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A Method for Rapidly Assessing the Distribution and Cover of Submersed Aquatic Vegetation in Rhode Island Estuaries

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Introduction

Eelgrass (*Zostera marina* L.) is a species of submerged aquatic vegetation (SAV) that grows in shallow coves and embayments in temperate estuaries around the world. Eelgrass removes dissolved nutrients from the water column and sediments and can help reduce water column turbidity (Dennison et al. 1993). Eelgrass beds help stabilize sediments and limit erosion by reducing wave action and currents (Den Hartog 1970, Taylor and Lewis 1970, Fonseca et al. 1982, Harlin et al. 1982, Fonseca et al. 1983, Fonseca 1996). Eelgrass is also an important forage and refuge habitat for many commercially important fin and shellfish such as scallops and juvenile flounder (Dennison et al. 1993, Raposa and Oviatt 2000). Despite these benefits, eelgrass is threatened by human-related problems including disease, mechanical disturbance, and nutrient-enrichment and water clarity issues related to watershed land-use practices (Short and Wyllie-Echeverria 1996, Duarte 2002).

In recognition of the values it provides and the threats it faces, 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 legislation (RI Coastal Resource Management Plan). In Narragansett Bay RI, additional protection is provided by the Narragansett Bay National Estuarine Research Reserve (NBNERR or Reserve), which prohibits anchoring and shellfishing in eelgrass beds within the Reserve's boundaries. Unfortunately, only 1.6 km^{-2} (approximately 400 acres) of eelgrass currently remain in the 342 km^{-2} Narragansett Bay (i.e., approximately 0.5% of the Bay area) (Chinman and Nixon 1985, Bradley et al. 2007).

Eelgrass can be used as an indicator of general ecosystem health because it serves as a foundation species that supports higher trophic levels and is affected by abiotic factors including light, nutrients, and temperature (Dennison et al. 1993). Mapping and monitoring eelgrass over time can therefore help identify how an estuary is responding to watershed-based anthropogenic impacts, climate change, and local management and regulatory activities. A variety of tools and methods are available for mapping and/or monitoring eelgrass, but each has its associated set of benefits and drawbacks.

The interpretation of remotely-collected aerial photography is a common approach for mapping the distribution, extent, and cover of eelgrass over relatively broad areas but this approach can be cost-prohibitive. For example, the 2006-2007 mapping effort in Narragansett Bay cost an estimated $150,000, not including supplemental costs to ground-truth the photographs in the field. This type of large-scale mapping is ideally conducted every 3-5 years, but three years have already passed since the last mapping effort in the Bay and there are currently no solid prospects for additional funding for another round of mapping. A second approach is to intensively monitor characteristics of target eelgrass beds in the field (A good example of this approach is SeagrassNet, which is a coordinated, global effort to monitor eelgrass status and threats using standardized protocols [Short et al. 2004]). This approach provides detailed information about metrics such as production rates, biomass, canopy height, and epiphyte cover but it is labor-intensive and the data are limited to the eelgrass beds from which they were collected.

In recognition of the limitations associated with both of the approaches described above, Neckles et al. (unpublished data) have recently developed an intermediate method for rapidly assessing eelgrass distribution, cover, and other metrics in Massachusetts. The method covers a smaller area than broad-scale aerial mapping but the costs in time and money are relatively small. It can provide additional information that is not obtained during SeagrassNet-type monitoring and, depending on which metrics are measured, the rapid assessment approach is not very labor intensive. Ideally, all three of these techniques would be used in combination to fully understand the status and trends of eelgrass and other types of SAV in an estuary. This is the approach put forward by Neckles et al. (unpublished data) who organized these methods into a hierarchical, three-tier approach to SAV mapping and monitoring. The tiers include Tier 1 (aerial photography mapping), Tier 2 (rapid assessments), and Tier 3 (Seagrassnet-type monitoring).

The overall goal of this project was to pilot the use of the Tier 2-Rapid Assessment method (hereafter T2-RA) for use in Rhode Island estuarine waters. This project took advantage of ongoing eelgrass mapping using aerial photography in Rhode Island's coastal lagoons in order to pilot the T2-RA and compare it to results from the aerial photograph mapping. More specifically, this project will be used to 1) directly compare results from the T2-RA and aerial photography mapping techniques, 2) estimate the amount of time that needs to be devoted to T2-RA monitoring, and 3) recommend a general methodology for using the T2-RA in the coastal ponds and in parts of Narragansett Bay (e.g., in the NBNERR).

Methods

Study Site

This study was conducted in Quonochontaug Pond, located in Charlestown, Rhode Island (Fig. 1). Quonochontaug is one of nine shallow coastal lagoons (ponds) located along the south shore of Rhode Island, west of Narragansett Bay. According to Rhode Island Sea Grant (http://seagrant.gso.uri.edu/coasts/quonny/index.html), Quonochontaug Pond is 302 ha in area with a mean depth of 1.8 m and a mean salinity of 29 ppt, making it one of the most saline and deepest of the coastal ponds. Quonochontaug Pond, which was permanently breached in the 1950s, supports extensive salt marshes along its southern shore and the western barrier beach remains largely undeveloped; most of the remaining shoreline, however, has been developed for residential housing.

The US Fish and Wildlife Service and the RI Department of Environmental Management are currently mapping SAV in the coastal ponds, in part to help explain patterns in waterbird use of the ponds. In fact, aerial photographs of the ponds, including Quonochontaug, were taken and groundtruthed in June and October 2009, respectively. Quonochontaug was therefore an ideal site to conduct a pilot study of the T2-RA and compare it to aerial photography-based mapping.

Rapid Assessment Methods

Geographic Information Systems (ARC-GIS) was used to establish T2-RA sampling stations by first overlaying the entire extent of Quonochontaug Pond with a grid consisting of 200-m hexagons. Point locations that represent field sampling stations were then randomly generated within every grid cell. All points that fell on open water habitat in the Pond were considered as viable sampling stations; points that fell on marsh or upland habitats were not (Fig. 2). This resulted in a total of 118 sampling stations.

The cover of both eelgrass and macroalgae was estimated at each location using a SeaViewer Sea-Drop ™ 950 underwater color video camera mounted to a custom frame (Fig. 3). The camera was equipped with a small light mounted to the frame to improve bottom visibility, an onboard digital video recorder (DVR) and screen to record all videos, and a Sea-Trak ™ global positioning system (GPS) wired into the DVR to visualize and record geographic coordinates on the screen. The camera frame was constructed from 1" PVC pipe and it included a 0.25 m^2 base that functioned as a quadrat. The camera was mounted facing down near the top of the frame so that the bottom quadrat was clearly visible within the camera's view field. This allowed field staff to clearly see the bottom of Quonochontaug Pond and estimate SAV cover within the 0.25 m^2 quadrat.

The same procedures were followed at each station to efficiently and consistently collect T2-RA data throughout the Pond. Using a small, flat-bottomed skiff, every station was located in the field by navigating using a shapefile of station locations that was loaded onto a stand-alone Trimble ® Geo-XT ™ GPS. Once the boat was on station, two anchors were thrown (one from the bow and one from the stern) to stabilize the boat and keep it from drifting. The DVR was then set to record and the camera and frame were lowered into the water at each of the four corners of the boat for within-station replication. It was lowered slowly to minimize sediment disturbance once the bottom was reached; if the sediments were disturbed after contact with the frame, estimates of SAV cover had to wait until the water column cleared. Cover of SAV types was visually estimated from the onboard screen using the Braun-Blanquet cover scale (Kent and Coker 1992). Cover classes within this scale include <1%, 2-5%, 6-25%, 26-50%, 51-75%, and >75%. Cover was generally estimated by one person, except when stations were difficult to see due to water clarity issues; in these cases at least two people worked together to collaboratively estimate cover. All video was recorded on the DVR and eelgrass and algae cover, secchi depth, water depth, and GPS location were recorded on hardcopy datasheets. All fieldwork was conducted in October 2009.

Data Analyses

Mean eelgrass cover at each station was calculated by averaging the midpoints of each cover class designation from the four corners of the boat. These data were then graphically displayed in GIS using graduated symbols (with larger symbols corresponding to higher cover estimates) and overlaid on top of the polygons delineated from photo-interpretation of the aerial photographs (for a general description of the methods used to photo-interpret the aerial photographs for eelgrass see Bradley et al. 2007).

The frequency of occurrence of eelgrass in Quonochontaug Pond was calculated using presence/absence data from each station and dividing the number of points where eelgrass was present by the total number of points sampled (and expressing as a percentage). Mean eelgrass cover throughout the Pond was calculated by averaging mean station cover across all sampling stations. Finally, an estimate of the number of samples required for future T2-RA monitoring in the coastal ponds was calculated in SigmaStat version 3.5 using the standard deviation of the cover data collected in this study. This sample-size estimate was based on the desire to statistically detect a difference in cover of 10% between years with a power of 0.8 and an alpha of 0.05.

Results and Discussion

Based on presence-absence data from the T2-RA, eelgrass was present in 29.6% of Quonochontaug Pond (Fig. 4). However, based on mean percent cover data from the T2-RA, eelgrass covered only 8.0% of the Pond. Based on aerial photograph interpretation, it was found that eelgrass covered 12.2% of the Pond. Four of the T2-RA sampling points were found to have eelgrass that was not also delineated as an eelgrass polygon during the photo-interpretation analysis (Fig. 4). In contrast, the photo-interpretation method revealed ten small, isolated eelgrass beds that were not identified as part of the T2-RA. Photo-interpretation also revealed much more detail about the shapes and edges of all beds in the Pond.

The T2-RA method produces two measures of eelgrass cover based on the type of data used. Presence-absence data results in frequency of occurrence estimates of eelgrass in the study area that are probably not indicative of true cover. However, percent cover data from individual locations results in overall cover estimates for the entire study area when averaged across locations. At least from this one example, the latter data seems most comparable with cover estimates from photo-interpretation mapping. The reason that presence-absence data from the T2-RA do not agree well with cover estimates based on photo-interpretation is because the T2-RA will document eelgrass even at densities as low as 1% cover, while in many cases these areas will not be delineated by photo-interpreters. Indeed, the mean cover of eelgrass in T2-RA points that were photo-interpreted as unvegetated was 5.9%. This compares to mean eelgrass cover of 34.4% from the T2-RA points that were interpreted as supporting eelgrass. Ultimately, both types of data produced from the T2-RA should prove useful for mapping and monitoring the extent and cover of eelgrass as long as this method is conducted repeatedly over time.

Based on this pilot effort, it was found that approximately 30 locations can be surveyed using the T2-RA method in a single day. This estimate of course depends on staff experience and efficiency, weather conditions, and the size of the study area (and thus the distance between consecutive stations). Using a sample size estimator and data from this pilot effort, it was found that 66 samples would be needed in order to detect a difference of 10% eelgrass cover in Quonochontaug Pond between two years (i.e., from 8% cover in 2009 to 18% or more in a subsequent sampling year). Larger sample sizes would be needed to detect smaller changes. This estimated sample size is similar to Neckles et al. (unpublished data), who found that only 65 samples were needed to detect "an increase in seagrass cover over two successive years with a high degree of power". However, their study site (Little Pleasant Bay, MA) is over twice as big as Quonochontaug Pond. The need for a relatively large sample size in Quonochontaug Pond is due to the fact that the vast majority of stations that were sampled did not support any eelgrass (0% cover), while a small number of stations supported eelgrass at covers of over 80%. In other words, the high variability among stations resulted in a high standard deviation and a subsequently high sample size for a relatively small body of water.

It is recommended here that three days be dedicated to any future T2-RA efforts in Quonochontaug Pond. Assuming 30 samples can be collected during an ideal day, this would likely ensure that the 66 samples are collected to detect a minimum change of 10% cover between years. Not only would the three days allow for extra time to collect the 66 samples in the event problems arise, it would also provide additional time to collect extra samples and thereby raise statistical power if no major problems were encountered. A smaller sample size may be needed when mapping in Narragansett Bay, especially if the goal is to examine specific areas or individual eelgrass beds (e.g., the large bed around the south end of Prudence Island in the NBNERR). This approach would likely result in decreased variability in cover among stations and, subsequently, lower sample sizes. As recommended by Neckles et al. (unpublished data), pilot data should be collected in order to determine the appropriate sample size at the beginning of any new study. From this, the appropriate grid cell size can be determined to fit within the pre-defined study area and accommodate the required sample size.

While the approach described above is appropriate for use in the Rhode Island coastal ponds and for specific locations/eelgrass beds in Narragansett Bay, it is likely that the T2-RA approach would not be effective for mapping eelgrass throughout the entire Bay. The sheer size of Narragansett Bay makes using this method ineffective; the area of Quonochontaug Pond is less than 1% of the area of the Bay. Based on the 66 samples required to accurately map the Pond and scaling up, it would take thousands of samples to do the same in the Bay with the same grid size. Alternatively, if the sample size were manually reduced to a logistically feasible number (e.g., 100), the result would be an exceedingly large grid cell size, low accuracy, and low statistical power. Instead, any T2-RA sampling in Narragansett Bay should be limited to accurately monitoring target areas or beds repeatedly over time with a high degree of statistical power. At least as a start, it is recommended here that long-term monitoring of eelgrass beds within the NBNERR should begin in 2010 with a pilot program to determine grid cell and sample sizes.

The protocols outlined here worked extremely well in this pilot program. The camera and frame/quadrat was very effective for observing and distinguishing between eelgrass, macroalgae and other bottom types as well as for distinguishing between different cover classes of vegetation (Fig. 5). During future efforts, it is recommended that a visual record of the station number and date/time of day be placed in front of the camera (e.g., using a piece of paper) at each station before lowering the camera and frame into the water. Without this record, it can be difficult to easily differentiate stations from one another on the DVR. Even though a sequential written record was taken of the stations that were sampled during this study, the field staff forgot to turn on the DVR at some stations so that the sequence of stations on the DVR did not exactly match the written sequential record. It was also found that even moderate winds made it nearly impossible to see the bottom of the Pond with the camera; since the Pond is so shallow these winds easily stirred up the bottom and significantly impaired water clarity. Lastly, it was found that a light attached to the frame is required to clearly see the bottom and differentiate vegetation and substrate types even at relatively shallow depths.

In summary, this pilot project demonstrated that the T2-RA is an efficient, useful tool for quickly estimating the distribution and cover of eelgrass in shallow estuarine habitats in Rhode Island waters. Although this pilot was conducted in the shallow Quonochontaug Pond, the method should work just as effectively in nearby Narragansett Bay. This method provided estimates of Pond-wide eelgrass cover that were similar to estimates from aerial photograph interpretation. It also provided information on eelgrass (and macroalgae) cover classes at individual locations within the study area. If desired, it can also produce data on a suite of additional eelgrass and environmental parameters (e.g., shoot length and density, production, secchi depth, water quality conditions, etc.) throughout the Pond. This method also provided permanent photographic documentation of eelgrass from each location. It is recommended here that the T2-RA be used to frequently quantify eelgrass distribution and cover in target areas within the NBNERR. In addition, since groundtruthing aerial photographs of the coastal ponds must happen during any Tier 1 mapping effort, it is further recommended that the T2-RA replace standard groundtruthing efforts in the ponds when feasible. If implemented, these recommendations will ultimately result in an extensive database on eelgrass demographics and will help to fill in the gaps that result when Tier 1 mapping is not feasible or when funding is not available.

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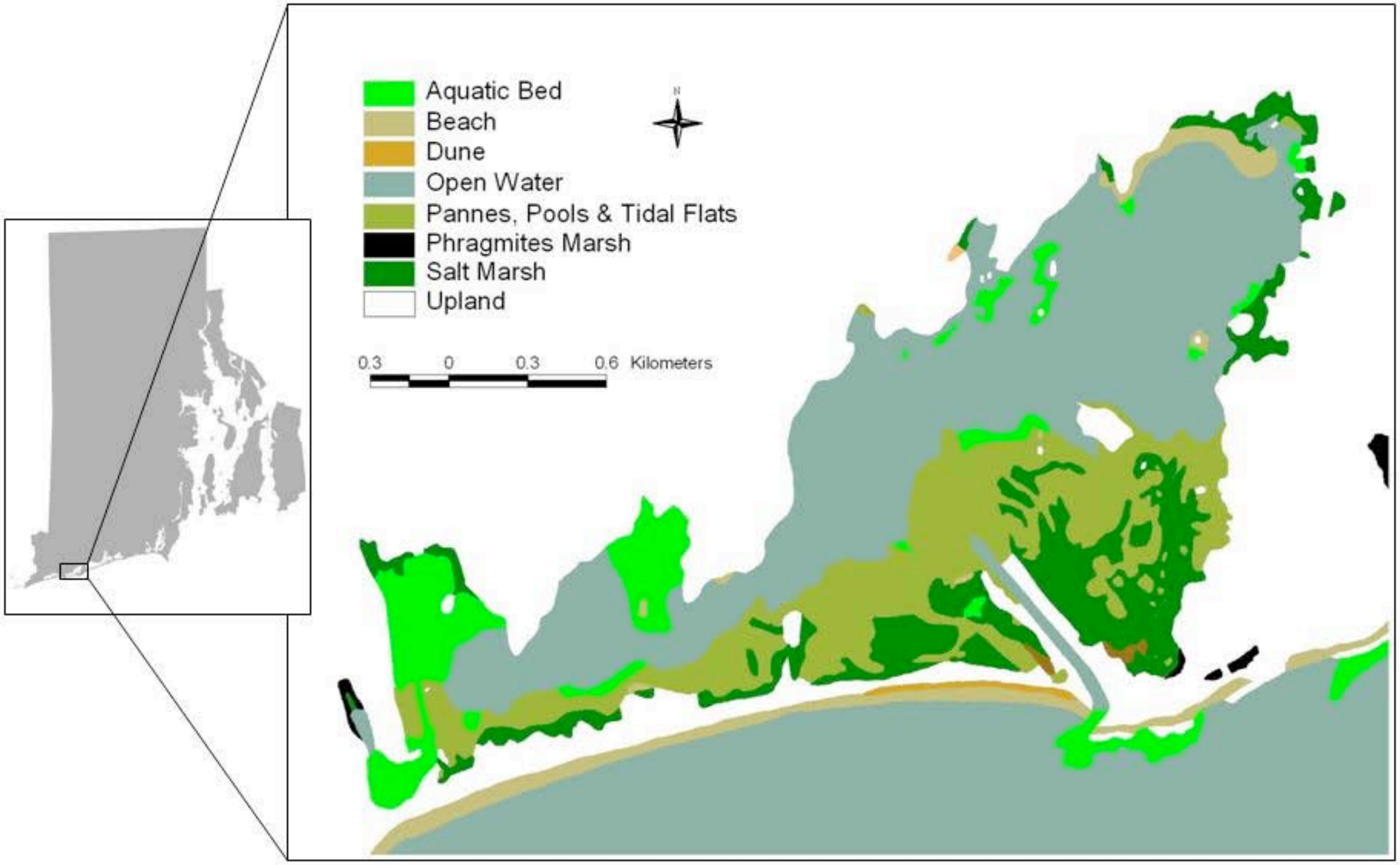

Figure 1. Map of Quonochontaug Pond along the south shore of Rhode Island. The map indicates the extent of major land cover classes using data provided by Rhode Island Geographic Information System (RIGIS; http://www.edc.uri.edu/rigis/). Aquatic beds as indicated in the map were delineated for RIGIS from 1999 aerial photography and do not represent the extent of eelgrass found during the current study.

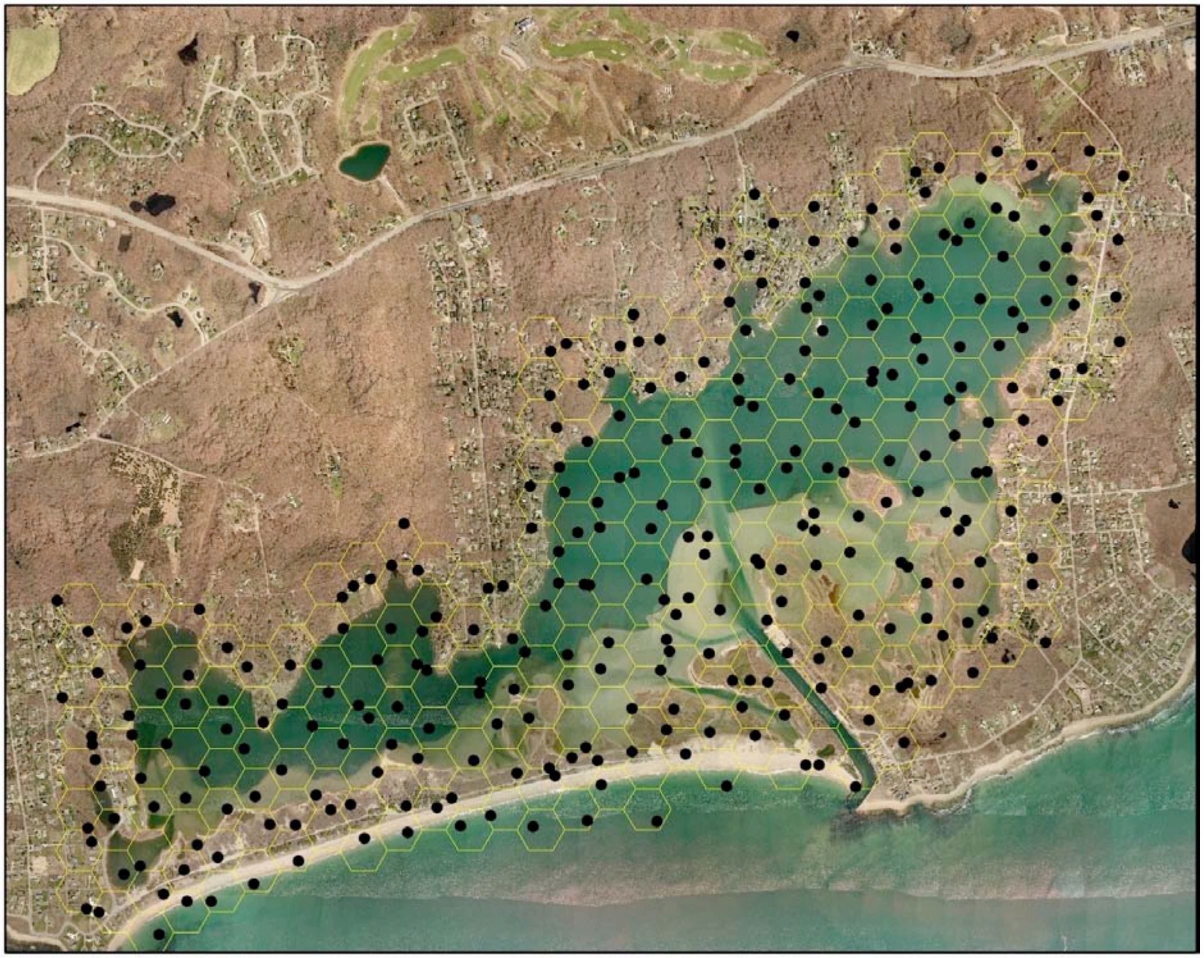

Figure 2. Map of Quonochontaug Pond with the overlay of 200-meter hexagon grid cells and the random sampling location within each cell. Although the surrounding upland was included when originally creating the grid cells, only those cells that actually fell over the Pond were sampled during this study.

Figure 3. Photographs of the underwater video camera and quadrat-frame used to map eelgrass as part of the Tier 2-Rapid Assessment (T2-RA) pilot described in this report.

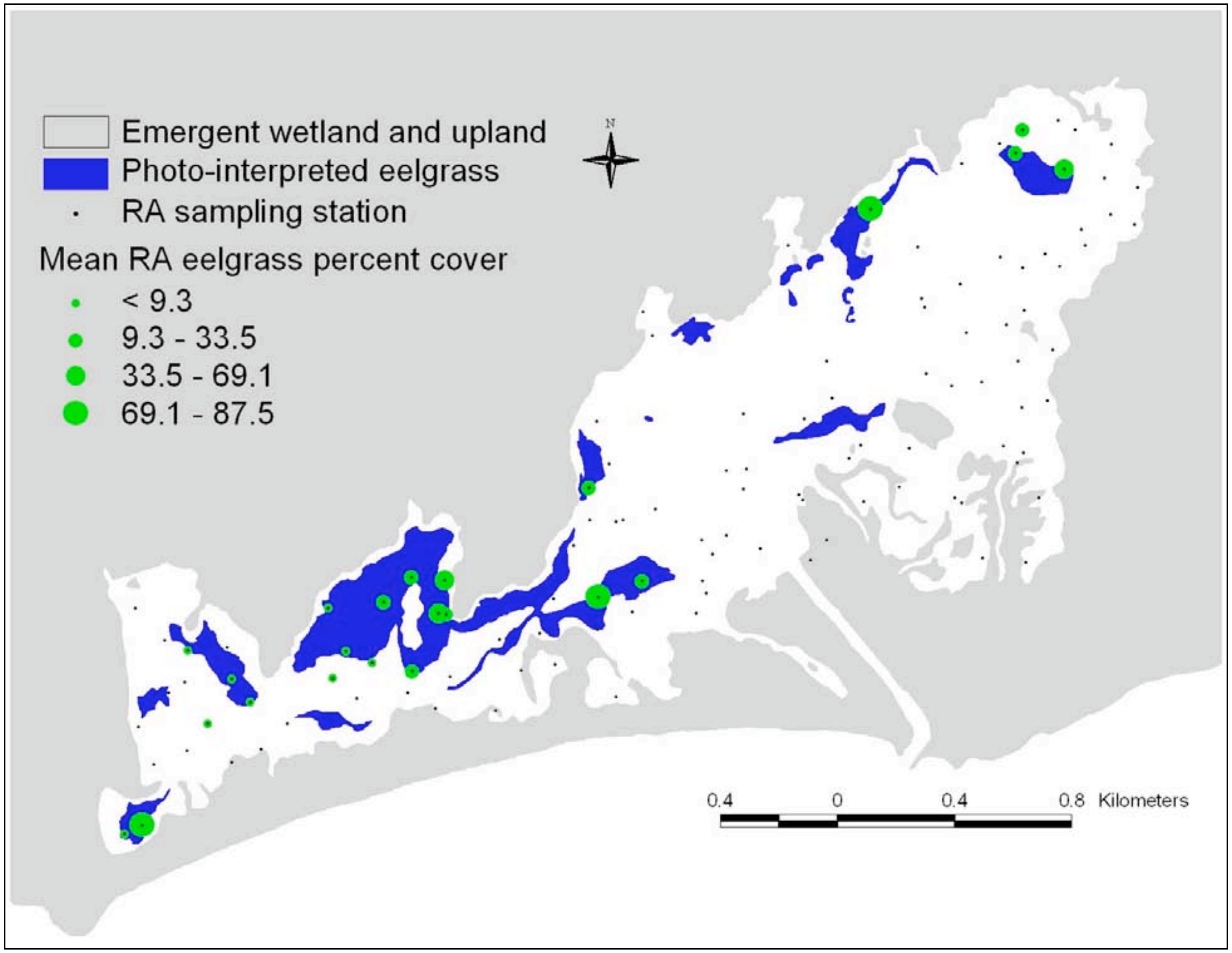

Figure 4. Comparison of eelgrass beds as derived from the Tier 2-Rapid Assessment (T2-RA) technique (green dots, shown as a graduated scale based on the percent cover of eelgrass) and from the interpretation of color aerial photographs (blue polygons).

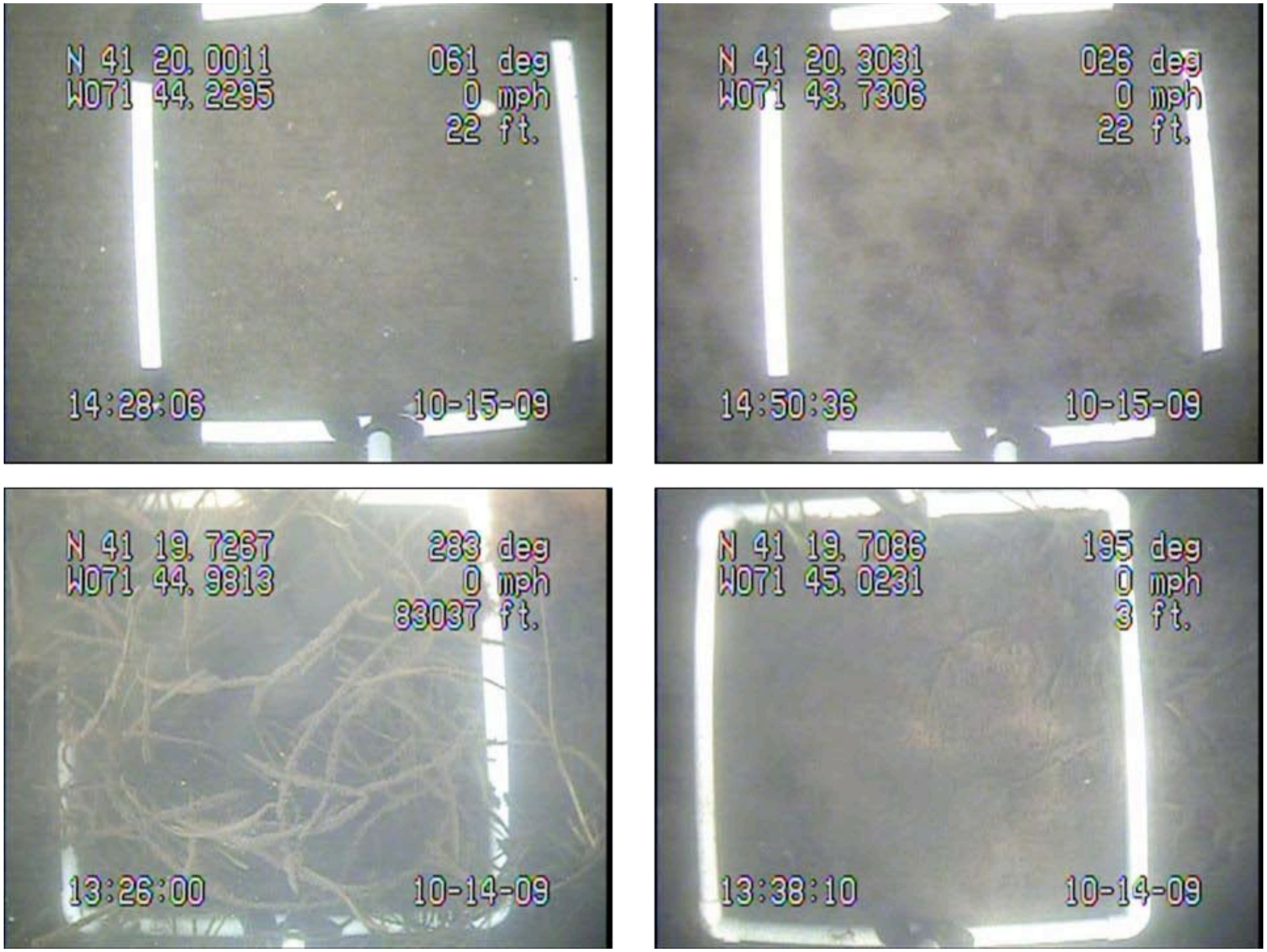

Figure 5. Examples of images obtained from the underwater video camera and DVR. Clockwise from top-left: bare sediment; moderate algae/detritus (classified as 26-50% cover); sparse eelgrass (6-25%); thick eelgrass (>75%).