Does turbidity or genetics account for morphological differences in eelgrass (*Zostera marina*) at two sites near Liberty Bay?

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STUDY GOALS

The rooted marine plant *Zostera marina* (eelgrass) shows a high degree of phenotypic plasticity in response to environmental conditions. Our goal was to explore whether light limitation and/or genetics could account for morphological differences between two populations of *Z. marina* growing near Liberty Bay.

BACKGROUND

Eelgrass is important to nearshore ecosystems because it provides habitat; it modifies physical and sedimentary processes; it alters sediment geochemistry; and it is a significant detrital carbon source. Because eelgrass is sensitive to water column turbidity, nutrient loading, and low dissolved oxygen, it is considered an indicator of coastal water quality.

A site assessment of biological resources in and around Liberty Bay in April 2006 showed that, despite the presence of suitable beaches, there was no eelgrass growing inside Liberty Bay north of Keyport and Lemolo. There was a small fringing bed of *Z. marina* on the western shore of Point Bolin (PB) and an extensive *Z. marina* meadow on Agate Passage near Sandy Hook (SH, Fig. 1). *Z. marina* plants at PB were unusually small (Fig. 2) and were limited to a very narrow depth range, < -1 m (MLLW). At low tide boat wakes impinged on the shore and resuspended bottom sediment, increasing turbidity over the PB eelgrass bed. *Z. marina* plants at SH were large (Fig. 2) and extended to depths of at least –2 m (MLLW). Water movement was vigorous at SH due to strong tidal currents in Agate Passage.

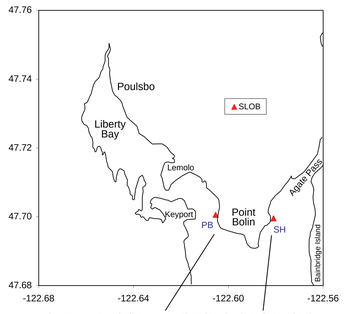


Figure 1. Map of Liberty Bay showing the locations of eelgrass beds and SLOB deployments.

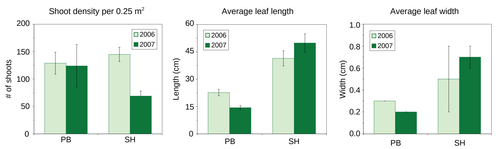
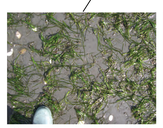


Figure 2. *Z. marina* measurements at Point Bolin (PB) and Sandy Hood (SH) during April 2006 and May 2007. (Left) Shoot densities per 0.25 m^2, (Center) Average leaf lengths, (Right) Average leaf widths measured above the sheath. Error bars show ± 1 SE among individual plants.



Small *Z. marina* plants at PB.

Large *Z. marina* plants at SH.

HYPOTHESES (Fig. 3):

1. Small plant size and narrow depth range of *Z. marina* at PB reflected a sub-optimal light environment.
2. Wakes from Liberty Bay boat traffic created higher turbidity levels at PB compared to SH.
3. The difference in *Z. marina* plant size at PB and SH was genetically controlled.

APPROACH

Field measurements- We measured turbidity and pressure with in situ sensors (self-logging optical backscatter sensors, or SLOBs) for one month in spring to determine whether resuspension of bottom sediment by boat wakes created a sub-optimal light environment for eelgrass growth (Table 1). Plant metrics (shoot density, leaf length, leaf width) were measured near the sensors to relate leaf size to turbidity levels. Leaf tissue were collected for DNA genotyping to differentiate the two *Z. marina* populations and to measure the genetic diversity. Sediment grain size distributions were measured as % weight of dry-sieved whole-ϕ size fractions.

Genetics- Eelgrass leaves were collected at 2 m intervals along a 100-m alongshore transect. Genetic diversity, degrees of clonality, and allelic richness of eelgrass beds were determined by comparing the polymorphism of ten DNA microsatellite loci characteristic of *Z. marina* (Reusch et al., 1999).

The SLOB at PB. The sensor window is 19 cm above the bed.

Figure 3. Conceptual model of environmental and biological factors influencing eelgrass. Parameters measured in this study are highlighted in yellow.

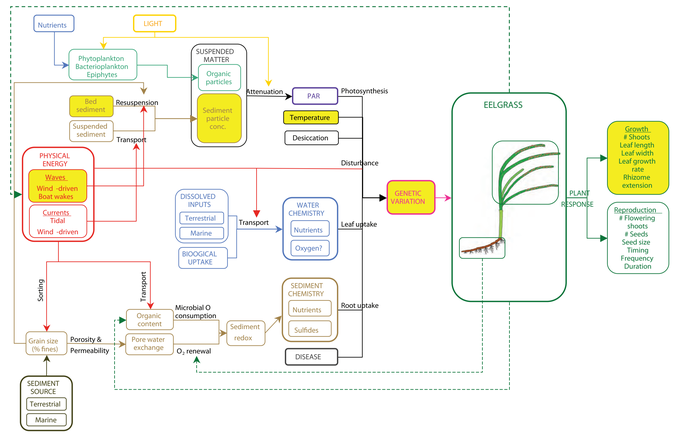


Table 1. Summary of field measurements, observations, and samples. From 18-April to 16-May, sensors sampled at 1 Hz for 40 minutes then turned off for 200 minutes throughout the deployment. On the last day (17-May), sensors sampled at 1 Hz for 56 minutes then turned off for 4 minutes throughout the day. The OBS were calibrated with sediment mixing experiments in the lab.

In situ sensors	Period	Depth, PB	Depth, SH
Optical backscatter	mid-April to mid-May	19 cm above bed	33 cm above bed
Pressure	mid-April to mid-May	19 cm above bed	33 cm above bed
Temperature	mid-April to mid-May	19 cm above bed	33 cm above bed
Discrete observations, samples	**Period**	**Depth, PB**	**Depth, SH**
Boat wakes	2-4 PM, 5/16/07	surface	surface
Suspended sediment concentration (n=5)	2-4 PM, 5/16/07	19 cm above bed	33 cm above bed
Bed sediment (n=1)	5/16/07	-0.4 m (MLLW)	-0.6 m (MLLW)
Z. marina depth ranges	4/30/06	0 to -0.6 m (MLLW)	0 to -2 m (MLLW)
Plant metrics (n=10); genetics (n=50)	5/16-17/07	-0.4 m (MLLW)	-0.6 m (MLLW)

RESULTS

Bed sediment grain size- Bed sediment under the PB SLOB had a slightly larger mean grain size (ϕ_{PB} = 2.48) and was less well sorted than bed sediment under the SH SLOB (ϕ_S = 2.60) (Fig. 4). The beach elevation at the PB SLOB was about 0.2 m higher than that of the SH SLOB (Table 1).

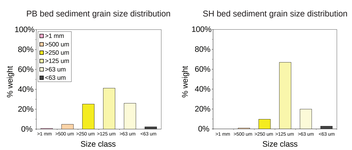


Figure 4. Sediment grain size distributions of bed sediment below the SLOBs shown as % dry weight. (Left) PB. (Right) SH.

Chris Curran and Jessie Lacy do a final check of the Point Bolin SLOB. Water level was -0.4 m MLLW.

Jessie Lacy and Greg Justin count eelgrass shoot densities at Sandy Hook. Picture taken at low tide (-0.7 m MLLW). Arrow points to the SLOB.

RESULTS (cont'd)

Turbidity- Average water column turbidity was slightly higher over the PB eelgrass bed than the SH bed (Fig. 5). For example, average suspended sediment concentration (SSC) over the last 21 hours of the deployment was 15.6±5.8 (1σ) mg/l over the PB eelgrass bed and 9.0±4.5 (1σ) mg/L over the SH bed (based on 4-minute averages) (Fig. 6). The OBS sensors were positioned so as to measure turbidity at the top of the canopy when eelgrass leaves were submerged and upright. Since Z. marina leaves were shorter at PB than at SH, the PB OBS sensor was closer to the bed than the SH sensor (Table 1).

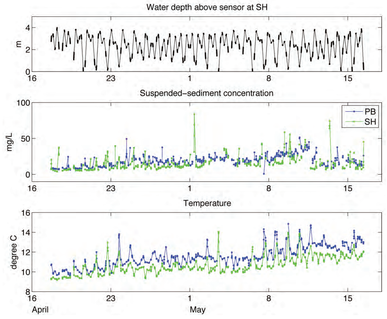


Figure 5. In situ sensor 10-minute averages from mid-April to mid-May at Point Bolin (PB, blue) and Sandy Hook (SH, green). (Top) water depth relative to the pressure sensor; (middle) SSC; (bottom) temperature.

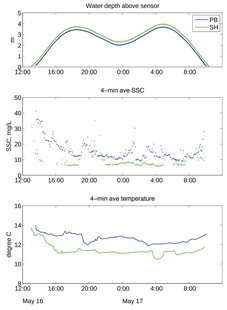


Figure 6. In situ sensor 4-minute averages on May 16 and 17 at Point Bolin (PB, blue) and Sandy Hook (SH, green). (Top) water depth relative to the pressure sensor; (middle) SSC; (bottom) temperature.

Boat wakes- Boat wakes were apparent in the pressure (water depth) record as an increase in variance lasting several minutes (Fig. 7). The pressure record was ground-truthed by documenting boat wake events during a 2-hour window on May 16. Some boat wakes were followed by higher turbidity, but there was more variability in the SSC records than could be accounted for solely by boat wakes (e.g. Fig. 8).

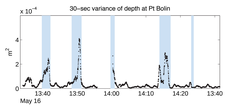


Figure 7. Variance of water depth at PB increased during documented boat wake events (blue).

Boat wakes break over the eelgrass bed and resuspend bottom sediment.

Genetics- The eelgrass bed at PB was genotypically richer than the bed at SH. There were 30 different genotypes at PB compared to only 12 genotypes at SH (n=50 plants sampled per site). Individual plants at PB were also more genetically diverse than those at SH. Eelgrass at SH primarily reproduced clonally via rhizome branching while at PB eelgrass appeared to reproduce primarily by flowering and seedling establishment. Small plants at PB could have been an annual population. An annual life cycle is a growth strategy in disturbed environments (Phillips et al., 1983).

SIGNIFICANCE

Lower light levels could have accounted for smaller leaf sizes at PB.

Boat wakes were not the only cause of higher turbidity at PB.

Other possible explanations:
- Turbidity increased with depth (PB sensor was 14 cm closer to the bed than SH sensor).
- Small eelgrass plants at PB were less effective in attenuating currents and waves.
- PB experienced more southerly wind waves than SH.
- Advection of sediment-laden turbid plumes from creeks near PB.

Pressure/OBS sensors were an effective way to monitor boat wake impingement on the shore.

Higher geneotypic richness in the PB eelgrass bed, indicative of generative (flowering) rather than vegetative (clonal) reproduction, suggests a population subject to greater physical disturbance than at SH.

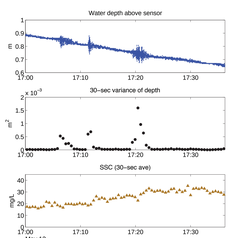


Figure 8. Boat wakes on May 12, apparent as increased water depth (top) and variance (middle) did not always correspond to inceased turbidity.

Phillips, R.C., Grant, W.S. and McRoy, C.P., 1983. Reproductive strategies of eelgrass (*Zostera marina*). Aquatic Botany, 16: 1-20.
Reusch, T.B.H., Stam, W.T. and Olsen, J.L., 1999. Microsatellite loci in eelgrass *Zostera marina* reveal marked polymorphism within and among populations. Molecular Ecology, 8: 317-321.