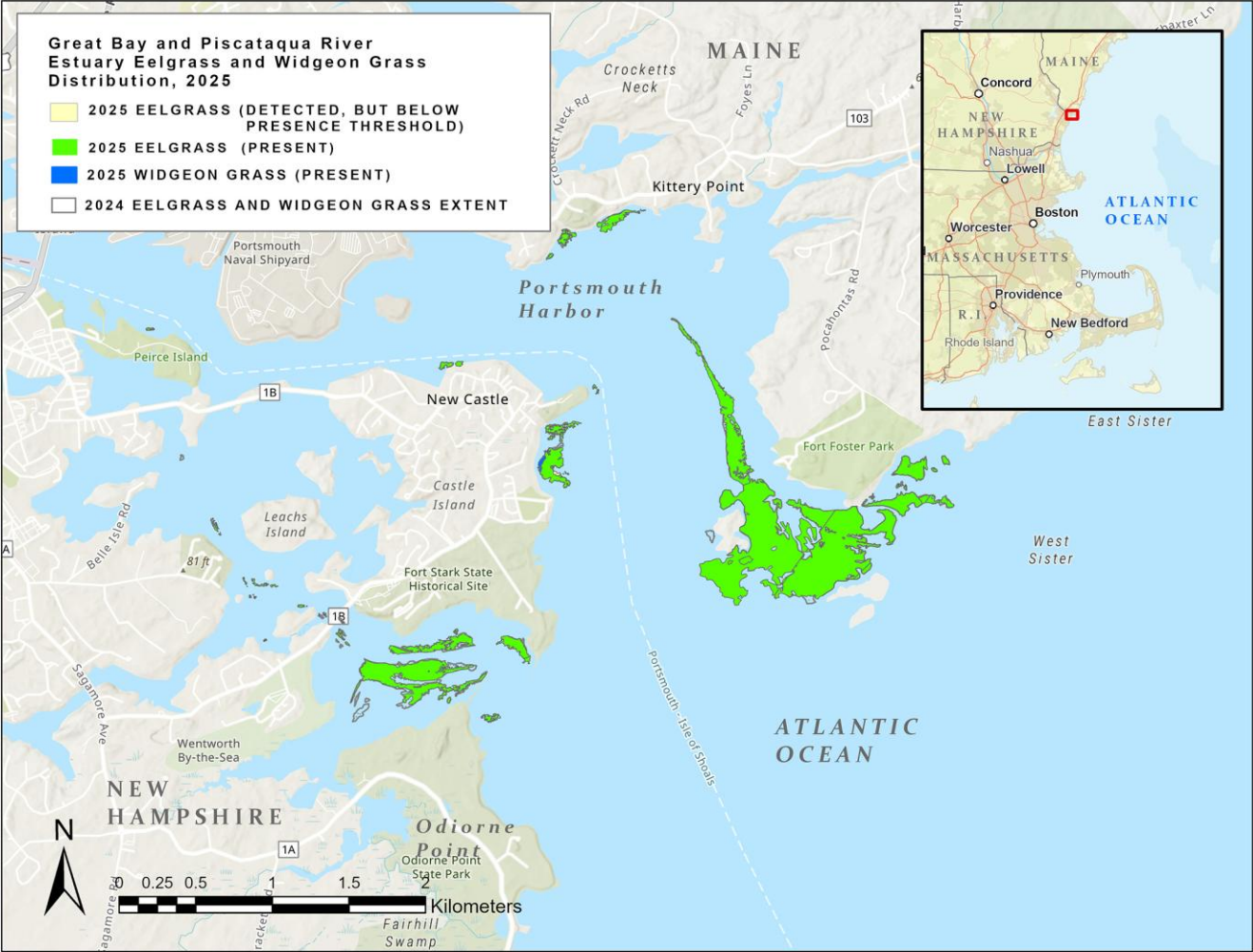


Figure A3 - 2025 Great Bay Estuary Survey – Map of the Distribution of 2024 and 2025 Eelgrass and Widgeon Grass – Portsmouth Harbor.

Appendix B – (2024 vs. 2025 Vegetation Aerial Images)

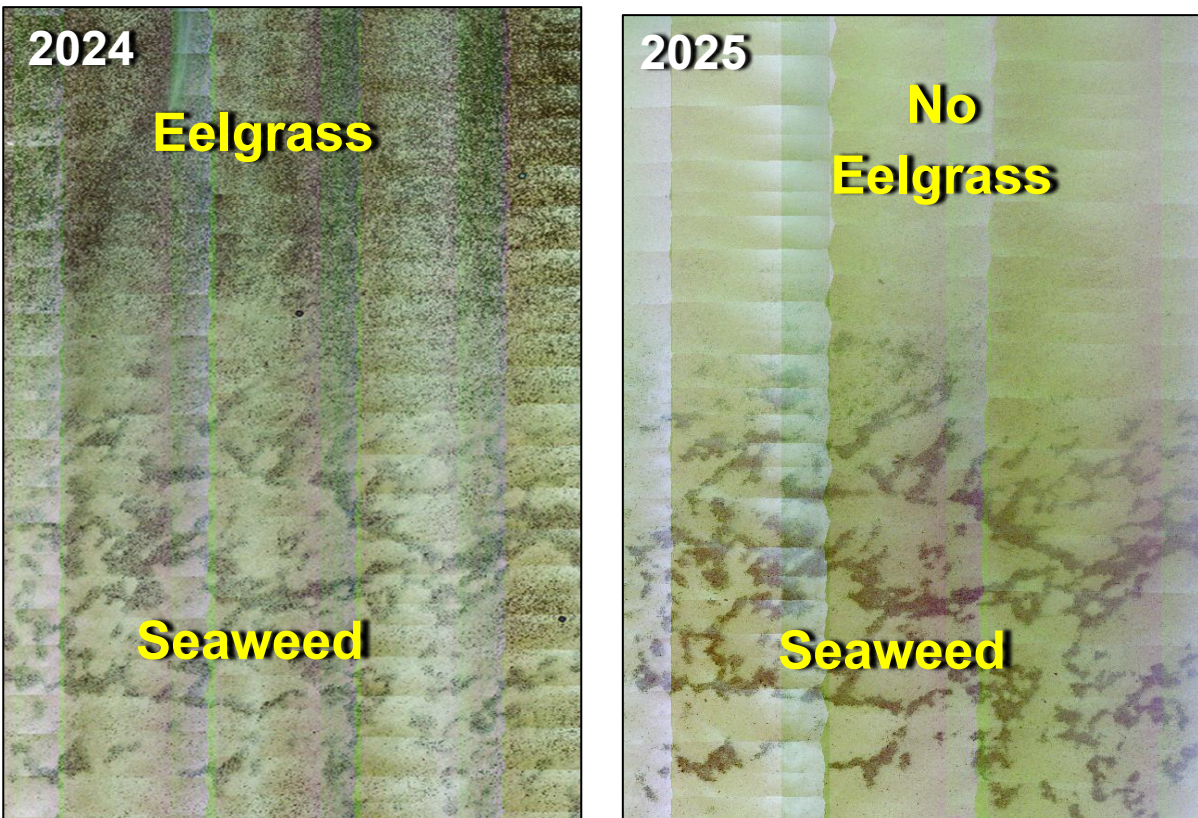


Figure B1 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Southwest Great Bay.

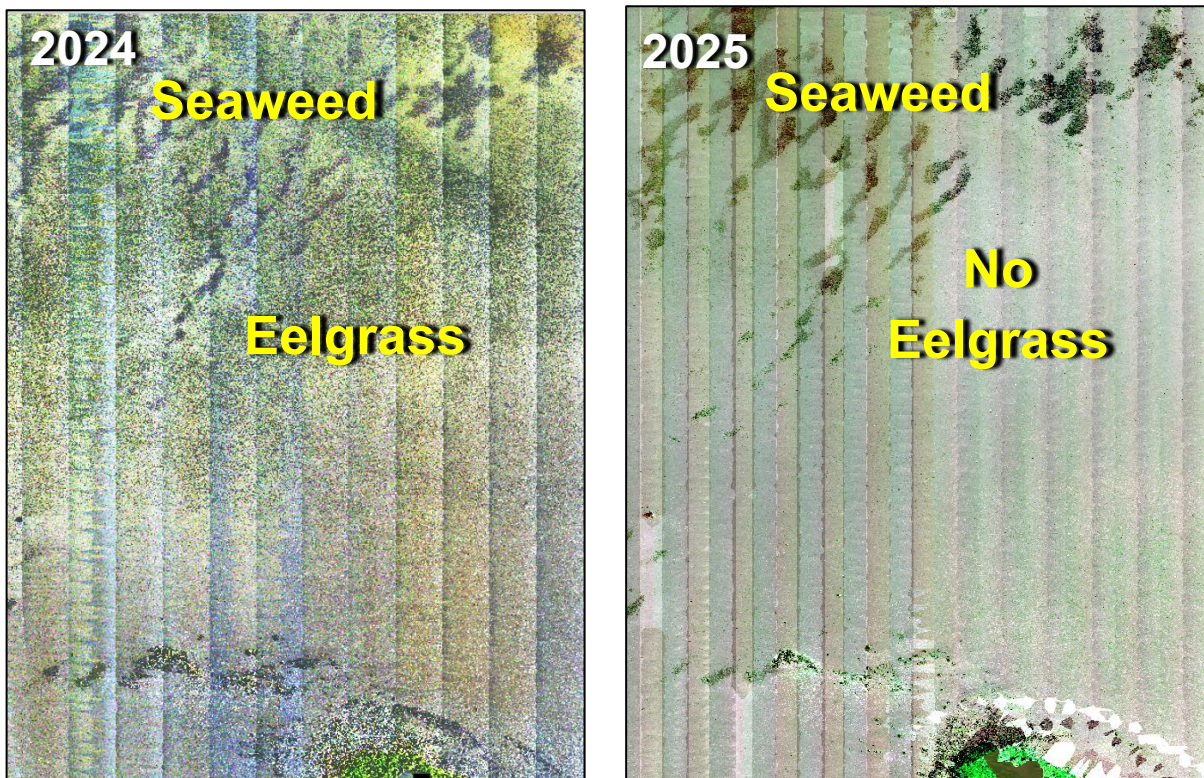


Figure B2 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Southeast Great Bay.

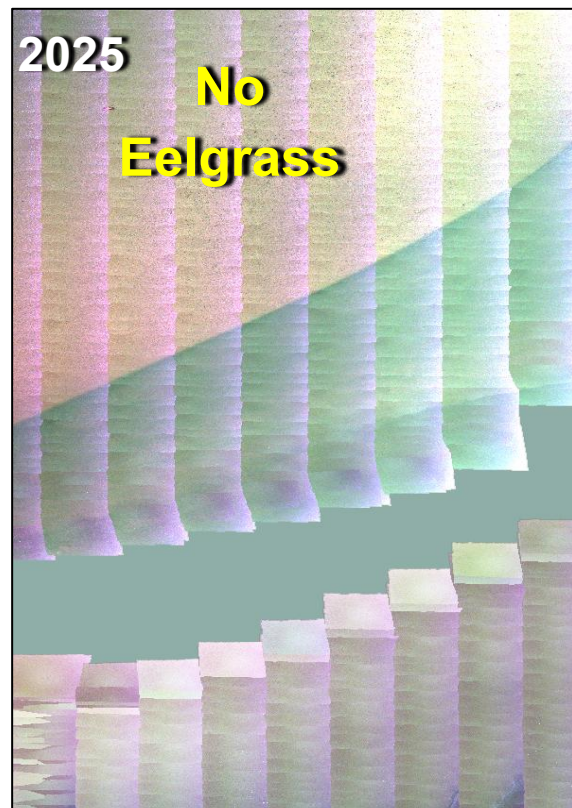
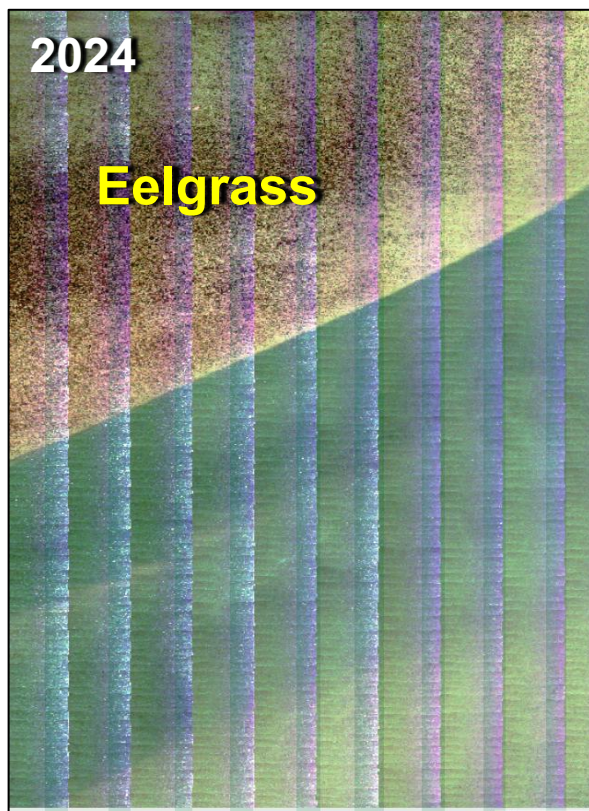


Figure B3 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Central Great Bay.

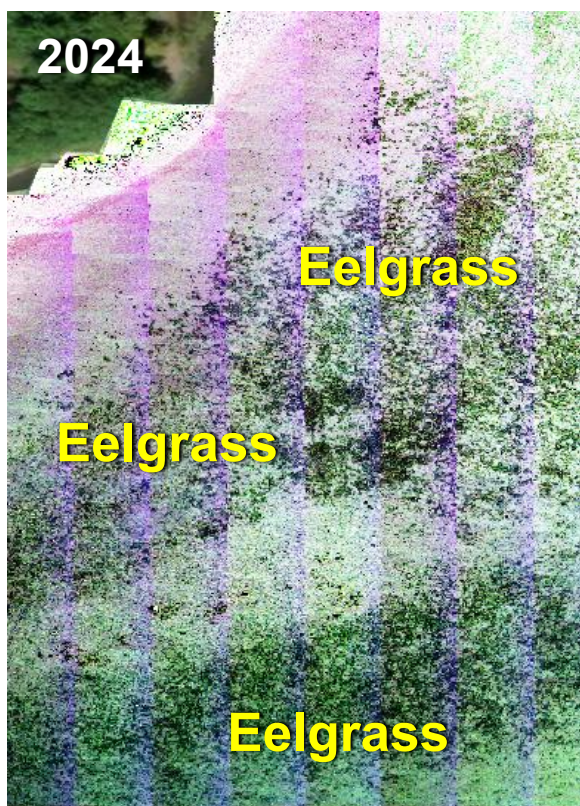


Figure B4 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Eastern Great Bay, East of Woodman Point.

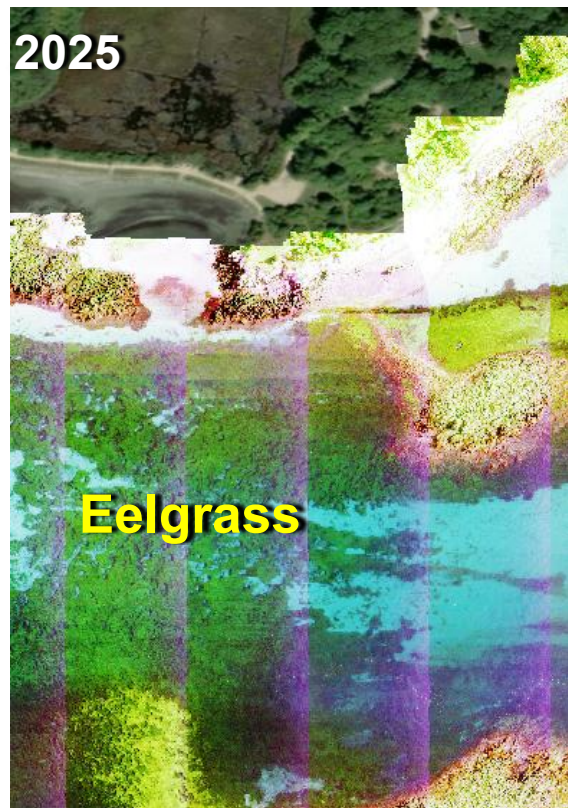


Figure B5 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Southeast of Fort Foster.

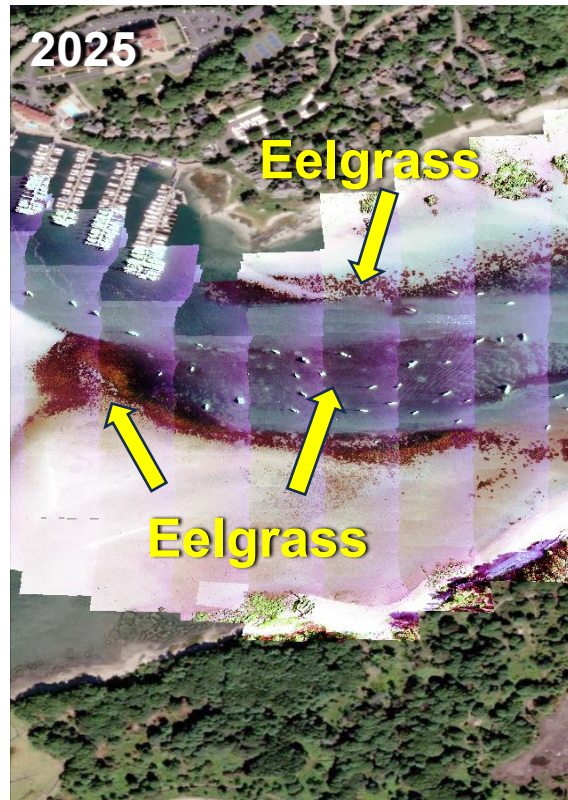
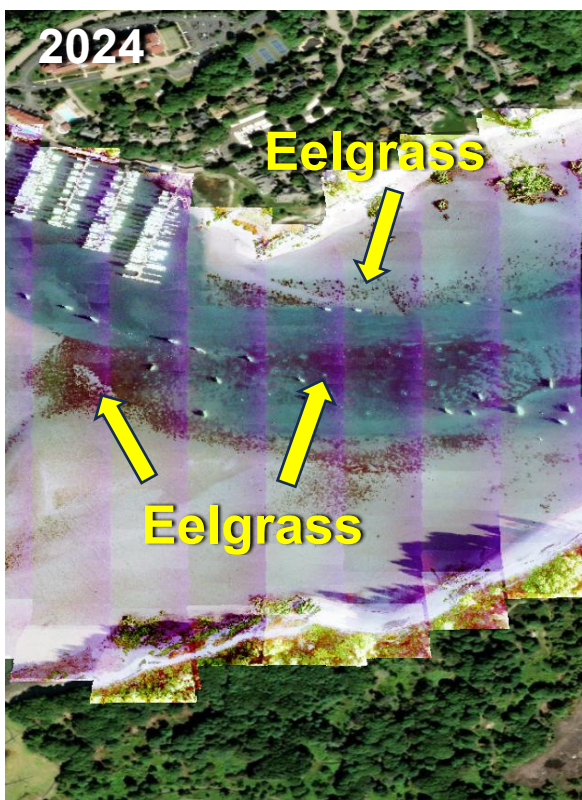


Figure B6 - 2024 and 2025 Submerged Aquatic Vegetation UAV Images, Little Harbor, Back Channel, Portsmouth, NH.

Appendix C – (Seaviewer HD Underwater Camera Images)



Figure C1 - Underwater HD Seaviewer Camera with PVC frame used to ground truth bottom type.

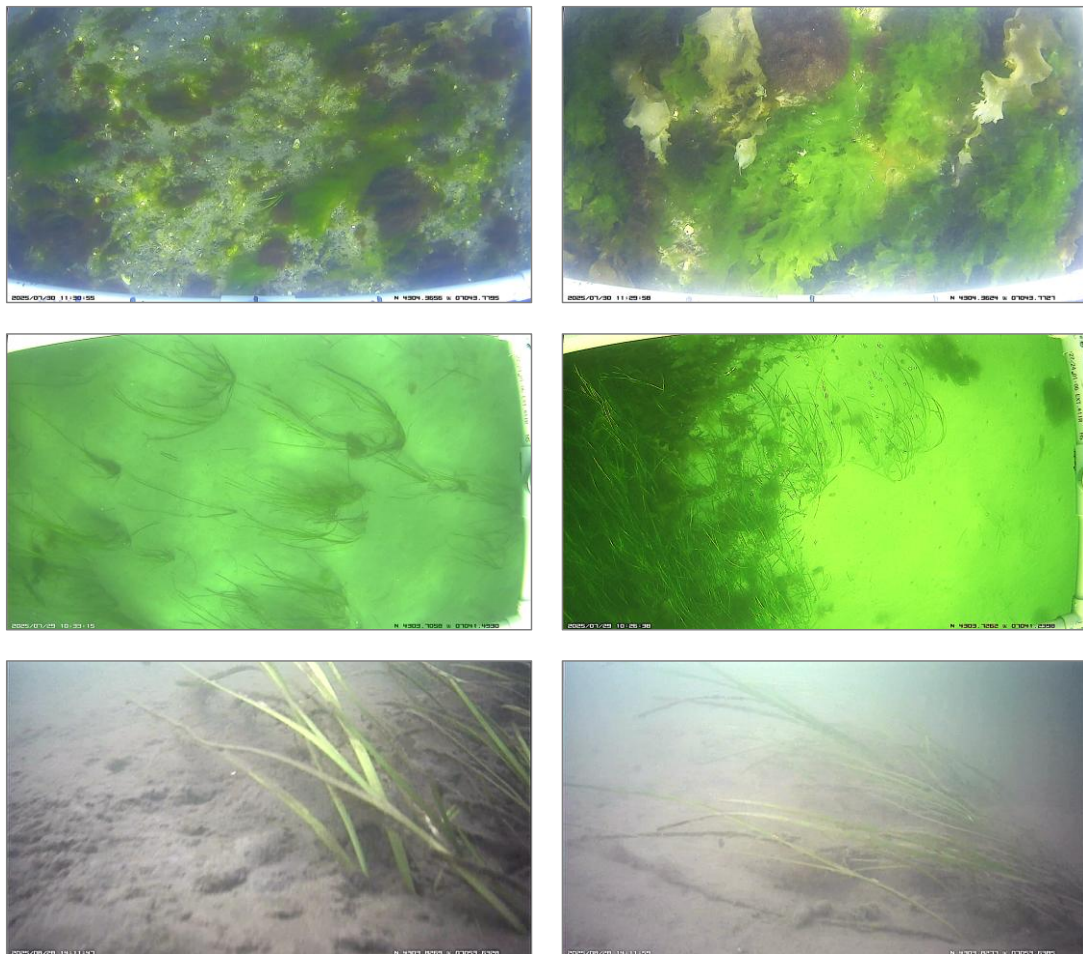


Figure C2 - Video Stills taken from underwater video showing coastal and Great Bay sites.