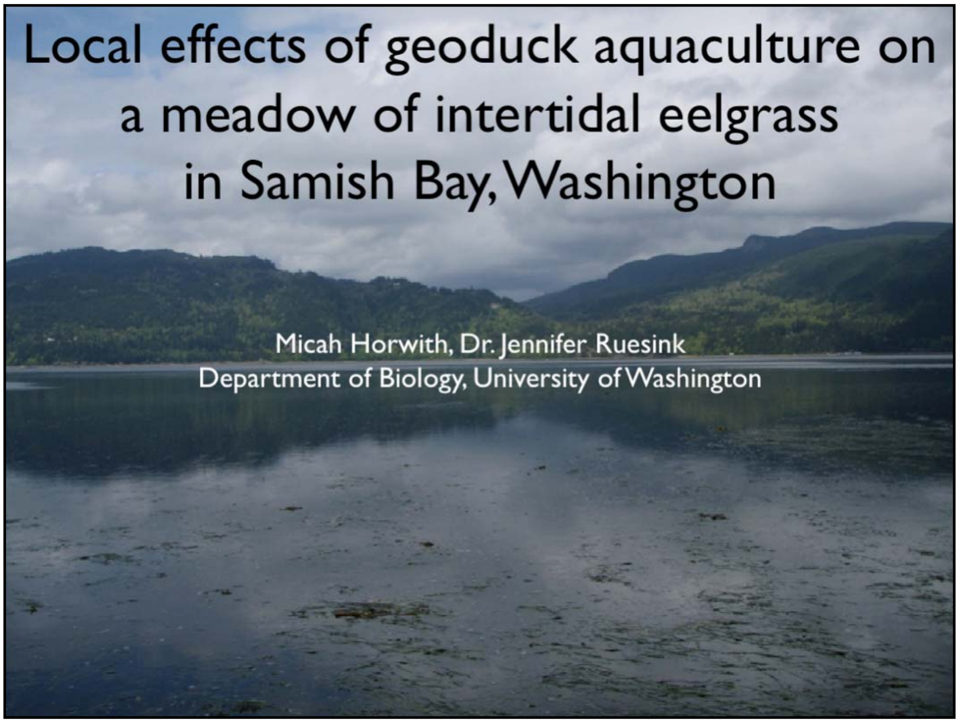
Local effects of geoduck aquaculture on a meadow of intertidal eelgrass in Samish Bay, Washington
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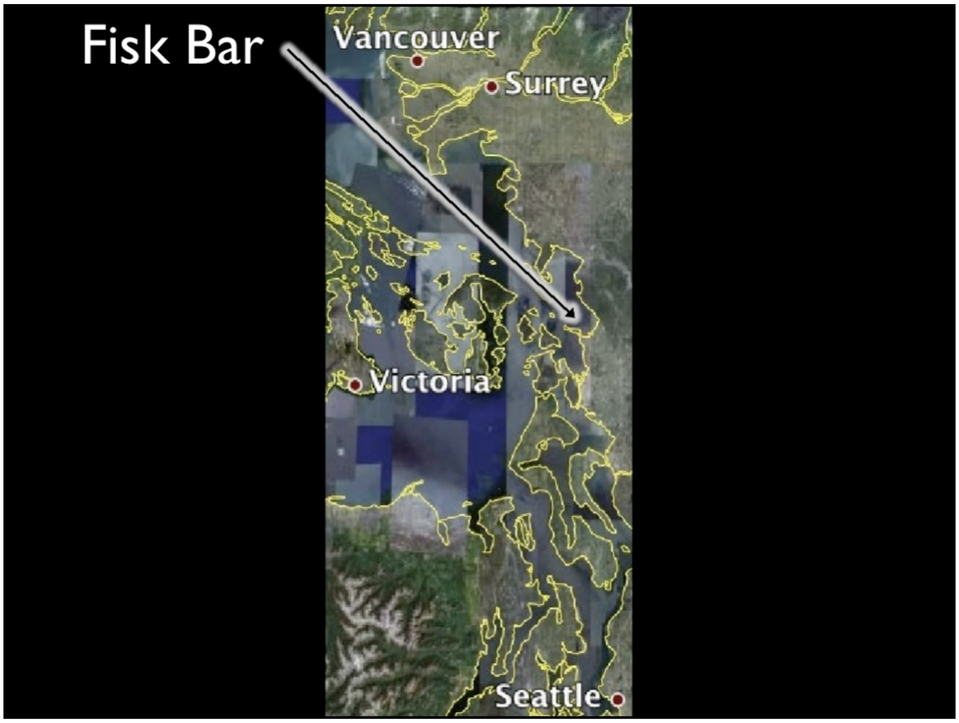


Samish Bay is in north Puget Sound, about halfway between Seattle and Vancouver, BC. Fisk Bar is the only geoduck farm maintained by Taylor Shellfish in north Puget Sound, and most aquaculture activity in this bay involves oysters and other clams.

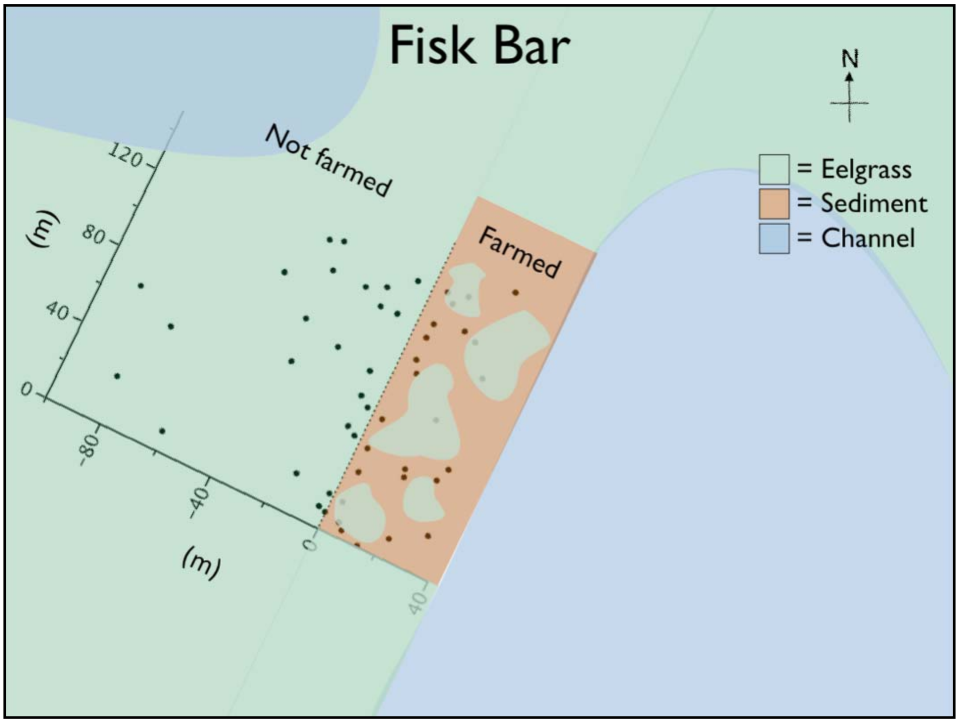
Samish Bay hosts the second largest eelgrass meadow in Puget Sound. This project is atypical, because geoduck farming and eelgrass do not normally overlap.

Eelgrass (*Zostera marina*)

- Long-lived, saltwater, flowering plant
- Forms meadow habitats
- Reduces erosion and wave action

Image credit: http://www.scientificillustrator.com/art/botanical/eelgrass.jpg

Eelgrass is a marine plant, not an alga, and in most places it flowers and produces seeds in the spring and summer. The plant reproduces sexually (via flowers and seeds) and asexually (via belowground spread). Eelgrass can form vast meadows that are important habitats for above and belowground invertebrates, as well as some vertebrates; meadows may be important feeding grounds for species of economic interest, such as dungeness crab and salmonids. Eelgrass changes its environment in the meadow by reducing erosion (with belowground roots and rhizomes) and by reducing wave action (with its long leaves).

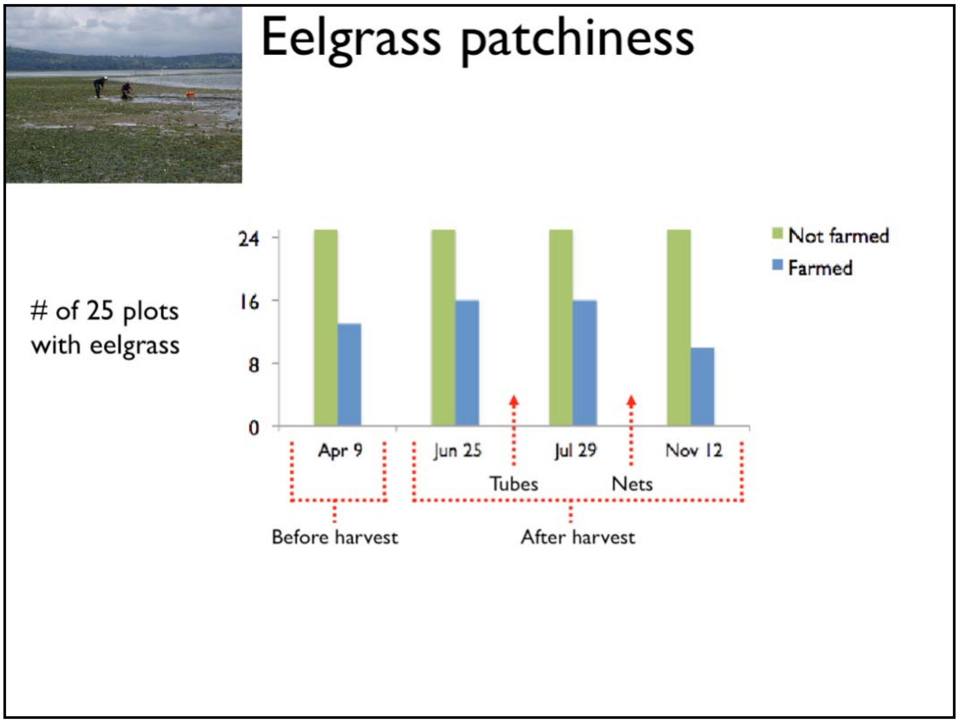


This is a cartoon of Fisk Bar. The farmed zone is adjacent to a channel, which is where boats approach. Within the farmed zone, eelgrass is patchily distributed, while outside, it is uniform at 100% coverage. Eelgrass did not occur in the farmed zone prior to the planting of a geoduck crop in the summer of 2002. Between the planting of that crop and our first sample in April of 2008, eelgrass had colonized the farmed area in patches.

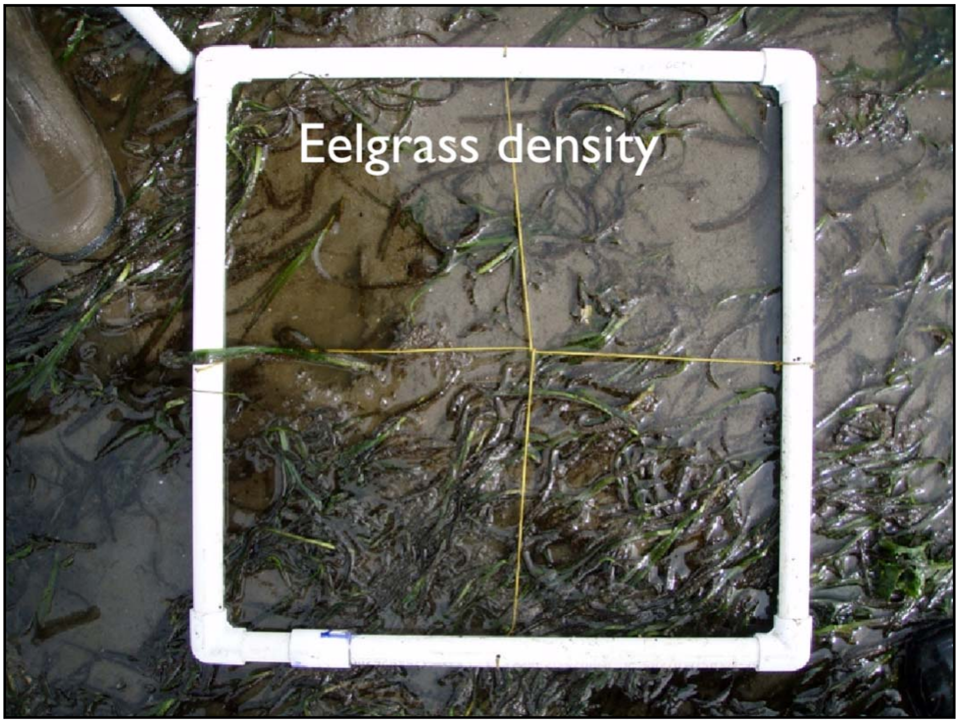
Geoduck harvest occurred in May of 2008 through the point-harvest technique, using a high pressure hose to liquify sediment around the geoducks in order to facilitate their removal. This photograph illustrates the patchy distribution of eelgrass within the farmed zone prior to harvest (eelgrass does not occur uniformly across the bar).

Tubes, serving as predator exclusion devices, were installed about one month after harvest, and a new crop of juvenile geoducks were planted into the tubes shortly thereafter.

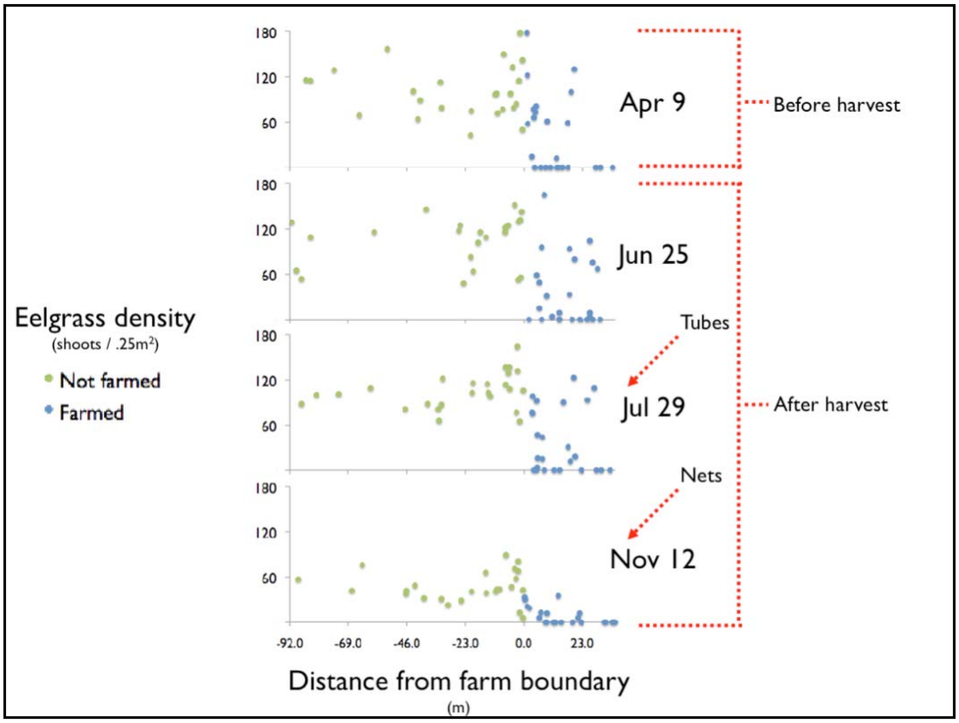
Nets were installed on Fisk Bar in late summer, as further protection for juvenile geoducks against predators.



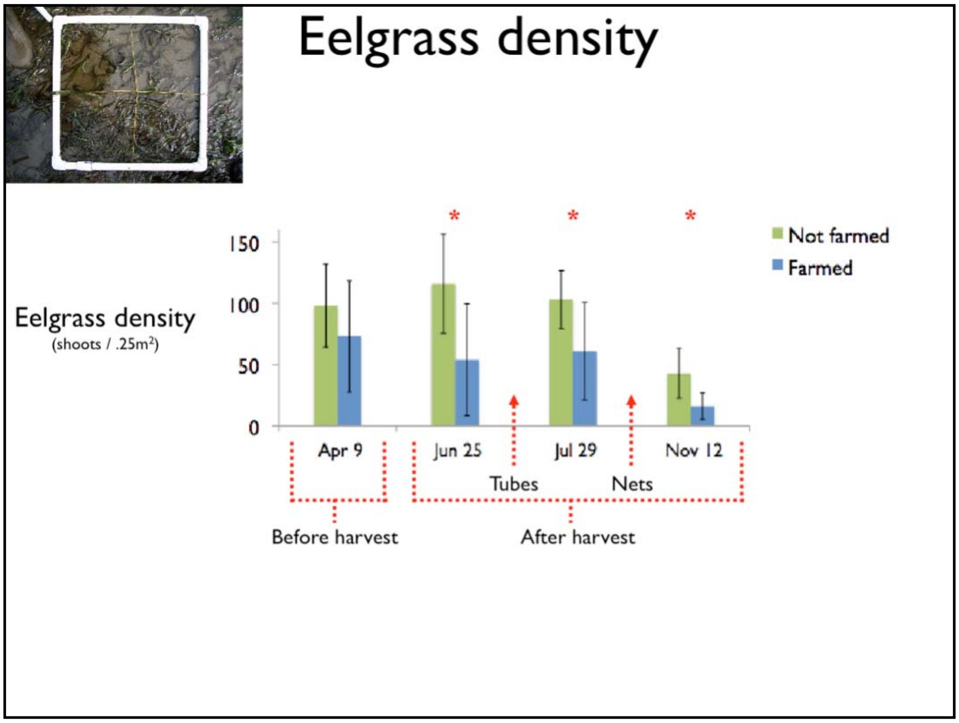
Eelgrass coverage outside the farmed area remained constant at 100% across all survey dates. Within the farmed zone, there were no significant differences in eelgrass coverage before and after harvest, indicating no change in coverage as an effect of farming.



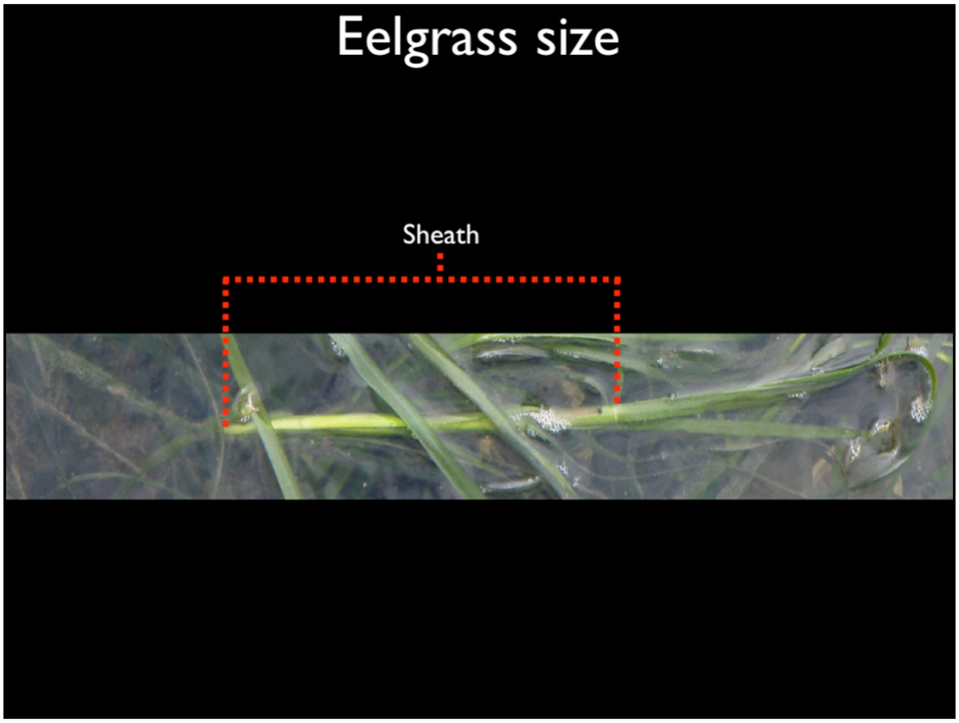
We measured eelgrass density by counting all seedlings, vegetative, and flowering shoots within a .5m x .5m area.



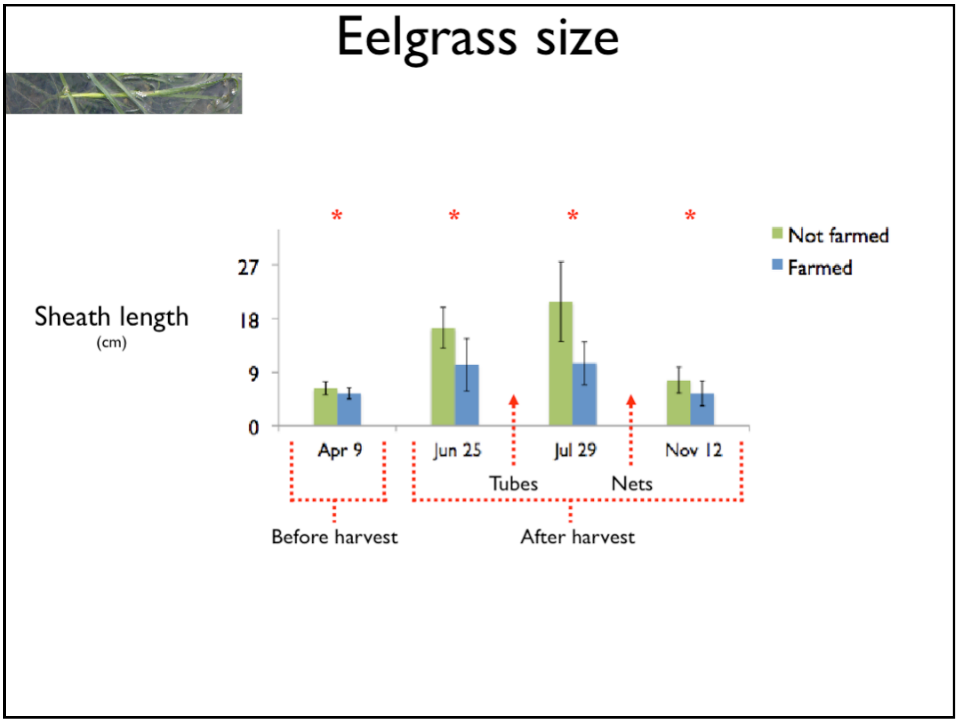
This graph illustrates the reason for our spatially-specific sampling scheme. By keeping track of the placement of our samples, we can look for spillover effects in all of our variables. Examining one set of axes at a time, we see on Apr 9th that there is no apparent pattern in eelgrass density as a function of distance from the farm boundary. This remains true across all sample dates; thus, there is no evidence so far for spillover effects of farming on eelgrass density (if there were a spillover effect, we might see an increase or decrease in eelgrass density as we near the farm boundary).



This graph shows eelgrass density only where eelgrass occurs; all empty patches in the farmed zone were removed from analysis. Before harvest, there was no significant difference in eelgrass density between the farmed and unfarmed zone. After harvest, the farmed zone had eelgrass that was significantly less dense than eelgrass outside the farmed zone, and this difference persisted across all subsequent surveys.



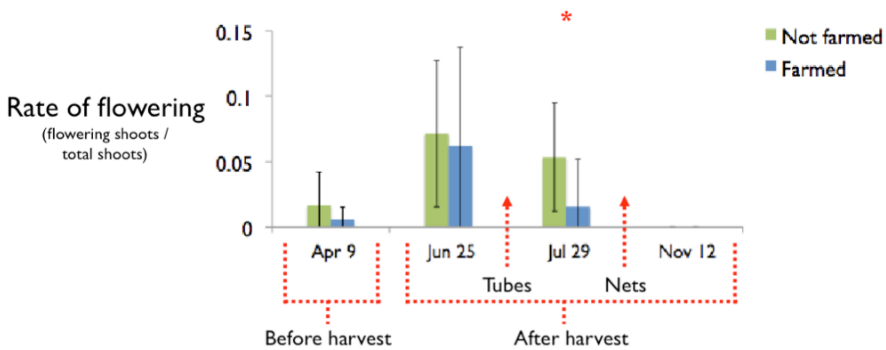
We measured a wide range of eelgrass characteristics, and this measure, sheath length, is a good proxy for plant size.



Before harvest, there was a small but significant difference in shoot size between the farmed and unfarmed zone, with eelgrass in the farm being smaller than eelgrass outside the farm. After harvest, this significant difference persisted, and increased in magnitude; plants within the farmed zone became even smaller than plants in the unfarmed zone.

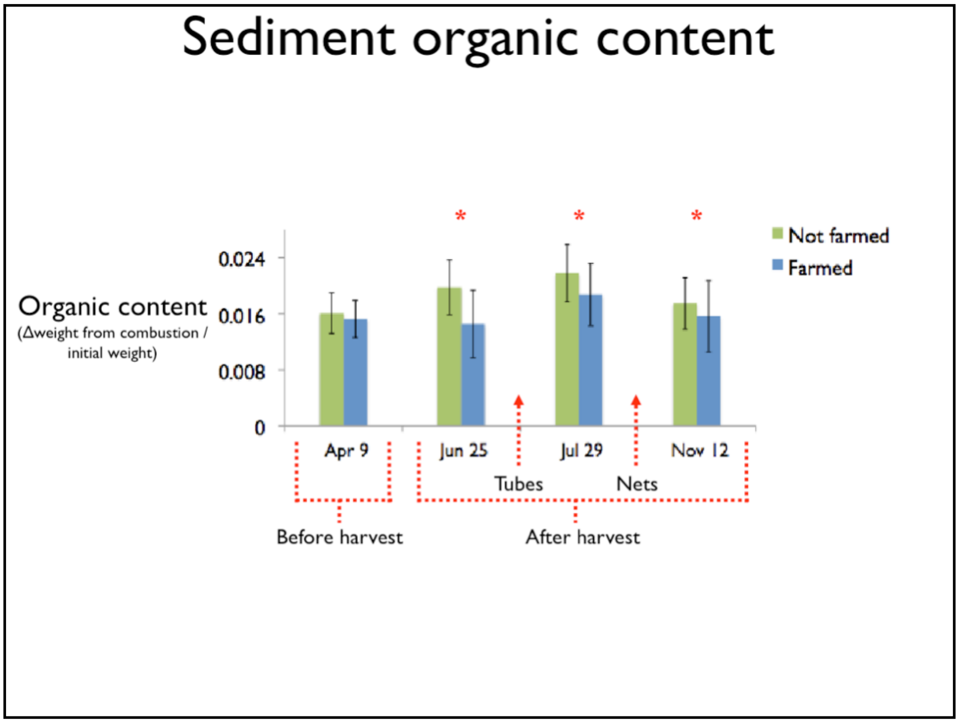
Eelgrass has two modes of reproduction: sexual and asexual. We measured rates of flowering by counting flowering shoots of eelgrass, in order to monitor the capacity for sexual reproduction in eelgrass in and outside of the farmed zone.

Eelgrass flowering



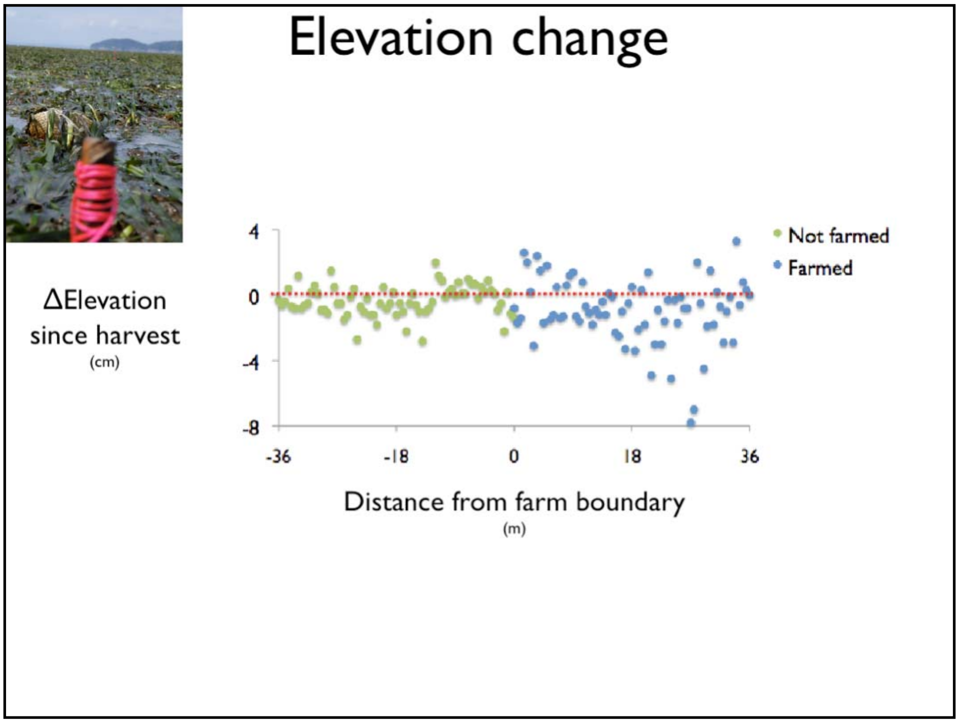
Before harvest and on Jun 25th, there were no significant differences in the rate of flowering for eelgrass inside and outside of the farmed zone. In late summer, however, eelgrass within the farmed zone had a significantly lower rate of flowering than eelgrass outside of the farmed zone.

We measured sediment organic content by collecting sediment samples, drying them, weighing them, placing them in a combustion oven, weighing them again, and calculating the difference in the two weights. The weight lost through combustion represents the organic content of the sediment.

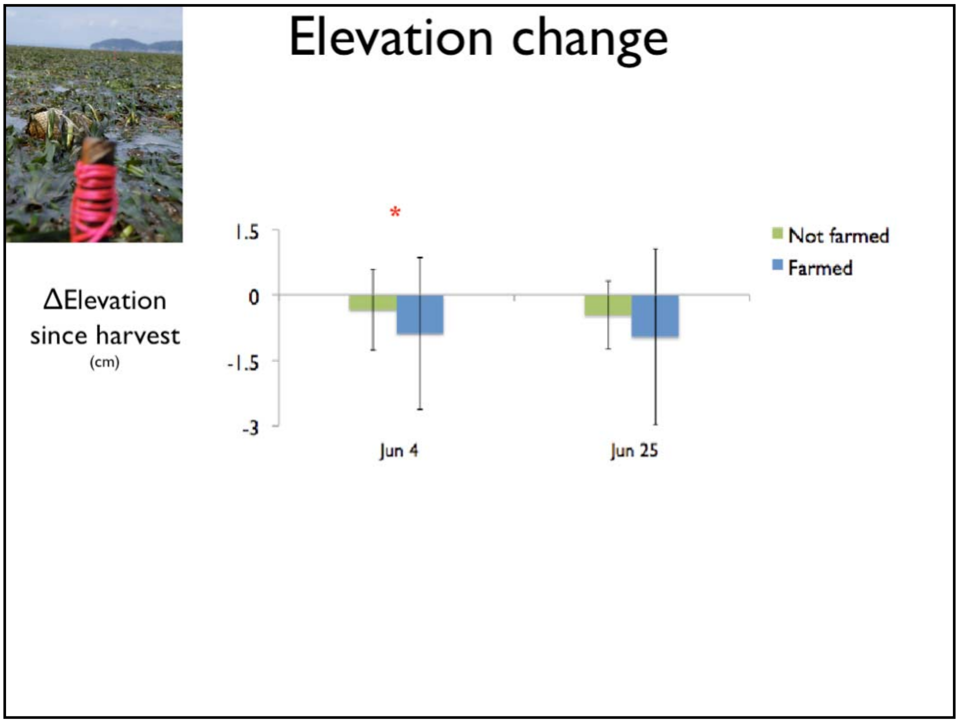


The farmed and unfarmed zones showed no significant difference in sediment organic content before harvest, but after harvest, the farmed zone demonstrated a significantly lower sediment organic content than the unfarmed zone. Sediment organic content has consequences for eelgrass growth and reproduction, and it is important as a food source to infauna.

We measured changes in elevation by installing rebar stakes at 8m intervals on a line perpendicular to the farm boundary. By stringing mason line taut across the top of two rebar stakes, we measured the distance from the line to the sediment surface at set intervals, and collected data before and after each aquaculture event, in and outside of the farmed zone.



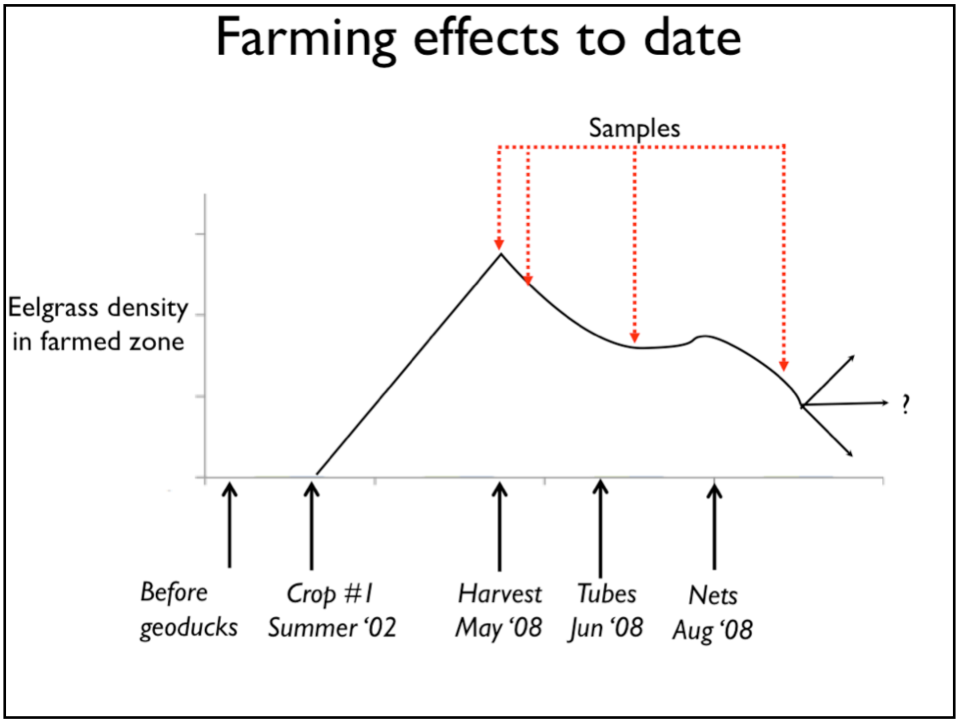
Elevation change was highly variable 30 days after harvest, with some points showing sediment accumulation and others showing sediment loss. On average, both the farmed and unfarmed zones showed sediment loss. Plotting change in elevation as a function of distance from the farm boundary, there is no evidence of spillover effects in elevation loss. Within the farmed zone, the high degree of variation suggests that geoduck harvest has spatially specific effects, rather than general effects; post-harvest geoduck potholes show a distinct loss of sediment elevation, but no loss is evident where geoducks have not been harvested.



At ~30 days after harvest, both the farmed and unfarmed zones demonstrated a significant loss in sediment elevation, and this reduction was significantly greater in the farmed zone than in the unfarmed zone. At ~60 days after harvest, both farmed and unfarmed zones still showed a significant loss in sediment elevation, but there was no longer any difference in this elevation loss between the farmed and unfarmed zones.

In summary, we have successfully detected a range of effects following geoduck harvest, tube implantation, and net installation. After harvest, eelgrass inside the farmed zone became significantly less dense than eelgrass outside the farmed zone. Before harvest, eelgrass in the farmed zone was slightly, and significantly, smaller than eelgrass outside the farm, and after harvest, this difference increased in magnitude and remained significant. After harvest in the late summer, eelgrass in the farmed zone demonstrated a rate of flowering significantly lower than eelgrass outside the farmed zone. Eelgrass patchiness in the farmed zone showed no response to farming activities. Finally, we have found no evidence of spillover effects for any measured variable.

After harvest, sediment in the farmed zone had significantly less organic content than sediment in the unfarmed zone. Both the farmed and unfarmed zones showed significant losses in sediment elevation after harvest. This loss was initially greater in the farmed zone, but this difference disappeared in the late summer. High variation in sediment elevation changes suggests that geoduck harvest has effects on sediment elevation only where geoducks were harvested directly.



This is a cartoon of the history of eelgrass density on Fisk Bar (no data are involved). Before the site was cultivated, eelgrass was absent on Fisk Bar. Between the implantation of the geoduck crop in the summer of 2002 and their harvest in the summer of 2008, eelgrass colonized the bar in patches; these patches were no different in density to eelgrass outside of the farm. After harvest, the eelgrass patches in the farm became significantly less dense than eelgrass outside the farm, and this difference persisted through subsequent surveys. Eelgrass within the farm showed characteristic seasonal patterns, becoming more dense in the summer and less dense in the winter. Future work on this project will provide insight into patterns and rates of recovery in eelgrass within the farmed zone.

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