Restoration of Eelgrass in Casco Bay: Feasibility Tests in 2015

A Project Sponsored By US Geological Survey, Casco Bay Estuary Partnership, Maine Department of Environmental Protection, The Nature Conservancy in Maine, and Friends of Casco Bay

With Active Partners: Town of Brunswick Marine Resources; Resource Access International; USFWS Gulf of Maine Program; Bowdoin College Environmental Studies; Southern Maine Community College; Mt. Desert Island Biological Laboratory; Citizens of Flying Point, Freeport; Maine Coastal Program Restoration Program;

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Background/Justification

Over half of the eelgrass (*Zostera marina*) has disappeared from Casco Bay. Mapping from aerial photography acquired in August 2013 revealed 1,477 ha of eelgrass, whereas during the previous mapping interval (2001-2002) the bay supported 3,338 ha (MDMR 2012, Barker 2013, MDEP 2013). Reconstruction of local observations indicated a rapid eelgrass decline that occurred largely between 2012 and early 2013. The most extreme eelgrass decline occurred in the upper bay, with nearly complete loss of vegetation from Maquoit Bay, Middle Bay, and Recompense Cove (Fig. 1). Experimental evidence implicated bioturbation by invasive European green crabs (*Carcinus maenus*) as a leading cause of eelgrass loss (H.A. Neckles, *in press*). In 2014, mapping and ground-based studies showed that eelgrass area and density continued to decline in some areas of the middle and lower bay (preliminary data, Casco Bay Eelgrass Consortium). Given the valuable services provided by eelgrass ecosystems, the loss of vegetation is expected to precipitate a range of impacts, including reduced fish and wildlife populations, degraded water quality, increased shoreline erosion, and reduced capacity to remove anthropogenic carbon dioxide emissions and mitigate coastal acidification (Orth and Moore 1983, Duarte 2002, Greinier et al. 2013). Therefore, reversing eelgrass loss in Casco Bay is of critical ecological and economic importance.

Natural eelgrass revegetation following large-scale declines occurs through germination and survival of seedlings to form new patches and subsequent lateral expansion of patches by vegetative propagation (Olesen and Sand-Jensen 1994, Harwell and Orth 2002, Greve et al. 2005). In July 2014, surveys of sites throughout the lower intertidal zone of Maquoit Bay revealed exceptionally low rates of new patch (i.e., generated from seedlings) recruitment (H.A. Neckles, personal observation). Site visits in April 2015 revealed that although some natural revegetation of areas in lower Maquoit Bay is occurring, there has been no recovery of eelgrass at the upper end of Maquoit and Middle Bays, which are more distant from the large remaining stands of eelgrass in Casco Bay (H.A. Neckles, personal observation). The rate of natural revegetation of upper Casco Bay will likely be limited by the proximity of seeds, so that habitat recovery could potentially be hastened by restoration of eelgrass beds to serve as seed sources for subsequent natural recruitment (e.g., Short et al. 2002, Orth et al. 2006).

Both natural eelgrass recovery and successful restoration in Casco Bay will depend on diminished green crab impacts. Historical evidence suggests that the abundance of green crabs in New England is regulated at least in part by water temperature, with population declines following periods of colder than average temperatures (Welch 1968, Berrill 1982). Several green crab monitoring efforts were undertaken in Casco Bay during 2014 (Brewer, MDEP; Couture, Resource Access International; Beal, UMaine-Machias). Preliminary data from these efforts indicate considerable spatial and temporal variability in the summer-2014 green crab populations, with reduced crab numbers in some upper-bay locations and sustained high numbers in parts of the lower bay, despite the cold winter of 2013-2014. Previous eelgrass restoration efforts in New England have used cages to protect newly-transplanted eelgrass from green crabs until the plantings expanded into patches that were big enough to persist unprotected (Great Bay, NH: Davis and Short 1997; Narragansett Bay, RI: NOAA 2013. Recently, effective control of green crabs through trapping has allowed successful eelgrass restoration in Little Port Joli Estuary on the Atlantic coast of Nova Scotia following initial habitat destruction by green crabs (MTRI and Parks Canada 2014). Presumably, the need for long-term green crab control to minimize damage to eelgrass restoration plots in Casco Bay will depend on crab densities, but the green crab population threshold for vegetation survival is as yet unknown (Kanary et al. 2014).

The purpose of this project is to determine approaches for eelgrass restoration that yield the highest success rates in the fine sediments of upper Casco Bay and to build local capacity for eelgrass restoration. At two test sites, we will combine different planting methods with different levels of green crab control. In order to train a cadre of people in eelgrass restoration techniques, this project will involve professionals from federal, state, local government, and nongovernmental organizations with interest in and responsibility for eelgrass conservation and management in Casco Bay. We will also engage citizens in planting efforts that can be performed safely and effectively by non-professionals. The information generated by this project will inform decisions about the potential for large-scale restoration of eelgrass beds in upper Casco Bay and provide the training necessary to undertake such efforts.

Objectives

The goal of this project is to identify locations and planting methods that will lead to successful establishment of eelgrass beds within the large portion of Casco Bay that is now devoid of vegetation. Our specific objectives are to:

1. Identify sites in Casco Bay that are suitable for large-scale eelgrass restoration;

2. Identify eelgrass transplanting methods that yield the highest success rate in Casco Bay;

3. Determine whether green crab control is required to restore eelgrass in Casco Bay; and

4. Identify environmental factors contributing to measured rates of eelgrass restoration success.

Methods

Test Sites

We identified two sites in upper Casco Bay adhering to the criteria identified by Short et al. (2002) for optimal transplantation of eelgrass in the northeastern U.S. Most importantly, the sites supported extensive eelgrass up until the recent loss of vegetation (see also Fonseca et al. 1998). In addition, sites are characterized by sediments of < 70% silt/clay particles and high light availability (ideally, an average of > 18% surface irradiance; Evans and Leschen 2010). In addition to meeting ecological criteria for eelgrass transplanting, test sites are easily accessible and have local support.

The first test site, off Flying Point at the mouth of Maquoit Bay, Freeport (Figure 2), historically supported a continuous eelgrass meadow from the lower intertidal zone out to the offshore islands (MDMR 2012). Shoreline residents noticed that most of the eelgrass disappeared from this site between 2012 and 2013; in August 2013, no eelgrass was present along the shoreline, but small beds persisted around the offshore islands between Flying Point and Harpswell Neck (MDEP 2013). In late 2014, an active and concerned group of citizens approached the Maine Coastal Program - Habitat Restoration Coordinator about the potential for restoring eelgrass in this area. By May 2015, small eelgrass patches were present throughout the shallow subtidal zone along this shoreline, thus natural recruitment from nearby eelgrass beds has likely been occurring since winter of 2013-2014. The low patch density makes this an ideal site to test planting methods; the natural recruitment indicates that the environment supports eelgrass growth, thus the primary variables influencing success will be related to the planting process.

The second test site, off Simpson Point in Middle Bay, Brunswick (Figure 2), historically supported eelgrass from the lower intertidal zone to the central channel (MDMR 2012). At the mapping scale, all of the eelgrass in upper Middle Bay had disappeared by August 2013 except a small bed about 750 m offshore of Simpson Point (MDEP 2013). In May 2015 that mapped bed was still present, and some patches of eelgrass (ca 50-cm diameter) occurred closer to shore. These patches could be additional remnants that were smaller than the resolution of the 2013 aerial photography, or new recruits from winter of 2013-2014. The majority of the inshore subtidal zone between Simpson Point and Pennelville Road remains unvegetated, as does the formerly-vegetated intertidal zone. This site provides an ideal location to determine the feasibility of large-scale restoration in upper Casco Bay: there is public access to the shore, and, as an area of high recreational shoreline use, there is an opportunity for public education.

Experimental Design

Approaches for transplanting eelgrass include anchoring individual shoots (Orth et al. 1999) or pairs of shoots (Davis and Short 1997) directly to the sediment, attaching multiple shoots to planting fabric (Pickerell et al. 2012) or various types of frames (Short et al. 2002, Leschen et al. 2010, Kidder et al. 2013) that are then weighted or secured to the sediment, and planting plugs of shoots with intact sediments (Fonseca 1998). Bare-root methods (i.e., methods that involve harvesting and transplanting eelgrass shoots only, without intact sediments) are preferred for minimizing potential impacts to donor sites (Davis and Short 1997, Evans and Leschen 2010) and are the only methods that will be tested in Casco Bay. Each bare-root method offers a different set of advantages, and not every method is suitable for every restoration setting; in particular, some methods are more effective in fine sediments and some are more effective in sandier sediments. We will test a variety of transplant methods to determine the most efficient and successful approach for restoring eelgrass in different areas of Casco Bay. In general, methods in which eelgrass shoots are attached to a substrate before planting require a considerable investment of time in preparing the planting units but require less time in the water for planting; some types of planting units can be dropped into the water off the side of a boat. In contrast, methods in which eelgrass shoots are anchored directly to the sediment require less preparation time but are much more labor-intensive for planting, and often require SCUBA. We will test the following methods with a range of planting-unit complexity:

> Biodegradable grids (Kidder et al. 2013). A biodegradable grid consists of a square frame of untreated lumber that is laced with sisal twine and weighted with small sandbags. Frames are 0.5 m x 0.5 m and enclose twine grids with ca. 7-cm openings. A single grid planting unit consists of 20 shoots, evenly spaced, attached to grid intersections with biodegradable floral tape. The grid is placed directly on the substrate. The grid holds the eelgrass in place during early establishment, then all the grid components biodegrade so only eelgrass remains. This method has generated a high success rate in Frenchman Bay, Maine (Kidder et al. 2013) and will allow comparisons between these two regions of Maine's coast.
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> Burlap disk method (Pickerell et al. 2012). A disk of loosely-woven burlap has 20 holes punched into the fabric in an outer and inner ring of 10 holes each, spaced evenly so that the 2-hole sets form a spoke-like pattern in the fabric. One eelgrass shoot is woven through each set of holes with the rhizomes pointing toward the center of the disk and the leaves radiating to the outside. The planting units, consisting of 10 shoots each, are buried in the sediment by hand. The burlap disk anchors the eelgrass during early establishment, then the burlap biodegrades so only eelgrass remains.
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> Shell method (adapted from Lee and Park 2008). A planting unit consists of a clam shell (*Mercenaria mercenaria*) with a hole drilled several centimeters from the shell edge, into which two eelgrass shoots are inserted at the rhizomes. The shells are buried by hand in the substrate so that the rhizomes are just beneath the sediment surface. The shell serves as a natural shoot anchor. All shells will be collected from Casco Bay to ensure that no disease organisms are introduced into local waters.
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> Horizontal rhizome method (Davis and Short 1997). Two eelgrass shoots are anchored directly to the sediment using a biodegradable staple. The rhizomes are aligned parallel to one another and pointing in opposite directions. During planting the rhizomes are pressed horizontally into the sediment, and a bent bamboo skewer is used as the staple. The skewer biodegrades so only the eelgrass remains. This method does not require any advance preparation of the planting units but generally requires SCUBA for large-scale planting efforts.

At each site we will establish replicate eelgrass transplant plots in the shallow subtidal zone. Plots will be along a transect parallel to the shoreline at a depth slightly below the elevation of spring low tides; this placement will permit the highest possible light availability while protecting the transplants from intertidal disturbance such as ice scour. Water depth within the plots will be about 20 cm at low tide.

At Flying Point, we will establish up to 24 small (1.5 m x 1.5 m) transplant plots along a transect about 130 m offshore (Figure 3). Each plot will include one set of each planting method (i.e., one biodegradable grid; one burlap disk; five horizontal rhizome units; and five shells). The plots will be located in large patches of bare substrate within an area of low-density natural eelgrass patches. No natural eelgrass patches will be disturbed. Each transplant plot will be marked with a single wooden garden stake.

At Simpson Point, we will establish six large (7 m x 7 m) plots along a transect about 250 m off shore (Figure 4). Three plots will be protected from green crabs by continuous crab traps deployed at the corners. The plots will be about 30 m apart, so the entire transect of six plots will be about 192 m long. In each plot, four small subplots will be established that each include one set of each planting method; the "subplots" at Simpson Point are equivalent to the "plots" at Flying Point.

Eelgrass collection and transplanting

Eelgrass for transplanting will be collected from a healthy, extensive donor bed at Broad Cove, Cumberland. Eelgrass will be collected by hand following the low-impact methods described by Davis and Short (1997). This approach restricts shoot collection to the edges of small patches, where plants are easy to remove without disrupting the root-rhizome layer of the eelgrass bed. Personnel will be trained to locate individual shoots, gently uproot 3 – 5 cm of the rhizome, and snap off the rhizome by hand to collect the shoot. The shoot density of the donor site will be determined, and no more than 10% of the shoots will be collected from any 1 m^2 area. We will collect a total of about 2700 shoots to supply the 1200 shoots per site plus about 10% overage to account for shoots that are unusable (e.g., damaged or reproductive shoots). Maintaining eelgrass at low salinities minimizes potential infection and spread of wasting disease (caused by the naturally-occurring slime mold *Labyrinthula zosterae* Porter and Muehlstein) in the collected shoots (Burdick et al. 1993); therefore, seawater from the collection site will be diluted with distilled water to 15 ppt as a storage medium. The plants will be transported and stored overnight in aerated, diluted seawater, and will be transplanted at the test sites the day after they are collected.

Test-site Monitoring

Eelgrass transplant success will be monitored after 2 weeks, 4 weeks, 8 weeks, 16 weeks, 6 months, and 12 months after planting. The following eelgrass parameters will be measured within each planting-method subplot:

Percent shoot survival: Number of surviving shoots/Number of shoots planted

Shoot density: Number of shoots within a 1 m^2 quadrat surrounding the subplot

Canopy height: Height of the vegetation ignoring the tallest 20% of the leaves

Number of reproductive shoots

Environmental measurements at each site will include the following controls on eelgrass growth and survival and general environmental characteristics:

Underwater light availability: Calibration of Onset HOBO light intensity loggers to photosynthetically active radiation (Long et al. 2012) and deployment of in-air and submerged loggers for three to five days.

Water temperature: Continuous measurement over the course of the study using Onset Tidbit temperature loggers.

Sediment texture and organic content: One sediment sample will be collected from the center of each large plot (Simpson Point) or adjacent to each small plot (Flying Point) using a 60-cc syringe corer (plastic syringe with graduated tip cut off flush with the zero volume mark). Samples will be collected by placing the cut off end of the syringe barrel at the sediment surface, holding the plunger at a constant height at the sediment surface, and pushing the barrel into the substrate. The sediment-filled syringe is then extracted gently from the substrate and the top 10 cm of sediment extruded into a labeled plastic bag. Particle-size distribution (gravel, sand, silt, clay fractions) will be determined by wet sieving and pipette methods; organic content will be determined as percent loss on ignition at 450 ^{o}C (Erftemeijer and Koch 2001).

Sediment sulfide concentration: Sediment sulfide concentration will be measured twice during the growing season adjacent (early and late summer). Porewater will be sampled in situ and placed into an antioxidant solution (5% zinc acetate) in the field. Sulfide will be measured colorimetrically according to Cline (1969).

Water quality parameters: DIN, NH_4, P, Si, pH, chlorophyll *a*, and total alkalinity will be measured twice per month during routine water quality monitoring by Friends of Casco Bay.

Sediment pH: Sediment pH will be measured twice per month using a pH meter equipped with a Corning rugged combination electrode (Green et al. 2004), using standard methods of Friends of Casco Bay.

Green crabs: Green crab catch per unit effort (CPUE) will be measured at each site using two baited traps deployed for 24 hours twice per month. This sampling schedule will allow comparisons to 2014 monitoring of CPUE at sites throughout Casco Bay.

Work Schedule

Eelgrass can be transplanted successfully during any season in New England waters (Evans and Leschen 2010), thus we will plant according to tidal schedules and observed patterns of water clarity in Casco Bay. Water clarity monitoring at four sites in upper Casco Bay from June to September, 2014, showed high light availability (seasonal average of the downward PAR attenuation coefficient, K_d, from 0.47 m^{-1} to 0.60 m^{-1}) with minimal temporal variation overall. At one western-shore site (Broad Cove) the water clarity did improve from late June (K_d =0.75 m^{-1}) to early July (K_d=0.54 m^{-1}, where a lower K_d indicates great water transparency); this was not observed at island sites (Cousins Island, Little Chebeague Island) and thus may have been related to land-based runoff. By transplanting in mid-June to early July, plants will be installed following the spring runoff period.

	2015			**2016**				**2017**
Activity	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar
Site reconnaissance	X							
Acquire permits	X							
Establish field sites	X							
Plant collection/transplanting	X	X						
Site monitoring		X	X	X?	X	X		
Data analysis							X	
Report preparation								X
Final Report								X

Expected Results and Products

This project will generate information on the best methods to restore eelgrass beds in upper Casco Bay to hasten ecosystem recovery. A report detailing project results and guidelines for eelgrass restoration will be made available to all partner organizations and other interested parties. In addition, results will be delivered in-person within appropriate settings, including meetings of the Casco Bay Estuary Partnership. If deemed useful to project sponsors and partners, we will also offer Webinars on eelgrass values and restoration techniques.

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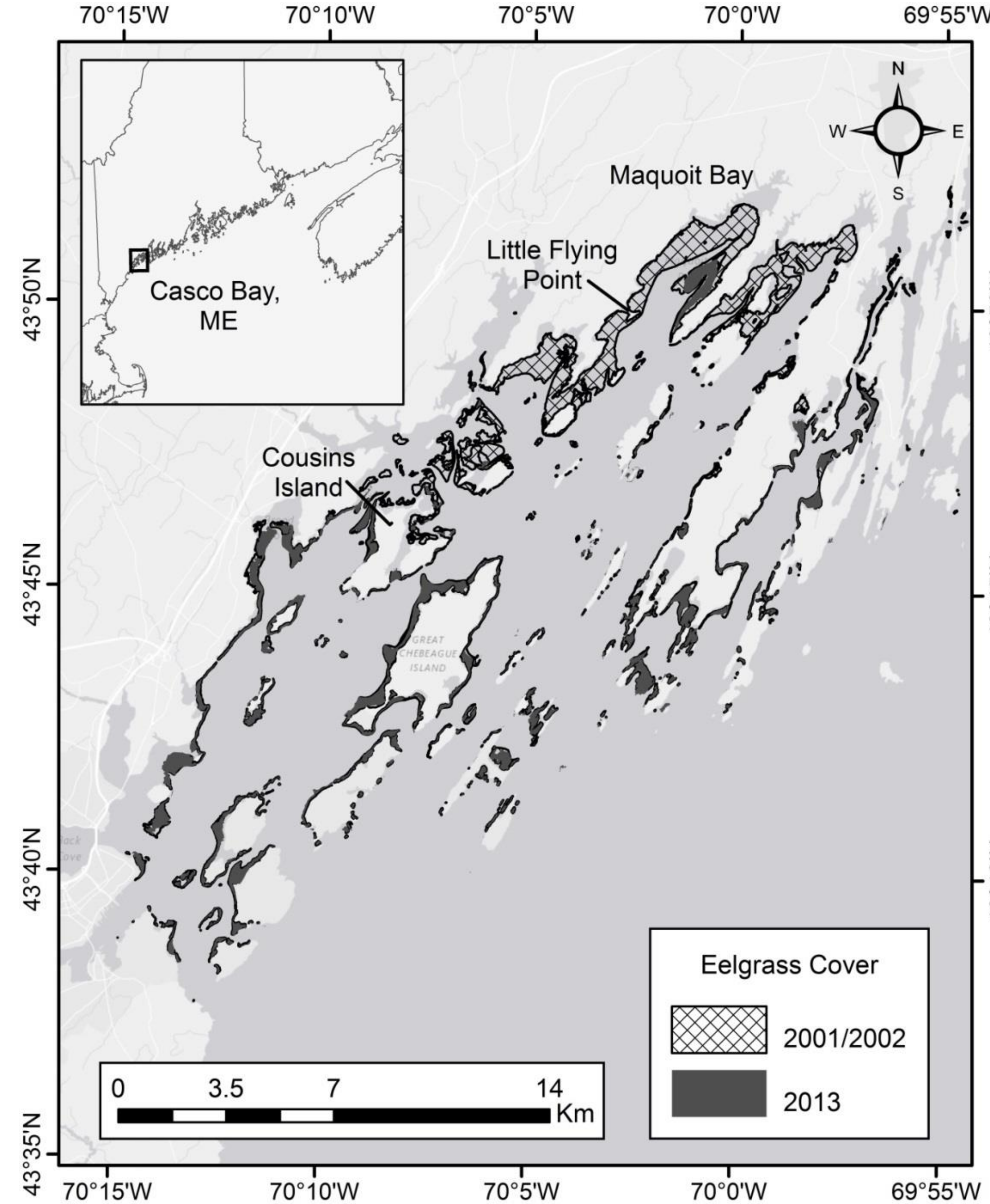
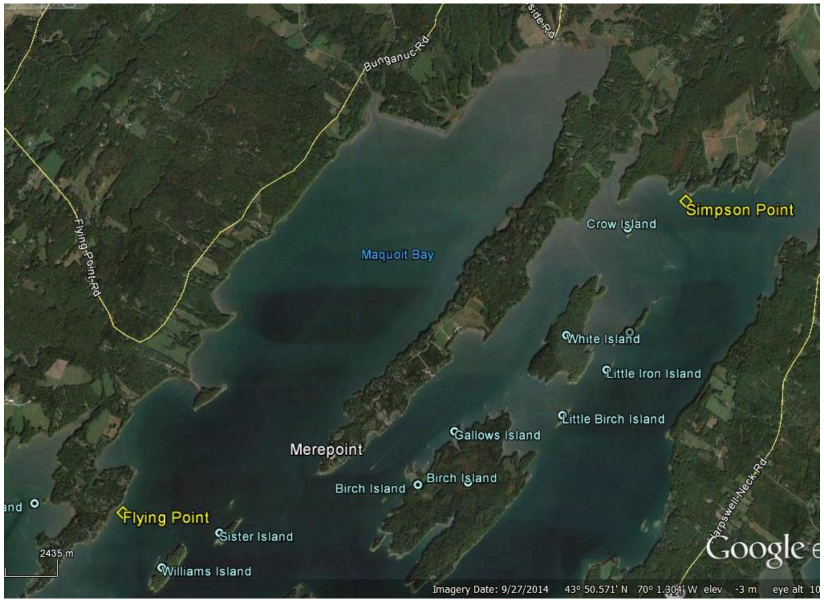


Figure 1. Casco Bay eelgrass distribution based on aerial photography acquired in 2001 and 2002 (crosshatched; MDMR 2012) and in August 2013 (shaded; Barker 2013, MDEP 2013). Where 2013 coverage is mapped, it overlays and largely coincides with the 2001/2002 distribution.



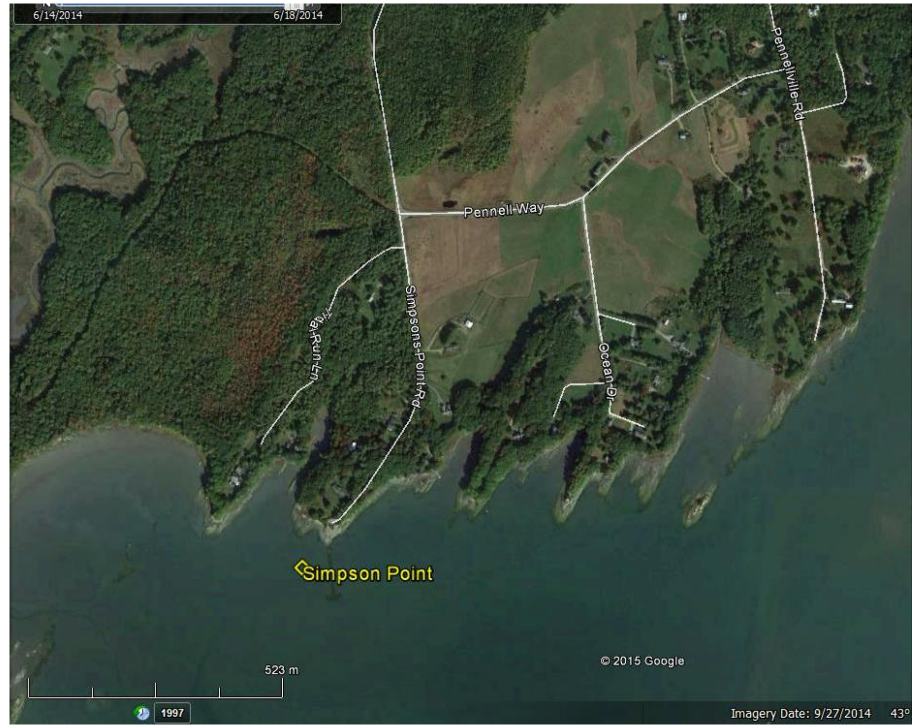


Figure 2. Eelgrass test planting sites in Casco Bay (identified in yellow).Top left: location map. Top right: Simpson Point detail. Bottom: Flying Point detail.

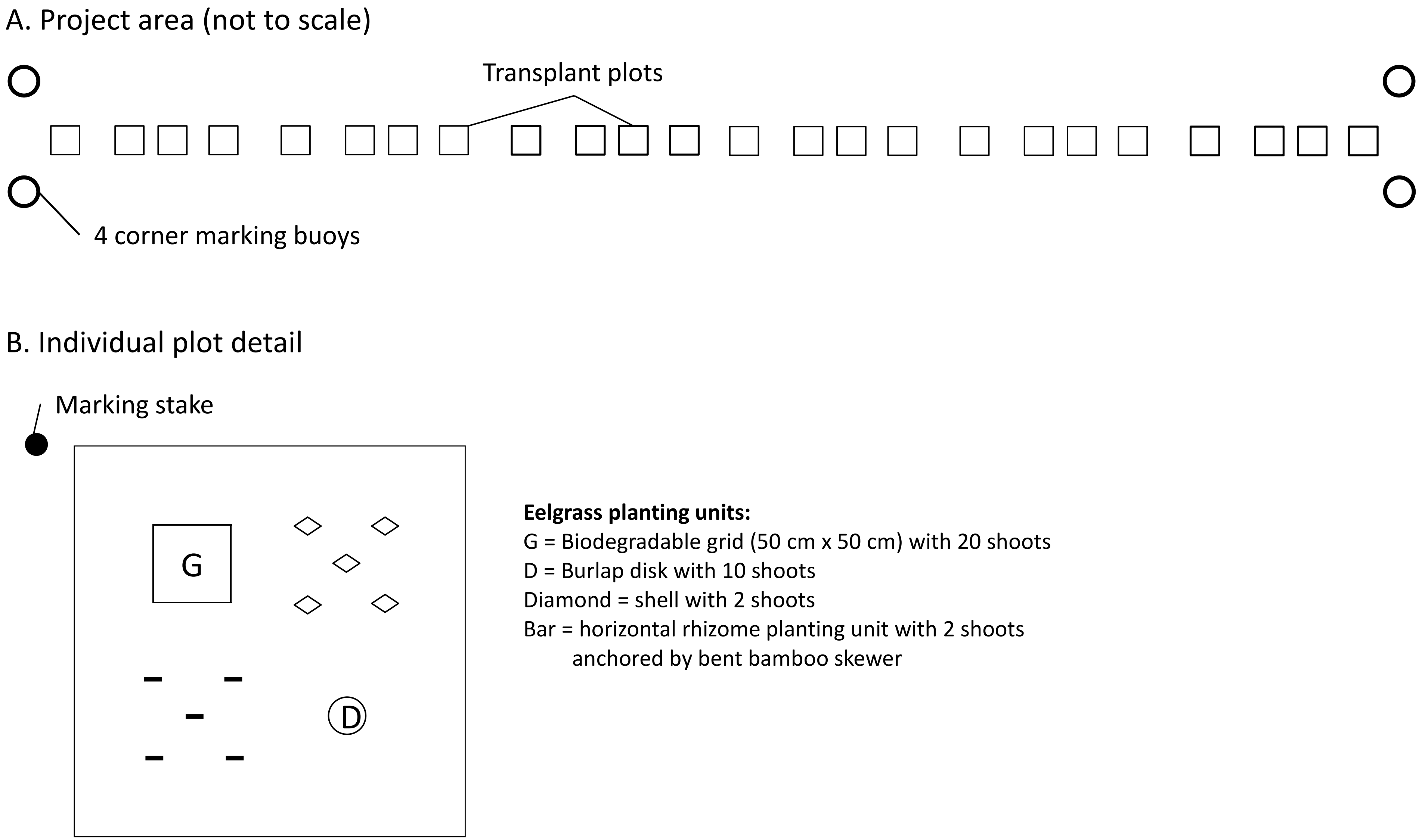


Figure 3. Eelgrass planting design at Flying Point.

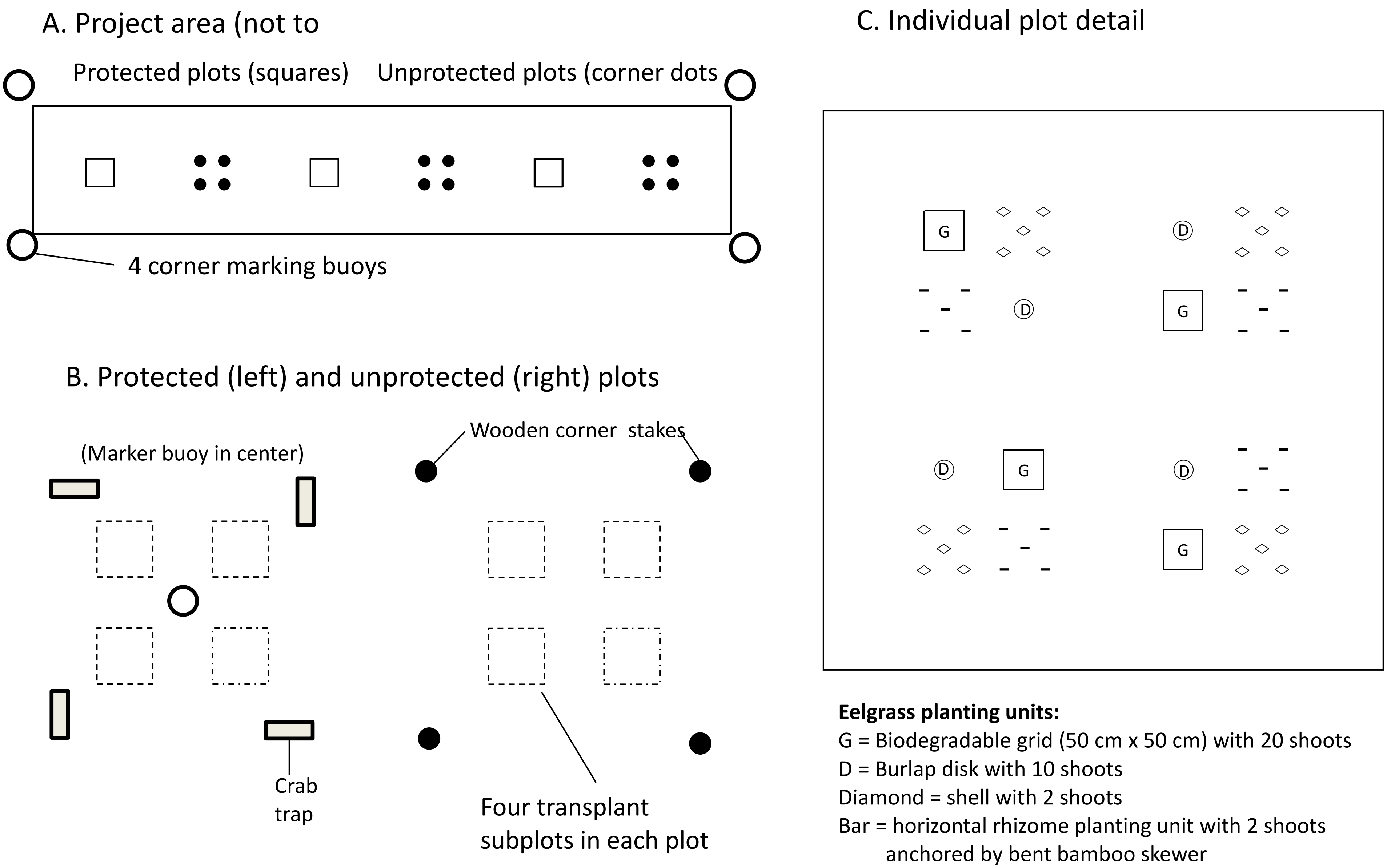


Figure 4. Eelgrass planting design at Simpson Point.