Southern Maine Seagrass Mapping
Aerial Photography Survey Coordination & GIS Mapping
Eliot to Cape Elizabeth

Prepared For

STATE OF MAINE
Department of Environmental Protection
Bureau of Water Quality
Division of Environmental Assessment

Prepared By

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Executive Summary

The Maine Department of Environmental Protection, Bureau of Water Quality, Division of Environmental Assessment contracted with Normandeau Associates, Inc. to map seagrasses in the coastal areas between the southern Maine boundary in the Piscataqua River and Cape Elizabeth. Normandeau managed the imagery acquisition, production and deliverables of low tide, high-resolution, true color aerial imagery produced by James W. Sewall Company. Normandeau used this imagery to delineate seagrass and estimate vegetation density using the four-category scale developed by Orth *et al.* (1991). Normandeau also performed field surveys to verify delineated beds, taking both GPS point data and underwater video footage at 252 locations. Results of the mapping indicate a slight overall increase in seagrass from previous mapping efforts in 2010 and 2019, although differences in methods among the three mapping efforts could account for some of the change. Approximately 873 acres of seagrass were mapped in 2021, including 859 acres of eelgrass (*Zostera marina*) and 13.7 acres of widgeon grass (*Ruppia maritima*). The largest increases in bed boundaries were observed at the mouth of the Piscataqua River in Kittery, south of Vaughn Island in Kennebunkport, near Biddeford Pool in Biddeford, and northwest of Richmond Island in Cape Elizabeth. An area where eelgrass beds were notably smaller than previous mapping occurred at the northeast side of Richmond Island in Cape Elizabeth.

1 Introduction

The Maine Department of Environmental Protection, Bureau of Water Quality, Division of Environmental Assessment (Department) contracted with Normandeau Associates, Inc. (Normandeau) to map seagrasses in the coastal areas between the southern Maine boundary in the Piscataqua River and Cape Elizabeth. The purpose of the work was to update mapping efforts conducted by the Maine Department of Marine Resources (DMR) from 2001 to 2010 and by an independent contractor for the Great Bay Estuary and Piscataqua River in 2019 to assess the extent and percent cover of seagrass, primarily eelgrass (*Zostera marina*). Eelgrass plays an important role in the nearshore environment by sequestering carbon, buffering acidification of surface sediments, oxygenating bottom water, reducing water column turbidity, and providing habitat, nursery grounds, food and refuge for a host of invertebrate and vertebrate marine animals, including commercially important species. The Department will use the results of the survey to inform seagrass protection, restoration and enhancement opportunities, and to assist with assessment of marine life use attainment based on mapped eelgrass change over time.

The Department contracted with James W. Sewall Company (Sewall) to acquire low tide aerial imagery during June-September 2021 of the supratidal, intertidal and shallow subtidal shoreline of Southern Maine (Eliot to Cape Elizabeth; Figure 1). Sewall subcontracted with Bluesky for aerial imagery acquisition. Normandeau managed the imagery acquisition, production and deliverables. Images were photointerpreted to develop maps of the seagrass boundaries and estimated percent cover, mapping was field verified, and GIS maps and a summary report pertaining to seagrass distribution were produced.

2 Aerial Photography Survey Coordination

Sewall subcontracted with Bluesky to collect high-resolution true color (RGB-NIFR) aerial imagery for use as a raster base image for coastal mapping projects on the coast of Maine. The imagery was captured at 5.7 inch (14.5-cm) ground sample distance (GSD) and was used to produce high resolution 6-inch (15 cm) orthorectified imagery with a 1-foot (30 cm) accuracy. The project area consisted of approximately 400 images on approximately seven flight lines with 60% forelap and 30% sidelap (Figure 2). An airborne global positioning system (GPS) and inertial measurement units (IMU) were utilized during the acquisition to improve the aerotriangulation solution. Bluesky acquired the raw imagery using a Vexcel Eagle 80-mm Mark 3 aerial camera mounted on a fixed wing aircraft and flown at an elevation of approximately 9,500 feet. Digital orthorectified imagery was created using the raw digital aerial imagery, ground control, aerotriangulation, and a digital elevation model. Existing State of Maine ground control was utilized in the aerotriangulation solution for this project.

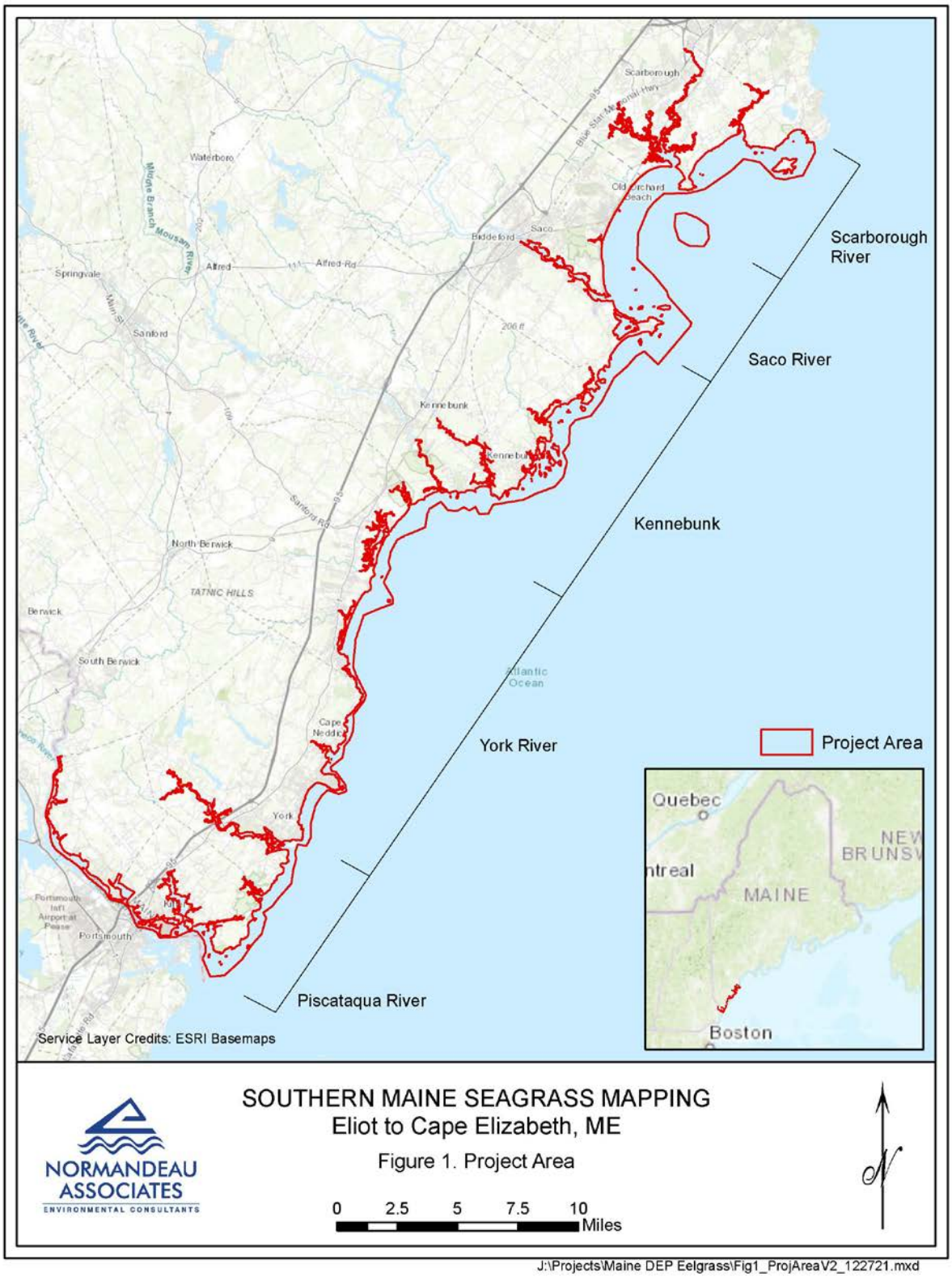


Figure 1. Project area for aerial imagery acquisition and seagrass delineation, 2021. The geographic sections were assigned by Normandeau for labeling and discussion purposes.

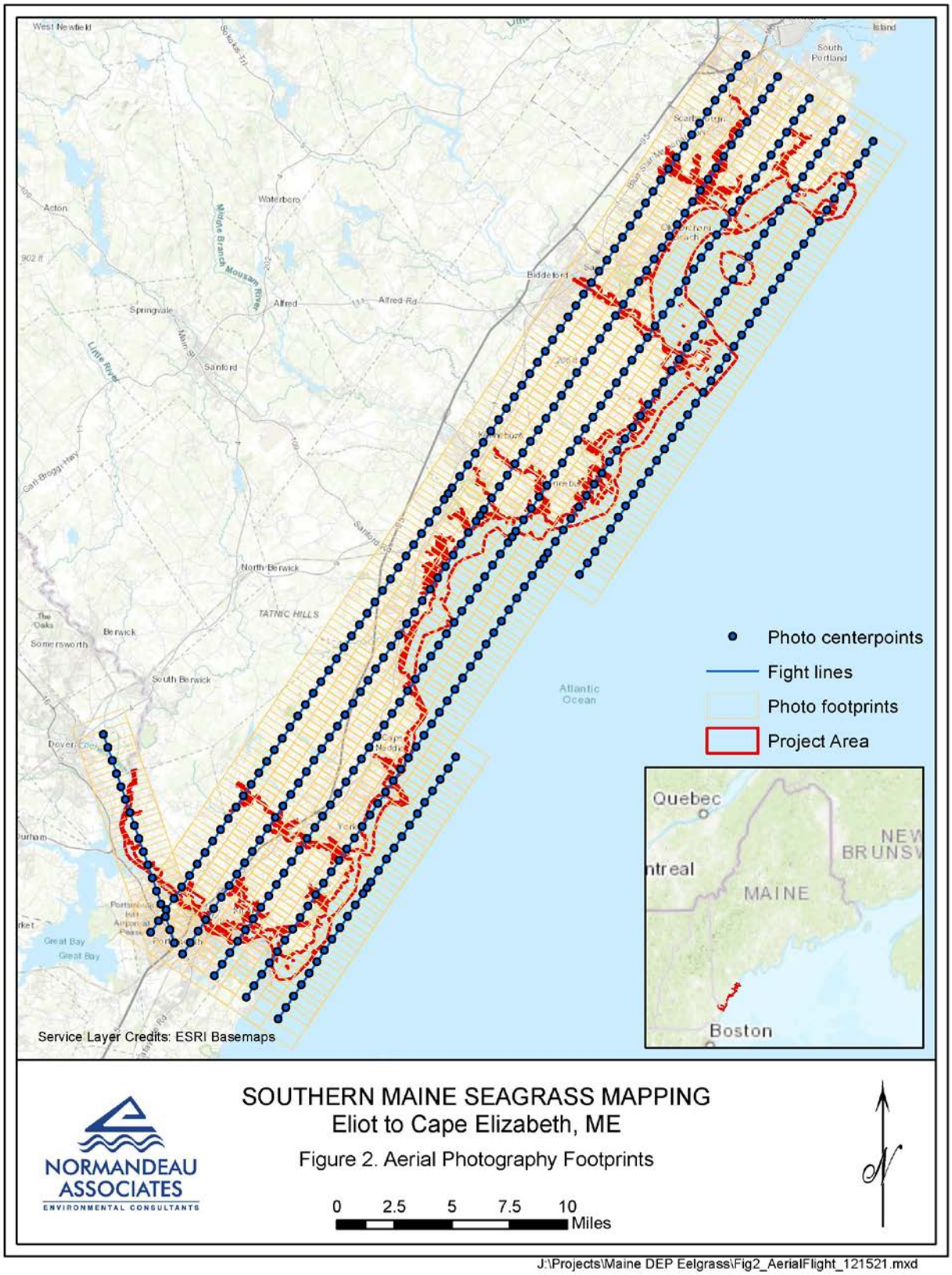


Figure 2. Flight lines, photo center points, and photo footprints for aerial flight photographs.

On June 28, 2021 Bluesky flew the project corridor, capturing approximately 400 photos across seven flight lines. This flight began recording at approximately 7:42 AM and concluded at approximately 10:15 AM on June 28, 2021, which was within the required two-hour window of the low spring tide of -0.9 ft mean lowest low water (MLLW) occurring at 8:39 AM as predicted by the Wells, Maine (NOAA Station ID 8419317) tide table. Flight and ground conditions were monitored the week leading up to the flight to capture best conditions, including early-mid morning, low sun angle (25-50°), low wind velocity (<10 miles per hour [mph]), and low cloud cover (<10%). Actual conditions included fair to mostly cloudy skies with a west and southwest wind between 5 and 12 mph according to the NOAA stations closest to the project area (Pease Air Force Base, Sanford Regional Airport, and Portland International Jetport). Notes from the flight crew indicated "cloud at 10-15,000 feet did cause some shadow on parts of the site". The survey did not occur immediately following a rain event, period of high winds, or during a phytoplankton bloom in order to minimize water column turbidity.

Due to concern for cloud cover and obstruction, the flight was flown again on June 29, 2021. Photos for this flight began at 8:03 AM and concluded at 9:42 AM, which was within the two hour window of the low spring tide of -0.4 ft MLLW occurring at 9:33 AM as predicted for Wells, Maine. Actual flight conditions included fair to a few clouds with westerly winds between 6 and 13 mph according to the NOAA stations closest to the project area. Notes from the flight crew indicated "crystal clear on today's flight. As expected low cloud developed inland, but managed to complete the block before it reached the area. Conditions looked very calm and clear at the surface." The survey did not occur immediately following a rain event, period of high winds, or during a phytoplankton bloom in order to minimize water column turbidity. The imagery from June 29 was used for both the draft and final imagery; none of the June 28 imagery was incorporated.

Sewall used the imagery from Bluesky to produce orthorectified photos and draft ortho tiles were provided to Normandeau on July 31, 2021. Sewall provided draft imagery as a mosaic on August 16, 2021. Normandeau used the draft mosaic to start desktop digitizing of seagrass beds and to plan target locations for field verification. Comments and corrections were provided from Normandeau to Sewall for processing of the final imagery. Final imagery was delivered to Normandeau on August 31, and was used for field verification of mapped seagrass beds during September and early October. The final imagery and metadata are included with this deliverable.

3 Seagrass Delineation and Mapping

3.1 Methods

3.1.1 Photointerpretation

Normandeau reviewed the shapefiles and imagery from previous seagrass mapping efforts to understand the previous distributions and photosignatures of seagrass. Sources included:

- 2010 Maine DMR Eelgrass: This shapefile (MEDMR 2010) contains a compilation of seagrass from multiple survey years. Each survey year has corresponding imagery including Biddeford Pool to Cape Elizabeth, and Casco Bay 2001-2002 [MEGIS 2001] and Eliot to Biddeford Pool, 2010 [MEGIS 2010]), which are publically available from the Maine.gov, Maine GeoLibrary. Imagery was flown and photographed timed near low

tide. Polygons were screen digitized and field verification was conducted by boat, on foot, and by plane. This dataset is referred to as MEDMR 2010 or 2010 mapping throughout this report, while actual years of survey were as follows:

  - Biddeford Pool to Prout's Neck, 2001
  - Biddeford Pool and east of Spurwink River to Cape Elizabeth, 2002
  - Kittery Point and south of Biddeford Pool, 2009
  - Piscataqua River to south of Biddeford Pool, 2010

- 2019 Great Bay Estuary Eelgrass: This survey includes the Piscataqua River in Maine and New Hampshire. The shapefile (NH GRANIT 2019) of eelgrass is publically available from the New Hampshire Statewide GIS Clearinghouse, NH GRANIT. This dataset was photointerpreted from orthoimagery collected on August 2, 2019. Field verification was performed at pre-selected locations and ad hoc locations using a drop camera from a boat, or by visual observations at low tide. Imagery can be viewed from the NH Coastal Viewer (https://nhcoastalviewer.unh.edu/Html5Viewer/index.html?viewer=NHCoastalViewer) and was obtained from an FTP site from the NH GRANIT project director.
- 2018 Casco Bay Eelgrass: This shapefile is outside of the 2021 southern Maine survey area but was reviewed for photo signatures. Both imagery (MEGIS 2018) and eelgrass shapefile (MEDEP 2018) are publically available from the Maine.gov, Maine Geolibrary (https://www.maine.gov/geolib/catalog.html). Imagery was acquired in June 2018 at low tide, and polygons delineating eelgrass were screen digitized. Field verification of digitized polygons was conducted by boat, on foot, and by plane.

These sources were reviewed to identify the photo signatures for eelgrass and widgeon grass, as well as other features in the area such as macroalgae and ledge. Normandeau and a Maine Department of Environmental Protection (DEP) boat captain conducted two days of field verification in the Piscataqua River area during the early stages of photointerpretation to allow the delineators to calibrate signatures in known eelgrass stands and in more complex or challenging areas. Signature calibration was performed on July 15 and 16, 2021 using the 2019 imagery of the Piscataqua River.

As the draft imagery arrived from Sewall, Normandeau's photointerpreters delineated seagrass and estimated vegetation density using the four-category scale developed by Orth *et al.* (1991), where 1=0-10% cover (very sparse), 2=10-40% cover (sparse), 3=40-70% cover (moderate), and 4-70-100% cover (dense; Figure 3).

The minimum map unit was assumed to be 0.5 acres (0.20 hectares), but areas as small as 55 square feet (0.001 acres; 0.0004 hectares) were delineated where shallow water and good lighting permitted higher resolution. Areas less than 0.07 acres (0.03 hectares) were typically combined with nearby beds. Combining patchy areas of this size is consistent with guidance for mapping submerged vegetation by DOC (1995) and NOAA (2001). Areas less than 0.07 acres that were adjacent to other small patches were mapped separately if consistent with previous mapping efforts. Strands of seagrass observed during field verification or individual clumps with a percent cover of ten or less that had no obvious signature were not delineated. Locations that

were identified in the field and/or by underwater video with a single dense clump (10% or greater) that were not discernable in the imagery were mapped with a circle having a minimum radius of approximately 10 feet (3 meters). This minimum size was chosen to encompass some of the location error associated with boat movement and GPS accuracy without exaggerating bed size. All GPS points taken during field verification are provided with this deliverable.

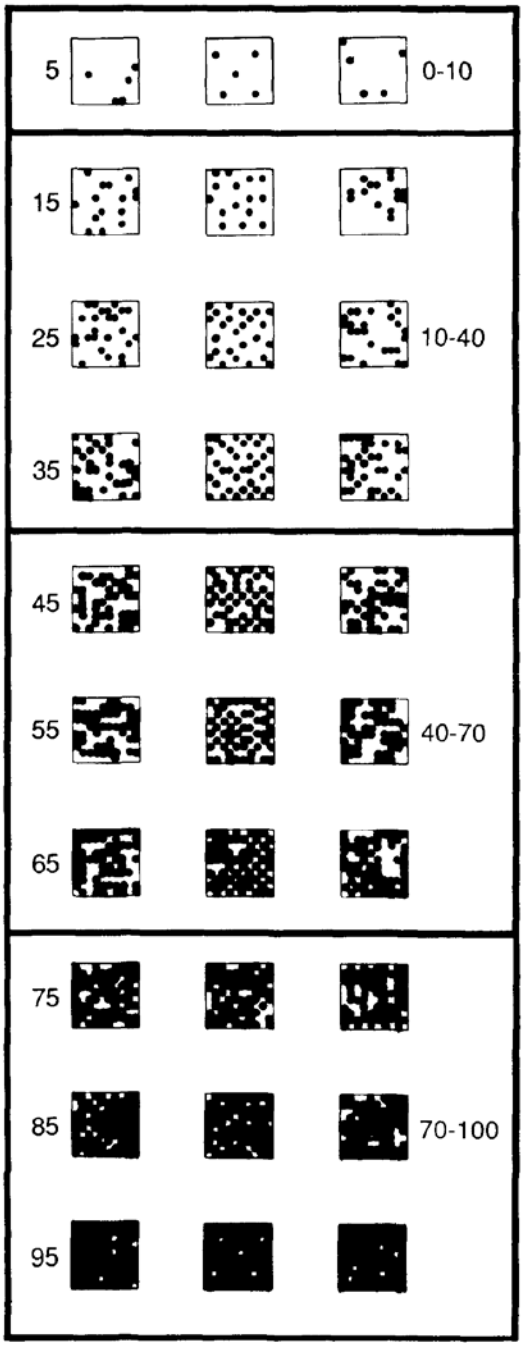


Figure 3. Depiction of Orth *et al.* (1991) percent cover classes.

For mapping and labeling purposes, the project area was broken into five geographic sections: Piscataqua River, York River, Kennebunk, Saco River, and Scarborough River (Figure 1).

Transect locations for field verification were pre-selected by the photointerpreters either because they were representative of typical conditions, or because the delineator had a question about a bed's features. Additionally, camera drops were planned for any 2010 mapped bed that was not given a designated transect.

Upon completion of field verification, each delineated polygon was numbered using geographic section abbreviations and sequential numbering moving from southwest to northeast, and from upstream to the mouth for rivers (Table 1). GPS point data and underwater video footage were used to refine percent covers in the final mapping. Because the field verification was conducted while Sewall was finalizing the imagery, mapped beds were again reviewed with the completed images to finalize bed boundaries and percent covers

Table 1. Project area sections and numbering system

Abbreviation	Geographic Section	Number of Polygons	Acres of Seagrass
PR	Piscataqua River	43	200.3
YR	York River	13	19.4
KB	Kennebunk	32	275.6
SA	Saco River	12	203.9
SB	Scarborough River	26	173.5
	Total	126	872.7

3.1.2 Field Verification

Field verification was conducted over ten days between August 26 and October 7, 2021. Field verification was performed only during acceptable weather and wave conditions, including no precipitation, minimal wind and waves, and not immediately following rain events where water turbidity would obscure seagrass. Numerous locations were visited throughout the project area to capture localized differences in seabed composition and water depth. Bed presence and absence was the main priority for field efforts, followed by bed boundary confirmation and percent cover. Some transect locations were modified in the field depending on progress, safety, and weather.

Field notes from all field efforts are provided in Appendix A. The field verification team consisted of a Maine Department of Environmental Protection (DEP) boat captain and two Normandeau staff, one to control the camera and the second to observe the video and record findings. Equipment included a Maine DEP vessel (20-foot Maritime Skiff with a 115 horse outboard motor), Ocean Systems High-definition (HD) underwater video camera and SeaViewer 950 Sea-Drop Analog underwater video camera, and Eos Positioning Systems Arrow Gold GNSS GPS systems that pair wirelessly to Android powered ruggedized field tablets and are capable of submeter accuracy. The camera was attached via cable and secured approximately one foot from the side of the vessel. A fin was attached to the camera to help achieve the desired orientation. The camera operator manually controlled the position of the camera by watching the viewer and observing water depths. Depth of the camera above the sediment varied depending on water clarity. Tow speeds during camera operation were typically less than one mph.

The GPS tablet was loaded with the Normandeau draft maps plus the seagrass maps from the 2010 DMR effort and the 2019 Piscataqua River delineations. The target field verification locations were also loaded that identifed bed presence-absence confirmation areas, boundary determination areas, and signature check areas to be reviewed in the field. The data dictionary on the GPS tablet incorporated points for seagrass presence (eelgrass, widgeon grass, and mix of both species), percent cover (0, 1-10, 10-40, 40-70, 70-100), macroalgae, epiphytes, and a generic point for additional comments and observations.

3.1.3 GIS

The final GIS file includes all mapped polygons as well as metadata containing survey and mapping specifics. Shapefiles for calibration check areas, transects for field verification, GPS data points of seagrass presence, percent cover, and comments/observations, and track log are also provided.

3.1.4 Quality Control/Quality Assurance

Photointerpretation was conducted by two primary interpreters. Prior to field verification, each delineator quality checked the other interpreter's file. Areas of disagreement were reviewed and adjusted based on mutual consensus. After field verification, the corrected maps were reviewed and compared with the videos to confirm the edits were accurate and the percent cover estimates were consistent with the video. In addition, a senior delineator checked approximately 12% (15/126) of all digitized polygons, comparing to the notes and videos from the field verification effort when necessary. Delineated polygons were simplified with the dissolve tool in ArcMap to combine percent cover data into one bed boundary. A random number generator was used in Microsoft Excel to generate 25 numbers within the total number delineated. The first 15 unique numbers were then used to select the seagrass beds for review. In addition to the 15 randomly selected polygons, the senior delineator reviewed all polygons that were not field verified (29), for a total review of 44/126 polygons or approximately 35%. The ArcMap Topology toolset was used to check for overlap, omissions, and inconsistencies in polygon shapes and all attribute tables were reviewed for completeness.

The accuracy of the GPS unit ranged from 0.5 to 30 feet among all field efforts, with approximately 94 percent of points having accuracy of 3.3 feet or less. The GPS receiver paired with the tablet was separate from the camera, resulting in typically five to ten feet of difference between a GPS point and the corresponding point from the underwater video. Occasionally GPS points and the boat track log did not line up, likely due to boat movement, so seagrass boundaries were adjusted to split the difference between these features if there was not a prevalent aerial signature.

3.2 Results

3.2.1 Field Verification

Field verification took place over ten field days between late August and early October. Transects and camera drops were used to collect information on seagrass beds, and 252 strategically targeted locations were visited. These locations covered 79% (99/126) of all mapped polygons. Field verification was paramount in determining presence-absence for areas that had overlapping signatures with macroalgae, deep water and/or ledge (Figure 4).

Eelgrass observed on sandy substrate (PR43)

Digitized mapping of eelgrass on sandy substrate (PR43)

Eelgrass observed among rockier substrate (SB05)

Digitized mapping of eelgrass in rockier substrate (SB05)

Figure 4. Seagrass Signatures

3.2.1 Final Maps

The final mapped seagrass dataset contains 126 mapped seagrass beds, and covers approximately 873 acres. 171.8 acres of seagrass were mapped as category 1, 0-10 percent cover, 115.8 acres of seagrass were mapped as category 2, 10-40 percent cover, 250.3 acres of seagrass were mapped as category 3, 40-70 percent cover, and 334.8 acres were mapped as category 4, 70-100 percent cover (Figure 5). Polygons that were visited in the field have an associated species identification, which is based solely on underwater video observation unless otherwise noted. Eelgrass was the dominant vascular species, covering approximately 859 acres. Sparse beds were often intermixed with a range of macroalgae species, comprised of red algae that appeared to include *Dasysiphonia japonica*, as well as sea lettuce (*Ulva lactuca*) fucoids (likely *Ascophyllum* and *Fucus* species), and kelp (*Laminaria digitata)*. Ectoprocts, chordates, and snails were occasionally observed on seagrass blades in the underwater video. Widgeon grass was noted in the Spinney Creek backwater, and covered approximately 13.7 acres. No other locations for this species were observed. Both video coordinates and field GPS points were used to refine the photointerpreted boundaries of mapped beds (Figure 6).

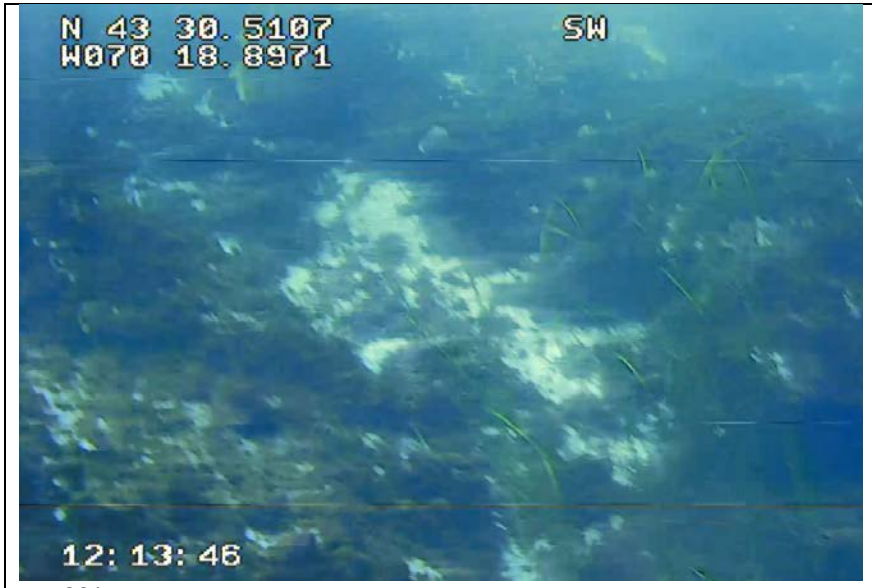
4 Discussion

4.1 Distribution and Coverage of Seagrass

Seagrass abundance was assessed by both percent cover and location (Table 2). The largest mapped beds with a cover class greater than one (0-10%) were located at the mouth of the Piscataqua River in Kittery, south of Vaughn Island in Kennebunkport, near Biddeford Pool in Biddeford, and northwest of Richmond Island in Cape Elizabeth. Large areas with a low percent cover include near Goose Rocks Beach in Kennebunkport, and near Ferry Beach in York. Other than in the Piscataqua River, very little to no seagrass was identified in the other major rivers within the Project Area, which included the York, Saco, Scarborough, and Spurwink Rivers. As expected based on preferred seagrass habitat, the extensive sand beaches that are exposed to open ocean and wave current were also unproductive for seagrass growth, including Long Beach in York, Ogunquit Beach, Wells Beach, Fortunes Rocks Beach in Biddeford, Old Orchard Beach, and Scarborough Beach. Seagrass was identified in areas with some protection from the open sea currents, and appeared in varying quantities through a variety of substrates. Shallow areas with softer substrate typically hosted the densest beds.

Table 2. Seagrass Acreage and Percent Cover by Survey Area

Project Area Section	Acres Seagrass				
	1-10% cover	10-40% cover	40-70% cover	70-100% cover	Total
Piscataqua River	60.6	27.4	49.2	63.1	200.3
York River	1.3	2.6	6.5	9.0	19.4
Kennebunk	48.0	55.7	77.9	94.1	275.6
Saco River	58.8	4.0	47.9	93.2	203.9
Scarborough River	3.1	26.1	68.8	75.5	173.5
Total	171.8	115.8	250.3	334.9	872.7



1-10% cover

10-40% cover

40-70% cover

70-100% cover

Figure 5. Percent Cover Categories Observed in the Field.

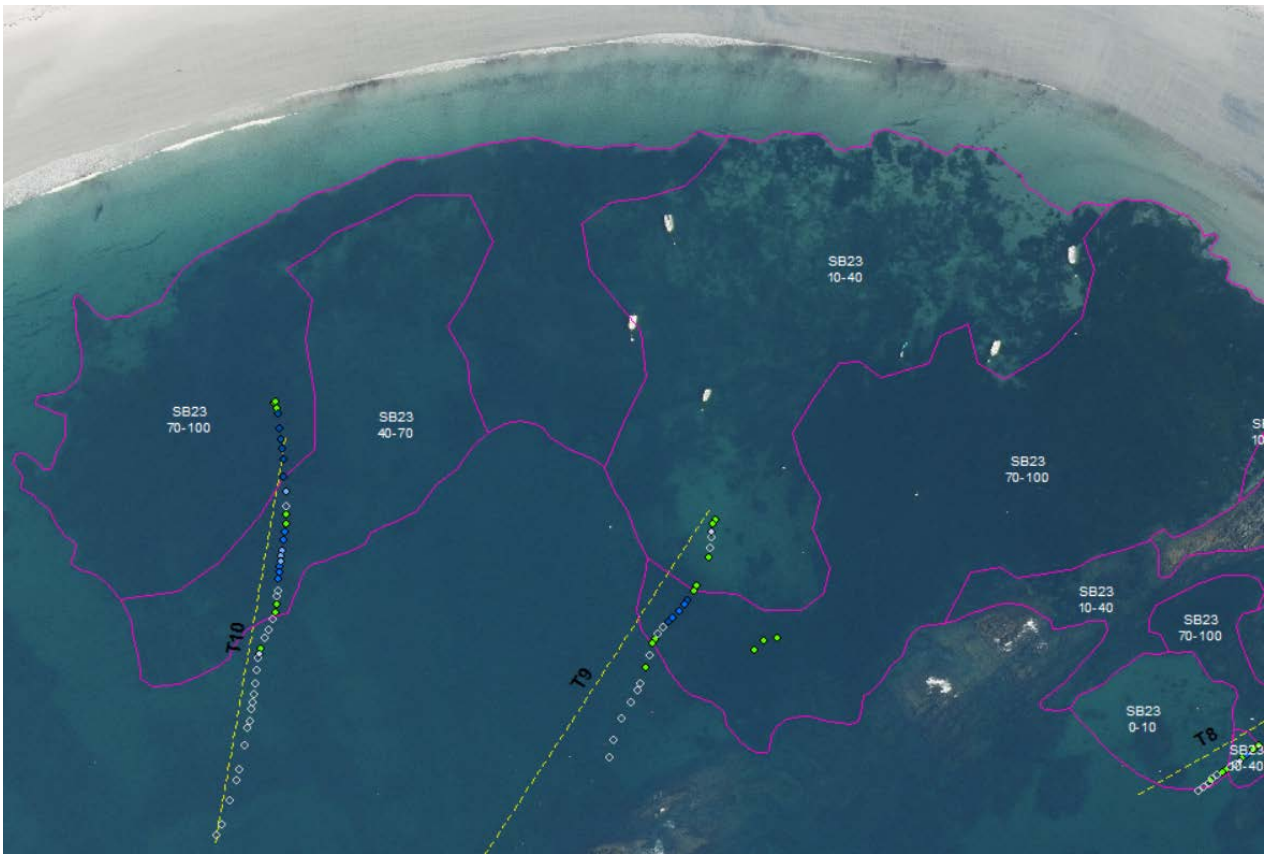


Figure 6. Field Transects, GPS points, and underwater video were used to inform seagrass boundaries during digitizing. (Hollow circles=0% cover, green=eelgrass presence, white= 1-10% cover, light blue=10-40% cover, dark blue=40-70% cover, purple=70-100% cover)

4.2 Comparison with Previous Years

The delineated beds from this effort are directly comparable to mapping from previous years. However, differences between methods and available information likely account for some of the differences in the mapping. Observer interpretation, imagery signature interpretation, and GPS accuracy could also account for differences in seagrass bed abundance and distribution. The 2010 Maine DMR data lacks species information associated with mapped polygons, but percent cover and year of survey is present within the data. The metadata does not describe the methods used for mapping or field verification. The 2019 polygons mapped for the Great Bay Estuary and Piscataqua River do not contain percent cover information. Methods for digitizing and field verification were generally similar, and overall level of effort appeared similar, with seven water-based field days and several targeted locations for field verification.

In general, seagrass coverage increased from the amount recorded in both 2019 and 2010 (Table 3). Seagrass coverage decreased from the 2010 amount in the Spinney Creek backwater, but increased from the amount mapped in 2019. This area was mapped entirely by field observation in 2021, as there were little to no aerial signatures from which to deduce presence. Lack of signatures could account for the varying abundance among survey years. In the Piscataqua River, the largest increase in seagrass presence was at the mouth of the river near Kittery Point. In the York River, new areas not previously mapped with seagrass were located just inside of the harbor, and the bed at the mouth of the river expanded from the 2010 boundary towards Harbor

Beach. In Kennebunk, seagrass increased south of Vaughn Island and was identified in new locations throughout this section of the project area. Seagrass was mapped in four new locations in the Saco River section, and near Biddeford Pool, seagrass beds were smaller than those previously mapped in 2010. Seagrass expansion was observed near the islands south of Prout's Neck, and adjacent to the west side of Prout's Neck east of the Scarborough River. The largest decrease in seagrass between the 2010 mapping occurred on the north side of Richmond Island in the Scarborough River section of the Project Area (Figure 7).

Table 3. Seagrass Area by Percent Cover and Year of Observation

Data source	Acres Seagrass				
	1-10% cover	10-40% cover	40-70% cover	70-100% cover	Total
Entire Project Area (Eliot to Cape Elizabeth)					
MEDMR2010	151.4	105.8	356.8	236.6	850.6
2021	171.8	115.8	250.3	334.8	872.7
Piscataqua River*					
MEDMR2010	58.56	10.92	38.33	49.77	157.6
2019	NA	NA	NA	NA	144.7
2021	60.6	27.4	48.6	63.1	199.7

* Limited to the area surveyed in 2019

Figure 7. Areas with the largest change in bed composition were observed south of Vaughn Island in Kennebunk (left, increase) and north of Richmond Island in Cape Elizabeth (right, decrease). Screen shots use the same scale. Pink beds correspond to 2021 mapping and blue beds are from the 2010 MEDMR mapping.

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6 Appendices

Appendix A. Field Notes

Field Calibration

07/15/2021, Thursday----------

Previous weather summary: heavy rain Saturday (7/10, 2.7 in) followed by scattered showers Sunday through Wednesday totaling over one inch across all days. Temperatures between 59 and 81 degrees Fahrenheit the week prior to field effort. [Pease Air Force Base]

Meet at Piscataqua River public launch on Williams Road off Route 103 in Kittery, ME, 09:00

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
15	Thursday			11:01	

Field Notes:

- Arrived at dock, launched vessel and set-up tablet and GPS system. GPS unit was unable to find satellites at the dock, however the tablets internal GPS was working. (GPS began working after the sampling of the second calibration check area)
- The team began with the closest calibration check area to the dock. The captain would position the boat on a shallow-side corner of the polygon. As the corner was approached the camera would be lowered to spot the edge of the eelgrass as it came into view.
- The captain ran a straight line from one shallow side corner to the other shallow side corner. He would then turn and repeat the process slowly working his way into the deeper area of the polygon.
- When the eelgrass edge was spotted it was marked on the map with an eelgrass point (green dot) as we moved across a bed percent covers were taken (if speed and visibility allowed). If conditions were not suitable for percent cover analysis, then just eelgrass presence was noted (green dot). Generic points were also placed to note observations or explain situations encountered in the field. This process was repeated at each pink polygon station [calibration check area].
- After the pink polygon closest to the dock was sampled, the team moved to the pink polygon farthest inland. From there we worked our way down river until the final pink polygon closest to the open ocean was surveyed.
- A few pink polygons we were unable to reach due to water level or impassable obstructions.

07/16/2021, Friday----------

Previous weather summary: heavy rain Saturday (7/10, 2.7 in) followed by scattered showers Sunday through Wednesday totaling over one inch across all days. Temperatures between 59 and 81 degrees Fahrenheit the week prior to field effort. [Pease Air Force Base]

Meet at Piscataqua River public launch on Williams Road off Route 103 in Kittery, ME, 07:00

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
16	Friday			11:47	

Field Notes:

- Began the day with all equipment working just fine (only trouble was track log). On this day we went out to mark the edges of eelgrass beds found in previous years. We would also run a few transects across them taking percent cover measurements. We also checked areas along our path in areas that look like they may support species colonization.
- The beds at the mouth of the Piscataqua River were surveyed first, in the same method in as the calibration check areas were surveyed. We moved up the coast sampling all past beds along the way and searched areas that looked like they may support eelgrass. All past beds from the mouth of the river to the back of York Harbor were surveyed.
- The overall results found a limited amount of newly colonized locations, however many historical areas had boundary expansion/reshaping. With heavy eelgrass percent cover as indicated on the map.

For both days [7/15, 7/16], the overall condition of the eelgrass was healthy, and did not appear to be suffering from disease such as wasting disease. Blades did not show signs of overgrazing. The amount of blades that were flowering were few compared to vegetative plants. The eelgrass was identifiable and the turbidity level was not an issue when it came to recognizing eelgrass on the camera. The eelgrass was extremely green in color and bright on the camera screen making it easy to spot. The eelgrass beds were located on soft substrate such as sand or mud and would end when the substrate changed to rock. Beds were in shallow water (less than 30 ft of water). Eelgrass was not very abundant when large amounts of kelp and algae were present. Epiphytes were present on the algae however I'll have to look at the footage to determine just how abundant and the make up (most likely Chordates and filamentous/microalgae algae). The turbidity was high in the river however it was not an issue for the camera. The turbidity did however limit our ability to spot eelgrass from the surface. Outside the mouth of the Piscataqua the turbidity was much lower and extremely clear near the largest eelgrass area on the map [Kittery Point]. Speed varied from site to site due to variable tide/current/wind conditions between them, typically between 1 – 2 mph when possible.

Field Verification

08/26/2021, Thursday----------

Previous weather summary: rain totaling 0.95 in (8/20) and 0.57 in (8/23) occurred the week prior to field effort. Temperatures during this same time ranged from an average low of 63 to an average high of 88 degrees Fahrenheit. [Portland International Jetport Weather Station]

Meet at Scarborough South public boat launch off King Street, near Pine Point Beach, west side of Nonesuch River, Scarborough, ME, approximately 09:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
26	Thursday	2:18	2:42	8:36	8:57

Field Notes:

- Arrived at launch in Scarborough River at 9 a.m. began survey on the large polygon at south edge of Cape Elizabeth. From there we moved southward down to the North side of Prout's Neck. Transects and polygon boundaries were ran along this stretch of coast.
- Transects in the Spurwink River were ran where water level allowed.

08/27/2021, Friday----------

Previous weather summary: rain totaling 0.95 in (8/20) and 0.57 in (8/23) occurred the week prior to field effort. Temperatures during this same time ranged from an average low of 63 to an average high of 88 degrees Fahrenheit. [Portland International Jetport Weather Station]

Meet at Scarborough South public boat launch off King Street, near Pine Point Beach, west side of Nonesuch River, Scarborough, ME, approximately 08:00

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
27	Thursday	3:01	3:23	9:17	9:43

Field Notes:

- Arrived at launch at 8 a.m. survey area encompassed the bay above Cape Elizabeth. This area was very busy with lots of Transects and large polygon boundaries. Finally one area missed north of Prout's Neck was sampled before heading in.

Both days water conditions were very similar. Clear sunny days with low wave activity and good water clarity. The eelgrass appeared to be health with lots of full green color and a low percent cover of epiphytic material in most areas. Old camera was used, however good water visibility made it feasible. Speed traveled was 1.5 mph on average with low turbidity.

09/07/2021, Tuesday----------

Previous weather summary: over the week prior to survey rain occurred on 9/2 (1.8 in) and 9/6 (0.14 in). Temperature ranged from an average low of 51 degrees to an average high of 76 degrees Fahrenheit. [Portland International Jetport Weather Station]

Meet at Scarborough South public boat launch off King Street, near Pine Point Beach, west side of Nonesuch River, Scarborough, ME, approximately 09:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
7	Tuesday		12:04	6:02	6:14

Field Notes:

- Arrived at launch at 9 a.m. surveyed areas from the south side of Prout's Neck down to the opening of the York River. The Scarborough River was also surveyed where the water level allowed, as well as the areas around Bluff and Stratton Island.
- Team ran all transects within area (except for t83 –t94 and a few Scarborough upriver transects). Had new camera for four hours till battery died then used old camera.
- Water condition were rougher than previous sampling days with 2 -3 foot swells, strong gusts at times, and higher turbidity making visibility difficult especially in shallow areas and in the river.
- The health of the eelgrass was beginning to decline with lots of dead eelgrass observed on camera, especially at the fringes of the eelgrass beds.
- Epiphytic cover was not very apparent on eelgrass.
- Speed and ability to stay on transect was difficult at times due to weather conditions.

09/08/2021, Wednesday----------

Previous weather summary: rainfall minimal from 9/3 on but 2.35 in on 9/2. Temperatures ranged from an average low of 56 degrees to an average high of 81 degrees Fahrenheit. [Pease Air Force Base]

Meet at Piscataqua River public boat launch on Williams Road off Route 103 in Kittery, ME, 08:00

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
27	Wednesday	12:18	12:43	6:41	6:57

Field Notes:

- Arrived at launch in Piscataqua River at 8 a.m. began surveying transects at the mouth of the rivers where wave action and depth allowed. From there moved up river surveying all available transects along the way until the very last at the top of the river.

- Water clarity was poor especially in the river. Camera picture was hard to see at times due to water conditions and trouble with new camera/ eventual use of old camera.
- Eelgrass health showed signs of die off beginning with lots of drift grass on the bottom, especially near edge of beds.
- Did not notice much epiphytic cover on eelgrass.
- Very difficult to stay on transects in river at times due to strong current. Definitely helps if transects in rivers run parallel to the shoreline.

09/17/2021, Friday----------

Previous weather summary: rainfall totaling 0.56 in on 9/10, 0.3 in 9/13 and 0.18 in on 9/16. Temperatures ranged from an average low of 51 degrees to an average high of 85 degrees Fahrenheit. [Pease Air Force Base]

Meet at Kittery pubic launch off of Route 103/Williams Ave. approximately 08:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
17	Friday	8:50	9:06	2:47	3:01

Field Notes:

- Launched from the dead duck boat launch on the Piscataqua River at 9 a.m. the team traveled from the mouth of the river northward up the coast towards York harbor.
- Headway speed was very slow as swell was large 4-6ft.
- Team traveled up the York River and began sampling at the most western transect.
- Water turbidity was feasible with efficient visibility for surveying. Grass was still present although signs of die off were present. Most upriver transects did not contain seagrass.
- Team worked their way to the mouth of the river and surveyed all transects in the mouth, where wave action would allow. Eelgrass was denser/dominant near mouth of river compared to upriver.

09/22/2021, Wednesday----------

Previous weather summary: No rain the week prior except for 0.31 in on 9/16. Temperatures ranged from an average low of 41 degrees to an average high of 82 degrees Fahrenheit [Sanford Regional Airport]

Meet at Saco River public launch, approximately 09:00
Seagrass checks on foot after boat survey

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
22	Wednesday	12:24	12:45	6:47	7:07

Field Notes:

- Launched in the Saco River at 9 a.m. began by heading upriver towards the most western transects. No eelgrass was found at the western cluster of transects.
- Water appeared to be completely fresh with extremely low salinity. Freshwater species of algae were observed on the camera in this area. Water visibility was good with clear image on the camera.
- Team made its way to mouth of the Saco while surveying transects. Very little to no seagrass was found in the river.
- Once out of the river the team began to survey the coastal transects just south of the mouth. These transects were protected by islands/peninsulas which kept the wave action down, however the wave action beyond this point was not feasible for travel/surveying.
- As with the York River the eelgrass here was more common at the mouth and sheltered cove near river delta.
- Evidence of eelgrass die off was also present.
- Surveys continued past battery life of both cameras so no video footage of some transects later in the day. (Camera was still operational just no recording.)
- After the team got back to the dock, I continued to check three other sites from land.
    - The first site was off Stage Neck Road in York. This spot was densely covered with Eelgrass however the die off here was in full swing with lots of drift and dead beds.
    - The next two sites were unsuccessful in locating eelgrass. The first location on sandy hill Ln (Piscataqua River) I observed no eelgrass from roadway. Visibility was clear enough to see bottom.
    - At site three Spinney Creek, I could not see through the water due to extremely high levels of turbidity. Even from standing right along the shore.

09/28/2021, Tuesday----------

Previous weather summary: Rainfall totaling less than one-half inch the week prior, with 0.2 in on 9/26. Temperatures ranged from an average low of 41 degrees to an average high of 77 degrees Fahrenheit [Sanford Regional Airport]

Meet at Kennebunk marina, approximately 08:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
28	Tuesday	4:53	5:04	10:44	11:31

Field Notes:

- Arrived at the Kennebunk marina at 8:30 a.m. after launching the boat the weather opened up which delayed the start by about 45 minutes.

- After a break in the weather the team headed out to the far end of the days transects near Saco.
- Wave action was high which made for slow travel. All the transects except for a few on the Kennebunk end where surveyed.
- Last few transects where called off that day due heavy rain showers that opened back up and large swell.
- Turbidity was feasible for camera viewing at transects however maintaining straight course was challenging.
- Eelgrass did show signs of die off with a lot of beds losing color (greyish brown color) however some beds still had green healthy grass.

09/29/2021, Wednesday----------

Previous weather summary: Rainfall totaling less than one-half inch the week prior, with 0.2 in on 9/26. Temperatures ranged from an average low of 45 degrees to an average high of 77 degrees Fahrenheit [Sanford Regional Airport]

Meet at Kennebunk marina, approximately 08:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
29	Wednesday	5:48	6:00	11:40	

Field Notes:

- Launched from same marina around 9 a.m. weather was more cooperative with light rain that held off for large parts of the day.
- Team began by visiting transects missed on day one list. From there the team sampled transects K61-K26 as well as O6 and O2 Webhannet to Cape Porpoise.
- Turbidity was feasible for viewing and wave action decreased as time went on.
- Weather conditions were better for sampling compared to the first day.
- Eelgrass health was in same condition as observed on first day.

09/30/2021, Thursday----------

Previous weather summary: Previous week's rainfall included 0.13 in on 9/25 and 0.28 in on 9/26. Temperature ranged between an average low of 49 degrees to an average high of 76 degrees Fahrenheit. [Pease Air Force Base]

Meet at Webhannet River public launch, approximately 08:30

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
30	Thursday	6:46	6:58	12:29	12:38

Field Notes:

- Launched boat around 9:30 a.m. at the dead duck boat launch in the Piscataqua River.
- We traveled north along the coast to our farthest transect O5 wave action was suitable but and then proceeded southward completing the remaining high and medium priority transects.
- The Team then surveyed lower priority transects as we headed back to the Piscataqua River as well as surveying previously marked eelgrass beds for presence/absence.
- Weather began take a turn for the worst towards the end of surveying with wind increasing and onset of rainfall.
- Turbidity was feasible for viewing and eelgrass beds were varying in health from location to location.
- Eelgrass was very uncommon in open coast areas during the days of surveying. Areas with a depth of 20ft or less with sheltered coast and a higher percent of soft/small gravely substrate (bays, coves, and behind islands/peninsulas) more commonly held grass compared to the "solid" rocky open coastline.
- Areas of high wave action and fast current were also unlikely to hold eelgrass.
- Even exposed open coast with soft substrate showed little to no signs of eelgrass (beaches).

10/07/2021, Thursday----------

Previous weather summary: Rainfall less than one-quarter inch the week preceding survey. Temperatures ranged from an average low of 44 degrees to an average high of 71 degrees Fahrenheit. [Pease Air Force Base]

Normandeau canoe crew, leaving from Bedford, NH office and heading to Spinney Creak (Piscataqua River) and Spurwink River, approximately 08:00

Date		High (AM)	High (PM)	Low (AM)	Low(PM)
07	Thursday		12:18	6:00	6:26

Field Notes:

- Weather was sunny 70's
- Water clarity in Spinney Creek was clear in the shallows, no visibility in deep or shaded areas
    - Widgeon Grass was primarily coated in sediment and primarily dispersed in individual to small clusters. Larger thick green clusters were present primarily along the northern shore.
- Water clarity in Spurwink River was achievable although not clear.
    - No grass was observed.

Appendix B. Distribution Maps and Density of Seagrass

PR01
PR02
PR03
PR04
PR05
PR06
PR07
PR08
PR09
PR10
PR11
PR12
PR13

Service Layer Credits: ESRI Basemaps

- Project Area
- 2010 Mapped Seagrass
- 2019 Mapped Seagrass
- 2021 Mapped Widgeon Grass

2021 Mapped Seagrass by Cover Class

- 1 (0-10%, very sparse)
- 2 (10-40%, sparse)
- 3 (40-70%, moderate)
- 4 (70-100%, dense)

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

0 0.5 1 1.5 2 Miles

N

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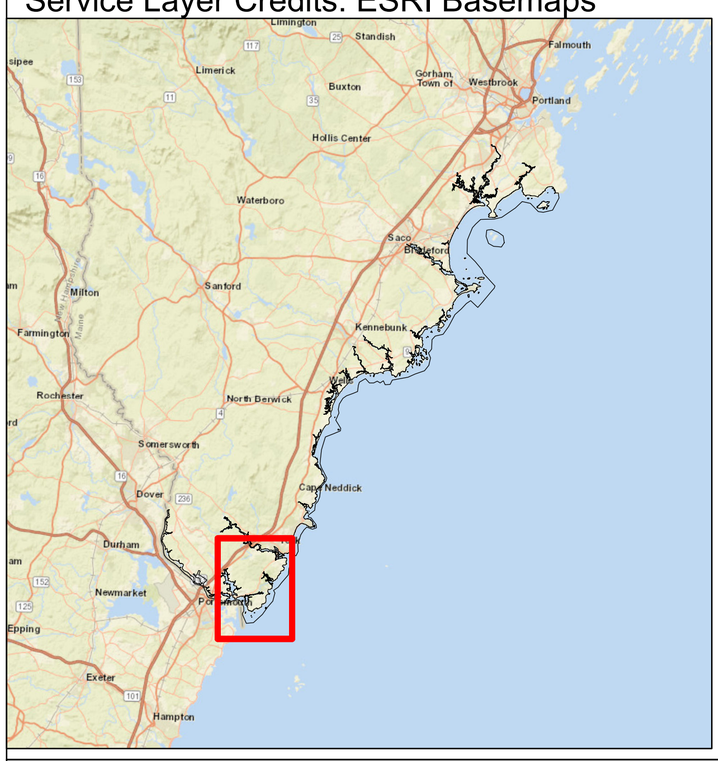
Service Layer Credits: ESRI Basemaps



Project Area

2010 Mapped Seagrass

2019 Mapped Seagrass

2021 Mapped Seagrass by Cover Class

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

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Eliot to Cape Elizabeth, ME

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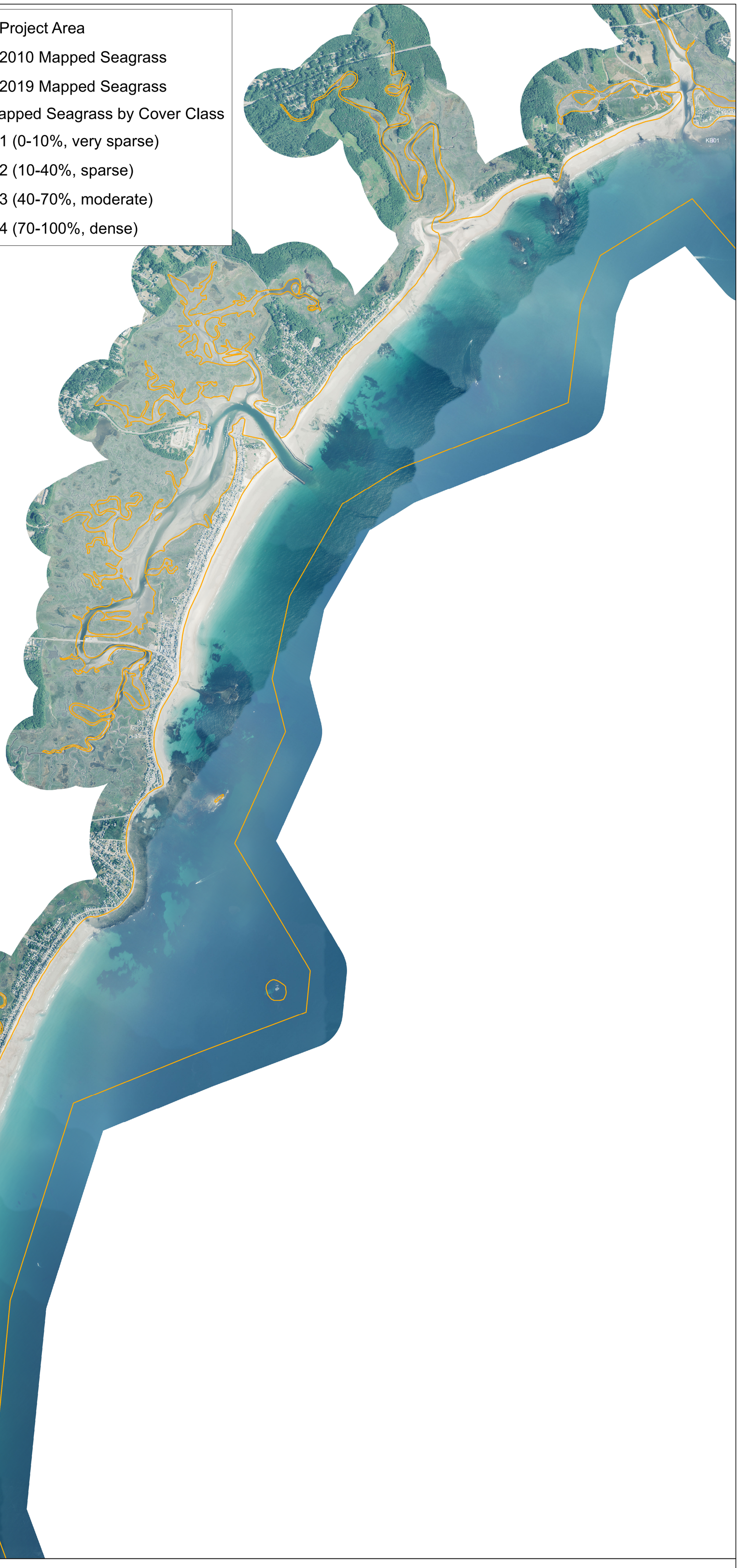

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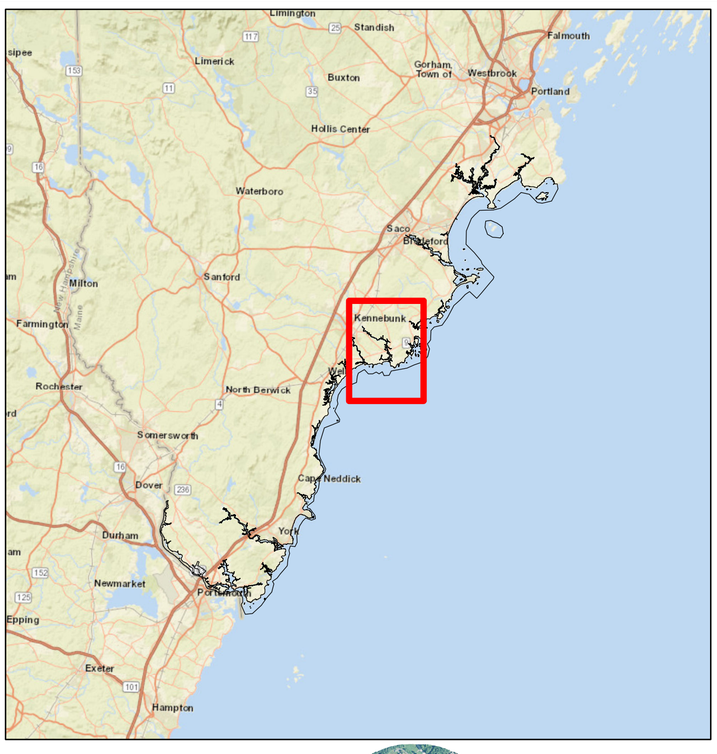

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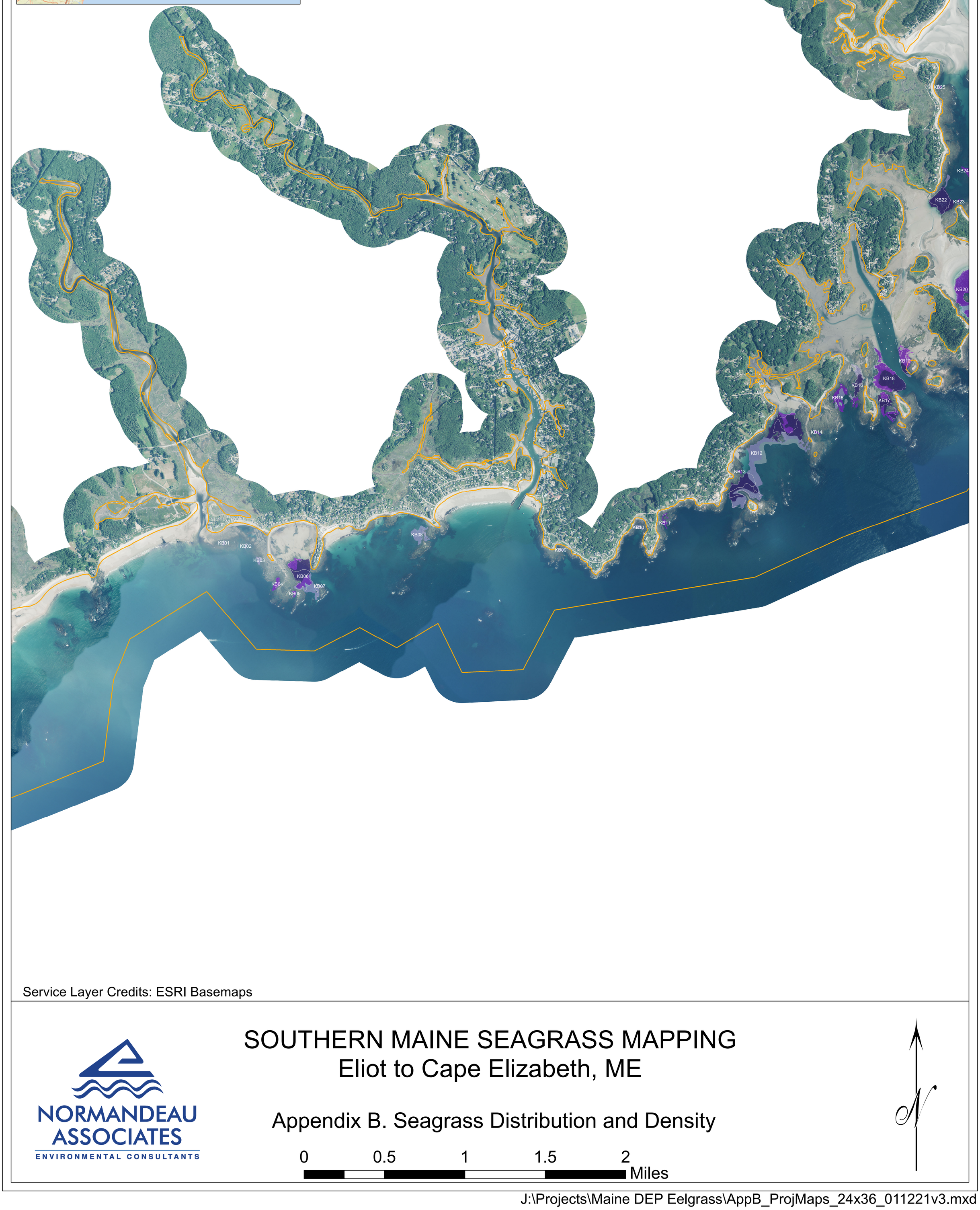

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

0 0.5 1 1.5 2 Miles

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SA09
SA08
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SA07
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SA05
SA03
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SA02
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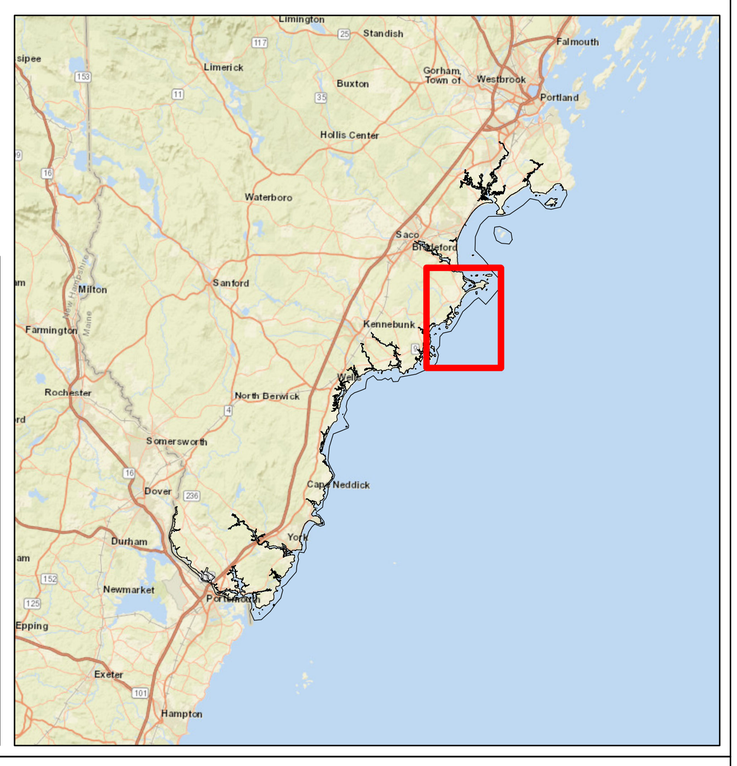
KB17

Service Layer Credits: ESRI Basemaps



- Project Area
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- 2019 Mapped Seagrass

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

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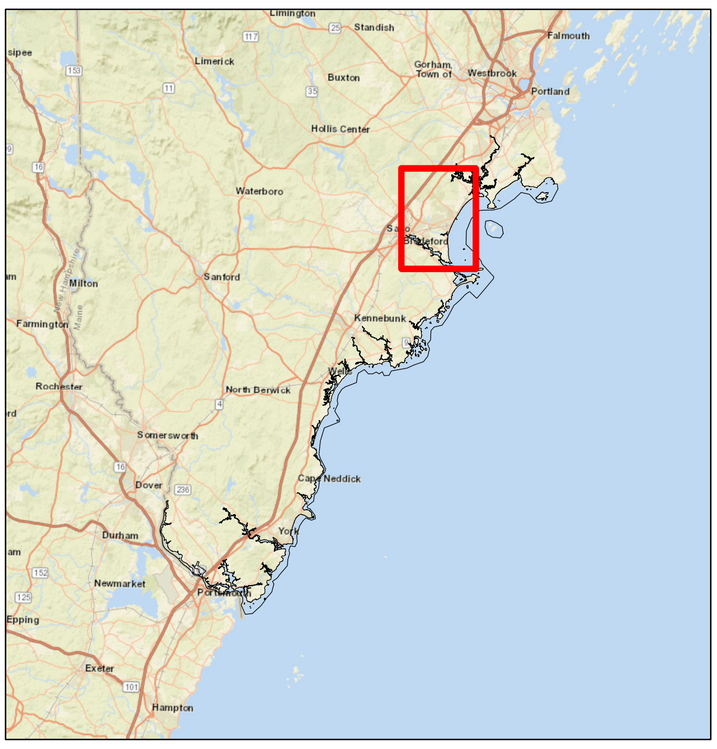

Project Area

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2019 Mapped Seagrass

2021 Mapped Seagrass by Cover Class

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SOUTHERN MAINE SEAGRASS MAPPING
Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

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SB02SB01

SB03

SB04

SB08

SB05

SB07

SB06

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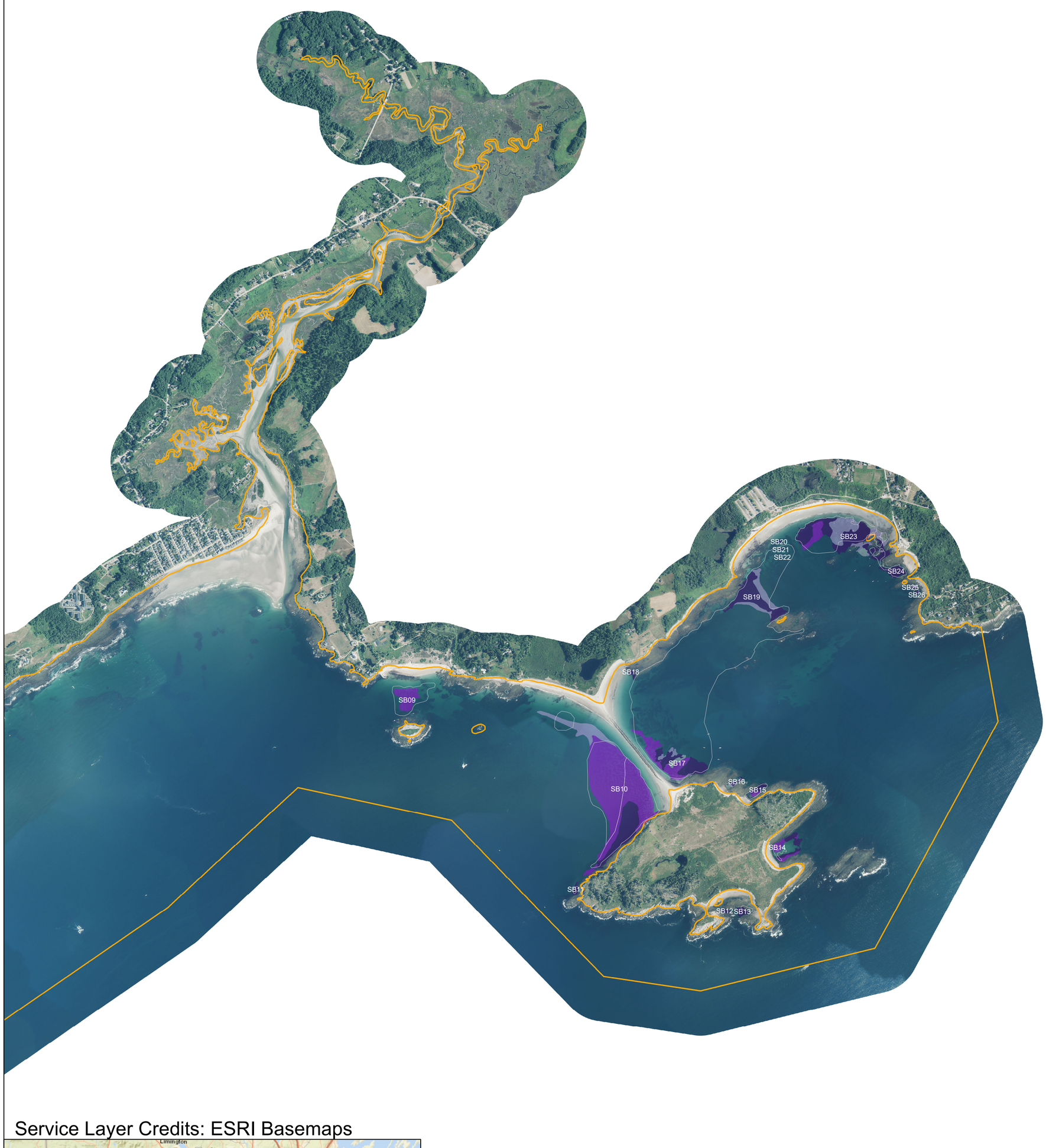

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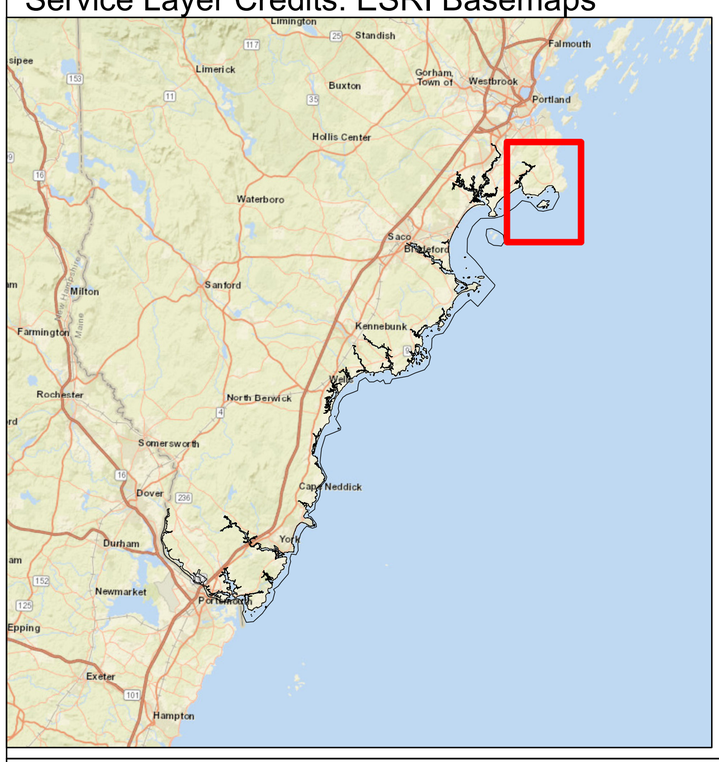

- Project Area
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- 2019 Mapped Seagrass

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Eliot to Cape Elizabeth, ME

Appendix B. Seagrass Distribution and Density

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