Spatial variation in the abundance of eelgrass (*Zostera marina*) at eight sites in western Newfoundland, Canada

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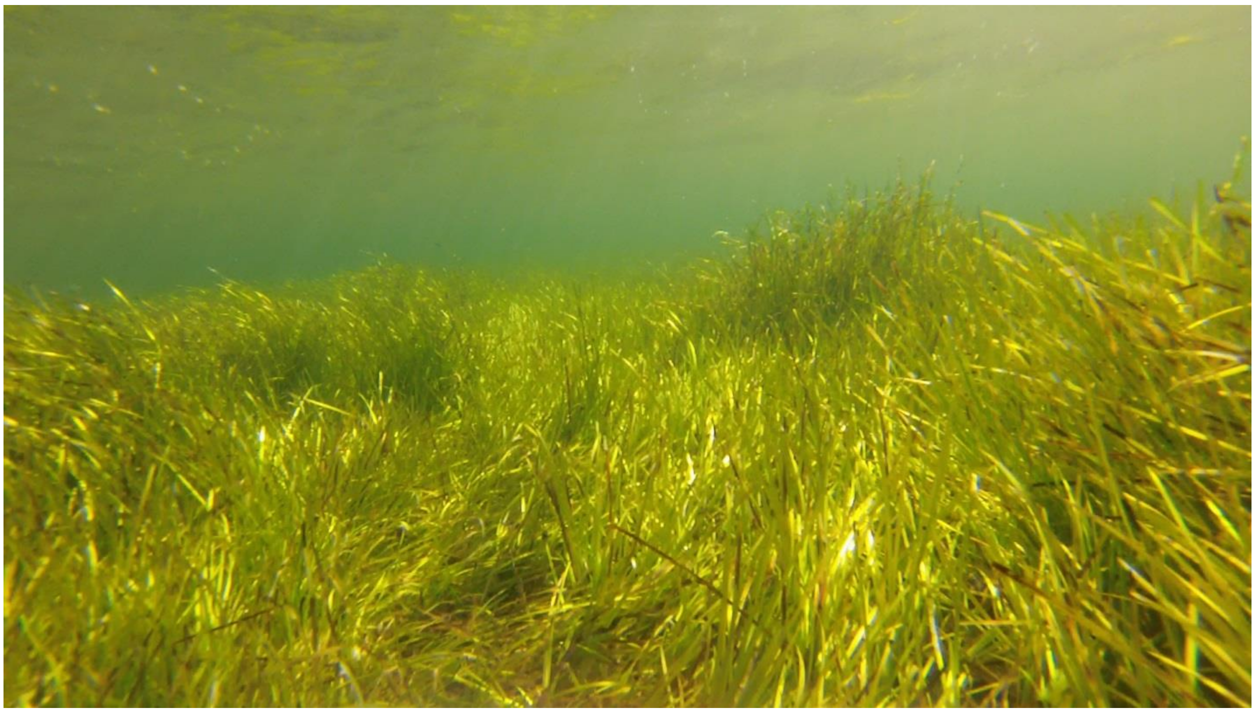

Summary

The abundance of eelgrass (*Zostera marina*) was quantified at eight sites along the west coast of Newfoundland (NL), Canada. Two video procedures were employed to generate preliminary data on the percent cover of eelgrass. A GoPro high definition camera was mounted on a two meter 1.3cm diameter PVC pipe and attached 30 cm above a 19 x 19 cm quadrat. Still images were generated of quadrats or of the benthos during free swims. A 3 x 3 grid was added to the center of each image and the mean percent cover was calculated from these grids. The percent cover of eelgrass ranged between 5.89 and 69.27 %. Eelgrass abundance increased between June/July and September at sites 2, 4, and 7, before decreasing again in October at site 7. Overall, the percent cover of eelgrass peaked at 81.18% in September at site 4. Globally, sea grasses are declining in response to multiple stressors, including eutrophication, shoreline development, climate change, and aquatic invasive species. Eelgrass provides critical ecosystem services to coastal environments by stabilizing shorelines, contributing organic biomass to coastal food webs, and by increasing habitat heterogeneity along shallow subtidal shores. The degradation and loss of this highly productive habitat can have dire consequences for the stability and integrity of coastal environments in Atlantic Canada. Efforts to conserve this habitat will have long term benefits for populations of commercially, recreationally, and culturally important coastal species.

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Introduction

Globally, sea grasses are declining in response to multiple stressors, including eutrophication, shoreline development, climate change, and aquatic invasive species (Hauxwell et al. 2001, Orth et al. 2006, Waycott et al 2009). The recent introduction of a number of invasive species has increased stress on this ecologically significant habitat and has likely contributed to declines in the overall abundance of the sea grass, *Zostera marina*, observed along Canada's Atlantic coast (Matheson pers. comm., Garbary et al. 2014).

Sea grasses provide critical ecosystem services to coastal environments by stabilizing shorelines, nutrient cycling, contributing organic biomass to coastal food webs, and by increasing habitat heterogeneity along shallow subtidal shores (Orth et al. 2006, Barbier et al. 2011). The three dimensional structure of eelgrass meadows provide important refuge and foraging habitat for fish and invertebrates (Heck and Thoman 1984, Hovel and Lipcius 2001). Numerous commercially and culturally significant species rely on the ecosystem services provided by eelgrass meadows either directly and/or indirectly (Hovel and Lipcius 2001, Hughes et al. 2002). The degradation and loss of this highly productive habitat may have dire consequences for the stability and integrity of coastal environments in Atlantic Canada (Orth et al. 2006, Barbier et al. 2011).

Through the Marine and Aquatic Resource Inventory initiative, Qalipu and Mi'kmaq Alsumk Mowimsikik Koqoey Association (MAMKA) have moved towards identifying ecologically significant habitats in western and central Newfoundland (NL), Canada. We have successfully identified important spawning habitat for Atlantic Salmon and have begun monitoring invertebrate, algal, and eelgrass communities. By identifying ecologically important habitats and communities we can better design projects that will aid in our ability to maintain ecosystem integrity and to conserve commercially, recreationally, and culturally significant species. Extensive video transects were carried out in Flat Bay, St, George's Bay, NL in 2012. Although substantial eelgrass beds were recorded, poor image quality prevented accurate analyses of eelgrass abundance. The objective of this study is to: 1) improve methodologies for capturing abundance data on eelgrass meadows and 2) to generate meaningful data on the distribution and abundance of eelgrass at eight sites in western NL.

Materials and methods

The percent cover of eelgrass (*Zostera marina*) was quantified between June and October, 2014, at eight sites in western NL, Canada: 1) St. Paul's inner gut, 2) St. Paul's outer gut, 3) Manual's, 4) Lark Harbour, 5) Two Guts Pond, 6) Piccadilly, 7) Little Port Harmon, and 8) Southwest Brook (Figure 1, Table 1). Sites 1, 3, 5, and 7 were located in protected harbours with low exposure. Sites 2, 5, 6, and 8 were located in harbours with moderate wave exposure or open shorelines that experience moderate wave exposure. Sites were chosen based on a posteriori knowledge of eelgrass presence or were chosen based on physical and topographical characteristics best suited for eelgrass.

Eelgrass percent cover

Two video sampling procedures were employed to determine the optimum method for collecting percent cover data while snorkeling. A GoPro camera was mounted to a two meter 1.3 cm PVC pipe 30 cm above a 19 x 19 cm quadrat. The quadrat was mounted to the PVC pipe using a t-bracket, allowing the quadrat to swivel in and out of the cameras field of view. The camera was mounted at a 90^o angle to the benthos during both sampling procedures and the quadrat was removed from the cameras field of view during free swims. A snorkeler would conduct eelgrass surveys by either 1) recording up to 32 haphazard quadrats within the eelgrass bed or 2) continually recording the benthos during a 5 to 10 minute free swim. These methodologies generated preliminary data on the percent cover of eelgrass at each site and will aid in developing optimum procedures for long term monitoring of eelgrass habitat in western NL.

A still image was generated for each quadrat and every 30 seconds in a free swim video. A 66 square grid was added to each image using ImageJ and a 3 x 3 grid was selected from the center of each image. The percent cover of eelgrass was quantified within each of the nine squares and the average of all the squares was used to determine the mean cover of eelgrass at each site. Sites 1, 3, 5, 6, and 8 were sampled once in late August and early September, sites 2 and 4 were sampled in July and September, and site 7 was sampled in June, September, and October (Table 1).

Table 1: Summary of geographic coordinates, sampling dates, sample size, and percent cover of eelgrass (*Zostera marina*) at eight sites along the west coast of Newfoundland, Canada

Site name	Site number	Latitude	Longitude	Sampling dates	Sample size (still images)	Mean percent cover (%)
St. Paul's inner gut	1	49.85658	-57.7966	7 Sep	12	5.89
St. Paul's outer gut	2	49.85703	-57.8036	1 Jul, 7 Sep	54	22.48
Manual's	3	49.12553	-57.9278	27 Aug	34	25.92
Lark Harbour	4	49.10043	-58.3824	2 Jul, 4 Sep,	72	68.78
Two Guts Pond	5	48.6452	-58.6548	3 Sep	22	13.48
Piccadilly	6	48.57708	-58.9038	3 Sep	22	69.27
Little Port Harmon	7	48.5143	-58.5372	24 Jun, 2 Sep, 7 Oct,	83	24.36
Southwest Brook	8	48.50755	-58.2884	23 Aug	11	7.42

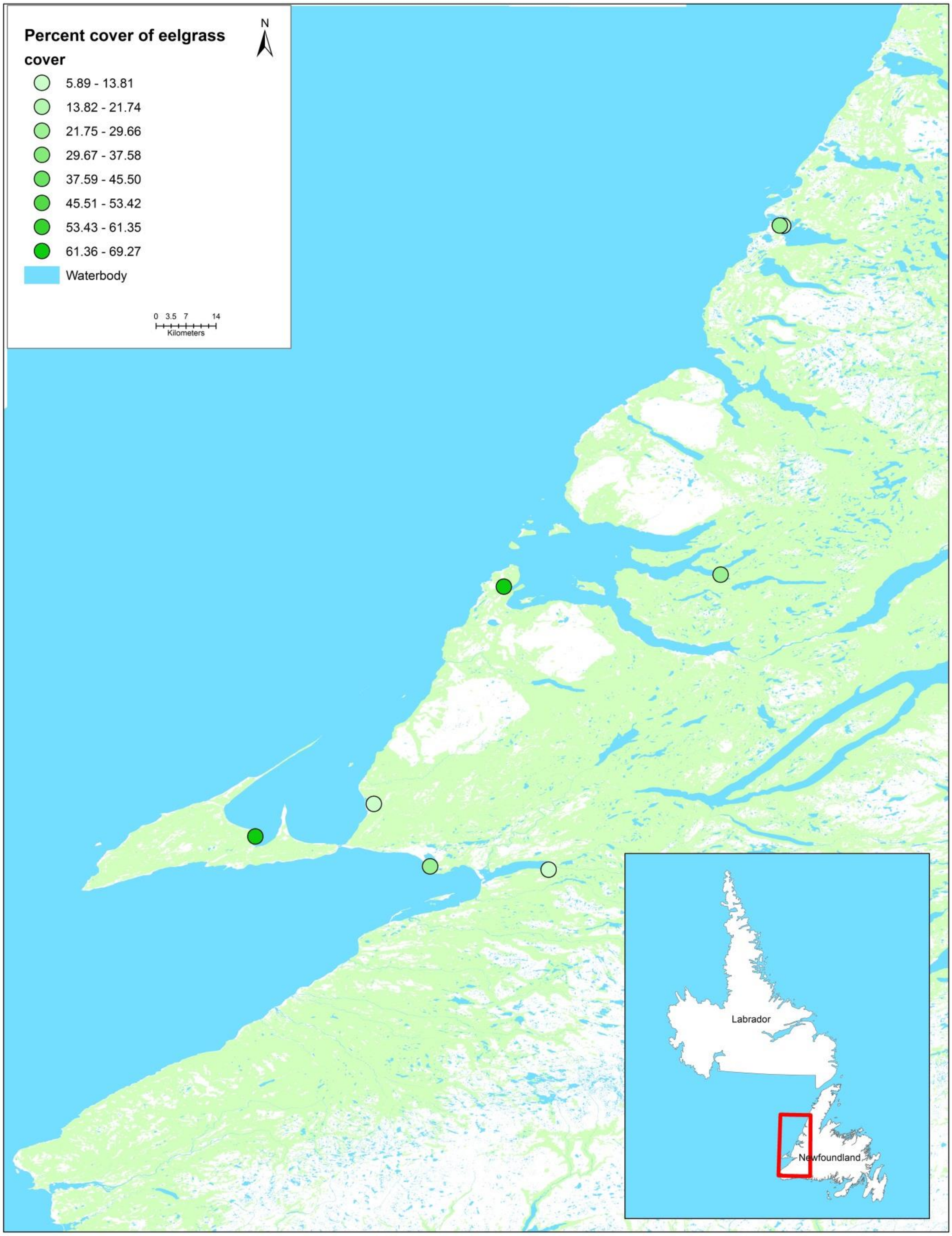

Figure 1: Geographic location and relative percent cover of eelgrass (*Zostera marina*) at eight study sites along the west coast of Newfoundland, Canada.

Results

The percent cover of eelgrass along the west coast of NL ranged between 5.89 and 69.27 %, with the greatest cover observed at site 6 (Figure 1, Table 1). Overall, the cover of eelgrass was significantly different between sites and was higher at sites 4 (68.78%) and 6 compared to sites 3 (25.92%) and 7 (24.36%; Figures 2 and 3, Tables 1, 2 and 3). The percent cover of eelgrass increased between June/July and September at sites 2, 4, and 7, before decreasing again in October at site 7 (Figures 4 and 5). Overall, the percent cover of eelgrass peaked at 81.18% in September at site 4 (Figures 2 and 5).

Both video procedures were adequate to document eelgrass cover, but there were differences in how the structure of the eelgrass meadow was captured. Quadrats would flatten eelgrass, remove the three dimensional structure of the eelgrass meadow, and result in a greater amount of the benthos being covered by flattened eelgrass shoots. During free swims, the vertical structure of the eelgrass shoots was more apparent, but it became difficult to discern the benthos from eelgrass shoots due shadows and a lack of light.

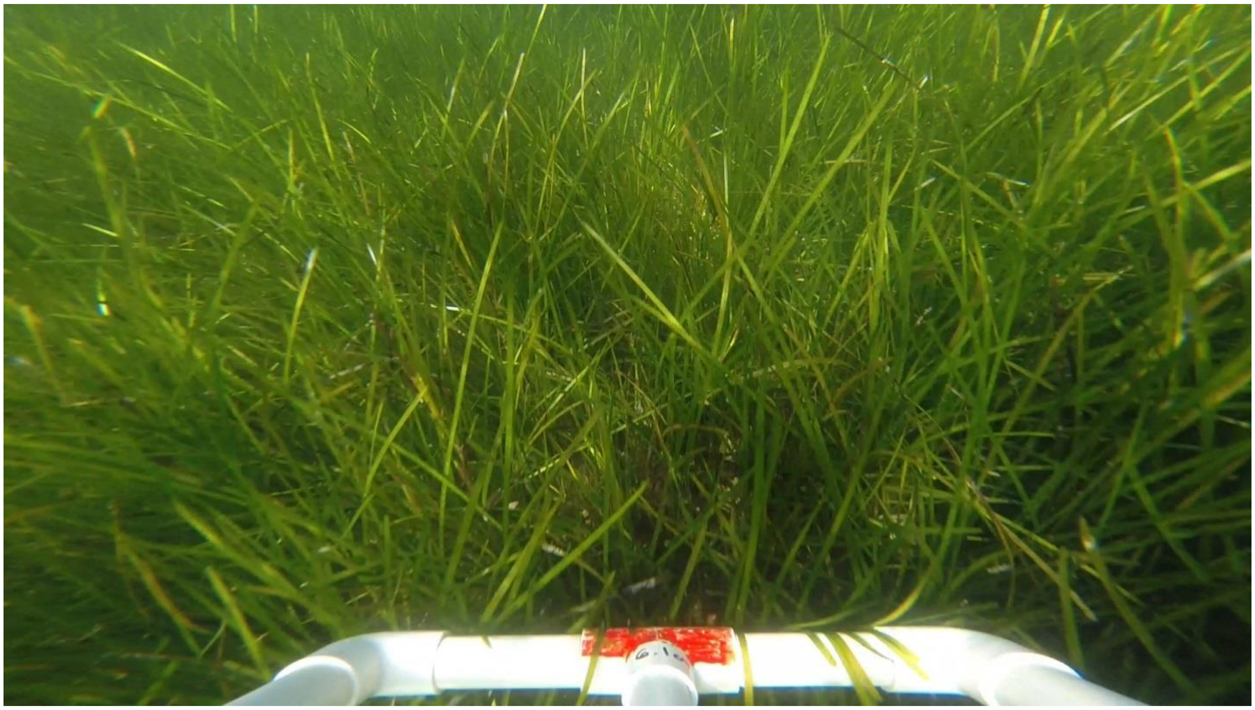

Figure 2: Representative image showing the cover of eelgrass (*Zostera marina*) at site 4 in September.

Figure 3: Representative image showing the cover of eelgrass (*Zostera marina*) at site 6 in September.

Table 2: Summary of a one way ANOVA (applied to raw data) showing the effect of Site (eight study sites) on the percent cover of eelgrass (*Zostera marina*).*Interpret cautiously as assumptions of ANOVA analyses were not checked.

Source of variation	**df**	**MS**	***f***	**P**
Site	7	201298.1	340.5502	<0.001
Error	2775	591.0966		
Corrected total	2782			

Table 3: Summary of two sample t-tests comparing the percent cover of eelgrass (*Zostera marina*) at sites of biological interest.

Two sample t-test	**P one tail**	**P two tail**
Sites 3 and 4	<0.001	<0.001
Sites 3 and 6	<0.001	<0.001
Sites 4 and 6	0.423681	0.847362
Sites 4 and 7	<0.001	<0.001
Sites 2 and 7	0.088178	0.176357

Figure 4: Representative image showing the abundance and three dimensional structure of an eelgrass (*Zostera marina*) meadow at site 2 in September.

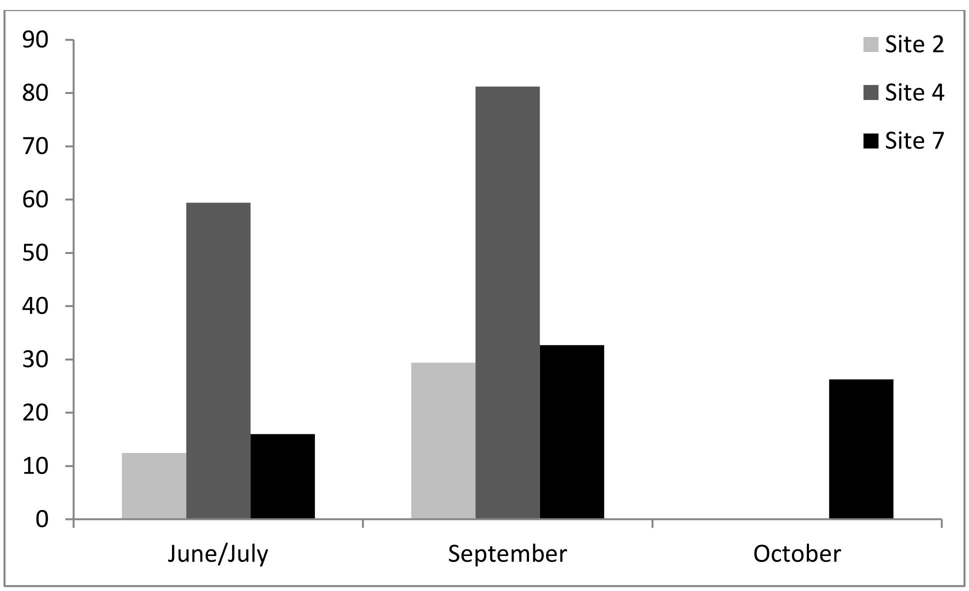

Figure 5: Change in the mean percent cover of eelgrass (*Zostera marina*) in June/July, September, and October at three study sites (2, 4, and 7) in 2014.

Discussion

Sea grasses are an ecologically significant habitat in coastal ecosystems worldwide (Hauxwell et al. 2001, Orth et al. 2006, Waycott et al 2009). Commercially, recreationally, and culturally significant fish, invertebrate, and shore birds rely directly and/or indirectly on the ecosystems services provided by sea grass meadows in shallow subtidal environments (Orth et al. 2006, Barbier et al. 2011). Degradation and loss of this productive habitat may have serious consequences for the integrity of coastal environments.

This study generated preliminary data on the abundance of eelgrass in western NL and was an essential step towards developing a long term eelgrass monitoring program. Five eelgrass meadows were identified to have greater than 20% eelgrass cover. Based on data generated during this study, sites with greater than 20% cover in September were deemed to be ecologically important eelgrass habitats and will be targeted for more in-depth monitoring in future studies.

Due to sampling limitations, the percent cover of eelgrass at site 3 may be low and not a true representation of the entire meadow. Data for site 3 currently represents the cover of eelgrass near the upper subtidal edge. Similarly, water quality at site 5 was poor and a shallow sloping shoreline prevented investigation of deeper eelgrass beds. Data at this site may also represent the upper subtidal and low intertidal margin of the meadow. Additional site assessments may reveal greater eelgrass abundance and distribution within these sites.

Future studies on identifying morphological characteristics and size of eelgrass meadows will be carried out at sites identified as ecologically important. In addition, studies will be carried out to document the invertebrate and fish communities utilizing these habitats. Overall, eelgrass abundance changes seasonally and appears to peak in late summer early fall. To improve resolution of spatial and temporal studies of eelgrass abundance, future projects will ensure sampling within a narrow temporal window. Furthermore, the establishment of permanent transects and the incorporation of GPS tracks will allow us to further investigate changes in the density and size of eelgrass beds. Finally, additional studies comparing video procedures are needed to determine how limitations of each technique affect the accuracy of data collection.

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