

***Sargassum Muticum* effects on *Costaria Costata* and Benthic Assemblages of Marine**

Primary Producers

Emily Duque Gallagher^{1,2}, Terrie Klinger^{2,3}

FHL 470: Research in Marine Biology
Spring 2021

Contact Info:

Emily Duque Gallagher

Email: duquee@uw.edu

Friday Harbor Labs, University of Washington

620 University Rd

Friday Harbor, WA 98250

¹Department of Biology, University of Washington, Seattle, WA 98195

²Friday Harbor Laboratories, University of Washington, Friday Harbor, WA 9825

³College of the Environment, University of Washington, Seattle, WA 98195

Key words: *Sargassum muticum*, *Costaria costata*, invasive, Salish Sea, kelp

ABSTRACT

The introduced species *Sargassum muticum* has been part of Salish Sea ecosystems since the 1940s. It has become extremely common in both Europe and North America, growing in the shallow subtidal. I combined a series of in-lab growth and fluorometry measurements with subtidal surveys to discern the possible direct effects of *S. muticum* on the native kelp, *Costaria costata*, and the broader macro-benthic primary producer assemblage. In the laboratory, *S. muticum* did not show a decrease growth or photosynthetic rate. Similarly, subtidal surveys showed no significant difference in primary producer assemblage composition within and outside beds of *Sargassum*. My results disagree with previous literature and suggest that likely both abiotic and biotic factors may play a complicated role in *Sargassum*'s influence as an invasive species.

INTRODUCTION

The introduction of a non-native species into a new ecosystem is cause for concern. When an invasive is aggressive they have the potential to heighten competition, increase predation, and alter long term evolutionary relationships between members of a community. The invasion of a seaweed such as *Sargassum muticum* is particularly concerning because its life history allows for quick reproduction and dispersal (Deysher and Norton 1981). In the Salish Sea the environment is vulnerable because the native canopy forming kelp, *Nereocystis luetkeana*, has seen declines of up to 63% in the southern part of the Puget Sound in recent years (Berry et al. 2021). Previous studies have suggested high competition between the *Sargassum* and *Macrocystis pyrifera* a close relative for *N. luetkeana* (Ambrose and Nelson 1982). This

increases concern because shrinking kelp beds compound the stress *Sargassum* has on canopy forming *Nereocystis* and other native macro-benthic kelp.

In an environment where access to space and light can influence fitness, *Sargassum*'s coarsely branched, canopy forming structure poses threat to species growing beneath it (Ambrose and Nelson 1982). It has been shown that *S. muticum* contributed to a significant reduction of primary productivity in ecosystems via a decreased biomass in native algal species in Ireland (Salvaterra et al. 2005). In other instances, it has been shown that *S. muticum* can have little effect on native algal assemblages but can significantly decrease the percent cover of certain algal groups (Olabarria et al. 2009). In tidepools where *S. muticum* has been able to colonize it can cause changes in assemblages, having the greatest effect on native Fucales (Viejo 1997). An analysis of historical trends in Denmark showed a significant decline in *Saccharina latissima*, a member of Laminariales family, from 1990 to 1997 suggesting that *S. muticum* is able to outcompete some native species (Staehr et al. 2000).

Understanding the extent of influence that *Sargassum muticum* has on kelps native to the Salish Sea could play a large role in persevering them and the environmental services they provide. Kelp in particular is extremely productive, as they are able to renew their length between three and four times during the year (Brady-Campbell et al. 1984) and are estimated to sequester carbon at a rate of 173 TgC yr^{-1} (Krause-Jensen et al. 2016). They are vital in creating three-dimensional habitat for near shore fish and invertebrates and are a large link in the food web (Calvert 2005, Siddon et al. 2008). Field experiments done in the Salish Sea show a reduction in total abundance of native kelps by *S. muticum* and larger effects on invertebrate communities, specifically *Strongylocentrotus droebachiensis* (Britton-Simmons 2004). Other

studies show a lower diversity due an increased abundance of dominant smaller organisms in *Sargassum* compared to non-canopy areas (Strong et al. 2006)

By monitoring growth and photosynthetic activity in *C. costata* (a common large bladed kelp) under the influence of *Sargassum*, I will be able to determine if percent cover of *Sargassum* and kelp growth have an inverse relationship. The data collected via subtidal surveying was designed to show larger scale shifts in assemblages without the confounding variable of the laboratory. I tested the following null hypotheses: (1) the increase in percent cover of *Sargassum* will have no effect *C. costata* growth; (2) the increase percent cover of *Sargassum* will have no effect on the photosynthetic activity of *C. costata*; (3) the percent cover of Laminariales and other native algae will not be affected by the presence of *S. muticum*.

METHODS

In-Lab Growth Experiments

To assess the possible effects of canopy forming *S. muticum* on *C. costata* I used two treatments and a control in outdoor tanks at Friday Harbor Labs (FHL). The transparent tanks were 125cm x 60cm x 28cm in size and contained 55 gallons of running seawater. Each tank contained five individual sporophytes of *C. costata* with an intact blade, stipe, and holdfast. I collected the *C. costata* from the FHL docks and tires (48°32'42.3" N, 123°00'43.3" W) and the *S. muticum* from the shallow subtidal surrounding the labs. I established a control treatment without any *Sargassum* cover and held down the kelp blades with landscape netting to avoid excessive exposure to air. The two treatments had an estimated 50-60% cover and 80-90% cover of *Sargassum*. Other than of the addition of *S. muticum*, the treatments and control were equal in

temperature and water flow. The ambient temperature was measured daily and ranged from 14°-10.5°C. The sporophytes were exposed to experimental treatments for six days.

I measured the growth of the specimens using the hole punch method. This method was first published by Mann (1973) and is well established. One hole was made in the kelp blade 5 centimeters from stipe to measure meristematic growth. Maximum length and width were also taken. Measurements were made on day zero and day six of the treatments.

I measured efficiency and activation of PSII using a Pocket Pea portable fluorometer. Measurements were taken in F_v/F_M and indicate the activity of PSII via chlorophyll fluorescence. Fluorometry measurements were taken on day zero and day six of treatment.

Drop-cam field sampling

To supplement laboratory treatments, I did surveys to understand the makeup of subtidal environments with a *Sargassum* canopy and without. Subtidal surveying was performed using an underwater quadrat attached to a camera. Pictures were taken along transects and analyzed for area using ImageJ. I sampled 12 quadrats within *S. muticum* beds and 12 without *Sargassum*. Benthic cover was grouped into four groups: kelps, green seaweeds, red seaweeds, and eelgrass. I calculated percent cover by dividing the area occupied by the total area of the entire quadrat.

Analytical methods

I analyzed possible significant difference in the fluorometry and growth measurements within a treatment (from day zero to six) using a paired t-test. I also used an analysis of variance (ANOVA) to test possible significant associations of day six growth measurements between all three treatments. For the data collected during subtidal sampling I used a t-test to assess possible

associations between percent cover of marine primary producers in relation to *Sargassum* presence. An arcsine conversion of the percentages was used prior to analytical tests.

RESULTS

Photosynthetic activity differed between treatments (Figure 2, $p=1.27E-20$).

Photosynthetic activity differed between day 0 and day 6 for the control only (Figure 1, $p=0.04156$).

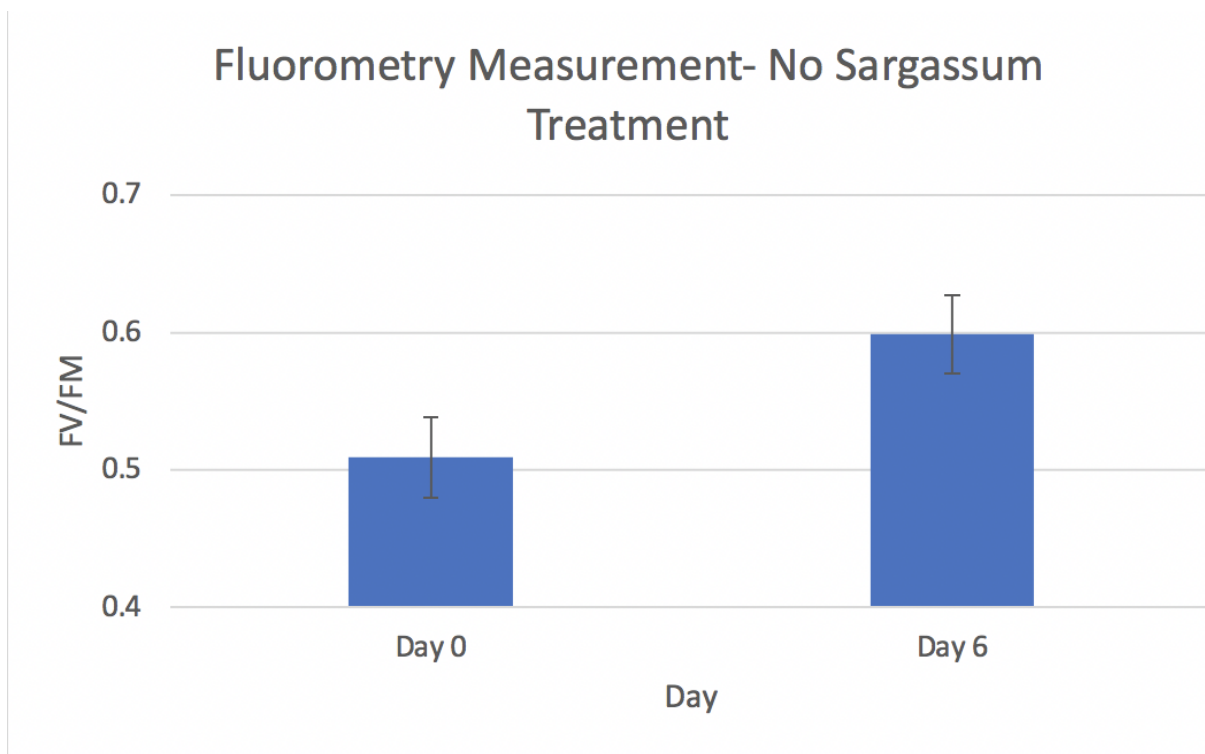


Figure 1: Fluorometry measurements showing the significant increase in fluorescence seen in the control tank.

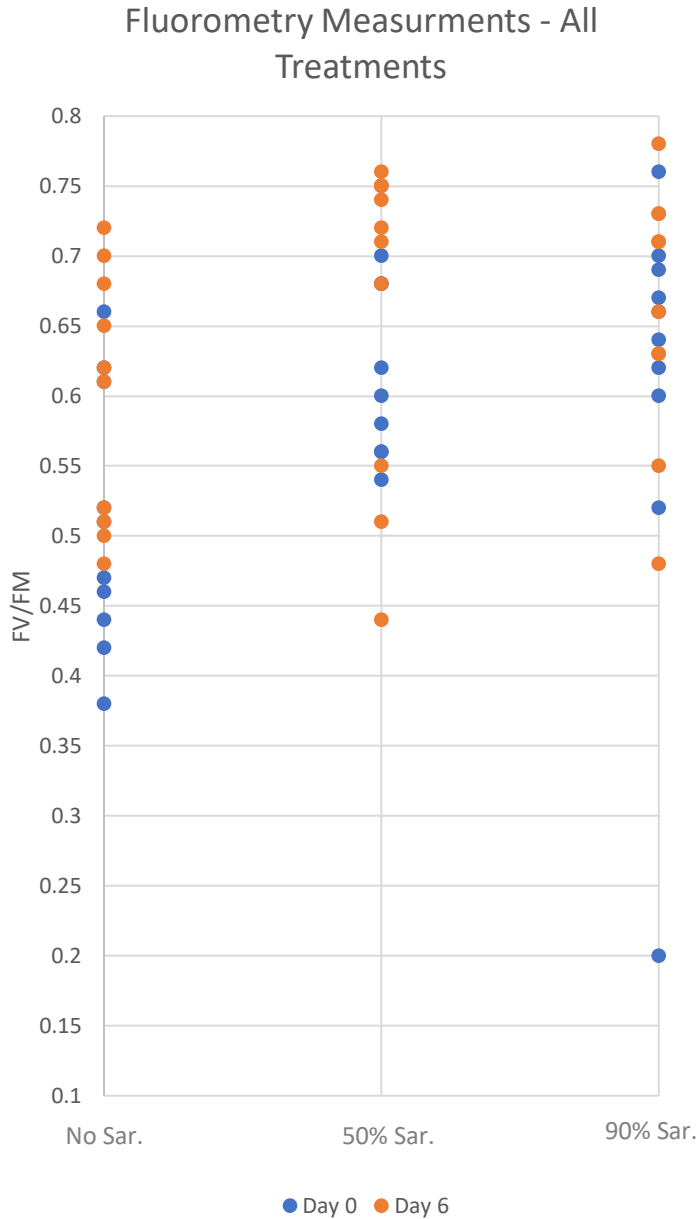


Figure 2: Fluorometry measurements for each treatment on day 0 and day six of experiment. Notice the significant change in photosynthetic level in the control.

Analysis of the growth data showed significant difference in the change in maximum width of kelp blades (Figure 3, $p=0.04967$). There were no significant findings in either maximum length or meristematic growth measurements when compared between treatments and control.

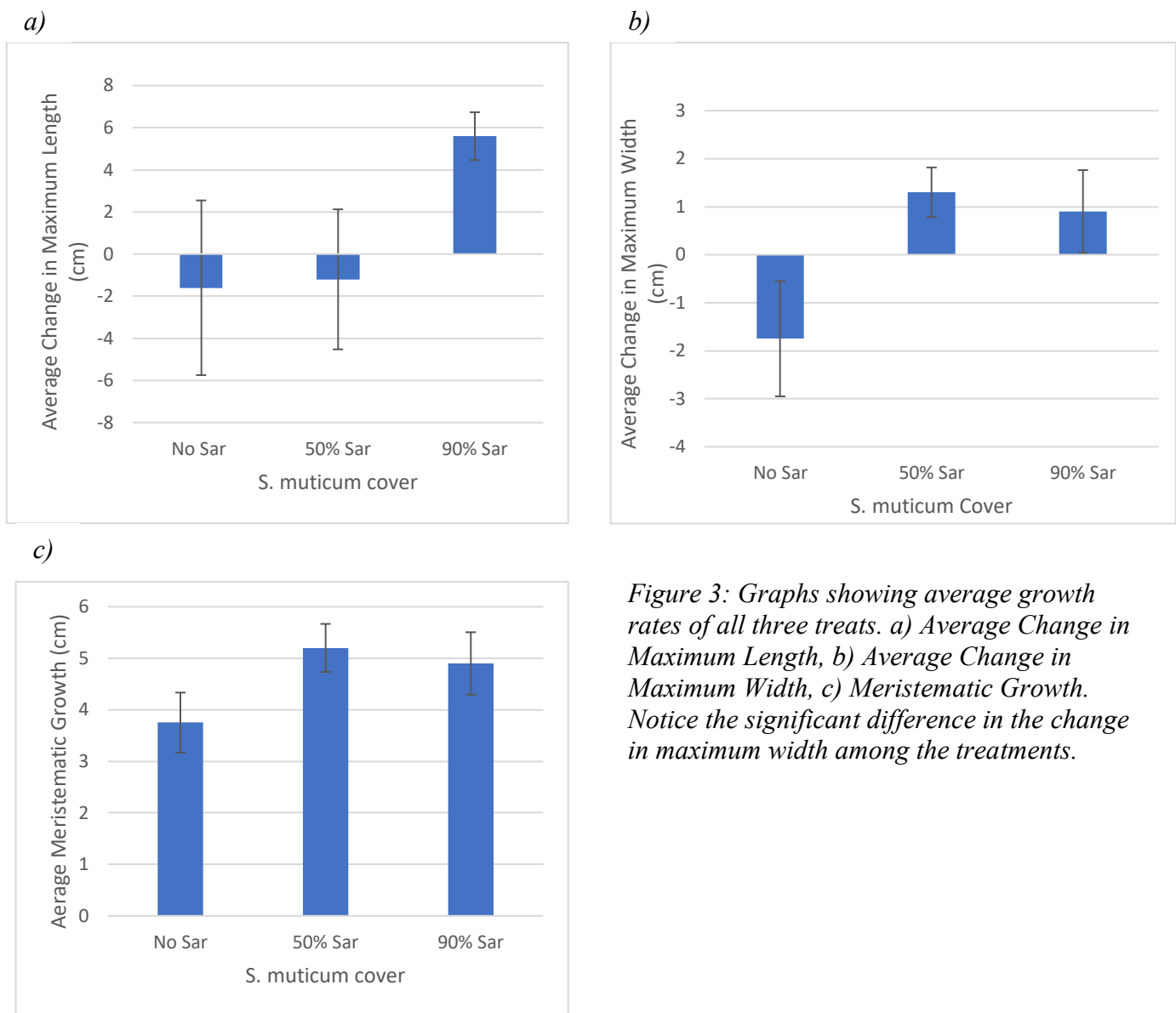


Figure 3: Graphs showing average growth rates of all three treats. a) Average Change in Maximum Length, b) Average Change in Maximum Width, c) Meristematic Growth. Notice the significant difference in the change in maximum width among the treatments.

I found no significant difference in the percent cover in any of the four groups of benthic macrophytes in relation to *Sargassum* presence. Data from the subtidal quadrats suggest an increase in Laminariales cover and a decrease of green seaweeds (mostly *Ulva*) when *S. muticum* was present (Table 1 and Figure 3).

Table 1: Percent cover of macroalgae and eelgrass assemblage within and outside of *S. muticum* beds.

Primary Producer	<i>S. muticum</i>	No <i>S. muticum</i>
Laminariales	42%	32%
Green	14%	28%
Red	5%	4%
Eelgrass	8%	10%

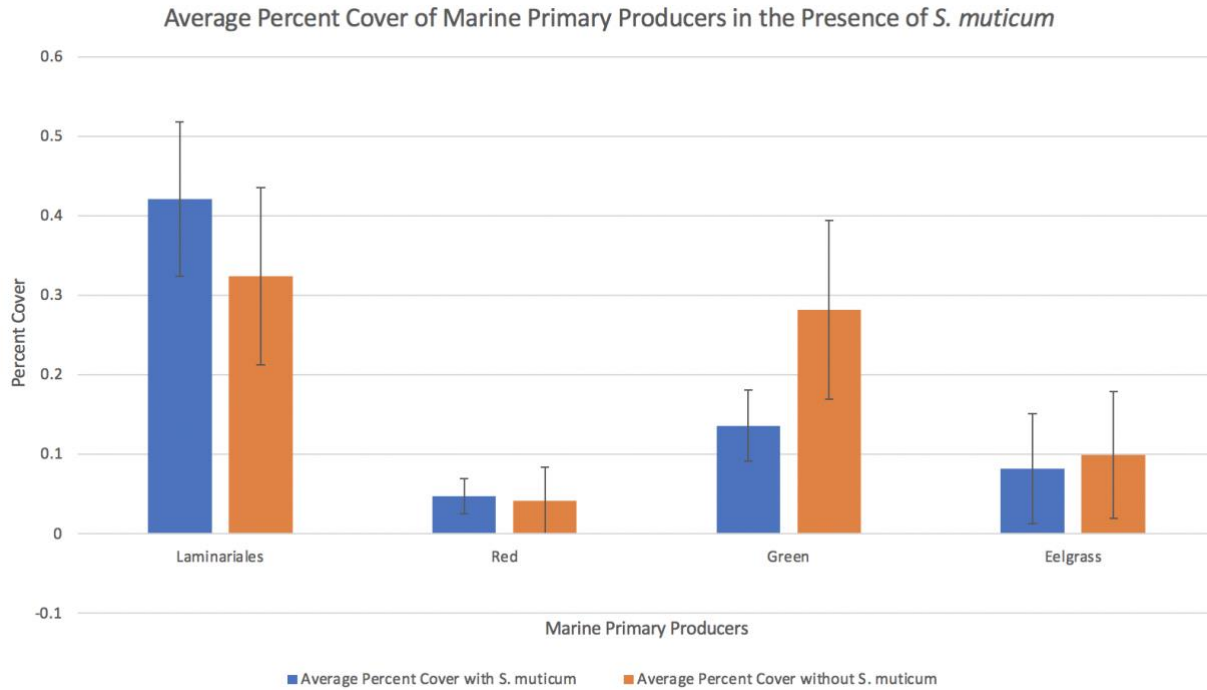


Figure 4: Difference in marine primary producer assemblages within and outside of Sargassum muticum beds in the near subtidal surrounding Friday Harbor Labs.

DISSCUSSION

I found that photosynthetic activity increased significantly in the control but remained about the same in all treatments with *S. muticum* cover. The increase in photosynthetic activity could be correlated to the increased light that the kelp was exposed to compared to that in the field. From this result, one would expect an increase in growth to be associated with increases in photosynthetic activity. I did not observe this. Meristematic growth was within a centimeter of difference for all treatments and was lowest in the control. The average growth in the meristem was about 5 centimeters for all treatments. The disconnect between fluorescence and growth results could possibly be due to the high levels of stress the kelp was under. Generated energy could be allocated differently under the high light levels and stark temperature changes (from 10°- 14° C in 24 hours).

Changes in both maximum width and length were most positive in treatments with *Sargassum*, with a significant difference in the width. The substantial tissue loss in the control sporophytes ((up to 9 cm) likely resulted in the significant decrease in width. Sporophytes in the treatments both increased in width. This increase could be a response to the increased shade as the alga attempts to increase surface area for light capture. My growth findings are in opposition to those previously found in the same region. Britton-Simmons (2004) found 2-to-3-fold increase in growth in the kelp *Laminaria bongardiana* when *S. muticum* was removed. I found the highest amount of average meristematic growth in the treatment with 90% *S. muticum* cover. This is opposed to published studies that indicate the influence of *Sargassum* has been shown to vary depending on its density, showing the highest impact in areas of high density (Ambrose and Nelson 1982, Viejo 1997, Britton-Simmons 2004). The differences in results are most likely due the experimental set up and constraints of the laboratory setting. The tanks could potentially have induced physiological changes in the kelp sporophytes that persisted throughout the experiment.

Alternatively, the lack of correspondence between increasing photosynthetic levels and growth might be explained by photoinhibition. The shock caused by increased light from the dock to the tanks could have resulted in photoinhibition in the initial days of experimentation. Photoinhibition can cause a decrease in photosynthetic activity of 40-60% in as little as five minutes (Bruhn et al. 1996). This lower activity on day zero and the subsequent recovery of PSII over six days, which occurs quickest in the first hours (Bruhn et al. 1996), could have contributed to the difference. The decrease in the average width of the control could also be a result of photoinhibition, as the blade degraded because energy was pushed to repair damaged photosystems. Data suggests this is likely because the no other growth measurements corroborate the findings associated with width.

I found no difference in community assemblage among subtidal quadrats. This is in contrast to previous findings that show a removal of the invasive led to native Laminariales being 4-5 times more abundant (Britton-Simmons 2004). In the subtidal one of the limiting factors is light, and *S. muticum* is an effective competitor. *Sargassum* has been shown to outcompete slow growing kelps both over an extended time-period of introduction and a negative correlation between percent cover of the invasive and native algal species (Staehr et al. 2000). Furthermore, the composition of native assemblages have been shown to change in the presence of *Sargassum* along with a decrease in species diversity and richness (Salvaterra et al. 2013). The inconsistent data found may be a result of seasonal variation. The increased cover of *Ulva* in areas without *Sargassum* could be because of time of year rather than effects induced by an invasive. Alternatively, the sampling method made it difficult to determine the subtidal substrate and minimize it as a confounding variable.

Ultimately, in order to make a full conclusion on the effects of an invasive like *Sargassum* more time is needed. The life stages and changes in morphology in both the invasive and native species can have major influences on the success of growth and recruitment, that can only be seen with time. The compounding factors of ocean warming, and kelp bed loss make further research into the relationships that *S. muticum* has with native species of the Salish Sea that much more important. The results of my study are inconclusive and show that more work need to be done. The effects of *S. muticum* are variable and have been shown to differ between sites and species (Viejo 1997, Staehr et al. 2000, Wilson 2001, Britton-Simmons 2004). Due to its biology, it is likely the range of *Sargassum muticum* will continue to grow and further research is needed to mitigate its impact.

ACKNOWLEDGEMENTS

This research would not have happened without the help of Terrie Klinger, who's guidance is invaluable. Further thanks to Tom Mumford, Megan Dethier, Robin Fales, Kindall Murie, and Joe Duprey for not only their teaching but for help problem-shooting when things go wrong. I would also like to thank the Mary Gates Endowment and Friday Harbor Labs Award donors for providing assistance throughout my research.

LITERATURE CITED

- Ambrose, Richard, and Bobette Nelson. "Inhibition of Giant Kelp Recruitment by an Introduced Brown Alga." *Botanica Marina - BOT MAR* 25 (January 1, 1982): 265–68.
<https://doi.org/10.1515/botm.1982.25.6.265>.
- Berry, Helen D., Thomas F. Mumford, Bart Christiaen, Pete Dowty, Max Calloway, Lisa Ferrier, Eric E. Grossman, and Nathan R. VanArendonk. "Long-Term Changes in Kelp Forests in an Inner Basin of the Salish Sea." *PLOS ONE* 16, no. 2 (February 17, 2021): e0229703.
<https://doi.org/10.1371/journal.pone.0229703>.
- Britton-Simmons, Kevin H. "Direct and Indirect Effects of the Introduced Alga *Sargassum Muticum* on Benthic, Subtidal Communities of Washington State, USA." *Marine Ecology Progress Series* 277 (2004): 61–78.
- Bruhn, J., and V. A. Gerard. "Photoinhibition and Recovery of the Kelp *Laminaria Saccharina* at Optimal and Superoptimal Temperatures." *Marine Biology* 125, no. 4 (June 1, 1996): 639–48.
<https://doi.org/10.1007/BF00349245>.
- Calvert, Elizabeth L. "Kelp Beds as Fish and Invertebrate Habitat in Southeastern Alaska," 2005.
<https://scholarworks.alaska.edu/handle/11122/6067>.
- Deysher, Larry, and Trevor A. Norton. "Dispersal and Colonization in *Sargassum Muticum* (Yendo) Fensholt." *Journal of Experimental Marine Biology and Ecology* 56, no. 2 (December 14, 1981): 179–95. [https://doi.org/10.1016/0022-0981\(81\)90188-X](https://doi.org/10.1016/0022-0981(81)90188-X).
- Mann, K. H. "Seaweeds: Their Productivity and Strategy for Growth." *Science* 182, no. 4116 (1973): 975–81.

- Olabarria, Celia, Iván F. Rodil, Mónica Incera, and Jesús S. Troncoso. “Limited Impact of *Sargassum Muticum* on Native Algal Assemblages from Rocky Intertidal Shores.” *Marine Environmental Research* 67, no. 3 (April 1, 2009): 153–58. <https://doi.org/10.1016/j.marenvres.2008.12.007>.
- Salvaterra, Tânia, Dannielle S. Green, Tasman P. Crowe, and Eoin J. O’Gorman. “Impacts of the Invasive Alga *Sargassum Muticum* on Ecosystem Functioning and Food Web Structure.” *Biological Invasions* 15, no. 11 (November 1, 2013): 2563–76. <https://doi.org/10.1007/s10530-013-0473-4>.
- Sánchez, Íñigo, and Consolación Fernández. “Impact of the Invasive Seaweed *Sargassum Muticum* (Phaeophyta) on an Intertidal Macroalgal Assemblage¹.” *Journal of Phycology* 41, no. 5 (2005): 923–30. <https://doi.org/10.1111/j.1529-8817.2005.00120.x>.
- Siddon, Elizabeth Calvert, Christopher E. Siddon, and Michael S. Stekoll. “Community Level Effects of *Nereocystis Luetkeana* in Southeastern Alaska.” *Journal of Experimental Marine Biology and Ecology* 361, no. 1 (June 20, 2008): 8–15. <https://doi.org/10.1016/j.jembe.2008.03.015>.
- Stæhr, Pa, Mf Pedersen, Ms Thomsen, T Wernberg, and D Krause-Jensen. “Invasion of *Sargassum Muticum* in Limfjorden (Denmark) and Its Possible Impact on the Indigenous Macroalgal Community.” *Marine Ecology Progress Series* 207 (2000): 79–88. <https://doi.org/10.3354/meps207079>.
- Strong, James, Matthew Dring, and Christine Maggs. “Colonisation and Modification of Soft Substratum Habitats by the Invasive Macroalga *Sargassum Muticum*.” *Marine Ecology-Progress Series - MAR ECOL-PROGR SER* 321 (September 8, 2006): 87–97. <https://doi.org/10.3354/meps321087>.

- Viejo, Rosa M. “The Effects of Colonization by *Sargassum Muticum* on Tidepool Macroalgal Assemblages.” *Journal of the Marine Biological Association of the United Kingdom* 77, no. 2 (May 1997): 325–40. <https://doi.org/10.1017/S0025315400071708>.
- Wilson, C. Melissa. “Is *Sargassum Muticum* a Benign Invader of Tidepools on the Pacific Coast of North America?” California State University Monterey Bay, 2001.