Narragansett Bay
Research Reserve

Technical Report 2013:2

Using Underwater Video to Map Subtidal Habitats and Eelgrass (*Zostera marina*) Around Prudence Island, Rhode Island

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1. Introduction

This report describes a recent project by the Narragansett Bay National Estuarine Research Reserve (NBNERR or Reserve) to map the distribution and extent of subtidal habitats (with a focus on eelgrass *Zostera marina*) within the Reserve's estuarine boundary. Comprehensive subtidal mapping data that focus specifically on Prudence Island (the largest component of the NBNERR) do not exist, but some data for the Island are available from broader mapping efforts that have occurred in Narragansett Bay. For example, McMaster (1960) conducted one of the first efforts to characterize and map substrate types in Narragansett Bay; he found that the subtidal areas directly around Prudence Island were dominated by sand (north end of the Island), silty-sand (west side), clayey-silt (southwest side), and a sand-silt-clay mix (southeast and east sides). More recently, the US Geological Survey (USGS) conducted multibeam and side scan mapping in parts of Narragansett Bay, including along the southeast side of Prudence Island (McMullen et al. 2007). In contrast to McMaster (1960), this study characterized sediments around the southeastern side of the Island as sandy. Finally, the MapCoast Partnership (www.mapcoast.org) provides a clearinghouse for subaqueous mapping data from coastal Rhode Island and it is attempting to create a seamless soils/sediment database of Rhode Island's entire coastal plain. Combined, these resources provide some insight into the composition and distribution of subtidal habitat types around Prudence Island, but higher-resolution maps of all benthic habitats and resources are still needed. The project described in this report was conducted in part to help fill this gap.

Efforts that specifically focus on mapping subtidal eelgrass in Narragansett Bay (including Block Island and Rhode Island's coastal ponds in some instances) have typically been conducted at approximately 5-10 year intervals. To date, these have occurred in 1996 (Huber 1996), 2006 (Bradley et al. 2007), and 2012 (Bradley et al. 2013). In each case, submerged aquatic vegetation (SAV; almost exclusively eelgrass) composition, distribution, and extent was mapped by collecting, interpreting, digitizing, and groundtruthing a series of georeferenced aerial photographs.

Due in part to cost considerations, Bay-wide eelgrass mapping is now planned to occur at 5-year intervals. To help fill the temporal gaps between mapping effort products, the NBNERR began developing a method for rapidly assessing eelgrass and benthic habitats in 2009 (Raposa and Bradley 2010). This pilot in Quonochontaug Pond, a coastal pond on Rhode Island's south coast, worked effectively and it was recommended that the rapid assessments be used to map eelgrass distribution and cover around Prudence Island (and possibly other areas in Narragansett Bay) every year. This mirrors the three-tiered hierarchical monitoring strategy for SAV that was developed by Neckles et al. (2012) and adapted for Narragansett Bay by Raposa and Bradley (2009). With this approach, hierarchical eelgrass monitoring in Narragansett Bay would include broad-scale aerial photograph-based mapping every 5 years (tier 1), annual rapid assessments around Prudence Island with underwater video (tier 2), and intensive monitoring (analogous to SeagrassNet; www.seagrassnet.org) at a small number of sites each year (Hudson, unpublished data).

The goals of this project were to: 1) map the distribution and cover of all subtidal benthic habitats and resources in the shallow subtidal zone around Prudence Island with underwater video, and 2) conduct the first round of tier 2 underwater video mapping of existing eelgrass beds around Prudence Island. The former will complement contiguous intertidal and terrestrial habitat maps for Prudence Island that are currently being generated by the NBNERR; the latter will provide a baseline dataset to compare with future annual tier 2 eelgrass mapping datasets. The results of these combined efforts will be the first high resolution maps focused on the composition and distribution of all major benthic habitat types, as well as maps showing the distribution and cover of eelgrass around Prudence Island.

2. Methods

2.1 Study site

This study was conducted in the shallow subtidal zone around Prudence Island, RI. Prudence Island is in the approximate center of Narragansett Bay and is the largest island in the Reserve. Due to its central location, Prudence Island sits in the general transition area between the more eutrophic Upper Narragansett Bay and the relatively nutrient-poor areas further down the Bay near its mouth with Rhode Island Sound. This location makes Prudence an excellent location to monitor large-scale and long-term ecological changes that might occur in the Bay due to management activities and climate change.

2.2 Underwater Mapping Methods

2.21 Benthic habitat mapping in 2011

All underwater mapping was conducted around Prudence Island in subtidal waters up to 18 ft. in depth (which represents the extent of the Reserve's jurisdictional boundary). We used geographic information systems (ArcGIS v. 10) to establish mapping stations by overlaying the entire extent of Prudence Island's subtidal zone with a grid consisting of

250-m diameter hexagons. A single random point was then generated within every grid cell to represent individual sampling stations. This initially resulted in 343 sampling stations. All points that fell on actual open water were considered as viable sampling stations; points that fell on marsh or upland habitats were discarded. This resulted in a final total of 188 potential sampling stations (Fig. 1).

The composition and cover of all subtidal habitat types at each station was determined with a SeaViewer Sea-Drop ™ 950 underwater color video camera mounted to a custom frame (Fig. 2). 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 all subtidal habitat types around Prudence Island and estimate their cover within the 0.25 m^2 quadrat.

Every station was located in the field by navigating by boat using a shapefile of station locations that was loaded onto a stand-alone Trimble ® Geo-XT ™ GPS. Once the boat was on station and anchored, the DVR was 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 as recommended by Neckles et al. (2012). 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 benthic habitat cover were made after the water column had cleared.

Cover of benthic habitat types and features was visually estimated from the onboard screen using a modified Braun-Blanquet cover scale (Kent and Coker 1992). Cover classes used for this study included <1-5%, 6-25%, 26-50%, 51-75%, and >75%. Benthic habitats and features were broken in three broad groups. Base substrates included any fine-grained particles that comprised the actual sediment (e.g., sand, silt). Abiotic surface features included anything that was found on top of the base substrates that was not alive, including rocks of all sizes and shells. Finally, biotic surface features included any living organism found on the surface of the sediments (e.g., macroalgae, shellfish beds). Cover was generally estimated by one person from the DVR, 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. When possible, macroalgae was broken down into green and brown/red subgroups and the cover of each (as well as for total algae) was estimated. All video was recorded on the DVR and subtidal habitat cover, water depth, and GPS location were also recorded on hardcopy datasheets. All fieldwork was conducted between August 16 and November 16, 2011.

2.22 Eelgrass mapping in 2012

A second round of underwater video mapping that focused exclusively on eelgrass occurred in 2012. The same hexagon-random point method was used to randomly select points within areas where eelgrass beds are known to exist around Prudence Island. The first area includes a small bed just to the south of Sheep-pen Cove on the northeastern side of Prudence Island (Fig. 3). The second area is along the western side of Prudence Neck, where Save The Bay transplanted eelgrass from 2002-2010 as part of its eelgrass restoration efforts. The third area supports Prudence Island's largest eelgrass bed, which stretches from just south of the Prudence Island lighthouse to the southwestern side of the island. Because of the smaller sampling area in 2012, hexagons were reduced to 50-m diameter for the Sheep-pen and Prudence Neck beds and to 75-m diameter for the South Prudence bed to ensure that an adequate number of sampling stations was established. Hexagons and random point sampling locations were extended into a 50-m buffer around the known boundaries of each eelgrass bed in order to be able to capture bed expansion should it occur in the future. Using this approach, a total of 143 eelgrass mapping stations was ultimately established (23 in Sheep-pen Cove; 19 along Prudence West; and 101 along South Prudence). When eelgrass and/or macroalgae was encountered at a station, the cover of each was estimated using the Braun-Blanquet cover class method as described above. All fieldwork was conducted between July 27 and September 25, 2012.

2.3 Data Analyses

The frequency of occurrence (hereafter referred to as 'frequency') of each subtidal habitat type around Prudence Island was calculated by dividing the number of points where a given habitat was present by the total number of points sampled (expressed as a percentage). Mean percent cover of each surface habitat type at each station was calculated by averaging the midpoints of each cover class designation from the four within-station replicates. Mean overall cover of each habitat type around all of Prudence Island (or across all eelgrass bed areas in 2012) was then calculated by averaging mean station cover across all sampling stations. These data were then graphically displayed in ArcGIS using graduated symbols (with larger symbols corresponding to higher cover estimates) or, when appropriate, as classified percent cover maps where cover was derived from inverse distance weighted interpolation of sample point values using ArcGIS Geostatistical Analysis (power=2 [held constant for all cover types]; default settings for output cell size [min. dimension / 250] and search radius [12]).

3. Results and Discussion

3.1 2011 Subtidal Habitat Mapping

Of the original 188 sampling stations identified using ArcGIS, 156 were sampled during this study. The remaining stations were not sampled either due to a lack of time or because the water at those stations was either far too shallow or it greatly exceeded the 18-foot depth boundary of the NBNERR. The diversity of subtidal habitats at these 156 stations was relatively low as only 12 benthic habitat types were identified. This included 3 base substrates (sand, silt, and a sand/silt mixture), 5 abiotic surface cover types (pebble, gravel, cobble, boulder, and shell), and 4 biotic surface cover types (eelgrass, macroalgae, floc, and live shellfish beds). Rock sizes were based on a modified Udden-Wentworth grain size classification system (Wentworth 1922). We used floc as a general biotic surface cover type to include any highly decomposed unidentifiable organic material, which was often found settled on the sediment surface. Attempts were made to quantify macroalgae as green or red/brown separately but in a number of cases, this was not possible due to poor video clarity; in these cases macroalgae was quantified as a whole.

Table 1 includes the frequency and percent cover of each of these subtidal habitats around Prudence Island. In general, base substrates were dominated by a mix of sand and silt, followed closely by only sand and only silt. Based on cover, 67% of the entire subtidal bottom surface was bare base substrate and 28% was covered by a relatively even mix of abiotic (e.g., rock and shell) and biotic surface cover types. Abiotic surface cover types only included rocks (pebble, gravel, cobble, boulder) and shell. Rocks and shell were found at most stations around Prudence Island, but were consistently sparse as evidenced by low mean cover values for these habitats. Biotic surface cover types were dominated by macroalgae (46% frequency; 9% cover); eelgrass, shellfish beds, and floc were far less common.

The cover of all subtidal habitat types combined totaled approximately 95%. The missing 5% is likely due to observer error and subjectivity associated with estimating cover classes and to turbid water that occasionally made observations difficult. In addition, errors can be introduced by taking midpoints for each cover class when calculating mean percent cover at various scales (i.e., within stations and across the entire study area). Despite these issues, the total cover of all benthic habitats recoded in 2011 generally approximated the true cover of 100%.

3.11 Base substrates. The subtidal waters around Prudence Island were comprised of a mix of sand and silt (found at 44% of the stations), silt (33%), and sand (29%) (Table 1). These combined percentages exceeded 100% because at some stations more than one substrate type was recorded among within-station replicates. In general, siltier substrates were found in association with coves along the north and northeastern sections of Prudence Island; sandier substrates were found along the southern half of the Island, particularly off the west side of Prudence Neck (Fig. 4). In contrast to our study, McMaster (1960) identified 12 substrate types in coastal Rhode Island by analyzing actual grab samples. The disparity in the number of sediment types between studies suggests that observer interpretation of underwater video without concurrent groundtruthing is not the most accurate way to identify and map base substrate types. Some of our general spatial patterns agree well with McMaster (1960) who noted that parts of the western side of Prudence Island are dominated by sand, while much of the remainder of the island is dominated by finer sediment particles such as silt.

3.12 Abiotic surficial cover types. We identified 5 abiotic cover types including pebble, gravel, cobble, boulder, and shell. Rocks (all size classes combined) were found at 49% of all stations at a mean cover of 7%. Similarly, shell was found at 89% of the stations at a mean cover of 8% (Table 1). This indicates that while these abiotic surface features are ubiquitous around Prudence Island they are also generally sparse. Figures 5-9 show the interpolated distributions of each of the 5 abiotic cover types around Prudence Island. As with base substrate types, our ability to identify and characterize abiotic cover types was limited by our reliance on only underwater video. While grain and rock size classifications are well-defined (e.g., Wentworth 1922), we were not able to actually measure any rocks remotely and instead had to rely on video interpretations. In the future, the quadrat could be marked off to improve our ability to estimate rock size classes if necessary.

3.13 Eelgrass. Eelgrass was only found around the southern end of Prudence Island during our 2011 broad-scale mapping effort (Fig. 10). This agrees fairly well with maps of eelgrass distribution and cover from the 2006 tier 1 aerial photograph mapping effort (Bradley et al. 2007). For example, in our study, eelgrass was present at 6% of the stations, while it covered 1.4% of the subtidal area within the same mapping extent during the 2006 study (Table 1). However, in 2011 we missed a small but persistent bed near Sheep-pen Cove on the northwest side of Prudence Island and a small, highly fragmented transplant area along the western side of the Island. This suggests that eelgrass mapping using underwater video at moderate scales (e.g. around all of Prudence Island) may not be the best method for creating accurate maps of eelgrass distribution because of the relatively high probability of missing small, scattered, and highly fragmented eelgrass beds. In order to create these maps and capture more accurate estimates of percent cover, smaller-scale and higher-resolution mapping efforts in areas known to support eelgrass are recommended (see below).

3.14 Macroalgae. Macroalgae was present in almost half of the subtidal study area (i.e., at 46% of the stations), but only at a mean cover of 9% indicating that it was generally sparse around much of the Island (Table 1). This agrees well with recent macroalgae surveys around the shoreline of Prudence Island, which show that while algae is relatively ubiquitous around the Island, it is only highly abundant in some of the coves toward the northern end of the Island (Raposa et al. 2011). Green macroalgae was largely restricted to the northern half of Prudence Island, while red/brown algae and total algae were much more ubiquitous (Figs 11-13). Areas where total algae cover was highest include the coves on the northern half of Prudence Island, around the northern tip of the Island and along the northeastern side of Prudence Neck (Fig. 13). Visibility issues limited our ability to differentiate between red/brown and green macroalgae, but in general red and brown algae was found 2.56 times more often than green algae.

3.15 Shellfish beds and floc. Live shellfish beds (almost exclusively slipper shell *Crepidula fornicata* beds) were not common around most of Prudence Island (they were found at only 5% of all stations at a mean overall cover of 0.8%). However, these numbers may vary somewhat since it was often difficult to determine whether the shellfish beds were alive or dead from underwater video alone. Based on our mapping, live shellfish beds were only found on either side of Prudence Neck and directly off the northern tip of the Island (Fig. 14). While we documented the presence and general distribution of *C. fornicata* beds around Prudence Island, we found no evidence of blue mussel *Mytilus edulis* beds. In contrast, Altieri et al. (2006) documented and mapped 3 distinct *M. edulis* beds (totaling approximately 27.9 hectares) around Prudence Island in the spring of 2001. Five of our sampling locations fell within the general area of the previously delineated mussel beds, but mussels were never seen at any of these stations. Altieri et al. (2006) defined a mussel bed as any area with at least 25% cover of mussels, which suggests that our mapping efforts should have detected them if they were still present in 2011. Instead, these beds may have either greatly decreased in size or disappeared altogether. Indeed, most beds delineated in the spring of 2001 had all but disappeared by the fall of 2002 (Altieri et al. 2006). As is the case with small, sparse eelgrass beds, accurate mussel bed assessments may require the use of targeted, high-resolution mapping in areas where beds were previously found.

Floc was sparse around much of Prudence Island, although its cover and extent was highest along the western side of Prudence Neck (Fig. 15). However, the latter finding may be due in part to the fact that this area is comprised largely of sandy substrates and it is likely easier to see dark organic floc on this lighter colored substrate. This indicates that floc cover and distribution based on underwater video is probably not accurate as it largely depends on the underlying substrate type.

3.2 2012 Eelgrass mapping

We sampled 118 of the original 143 sampling stations in 2012; the remainder were not sampled for the same reasons described previously for 2011. The higher-resolution mapping in 2012 that targeted areas known to support eelgrass was much more effective for estimating small-scale eelgrass distribution and cover patterns. In the three areas combined, eelgrass was present at 57% of all sampling stations at a mean cover of 28% (Table 2). Extensive eelgrass beds were found stretching from the southwestern side of Prudence Island all the way up to near the lighthouse on the eastern side of the Island (Fig. 16); in this area eelgrass was found at 74% of the stations at a mean cover of 40%. However, very little eelgrass was found near Sheep-pen Cove (47% of stations; 5% cover) and the Save The Bay eelgrass transplants on the west side of the Island were not found at all (0% of stations; 0% cover). When our data are overlaid on top of new 2012 tier 1 eelgrass polygon delineations, there is good agreement between the data from the west side and south end areas, but not at Sheep-pen Cove. In the latter case, much of what was mapped as eelgrass from aerial photographs in 2012 was in fact confirmed to be macroalgae using our underwater video method, illustrating the additional value of underwater video as a tool for groundtruthing tier 1 aerial photography mapping products.

Within the three eelgrass mapping areas, macroalgae was actually found more frequently than eelgrass (macroalgae was present at 63% of the stations; eelgrass at 57%; Table 2). In general, however, macroalgae was quite sparse with a mean overall cover of only 9%. Macroalgae was most common at the Prudence West area (present at 94% of the stations), but the highest cover was found at the Sheep-pen Cove area (19%). Similar to our larger-scale observations in 2011, this 2012 effort shows that relatively sparse macroalgae beds are ubiquitous around much of Prudence Island.

Our data also show that eelgrass and macroalgae cover varies with water depth around Prudence Island (however, our depth data must be considered as general estimates since depth readings were taken with a boat fathometer; depth also obviously varies over the tidal cycle). Eelgrass cover was highest in the 0-9 foot depth range, with a peak between 3-6 feet. Cover decreased rapidly as depth increased past 9 feet and it was absent altogether at depths of 15 feet or greater (Fig. 17). Macroalgae was present at low cover at depths ranging from 0-18 feet, with a peak in the 6-9 foot depth range. The peak in eelgrass cover in shallow water suggests that eelgrass distribution and cover in parts of Narragansett Bay may still be limited by poor water clarity.

4. Summary

This study produced the first data and maps focused specifically on subtidal habitats around Prudence Island. These maps illustrate the Island's current composition and configuration of subtidal habitats and can serve as a baseline for detecting future changes. While our underwater video method was effective for rapidly assessing the distribution and cover of subtidal habitat types, it does have limitations. For example, it can be difficult to definitively identify some habitat types using only an underwater video camera. When considering base substrate types, field classifications of substrates into sand, silt, and sand/silt categories was often difficult and subjective. Field classifications can be augmented with subsequent analyses of the DVR in the laboratory, but this is not as accurate as taking and analyzing sediment cores from the field (e.g., McMaster 1960). Similarly, it was often difficult to determine whether or not *C. fornicata* beds were alive or dead, and to differentiate among different size-classes of rocks (e.g., between pebbles and gravel, gravel and cobble, etc.). Because of these limitations, the data and maps presented here should be interpreted cautiously.

The trade-off is the ability to rapidly assess the distribution of general habitat types across a relatively broad area, and this worked particularly well for eelgrass. For example, in 2012 two people were able to sample 118 stations across three areas in approximately three days. This illustrates that tier 2 rapid assessments can be an excellent method for efficiently and inexpensively monitoring eelgrass at moderate spatial scales. Rapid assessments could be done in years between the Bay-wide tier 1 aerial photograph mapping efforts to fill gaps, as well as in conjunction with tier 1 efforts to more accurately groundtruth initial polygon delineations in target areas.

We found a pattern in base substrates around Prudence Island that was relatively similar to what McMaster (1960) described over 50 years ago; we therefore do not recommend replicating base substrate mapping in the near future with underwater video. Instead, we recommend that the NBNERR continue to conduct tier 2 rapid eelgrass mapping around Prudence Island annually to track short-term fluctuations and to help fill gaps between tier 1 mapping efforts (e.g., the latest effort was in 2012 and the next is not targeted until 2016 or 2017). As shown here, annual tier 2 mapping will also be useful for quantifying changes in eelgrass across different depths. Finally, tier 2 mapping could be expanded to other areas within Narragansett Bay or in Rhode Island's coastal ponds as needed, and it could be used to more accurately map blue mussel (or other shellfish) beds around Prudence Island and elsewhere.

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Table 1. Frequency and mean % cover (+1 SE) of base substrates and abiotic and biotic surface cover types around Prudence Island, RI in 2011. Frequency is defined as the number of stations where a given feature was present, divided by the total number of stations (156), multiplied by 100.

	Frequency	Mean % cover
Base substrate		
Sand	29.49	17.20 (2.46)[a]
Silt	33.33	26.77 (3.14)[a]
Sand/silt mix	44.23	22.94 (2.62)[a]
Surface cover – Abiotic		
Total rocks	49.36	6.83 (1.15)
Boulder	4.49	0.54 (0.28)
Cobble	25.00	2.60 (0.65)
Gravel	32.05	2.93 (0.74)
Pebble	16.03	0.77 (0.30)
Shell	89.10	7.90 (1.01)
Surface cover – biotic		
Eelgrass	5.77	2.31 (0.98)
Total macroalgae	46.15	8.72 (1.43)
Green macroalgae	16.03	2.08 (0.69)
Red/brown macroalgae	41.03	5.30 (0.95)
Floc	13.46	1.79 (0.53)
Shellfish bed	5.13	0.82 (0.45)

[a] For base substrates, these data do not indicate true mean % cover; instead they are likely large underestimates. In the field, cover of all habitats, including base substrates, was based on what was visible with the camera and DVR. In many cases, much of the base substrate was not visible due to overlying abiotic and biotic cover types.

Table 2. Frequency and mean % cover of eelgrass and macroalgae in three areas known to historically support eelgrass. All data were collected with underwater video in 2012. Frequency is defined as the number of stations where a given feature was present, divided by the total number of stations in each area, multiplied by 100.

	Eelgrass		Macroalgae	
Location	Frequency	Mean % cover	Frequency	Mean % cover
Sheep-pen Cove	47.37	5.47 (2.37)	78.95	19.00 (4.22)
Prudence West	0.00	0.00 (0.00)	94.44	4.78 (1.24)
South End	73.97	40.46 (4.40)	50.68	6.98 (1.88)
Total	57.27	27.80 (3.40)	62.73	8.70 (1.52)

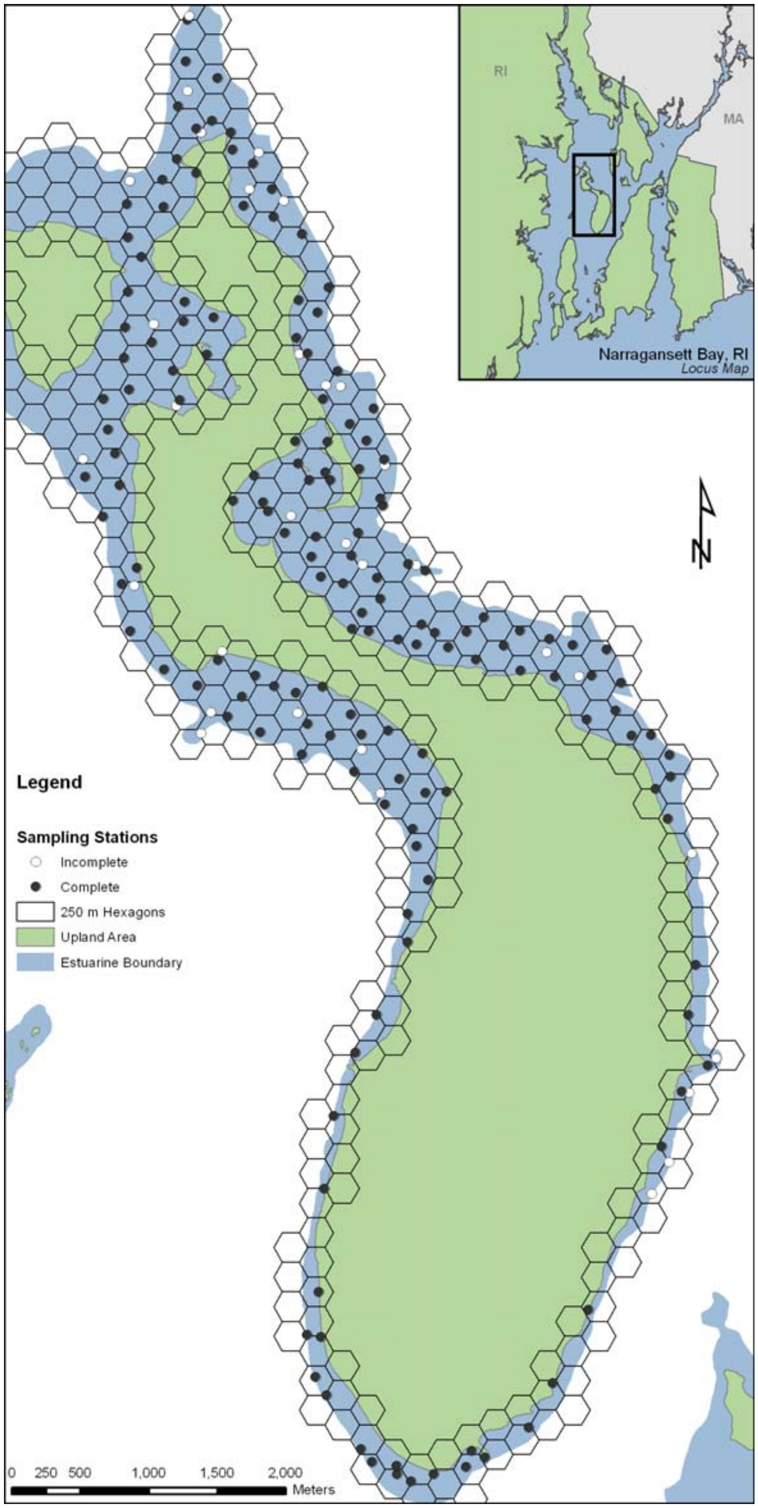

Figure 1. Underwater video mapping stations in 2011. Random points representing sampling stations were generated within each hexagon in the overlying grid. Stations that were sampled are shown in black; those that were not sampled are shown in white.

Figure 2. The tier 2 underwater video mapping system includes the camera and light, which are mounted on the PVC frame (right), and a DVR, GPS, and other accessories, which are mounted in the pelican case (left).

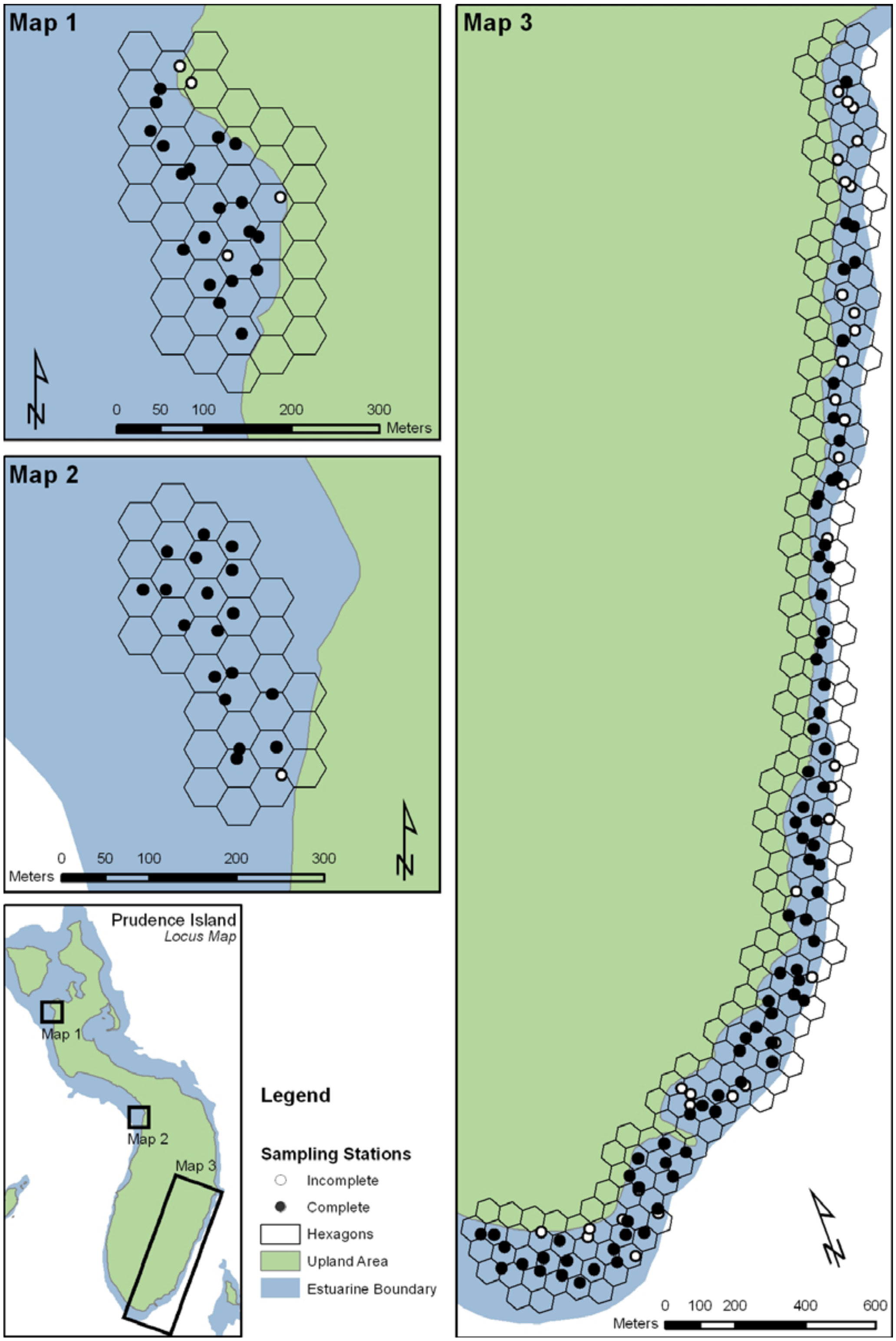

Figure 3. Tier 2 eelgrass mapping stations in 2012. Hexagons and sampling points are the same as described in Figure 1. Map 1=Sheep-pen Cove; Map 2=Prudence Neck; Map 3=South Prudence.

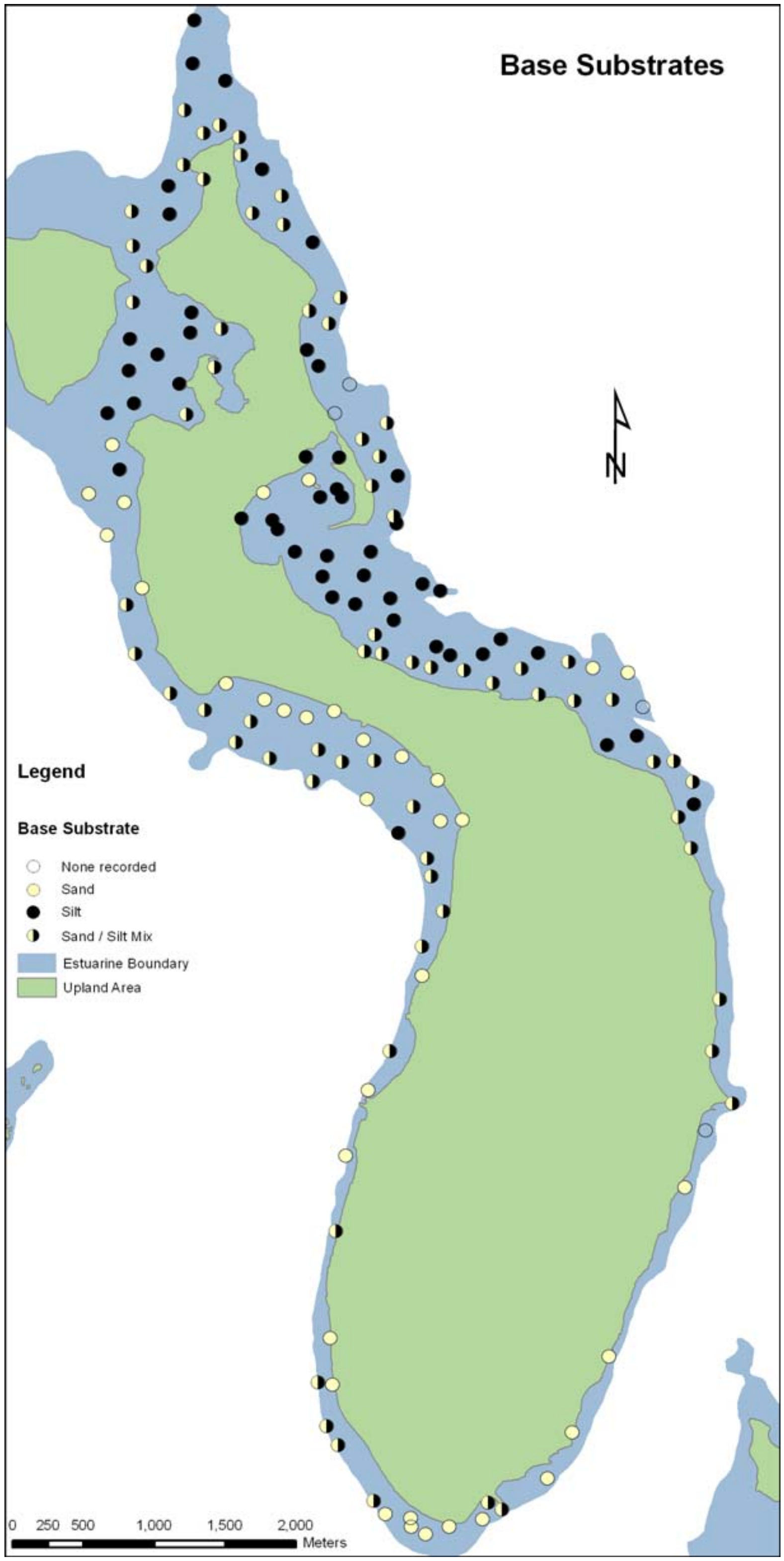

Figure 4. Composition of base substrates around Prudence Island in 2011 based on underwater video mapping.

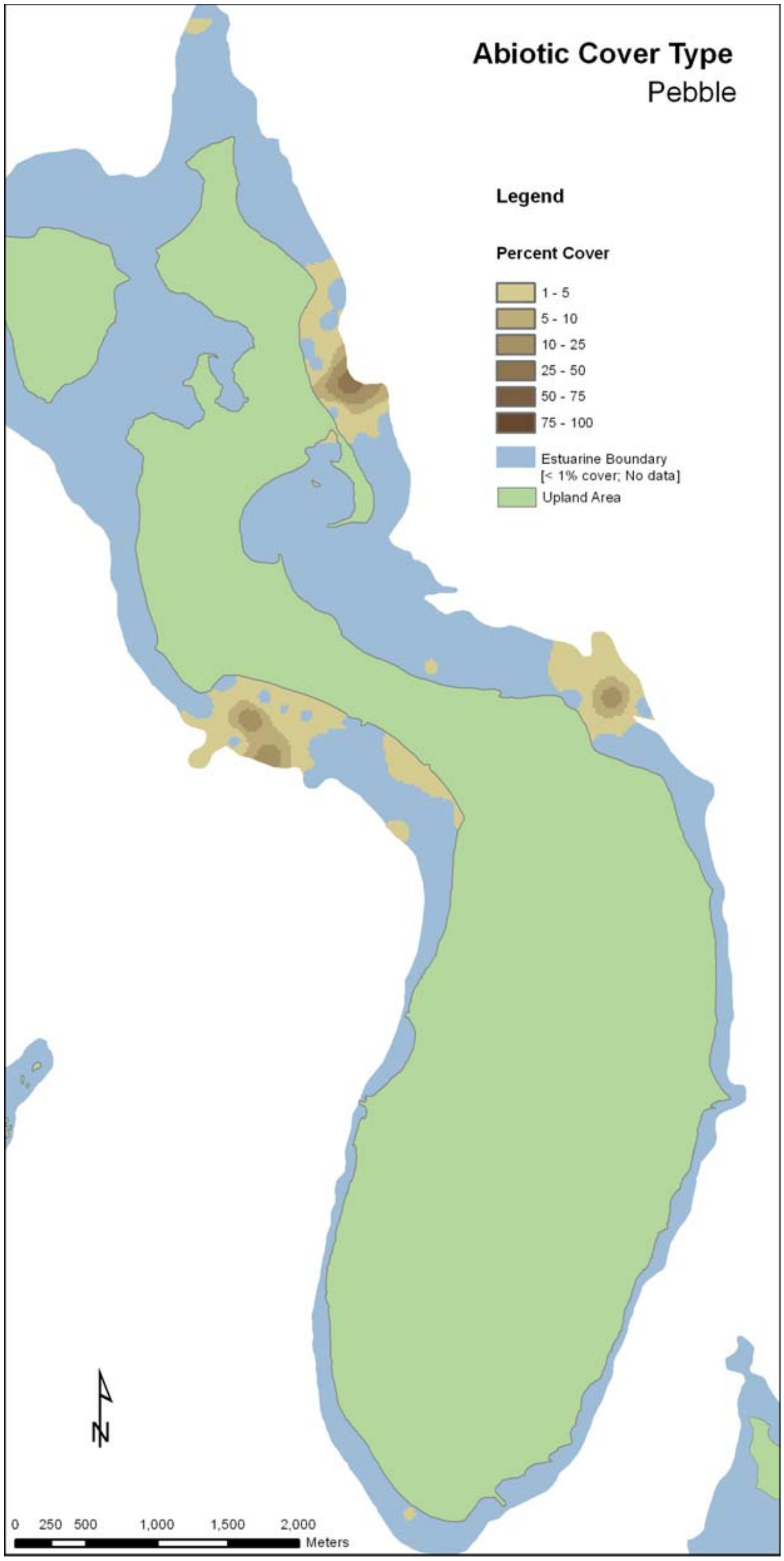

Figure 5. Cover of pebble habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

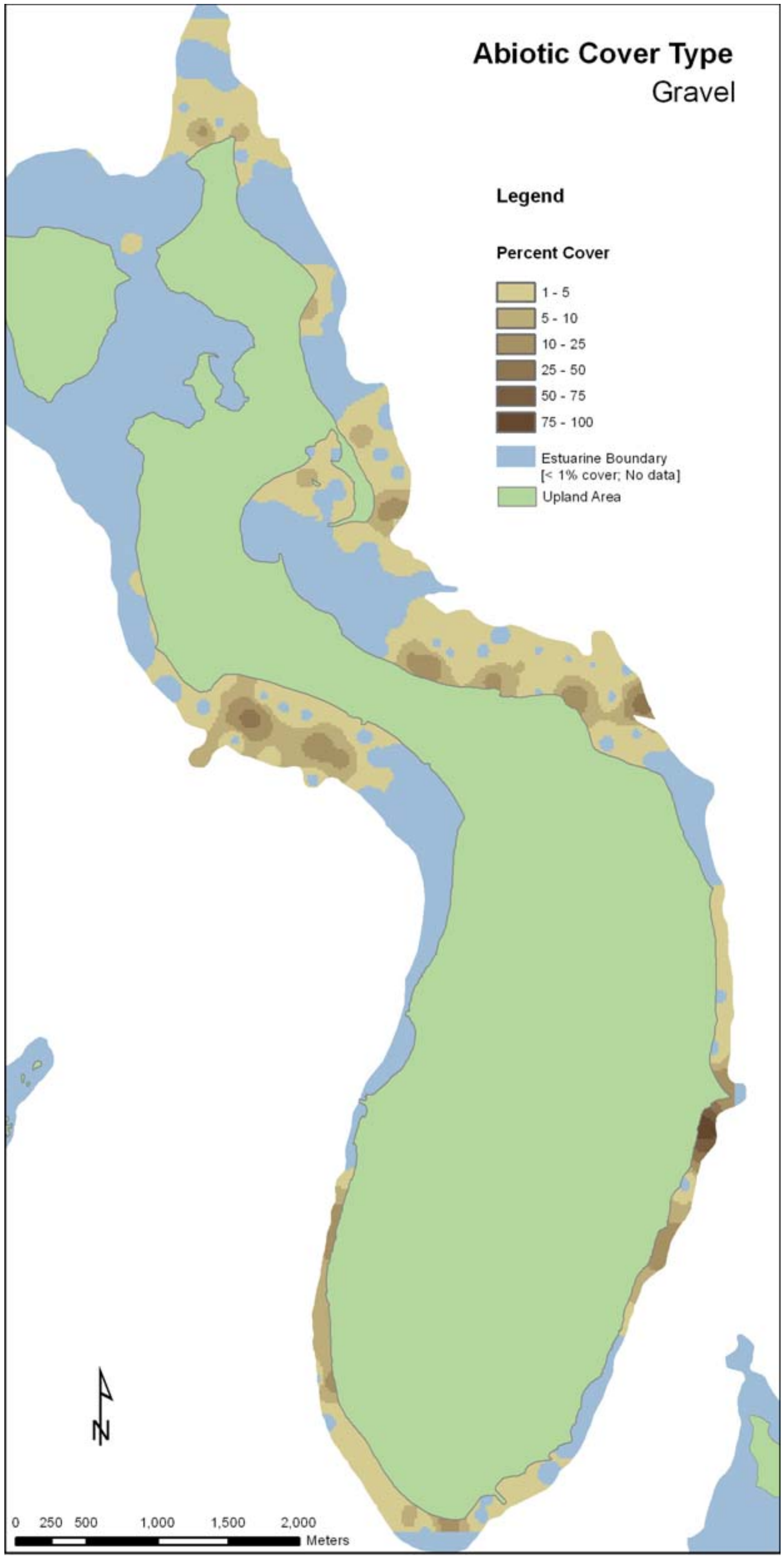

Figure 6. Cover of gravel habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

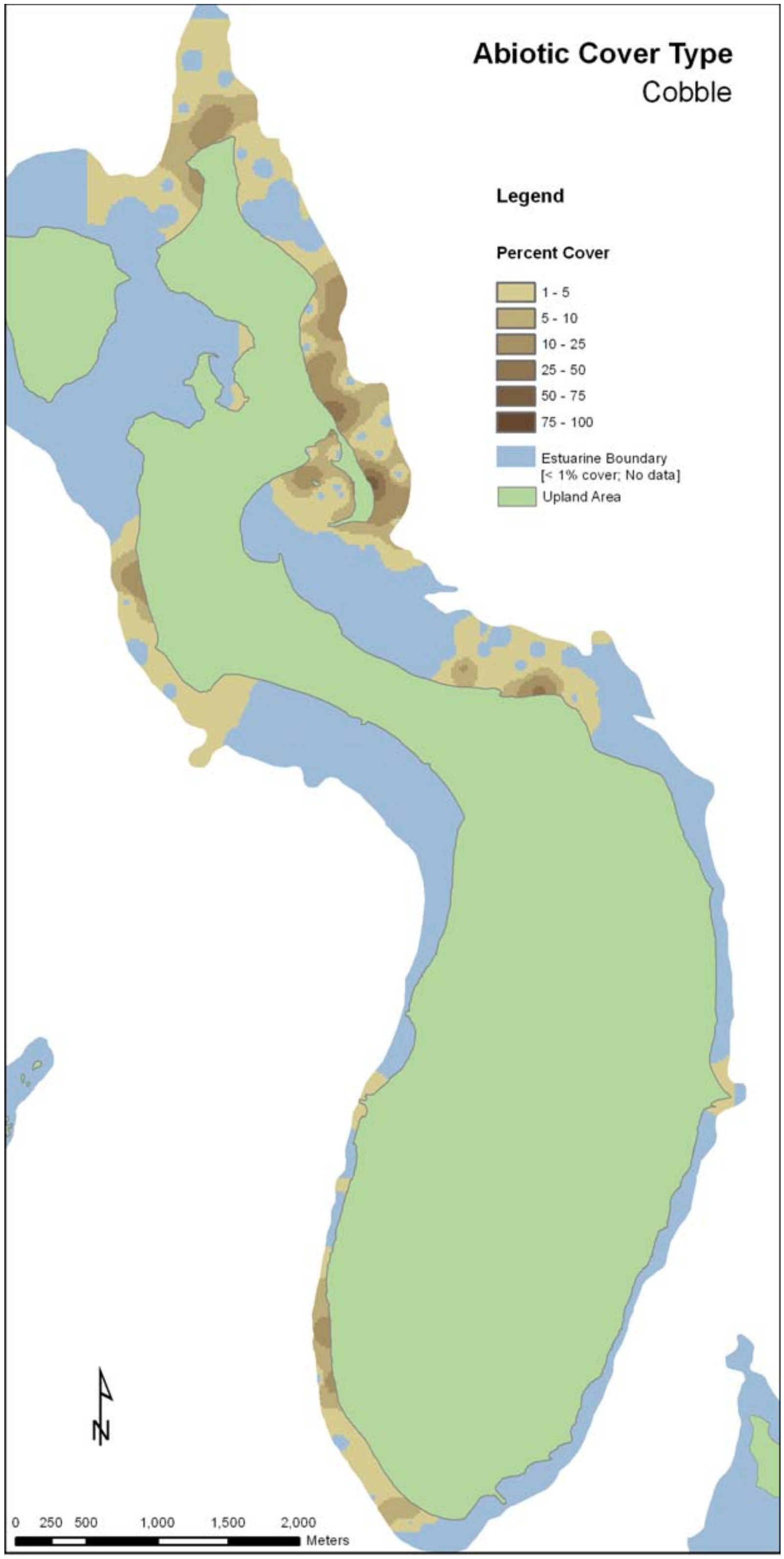

Figure 7. Cover of cobble habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

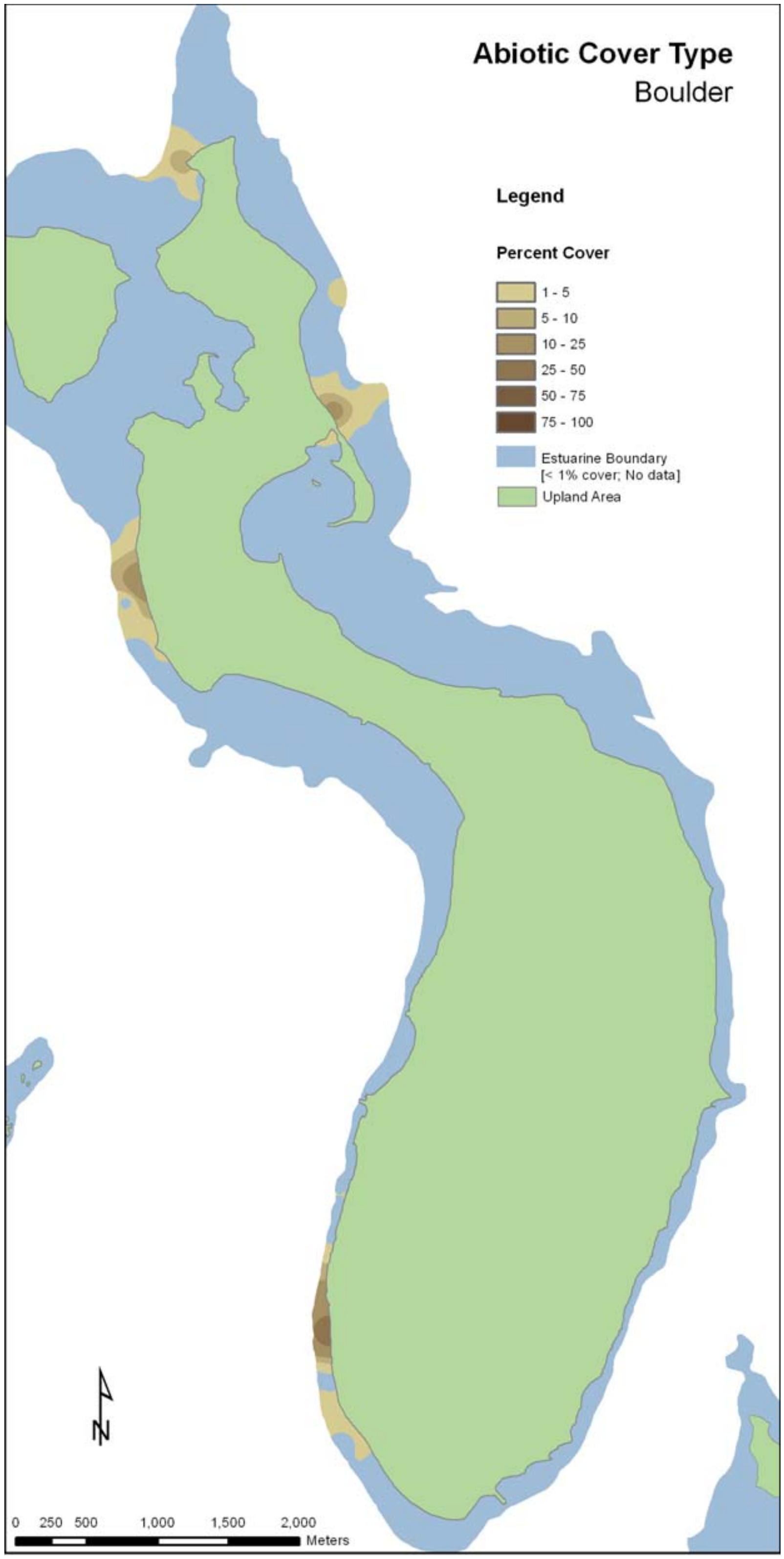

Figure 8. Cover of boulder habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

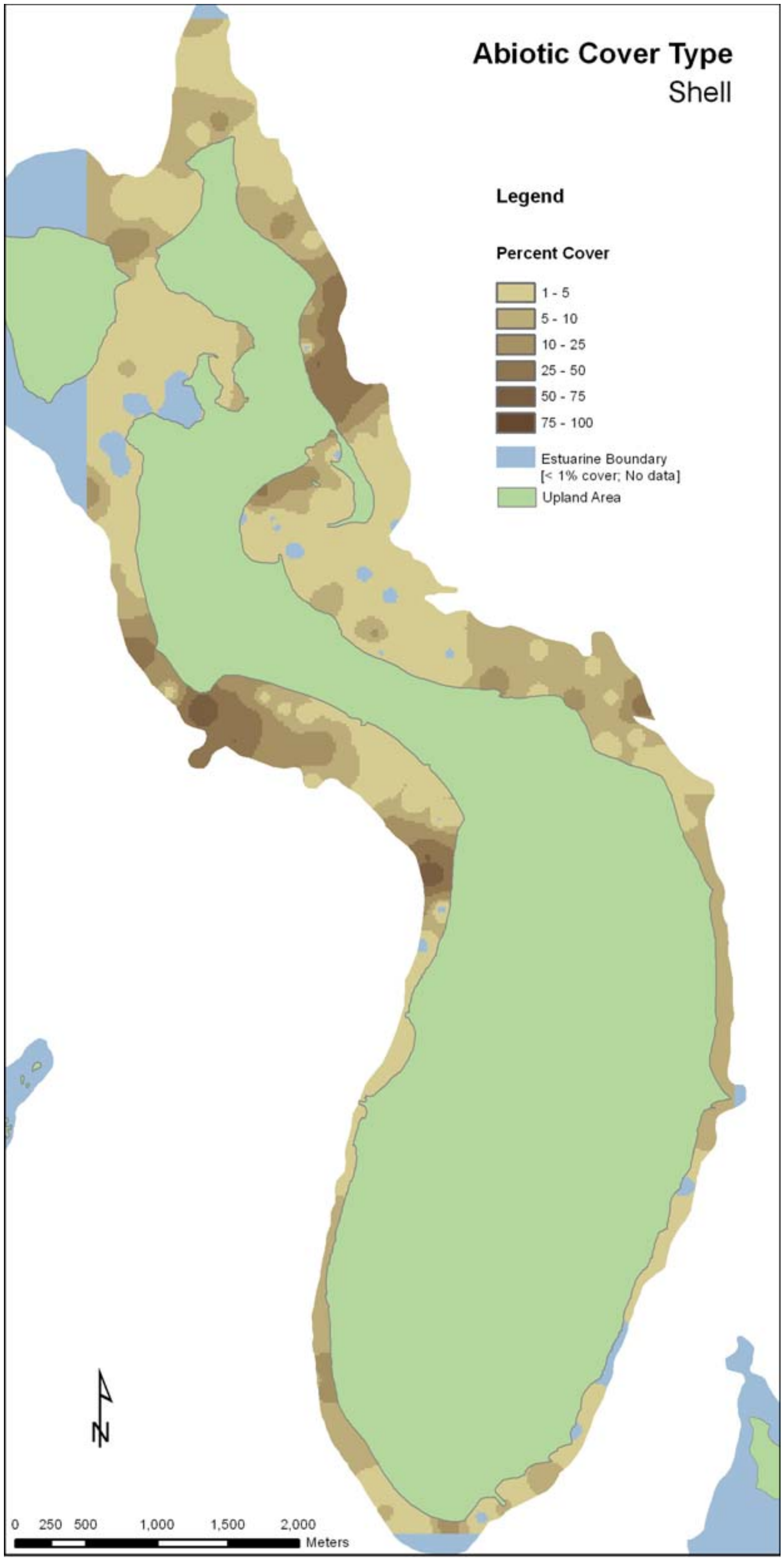

Figure 9. Cover of shell habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

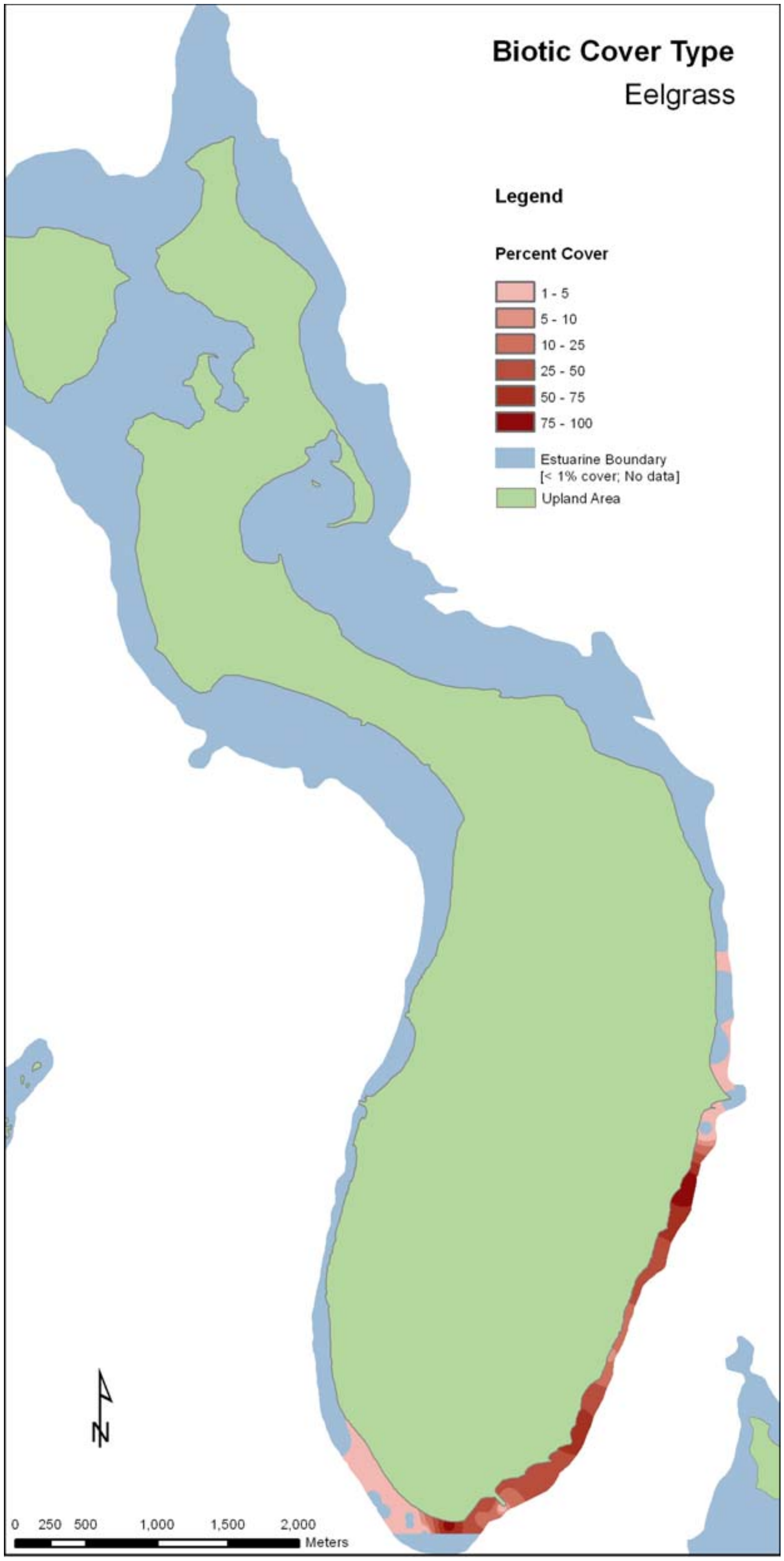

Figure 10. Cover of eelgrass beds around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

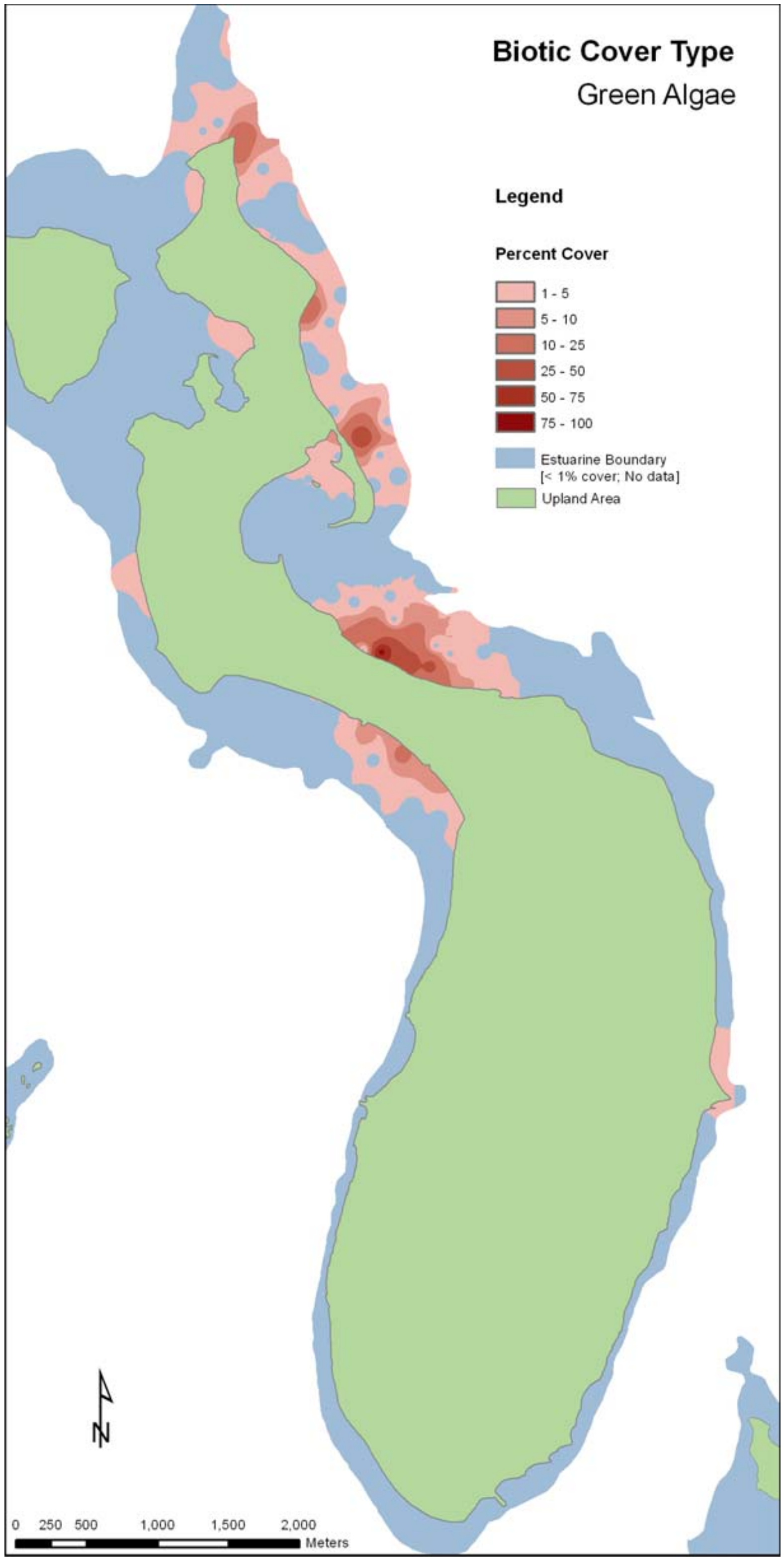

Figure 11. Cover of green macroalgae habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

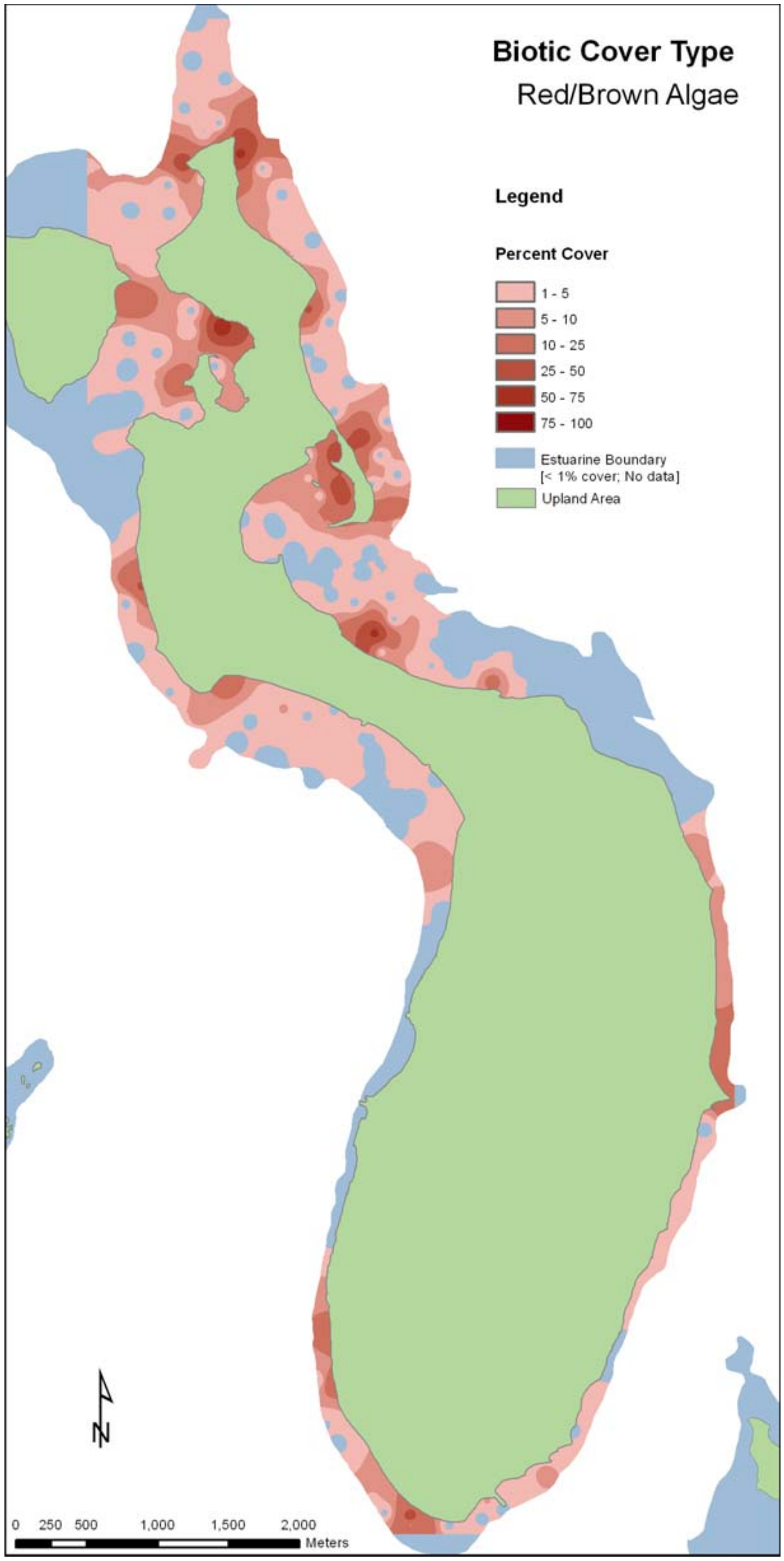

Figure 12. Cover of red/brown macroalgae habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

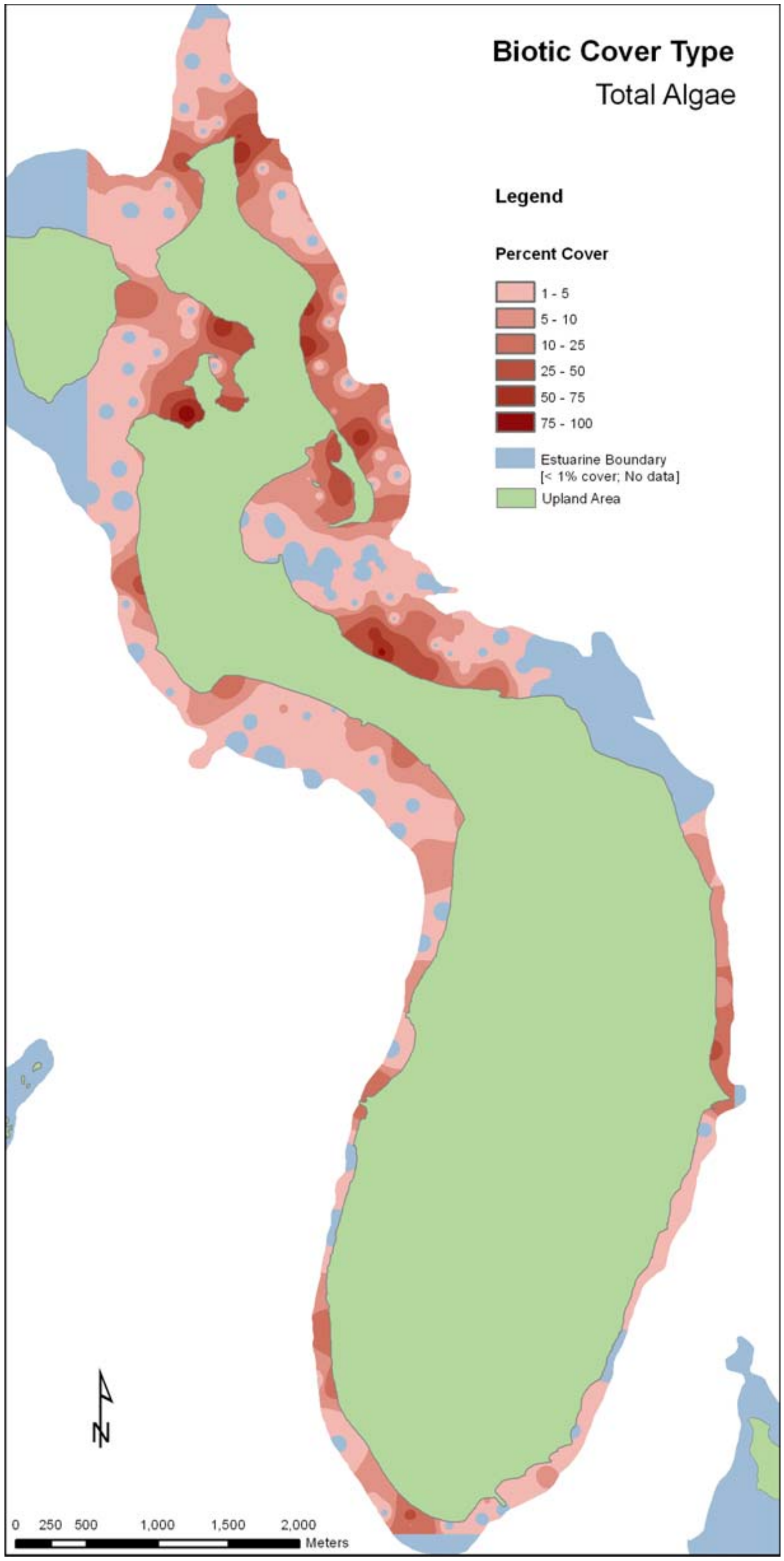

Figure 13. Cover of total macroalgae habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

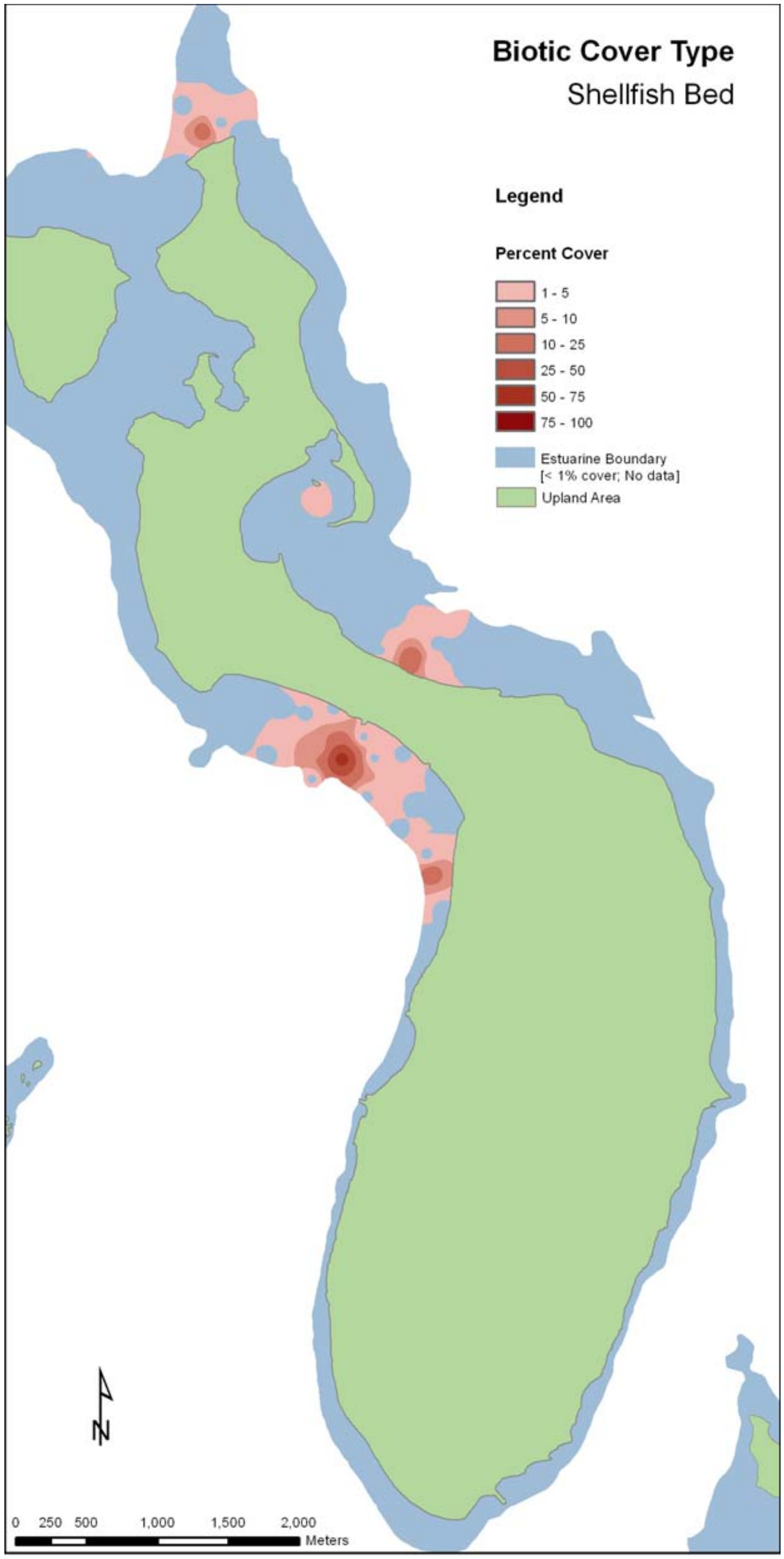

Figure 14. Cover of shellfish beds around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

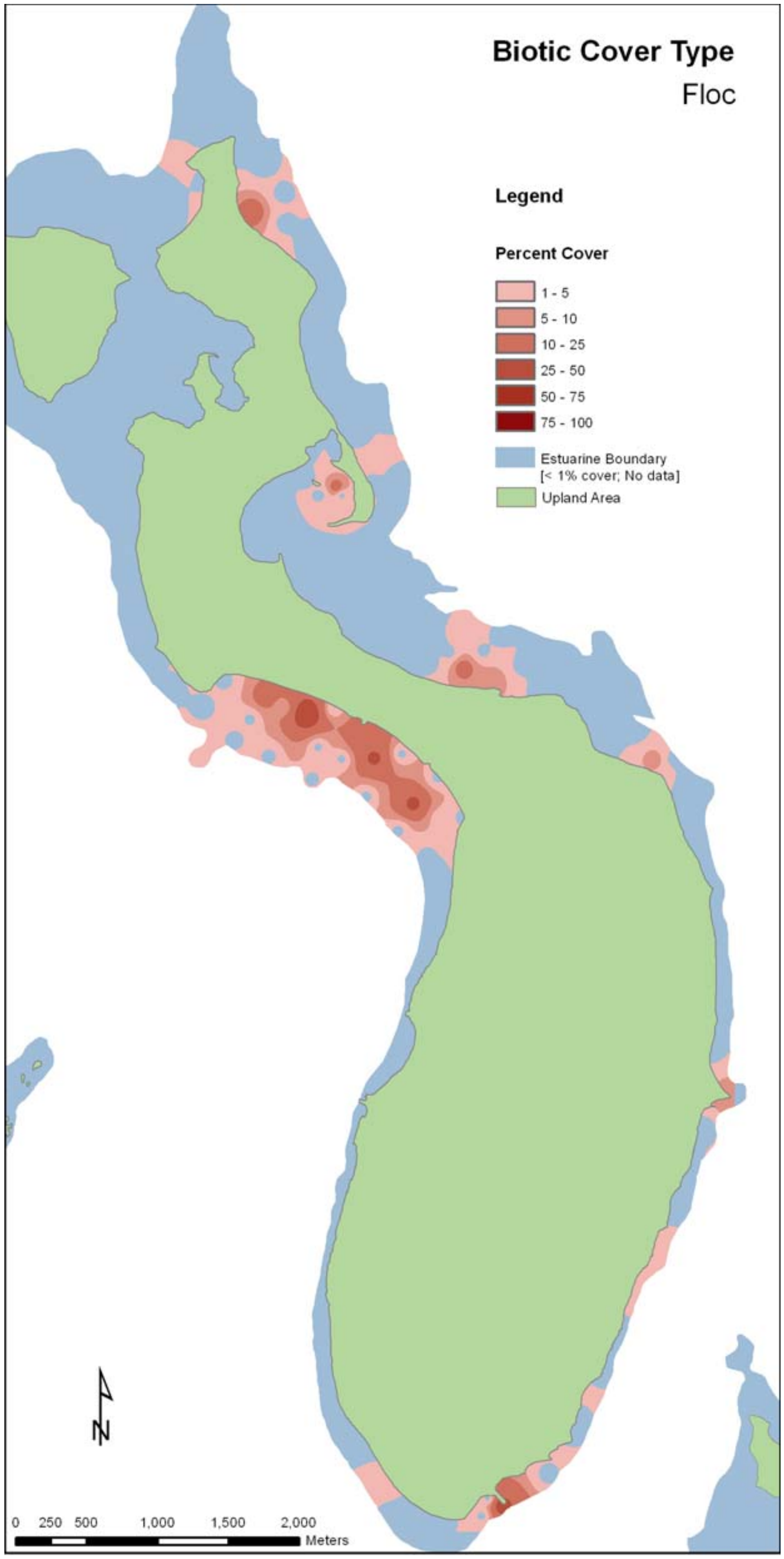

Figure 15. Cover of floc habitat around Prudence Island in 2011. Cover map was derived by interpolating among data from 156 underwater video sampling stations.

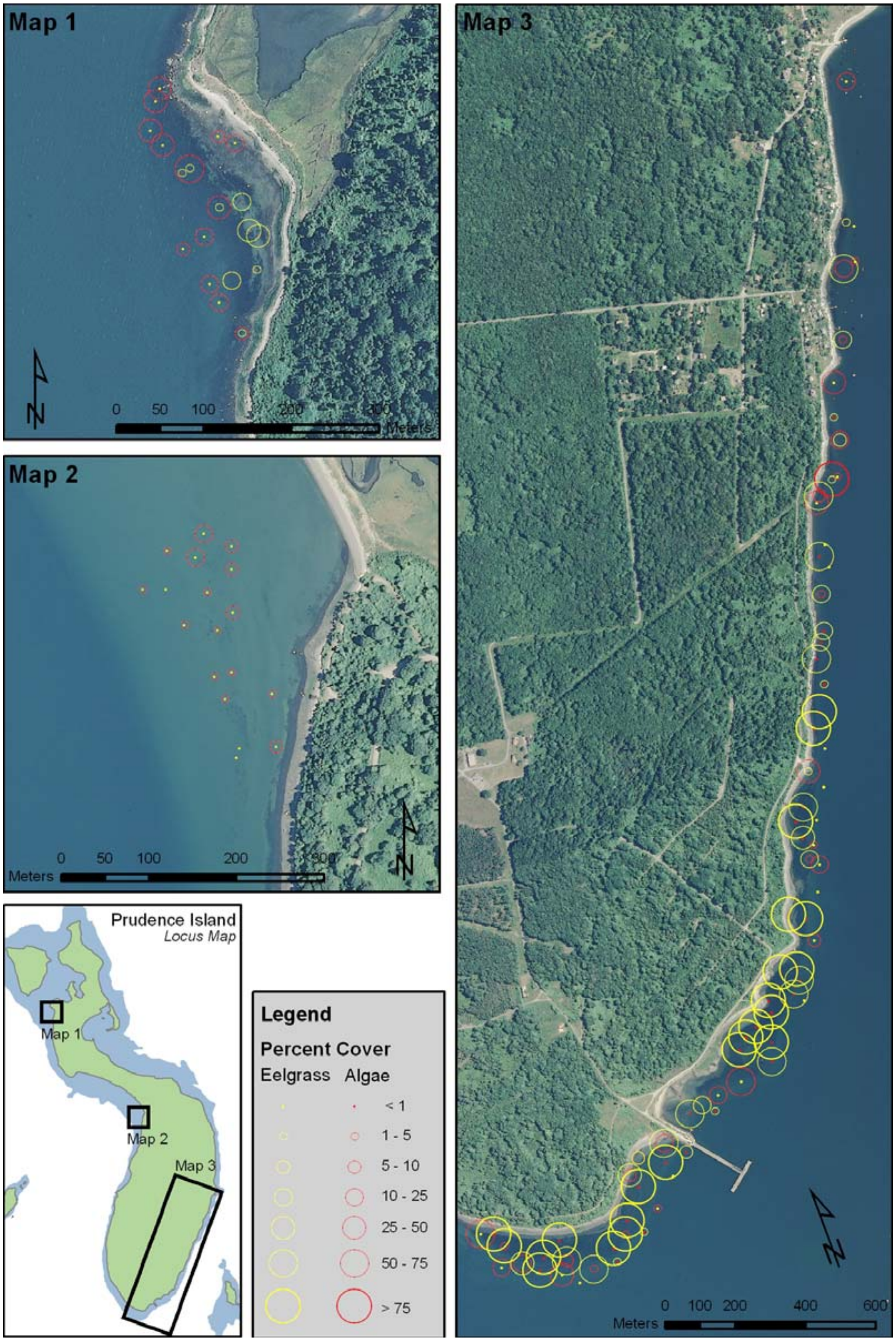

Figure 16. Cover of eelgrass and total macroalgae habitat in 2012 depicted with graduated symbols. Map 1=Sheep-pen Cove; Map 2=Prudence Neck; Map 3=South Prudence.

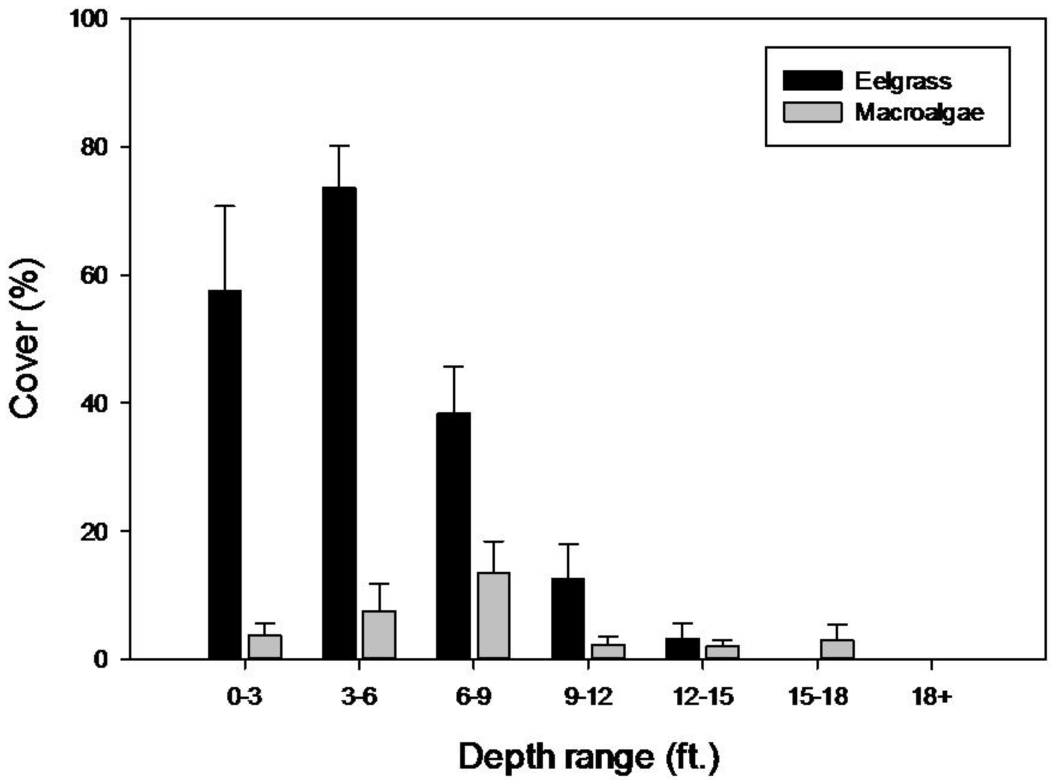

Figure 17. Cover of eelgrass and total macroalgae across different water depths at the South Prudence sampling area in 2012. Error bars are 1 SE.