Report on the Analysis of True Color Aerial Photography to Map and Inventory *Zostera marina L.* in Narragansett Bay and Block Island, Rhode Island

By

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In Memory of Helen Cottrell

Helen was a true steward for Narragansett Bay and coastal Rhode Island. She initiated and led the first-ever Submerged Aquatic Vegetation (SAV) Mapping project in Narragansett Bay in 1996. She also led the mapping of SAV in Rhode Island coastal ponds in 1999 and helped initiate and coordinate this updated mapping effort. She played an integral role in making this current mapping project possible. Helen's tireless dedication to protect Rhode Island's natural resources will be appreciated by generations to come.

Introduction

Eelgrass (*Zostera marina* L.) is a type of submerged aquatic vegetation (SAV), which grows in quiescent embayments along the northeast and northwest coasts of the United States. Eelgrass plays a crucial role in the health of coastal systems because it provides critical habitat for juvenile marine life, helps stabilize sediments, and aids in filtering particles from the water column (Dennison et al., 1993; Fonseca, 1996). Eelgrass has been deemed a critical marine resource and is currently protected by both Federal (Clean Water Act; 33 U.S.C. 26 section 1251 et seq) and Rhode Island (RI Coastal Resource Management Plan, Section 300.18) legislation.

Mapping the distribution and extent of eelgrass is a critical first step in understanding, managing, and protecting shallow-subtidal estuarine habitats. Map data provides essential baseline information for government agencies, town planners, and the scientific community. The only time eelgrass has been mapped throughout Narragansett Bay, RI was in 1996 when 99.5 acres of eelgrass were identified (Huber, 1996). During the past 10 years, results from some site-specific mapping efforts and improvements in geographic information systems (GIS) and mapping technology have illustrated a need to update the 1996 Bay-wide mapping project.

True-color aerial photography is a common tool for mapping eelgrass in shallow estuarine habitats. It is especially useful when mapping eelgrass in relatively large estuaries. This technique was used to map eelgrass in Narragansett Bay (118,550 acres of water and 630 miles of shoreline, Fig. 1) in 1996 and in Long Island Sound (Huber, 1996; Huber, 2003; Tiner et al., 2003; Tiner et al., 2007). However, aerial photography does have severe limitations including issues with water clarity, photographic quality, and challenges in interpretation of eelgrass photo-signatures. The overall goals of this project were to 1) conduct a complete and comprehensive survey of eelgrass throughout Narragansett Bay and Block Island; 2) analyze and compare eelgrass mapping techniques (photo-interpretation of true-color aerial photography vs. field-mapping methods); and 3) examine status and trends of eelgrass from 1996 to 2006.

Methods

Aerial Photography Acquisition

True color aerial photographs of Narragansett Bay and Block Island (Fig. 1) were taken by James W. Sewall Co. on August 5th 2006 following NOAA Coastal Change Analysis Program (C-CAP) protocols (Dobson et al., 1995). Based on C-CAP, photographs were taken at a low sun angle, two hours within low tide, when wind and atmospheric haze where minimal, and when water clarity was high. Water clarity was measured by volunteers using secchi disks as target dates for acquisition of aerial photography approached.

After the photography was reviewed and approved by project leaders, transparencies were returned to James Sewall Co. where they were scanned, distortions removed (using data from an airborne global positioning system and intertial measuring unit), and digital orthophotography was produced. The listed accuracy of the orthophotography was +/- 50 feet with a pixel resolution of 1.5ft.

Photo-interpretation

Orthophotography (1:12,000), prints, and transparencies were distributed to the Environmental Data Center at the University of Rhode Island for interpretation. All three formats were used for photo-interpretation.

Areas to be ground-truthed were identified using a mirrored stereoscope and orthophotography. Clues such as the presence of mounds of eelgrass wrack on shore, historical eelgrass data, and shoreline geomorphology were used to aid in delineations. Initial interpretations were then delineated by ‘heads-up’ digitizing on the orthophotography thereby geo-referencing delineations to the coordinate system used for the orthophotography (RI State Plane Feet, NAD83). After the photo-interpretation phase was complete, a copy of these data were made and set aside for later analysis and comparison.

Field work and ground-truthing

Because eelgrass photo-signatures from true-color aerial photographs are highly variable and can be flight specific, an effort was made to begin ground-truthing during the same growing season as when the photographs were taken (Fall 2006). Due to this limited timeline, the focus of the photo-interpretation phase was to quickly and thoroughly identify areas thought to be eelgrass (i.e. areas to be ground-truthed) and not necessarily to make precise delineations of eelgrass extent.

Ground-truthing began two months after the photography was taken. Since ground-truthing could not be completed during the 2006 growing season, fieldwork continued again during the summer of 2007. The original GIS delineations were taken into the field and viewed simultaneously with GPS position using a GeoXH Trimble GPS and a GPS-enabled tablet personal computer. Viewing GIS delineations and GPS location in real-time eliminated the need for using hard-copy maps (and the related guesswork with locating landmarks on maps and in the field) as the primary method of navigating to delineations thus speeding up the ground-truthing process considerably.

During ground-truthing, an effort was made to visit all delineations, locate the center of each delineation and if eelgrass was present, to determine the deepwater edge and the extent of the bed (Fig. 2). GPS data points were collected and coded for presence of eelgrass within and at the edge of eelgrass beds. In order to estimate errors of omission during the photo-interpretation process, additional GPS data points were collected and coded for presence of eelgrass at distance intervals along the shoreline where eelgrass is known to occur (e.g., East Passage Narragansett Bay, Fig. 3). Deepwater edges and the extent of the beds were determined at low tide using underwater video equipment, fathometer signals, view scope observations, and in limited cases, volunteer divers. The edge of an eelgrass bed was considered to occur when cover dropped to about 5-10%. Delineations were then re-digitized in the field using a GPS enabled tablet pc or in the lab using GPS data and field notes. Field delineations and observations were incorporated into the final GIS database.

Trend analysis

A major goal was to provide a comparison and analysis between the 1996 mapping effort conducted by the Natural Resources Assessment Group (NRAG) (Huber, 1996) and the data collected for this project in 2006. After a review of the methodology used for the 1996 project, it became clear that a direct comparison between the 1996 and 2006 datasets at a Bay-wide scale may not be valid due to major differences in mapping methods and technology (Table 1). However, three sites were selected to conduct direct comparisons between the two years (Fig. 4). The three locations were chosen because of similarities in ground-truthing efforts between 1996 and 2006 and because these three sites support some of the largest eelgrass beds mapped in Narragansett Bay in 2006. At two sites (Potters Cove in Jamestown and T-wharf at Prudence Island), the original 1996 photography was re-photointerpreted. Because the Potter Cove eelgrass beds were not mapped in 1996 (due to poor photo quality), only the photo-interpreted delineations done in 2006 were compared. Ground-truthing efforts were similar at the Fort Getty site and a direct comparison between delineations was considered valid after an adjustment of 1996 polygons to account for differences in geo-registration techniques.

Results

Eelgrass Extent and Distribution

During the fall of 2006 and summer of 2007, 465.5 acres of eelgrass beds were mapped in Narragansett Bay and around Block Island (Table 2, Fig. 5). The most eelgrass (208.9 acres) was found in the east passage of Narragansett Bay and the largest eelgrass bed (63 acres) in the study area was found at the Sakonnet Lighthouse. No eelgrass was found in most of the Sakonnet River or north of Prudence Island. The northernmost bed occurred at Sheep Pen Cove, along the western shore of Prudence Island, three miles north of Hope Island (Fig. 5)

Analysis of Mapping Techniques

One-hundred sixty (160) polygons were delineated throughout Narragansett Bay and Block Island. Of these 160 polygons, all but 15 (9%) were ground-truthed and 50 (31%) were found to be comprised of something other than eelgrass (macroalgae and rocks, e.g.).

During this study, 166.5 acres of eelgrass (36% of the total) were identified using only photo-interpretation techniques (Table 3). After ground-truthing and field mapping efforts, the total area of eelgrass almost tripled to 466 acres (Table 3). The total number of eelgrass delineations also increased by 36% (Table 4). However, these new delineations make up only 10% (50 acres) of the total acreage indicating that photo-interpretation was suitable for initially locating and identifying eelgrass beds, but a majority of the total acreage was determined by field-mapping techniques (largely due to the expansion of polygon size resulting from field-mapping of deep water edges) (Table 4).

Trend Analysis

Because of differences in GIS technology and ground-truthing methods, a direct Bay-wide comparison of the NRAG 1996 and the 2006 data sets was not conducted. However, three sites where analyzed for changes in eelgrass distribution and extent. At the Potters Cove (Jamestown) and T-wharf (Prudence Island) sites, the areal extent of eelgrass appears to have at least doubled in size over the past 10 years (Fig. 6). The eelgrass bed at Potters Cove represented one of the largest beds identified in 2006. While not originally identified during the 1996 mapping effort, this bed was identified upon re-examination of the photography that was flown in 1997. This area of Narragansett Bay (along with others) was re-flown in 1997 because of poor photo quality during the 1996 flight. A comparison of the photo-interpreted 2006 data, with the recent interpretations done of the 1997 photos, does indicate that this bed has expanded particularly to the north.

The T-wharf site was selected for a similar comparison because ground-truthing efforts were similar between the 1996 data and the current project (the deepwater edge was mapped extensively for both sites) (Andy Lipsky, Natural Resources Conservation Service, pers.comm). At T-wharf, eelgrass also appears to have expanded tremendously around the wharf and along the southern tip of Prudence Island (Fig. 6b). A re-examination of the 1996 photography confirms that there was very little eelgrass along the southern tip of Prudence Island. Finally, at the Fort Getty site, areal cover of eelgrass also seemed to increase slightly even accounting for differences in geo-registration (Fig. 7). The largest gain appears to be along the southern end of the site, although it is unclear how much ground-truthing was done here in 1996.

Discussion and Summary

In the fall of 2006 and summer of 2007, 465.5 acres of eelgrass were mapped in Narragansett Bay and Block Island. Of this total, only 166 acres (36%) were identified using photo-interpretation techniques only. During our field visits, eelgrass beds were generally found at a maximum depth of 10-14 feet at low tide in Narragansett Bay. At these depths, the identification of the deep-water edge of eelgrass beds in the Bay was not possible using aerial photography due to water turbidity. From this study, it was found that field identification of the deep-water edge combined with other field mapping techniques nearly tripled the acreage of eelgrass that was originally delineated in the lab. This study illustrates the need for comprehensive ground-truthing to accurately map eelgrass in Narragansett Bay.

A direct comparison of the areal extent of eelgrass mapped by NRAG in 1996 to data from this study was not conducted. According to the 1996 field data sheets, photo-interpreted polygons were ground-truthed for presence or absence of eelgrass and percent coverage. There was no indication that the deep-water extent of eelgrass beds was identified. Therefore, because of differences in mapping and ground-truthing methods, as well as differences in the availability of GIS technology in 1996, a one-to-one comparison between these two datasets was not conducted. However, an appropriate comparison between the two data sets may be possible if the previous mapping methods are further investigated or the 1996 photography is re-interpreted. A complete and comprehensive re-interpretation of the 1996 photography was not within the scope of this project.

At three sites within Narragansett Bay (Potters Cover, T-wharf, and Fort Getty) we were able to analyze and assess changes in areal extent of eelgrass cover over a 9 to 10 year period. At these sites, substantial increases in areal extent of eelgrass were observed from 1996 to 2006. When generally compared to the 99.6 acres mapped in 1996, our efforts (over 400 acres) would seem to show a substantial increase of eelgrass in Narragansett Bay. Tiner et al. (2007) also observed increases in eelgrass areal cover from 2002 – 2006 in Long Island Sound. However, it is worth noting that even if eelgrass cover has increased during the past 10 years in Narragansett Bay, the present acreage is still an order of magnitude less than the 6000 acres of eelgrass that occurs in Buzzards Bay, MA, an estuary of comparable size to Narragansett Bay (Costa, 2001). Also, eelgrass historically covered a much greater range throughout Narragansett Bay, including Greenwich Bay and the Providence River (Rhode Island Habitat Restoration Team, 2001)

This study showed that true-color aerial photographs are an effective tool for mapping eelgrass beds in Narragansett Bay when accompanied by a comprehensive ground-truthing efforts that incorporate field mapping techniques to help identify the deepwater edges of eelgrass beds. Additionally, results from this study stress the need to inventory and map eelgrass in Narragansett Bay and Block Island more frequently than at 10-year intervals. For example, the State of New Hampshire monitors and maps eelgrass in Great Bay, N.H. every 3 years (NHEP, 2006), and this general timeframe is recommended for mapping throughout the National Estuarine Research Reserve System (Moore and Balthuis, 2003). We recommend a similar interval (3-5 years) which would ensure better technological as well as mapping compatibility and comparability from survey to survey.

Regularly updated eelgrass maps would provide an important and useful tool for Rhode Island scientists, coastal managers, and planners. Mapping at more frequent intervals will result in a more accurate assessment of eelgrass changes over time, and provide a better indication of trends in the health of Narragansett Bay. Rhode Island has already taken steps toward improving the health of Narragansett Bay. Greatly improved waste water treatment plants within the watershed are scheduled to be operational between 2008 and 2010 with significant reductions in nitrogen inputs. The combined sewer overflow tunnel, built to reduce solids and bacteria inputs into the Bay is expected to be completed in October 2008. These projects have the potential to significantly improve water quality in Narragansett Bay and thus impact estuarine habitats such as eelgrass. A consistent mapping effort will allow us to monitor how eelgrass responds to these water quality improvements over time while providing us with a better understanding of how such actions can influence the health of Narragansett Bay.

Acknowledgements

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Considerable support and help was provided by Chris Powell of the R.I. Division of Fish and Wildlife whose knowledge of eelgrass in Narragansett Bay proved invaluable for this project.

Table 1. A comparison of methods between the NRAG 1996 eelgrass mapping effort and the current project.

Methodology	1996 NRAG	2006
Use of orthophotography	No	Yes
Use of GPS for mapping	No	Yes
Deep water edge determination	No	Yes
Geo-regristration of polygons	Zoom transfer scope	Orthophotography
Ground-truthing efforts	Unknown	Comprehensive

Table 2. Hydrographic distribution of eelgrass in the study area.

Location	Acreage
Block Island	61.3
East Passage Narragansett Bay	208.9
Narragansett Bay – Marine	114.2
Sakonnet River	28.4
West Passage Narragansett Bay	52.8
Total	465.5

Table 3. Comparison of final eelgrass acreage (photo-interpreted and using field mapping techniques) and acreage calculated solely from photo-interpretation.

Site	Final	Photo-interpreted only	Difference (%)
Block Island	61.3	21.7	39.6 (35)
Dutch Island	1.6	1.6	0
Gould Island	4.8	4.8	0
Hope Island	0.2	0.2	0
Jamestown	162.9	61.4	101.5 (38)
Little Compton	66.7	4.3	62.4 (0.06)
Middletown	6.0	0.7	5.3 (12)
Newport	65.2	30.0	35 (46)
NUWC	19.6	15.1	4.5 (77)
Prudence Island	26.3	16.6	9.7 (63)
Rose Island	19.0	3.6	15.4 (19)
Sachuest Point	27.0	6.5	20.5 (24)
Wickford	5.4	0	5.4 (0)
Total	466	166.5	299.5 (36)

Table 4. Comparison of the number of eelgrass polygons identified using different techniques (F = field verified, little or no photo-signature visible; R = random occurrence. Both are indications of error of omission).

Method of Identification	**Polygons (%)**
Photo-interpretation	63
Anecdotal (F)	16
Boat Observation (R)	12
Historical (F)	8

Figure 1. The extent of the study area for Narragansett Bay and Block Island, R.I.

Figure 2. A strategy for field-mapping eelgrass beds was developed whereby GPS and video data were collected at the intersection of the arrows and polygons to determine the deepwater edge and extent of each eelgrass bed.

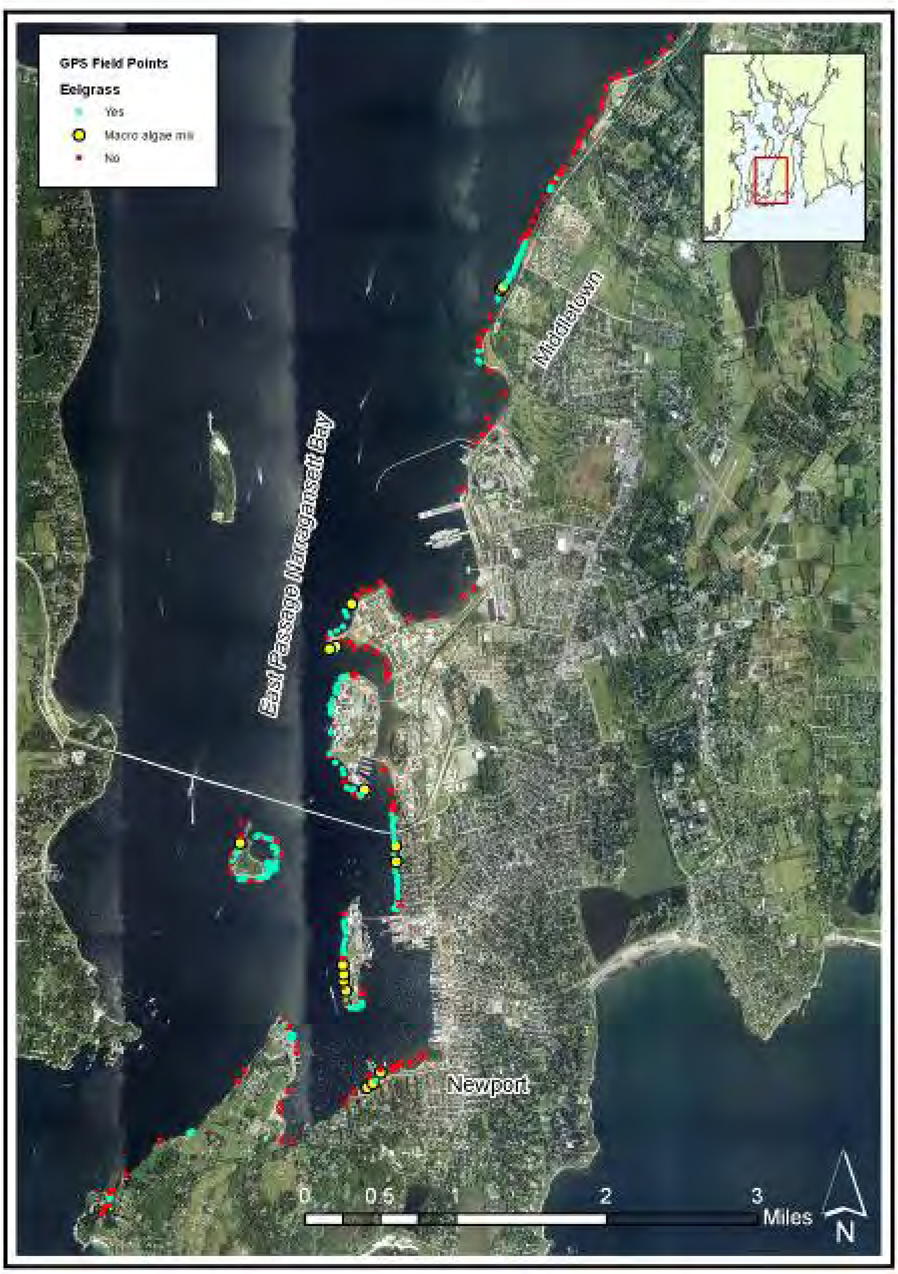

Figure 3. GPS points were collected by boat over two days for the areas near Newport and Middletown R.I.

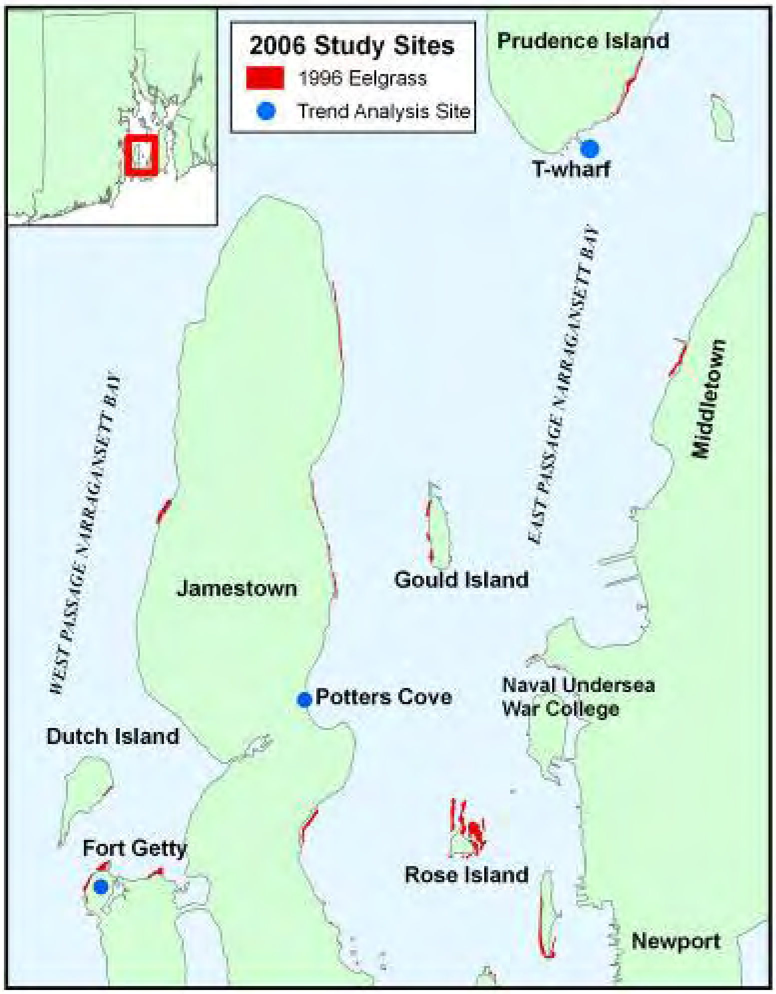

Figure 4. The location of the three selected sites for eelgrass trends analysis and other geographic references. For the T-wharf and the Potters Cove sites, aerial photography taken in 1996 and 1997 (respectively) was re-photointerpreted for eelgrass. A direct comparison of delineations was done for the Fort Getty site because ground-truthting extent and methods were similar.

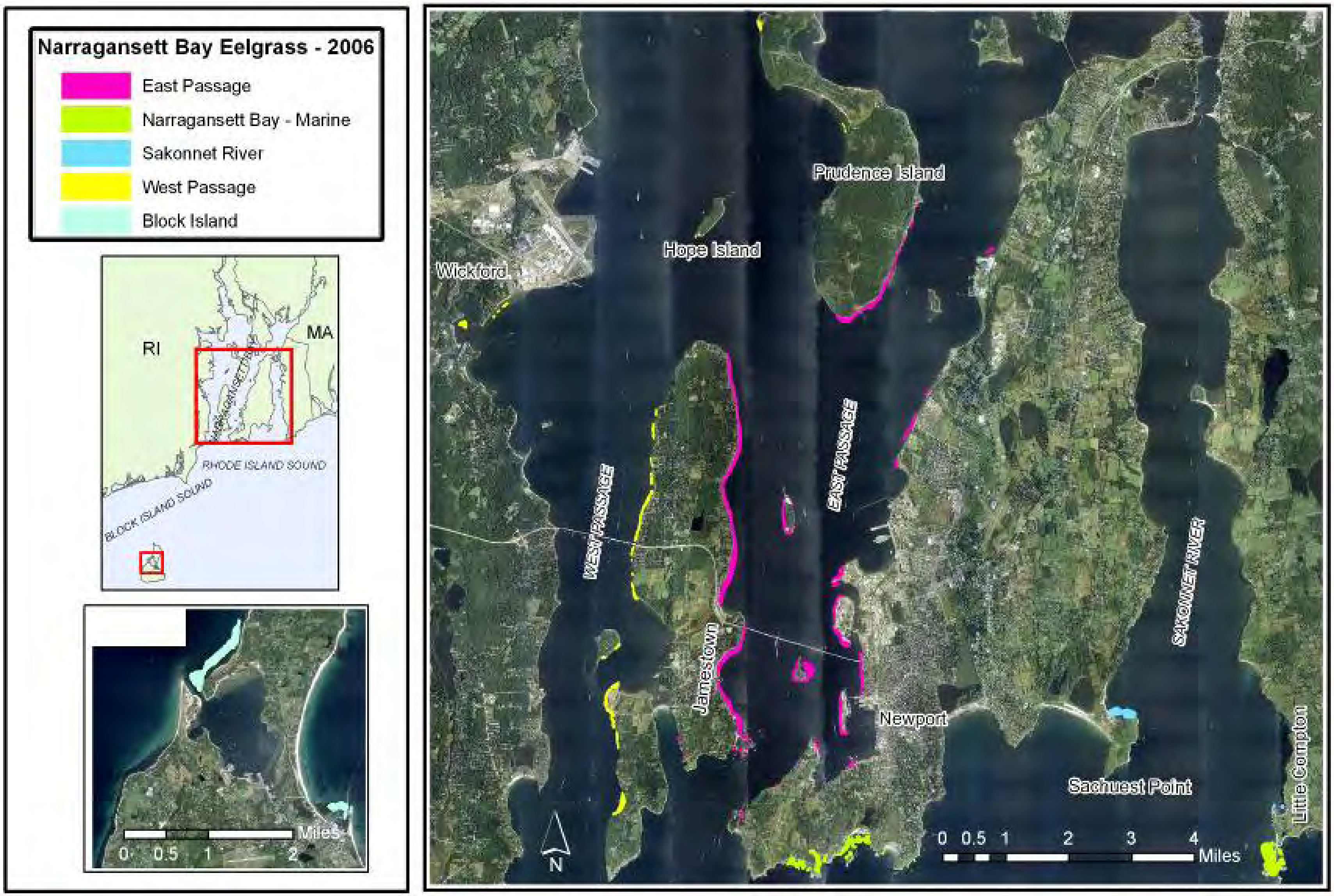

Figure 5. The distribution of eelgrass in Narragansett Bay and Block Island in 2006.

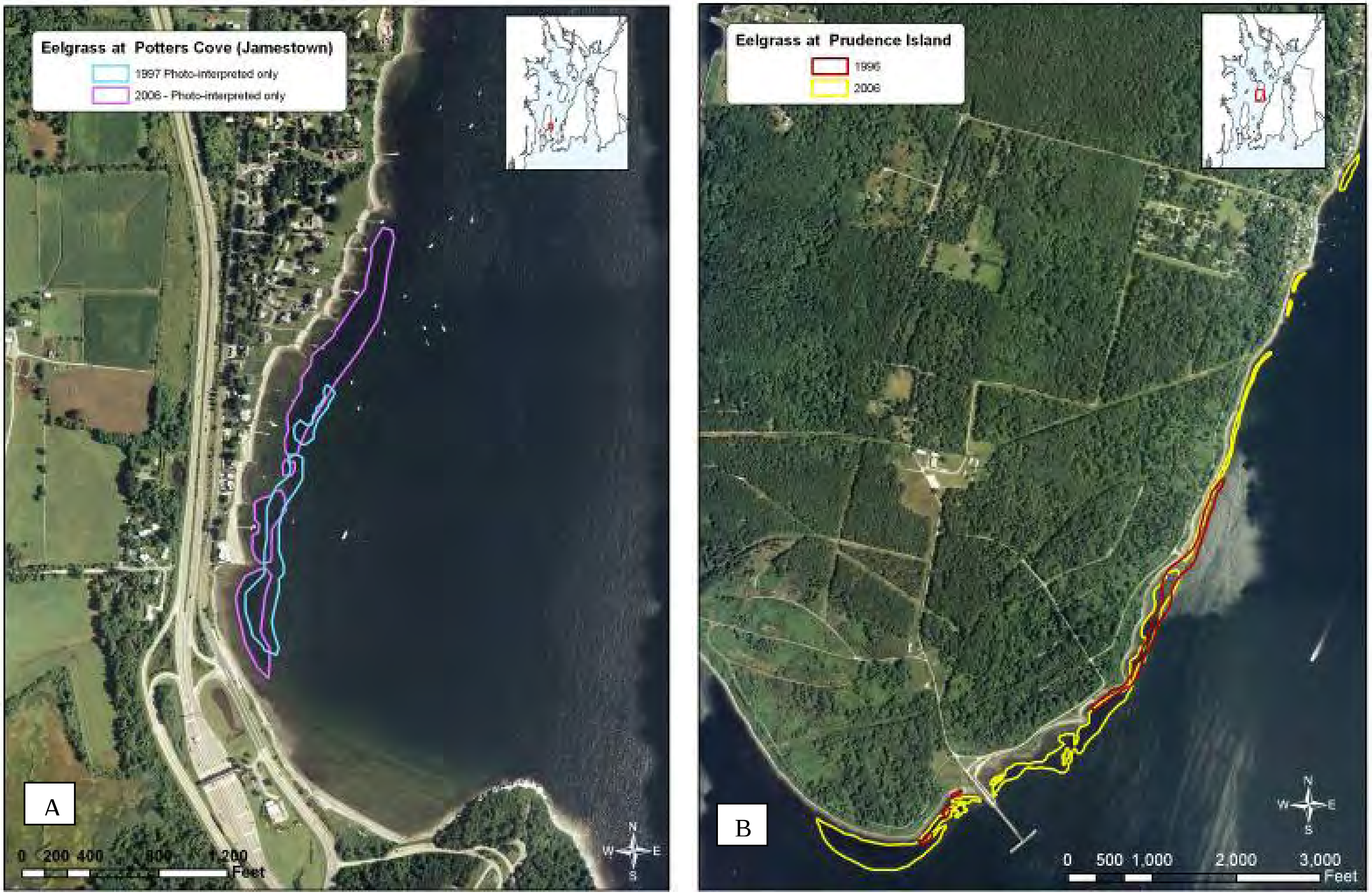

Figure 6. A comparison of eelgrass bed extent over a 9-10 year period at Potters Cove in Jamestown (A) and T-wharf at Prudence Island (B) shows substantial increases in areal coverage of eelgrass.

Figure 7. The eelgrass extent at Fort Getty in Jamestown over a 10 year period seems relatively unchanged in some areas and shows large increases in others. The 1996 data were adjusted slightly to account for differences in geo-registration.

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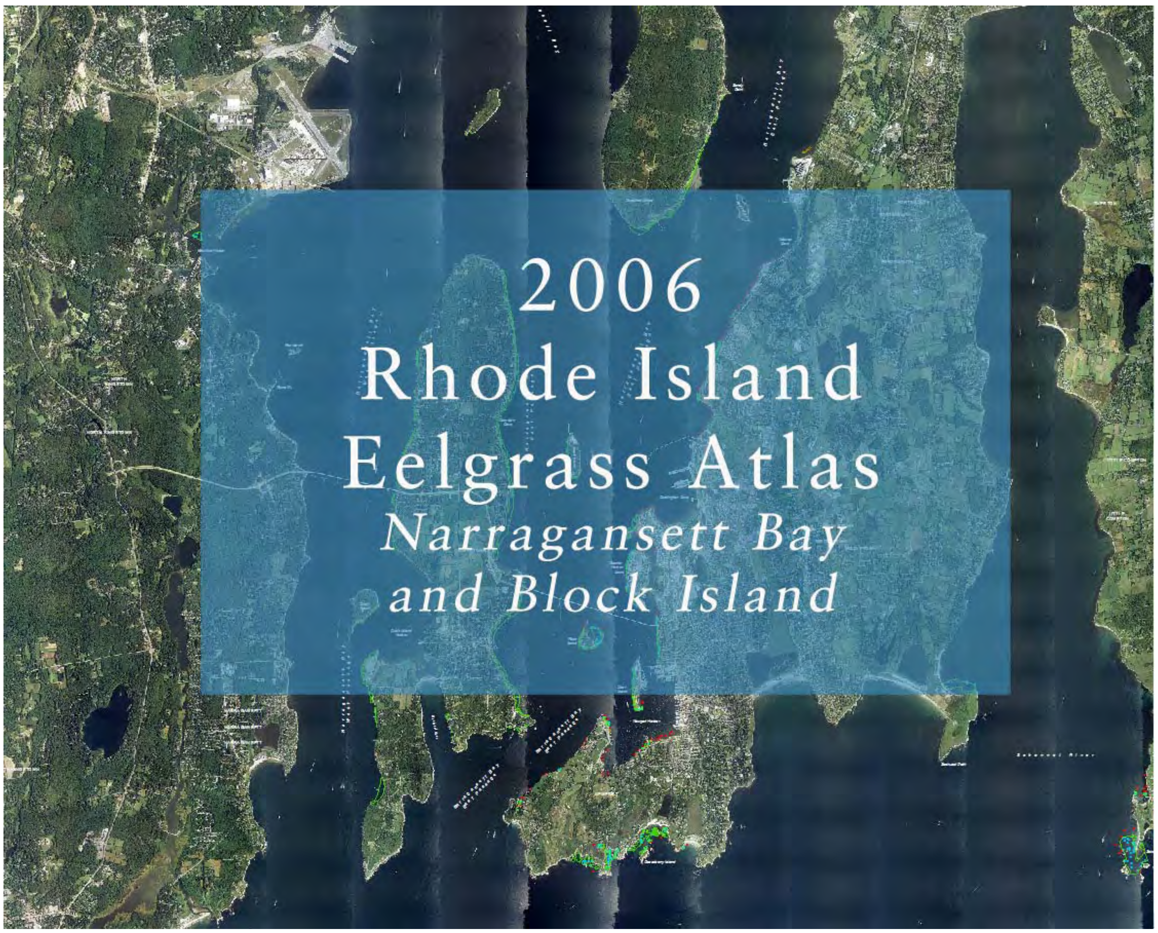
2006 Rhode Island Eelgrass Atlas

Narragansett Bay and Block Island



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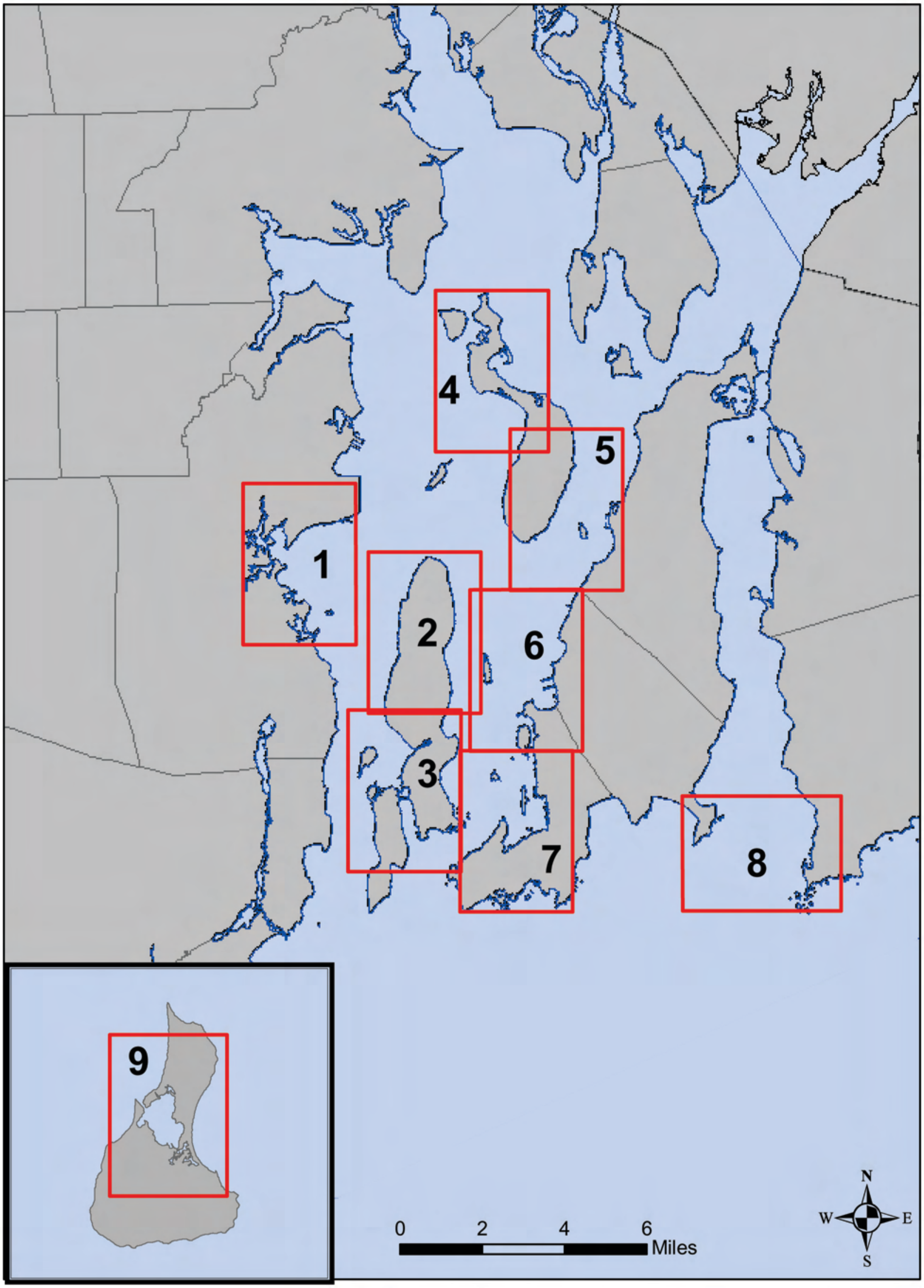

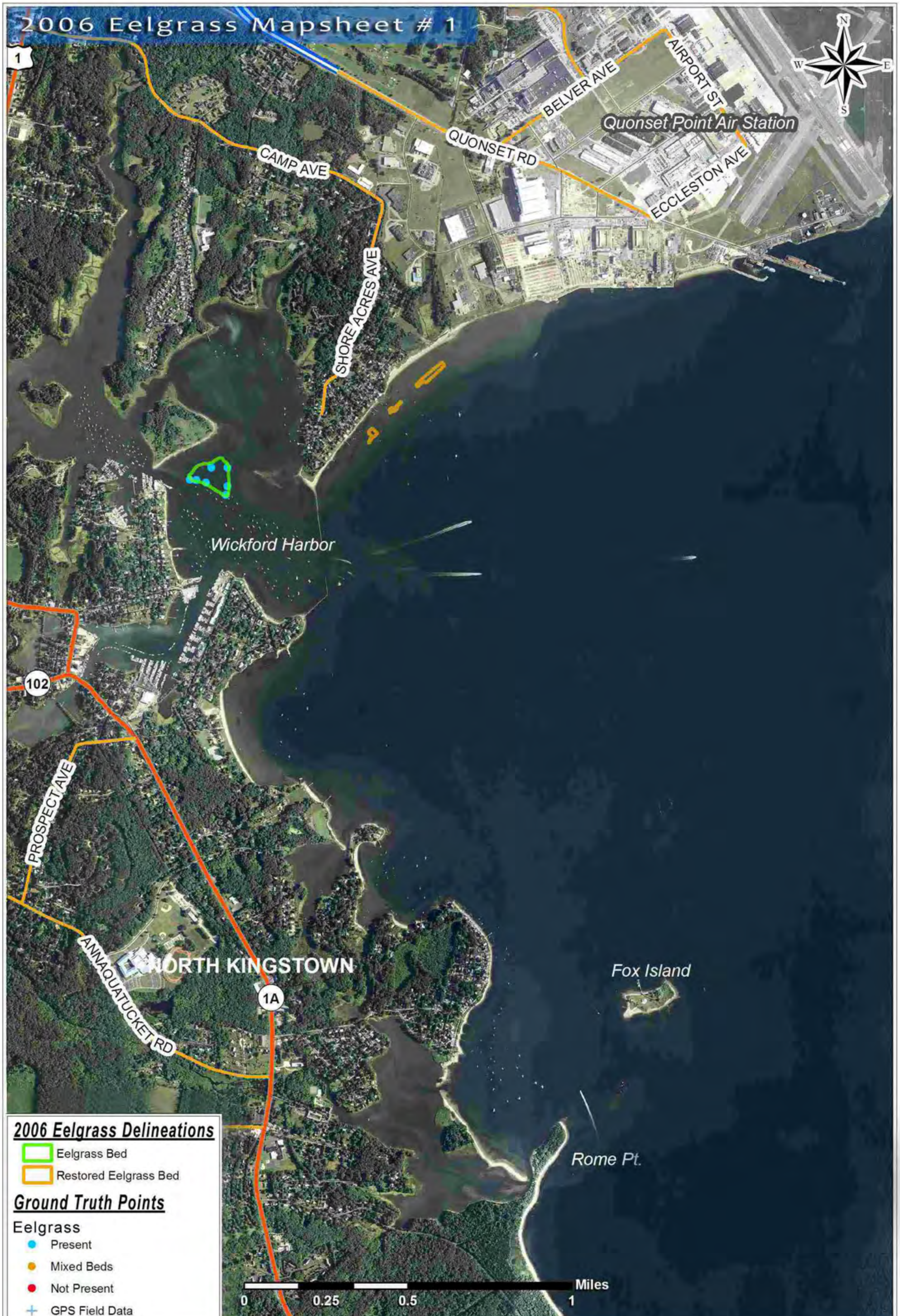
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AIRPORT ST
Quonset Point Air Station
QUONSET RD
CAMP AVE
ECCLESTON AVE
SHORE ACRES AVE
Wickford Harbor
102
PROSPECT AVE
ANNAQUATUCKET RD
NORTH KINGSTOWN
1A
Fox Island
Rome Pt.
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
Eelgrass
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Mixed Beds
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GPS Field Data
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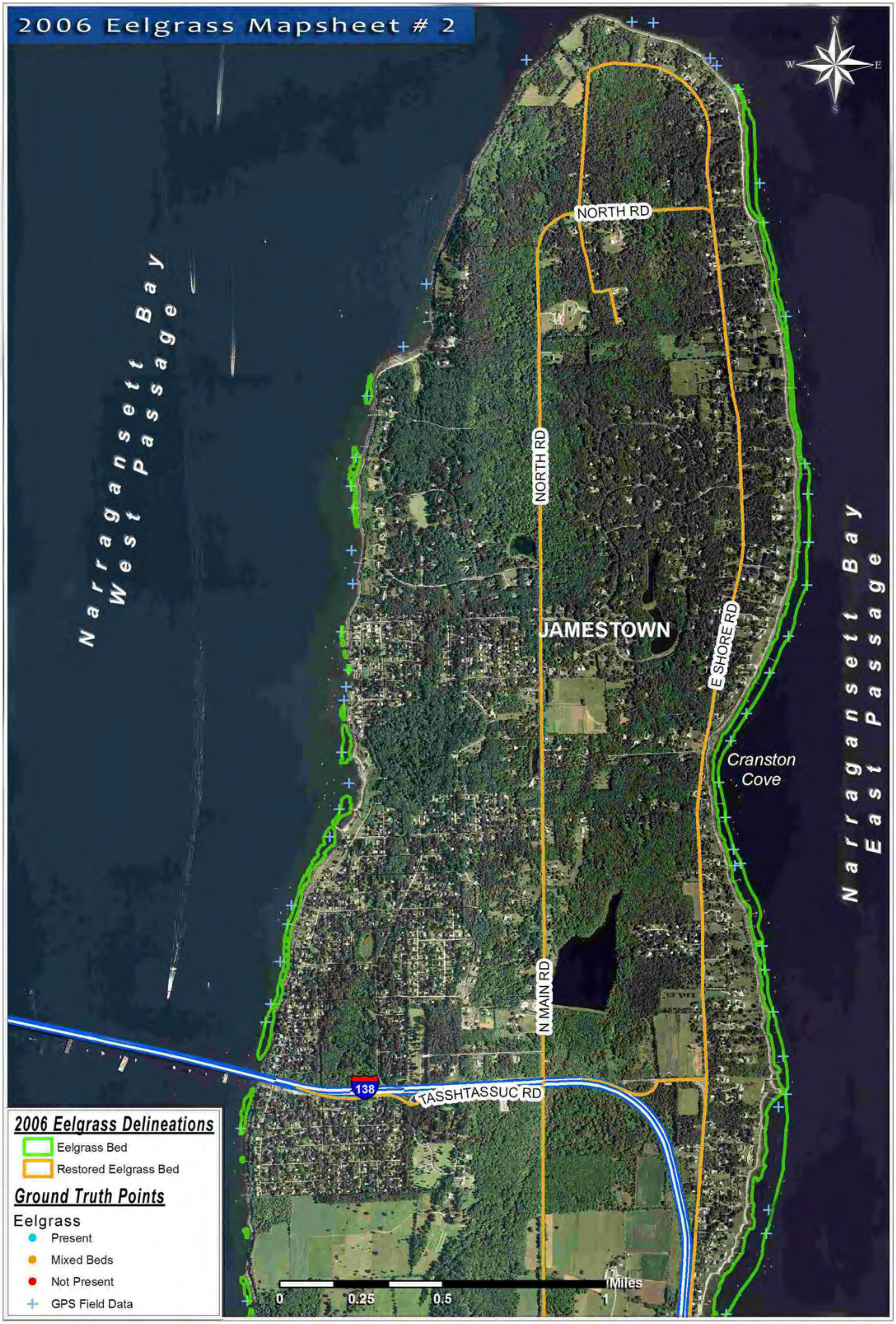

2006 Eelgrass Mapsheet # 2
N
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Narragansett Bay
West Passage
Narragansett Bay
East Passage
NORTH RD
NORTH RD
N MAIN RD
E SHORE RD
JAMESTOWN
Cranston Cove
138
TASSHTASSUC RD
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
Eelgrass
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GPS Field Data
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2006 Eelgrass Mapsheet # 3
Dutch Island
Dutch Island Harbor
Narragansett Bay West Passage
Narragansett Bay East Passage
Mackerel Cove
JAMESTOWN
E SHORE RD
138
N MAIN RD
NARRAGANSETT AVE
CONANICUS AVE
SOUTHWEST AVE
HAMILTON AVE
BEAVERTAIL RD
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2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
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GPS Field Data
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2006 Eelgrass Mapsheet # 4
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Patience Island
Potter Cove
Prudence Island
PORTSMOUTH
Narragansett Bay
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
Eelgrass
Present
Mixed Beds
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GPS Field Data
Miles
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2006 Eelgrass Mapsheet # 5
N
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Sandy Point
Narragansett Bay
East Passage
Prudence Island
Dyer Island
Weaver Cove
DEFENSE HIGHWAY
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UNION ST
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2006 Eelgrass Delineations
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Ground Truth Points
Eelgrass
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Mixed Beds
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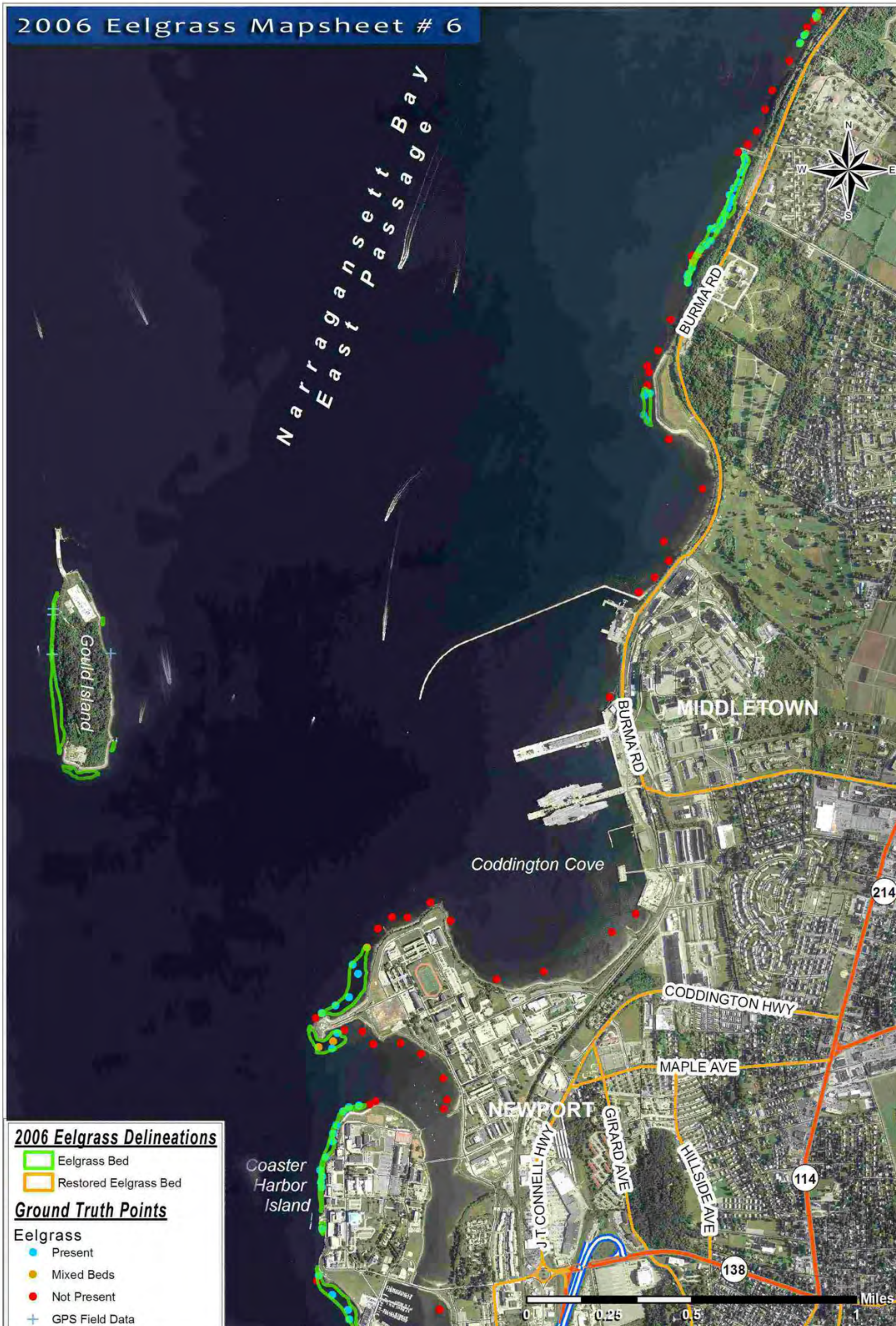
GPS Field Data



2006 Eelgrass Mapsheet # 6
Narragansett Bay
East Passage
Gould Island
Coddington Cove
MIDDLETOWN
NEWPORT
Coaster Harbor Island
BURMA RD
CODDINGTON HWY
MAPLE AVE
GIRARD AVE
HILLSIDE AVE
J T CONNELL HWY
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2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
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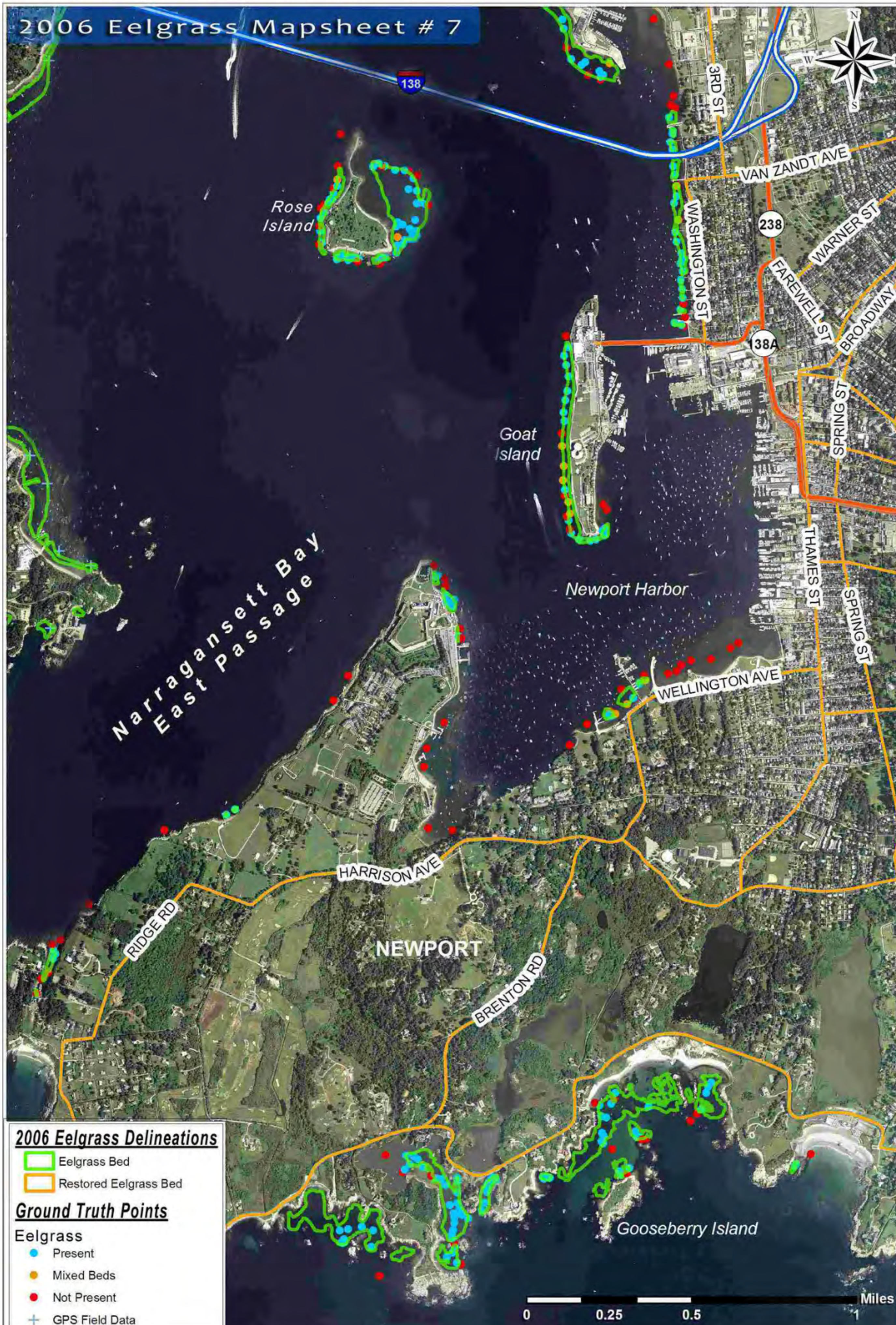

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Rose Island
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WARNER ST
FAREWELL ST
BROADWAY
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SPRING ST
Goat Island
THAMES ST
Newport Harbor
Narragansett Bay
East Passage
WELLINGTON AVE
HARRISON AVE
RIDGE RD
NEWPORT
BRENTON RD
Gooseberry Island
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
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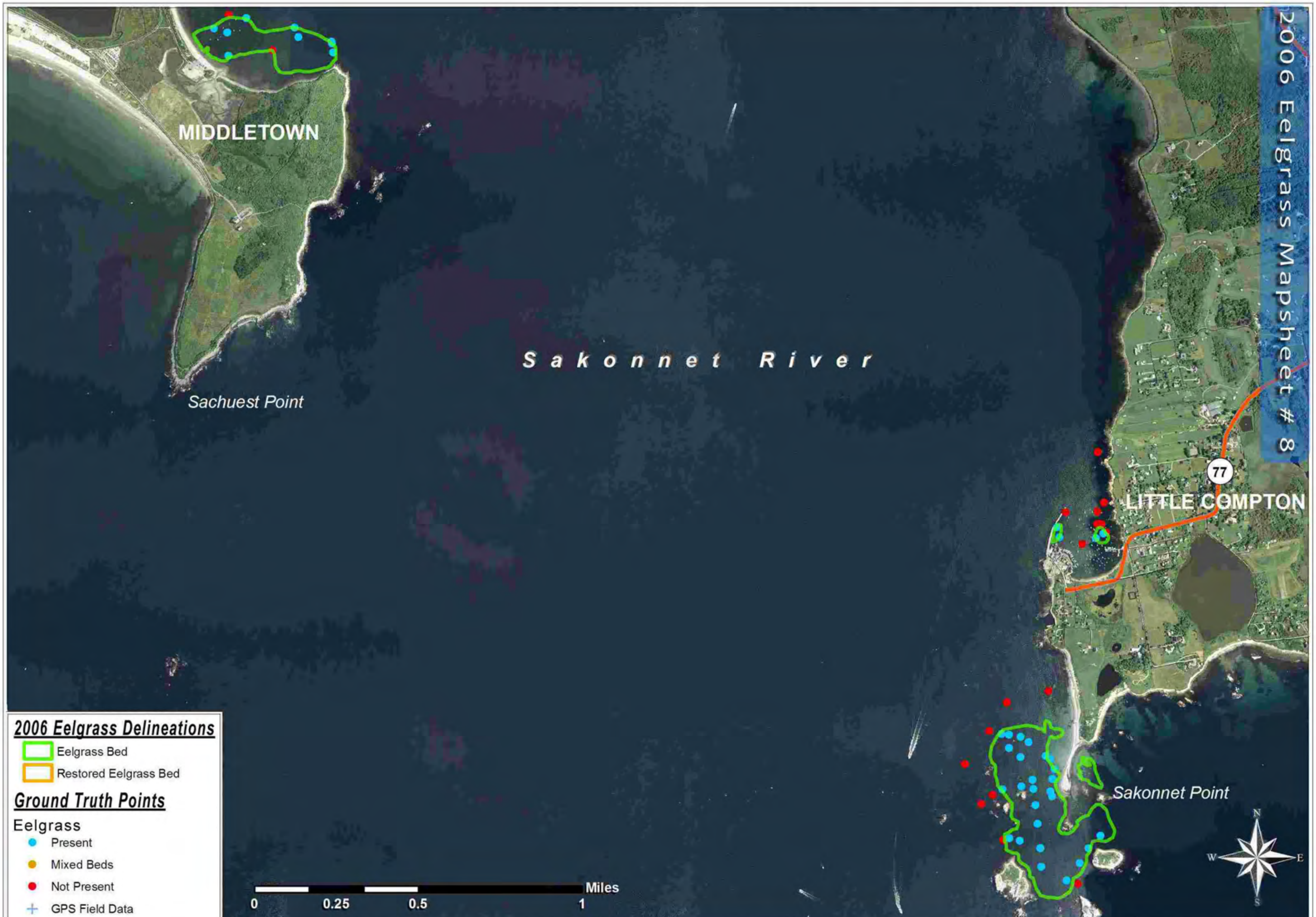
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MIDDLETOWN
Sachuest Point
Sakonnet River
LITTLE COMPTON
77
Sakonnet Point
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
Eelgrass
Present
Mixed Beds
Not Present
GPS Field Data
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2006 Eelgrass Mapsheet # 9
N
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Block Island Sound
Great Salt Pond
NEW SHOREHAM
OCEAN AVE
BEACH AVE
WEST SIDE RD
OCEAN AVE
WATER ST
SPRING ST
HIGH ST
CENTER RD
Old Harbor
2006 Eelgrass Delineations
Eelgrass Bed
Restored Eelgrass Bed
Ground Truth Points
Eelgrass
Present
Mixed Beds
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GPS Field Data
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