# *Fucal* Matters: Composition and Diversity of the Understory Assemblages at the Upper and Lower Limits of Canopy-Forming *Fucus distichus* zone

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*"From the union of the great sentinel of rock and the mercurial swathes of ocean, a child of little recognition yet great importance is born - the Fucus."*

- Indra Behar and/or Copernicus, 2021

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## Abstract

*Fucus distichus* is a canopy-forming seaweed that plays a key role creating habitats in the intertidal for small invertebrates and other understory algae. These habitats are important in influencing the composition and diversity of intertidal assemblages. It has been proposed that climate change and its consequential effects on the intertidal will likely alter the vertical distribution of *F. distichus* which could then affect the composition and diversity of the assemblages that rely on its canopy for survival. We compared the invertebrate and algal assemblages living under the *F. distichus* canopy between the upper and lower limits of the *F. distichus* zone to compare their composition and diversity. Our findings reveal a significant difference in assemblage composition across two zonal heights at the three sites we sampled at. Our results suggests that the potential shifts in *F. distichus* may have a negative effect on the diversity of the understory assemblages and force a homogenization of the intertidal community.

## Introduction

*Fucus distichus* (Phaeophyta) is a prominent canopy forming brown alga that can dominate large portions of the intertidal along the western shores of North America. The physical presence of this rockweed can have a significant effect on invertebrates and other algae (Ingólfsson 2008) and consequently *F. distichus* creates an important habitat that influences the composition of the surrounding intertidal assemblages. Rockweeds provide many services to the surrounding intertidal ecosystem and studies have consistently shown that their presence plays a key role in enhancing biodiversity and supporting many of the macro- and micro-invertebrates that reside in the intertidal. Canopy-forming seaweeds such as rockweeds can form microhabitats suitable for small invertebrates and juvenile fish, act as food for herbivorous grazers such as limpets and snails, and help to ameliorate the effects of desiccation for vulnerable invertebrates and algae during low tides by providing a cool and moist understory habitat (Jenkins et al. 1999, Edgar et al. 2004). These key roles that rockweed play in the intertidal makes it an important endeavor to monitor its distribution and survival while simultaneously conducting robust studies of its impact on the macro-fauna and flora that it provides canopy for.

An increasing concern among intertidal ecologists is the impact that climate change will have on the vertical distribution of rockweeds (Nicastro et al. 2013) As climate change and its various effects alter the distribution of *Fucus* along the intertidal, we can expect this to consequently have an impact on the fauna and flora that *Fucus* provide habitat and canopy for. Several studies have already found that understory assemblages respond significantly to a loss in seaweed canopy, with loss being attributed to several additive factors such as urbanization, climate and ocean warming, low tide stress, and thermal irradiation and stress (Helmuth et al. 2002, Tanaka et al. 2012, Martínez et al. 2012, Jueterbock et al. 2016). Although the specific responses of *F. distichus* to these increasingly stressful abiotic and biotic conditions have yet to be exactly determined, studies on the ecology and physiology of rockweeds predict a ‘squeeze’ in the vertical distribution of *Fucus*, with stresses applying pressure on both the upper and lower limit of its growth (Martins et al. 2019).

Although many past studies have been conducted on the removal of canopy-forming seaweeds and its effects on the understory assemblages, few have examined how the composition and diversity of the *F. distichus* understory differs across the upper and lower limits of its distribution. Quantifying the differences between the upper and lower limits of rockweed growth can help us better understand which groups may be most vulnerable to this ‘squeeze’ and therefore would be hardest hit from the impacts of climate change. Identifying the composition of the assemblages at these zone limits will allow us to better predict how the broader intertidal community could shift as a result of changes in rockweed distribution. We used an observational study to examine the assemblages that form under the canopy of *F. distichus* at the upper and lower limits of its growth and evaluated these differences using an NMDS analysis to help us better predict what the effects of climate change may have on the assemblages of invertebrates and algae throughout the intertidal. We hypothesized that there would be a detectable difference in assemblage composition and diversity between the upper and lower limits of the vertical distribution of *F. distichus* along the intertidal shores of San Juan Island.

**Methods**

Sampling was conducted on San Juan Island at three different sites: Cantilever Point (48.5462, -123.0097), Cattle Point (48.4499, -122.9632), and Deadman's Bay Preserve (48.5131, -123.1467) from May 20$^{th}$ to May 27$^{th}$ 2021 during low tides ranging from -1.7' to -3.2' that occurred from late morning to noon. We sampled fifteen 25cm$^2$ quadrats along each transect of 25m, with one transect each at the upper and lower limits of the *F. distichus* zone. We placed quadrats in areas that had at least 90% *Fucus* cover at each of the tidal heights. Within each quadrat we examined the *Fucus* for invertebrate grazers and algal epiphytes, then proceeded to examine the understory for invertebrates and algae. We counted the abundance of invertebrates to species when possible and genus when we could not identify it to species level. We estimated the perfect cover of algae which were identified to the species level – those we could not identify were classified to functional group.

Invertebrates and algae were separated during data analysis due to the different methods for measuring abundance. We compared abundances across height and site using an NMDS analysis for both invertebrates and algae. A Simper analysis was conducted to determine dissimilarity between the high and low zone across invertebrate species. A Simper analysis for algae was conducted but was less specific because of difficulties in identifying certain algae to a species level – the analysis compares certain species to morphological groups, which is useful but can be misleading. Total species richness was calculated with combined invertebrates and algae for each height at every site. A Simpsons diversity analysis was also performed for invertebrates and algae separately because abundance counts differed between the two. We included richness and diversity were chosen to be included due to the importance of considering abundance in conjunction with overall species richness to better estimate assemblage composition. All statistical tests were run using RStudio 1.2.5033.

## Results

The NMDS analysis revealed that there was a clear separation between both invertebrate (Stress = 0.1944, Figure 1) and algae (Stress = 0.1381, Figure 2) assemblages across the upper and lower limit. Cattle Point and Lime Kiln were more similar in assemblage composition whereas Cantilever was simultaneously least similar to the other two sites and more variable across high and low *F. distichus* tidal heights.

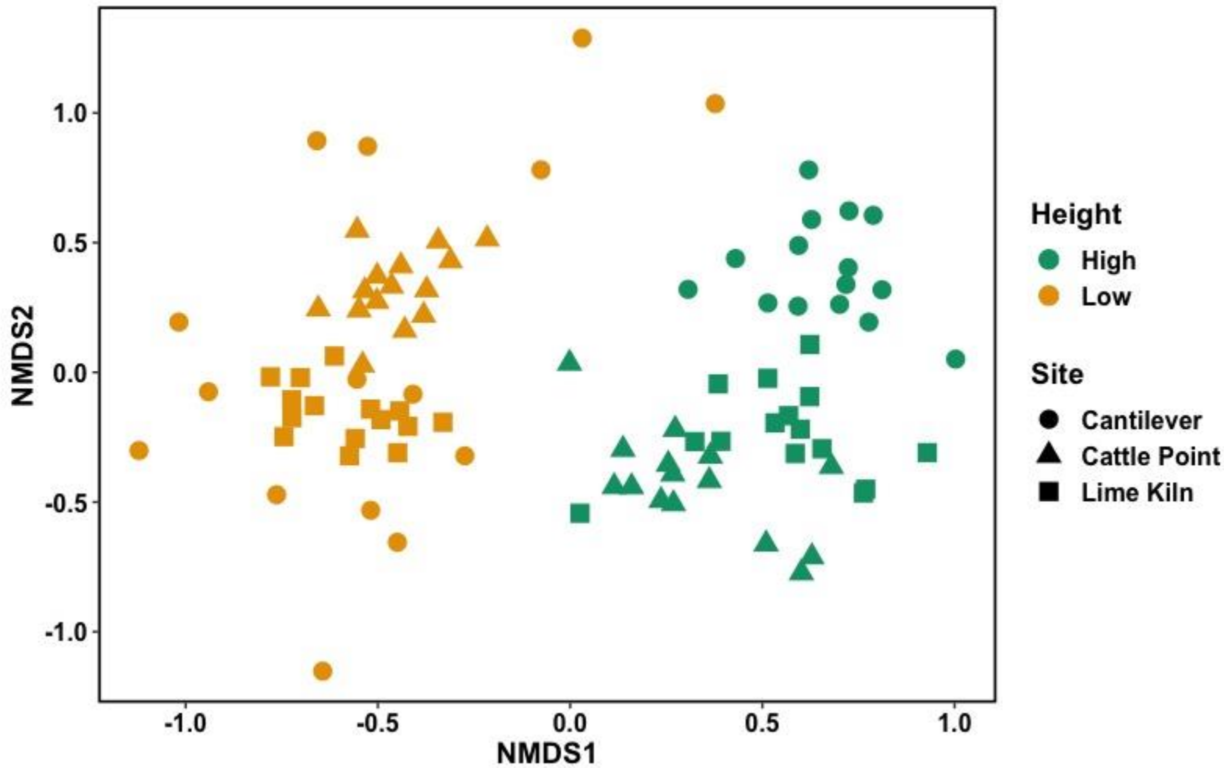


Figure 1: NMDS plot of invertebrates across High and Low limits of F. distichus growth. Stress = 0.1944. Shapes indicate site, colors indicate height of Fucus distichus growth, each point represents one quadrat.

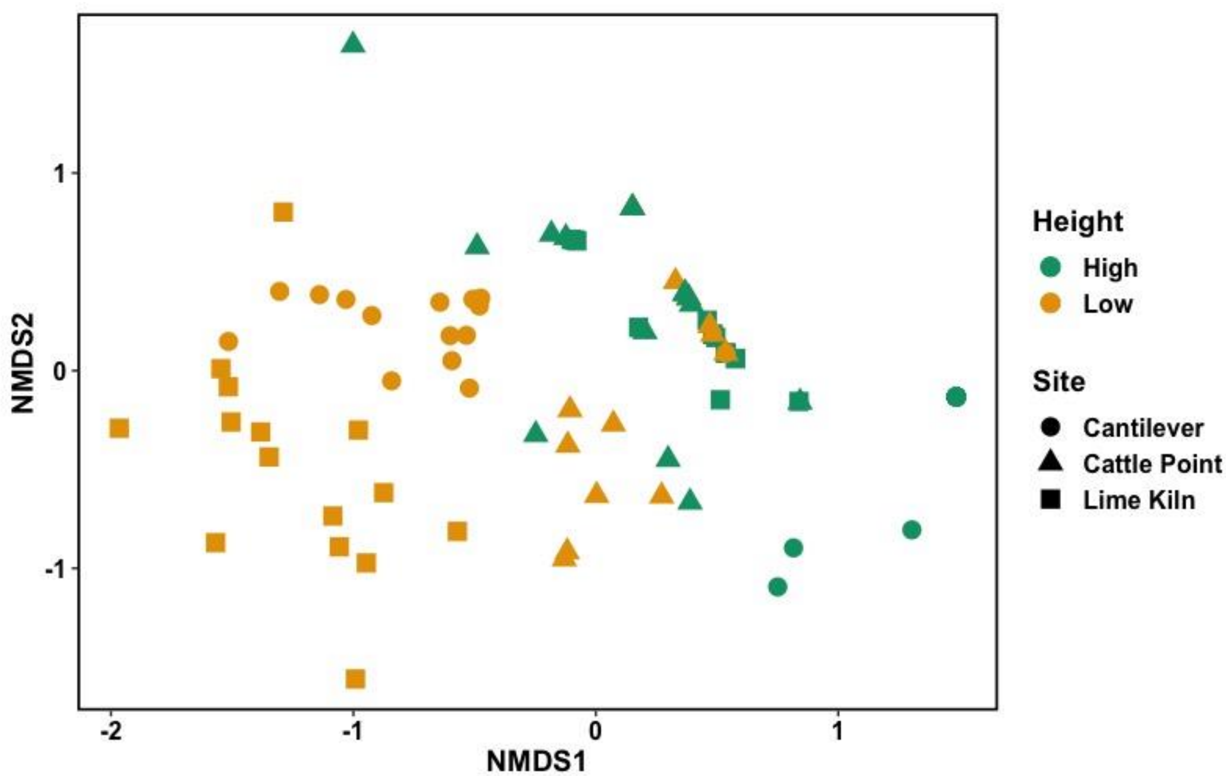


Figure 2: NMDS plot of algae across High and Low limits of F. distichus growth. Stress = 0.1381. Shapes indicate site, colors indicate height of Fucus distichus growth, each point represents one quadrat.

The Simper analysis revealed that 70% of the dissimilarities between invertebrate assemblages was attributed to three species: *Littorina scutulata*, *Chthamalus dali*, and *Semibalanus cariosus*, with this pattern being consistent across height and site. The only exception was Cattle Point, where *Anthopleura elegantissima* also contributed to dissimilarity between high and low *F. distichus* zones. The four groups of understory algae that contributed most to the dissimilarity across height and site were crustose *Petrocelis, Endocladia muricata*, filamentous red, and upright *Mastocarpus stellatus*. This pattern was consistent across sites and *F. distichus* upper and lower zones.

Species counts indicate that lower zones had higher species richness overall, a pattern consistent across the three sites (Figure 3).

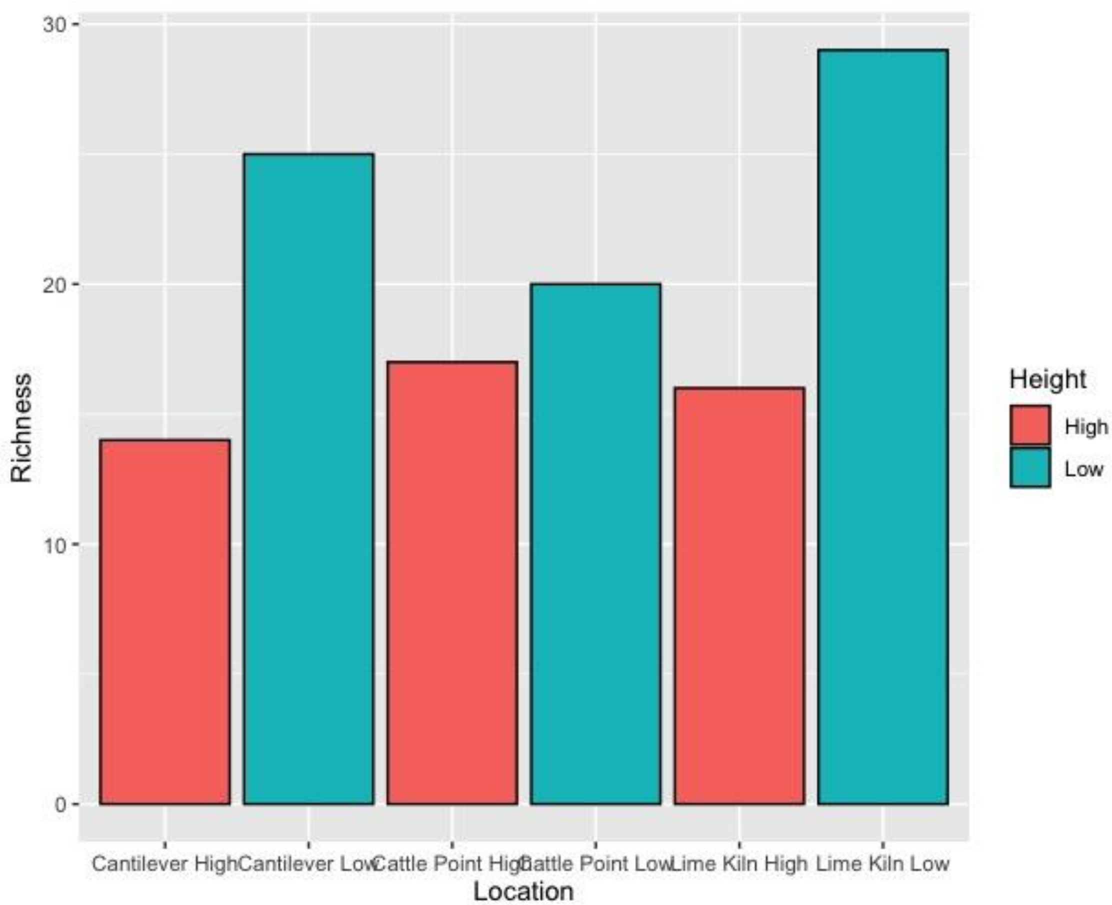


Figure 3: Total cumulative richness of each site at each height of Fucus growth. Richness was calculated by total number of species counted and recorded at each height per site

This pattern remains consistent when abundance is considered using the Simpson's diversity analysis for both invertebrate (Figure 4) and algal assemblages (Figure 5). Simpson's diversity varied across sites, a pattern consistent when comparing between invertebrate and algal assemblages. Both high and low Lime Kiln transects had higher diversity than any transect at Cattle Point, but both high and low transects at Lime Kiln are lower in invertebrate diversity compared to Cattle Point. Cantilever was most variable across all diversity analyses.

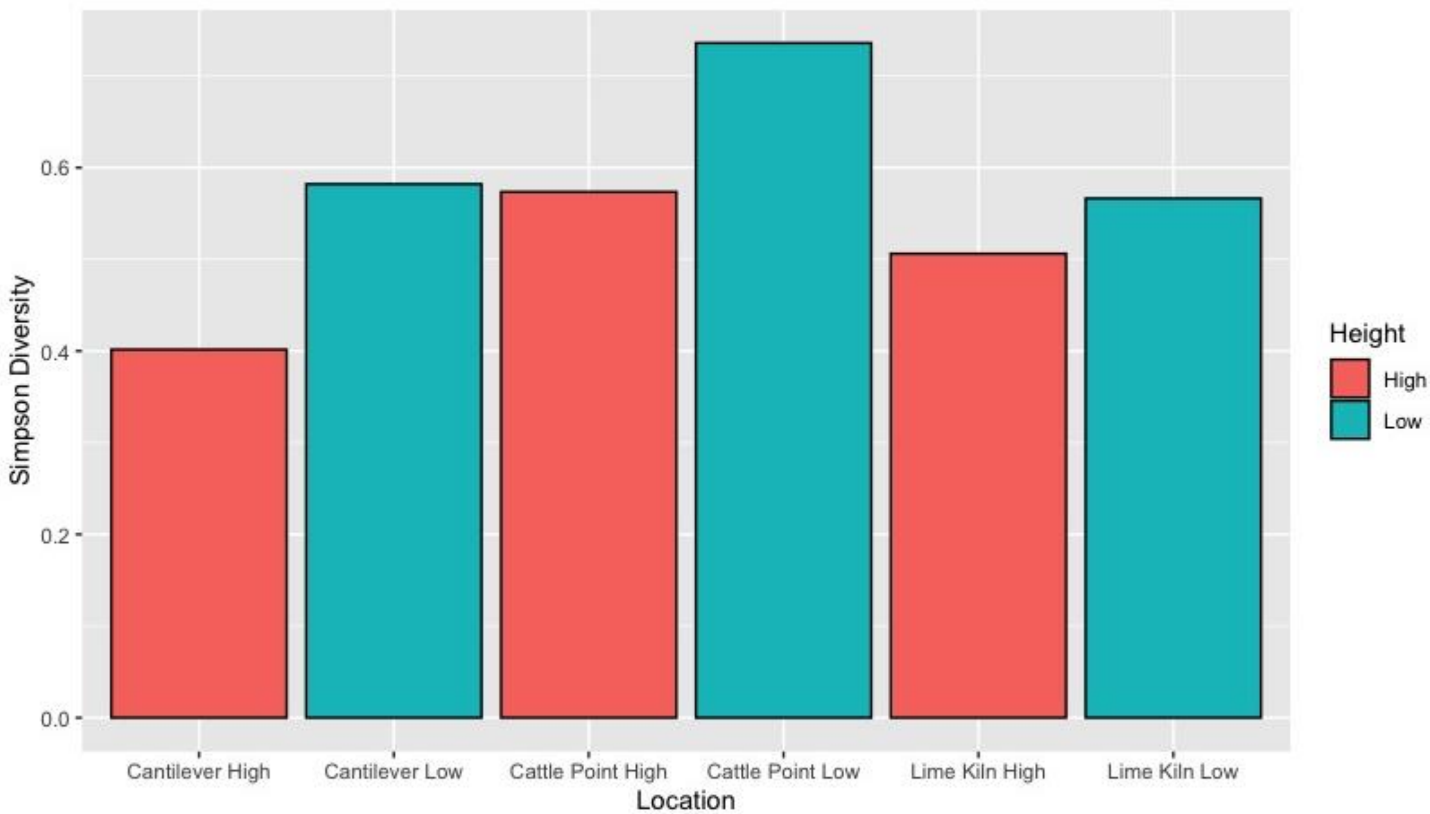


Figure 4: Mean Simpson diversity for Invertebrates across Fucus growth zones at each site, colors represent different zonal height

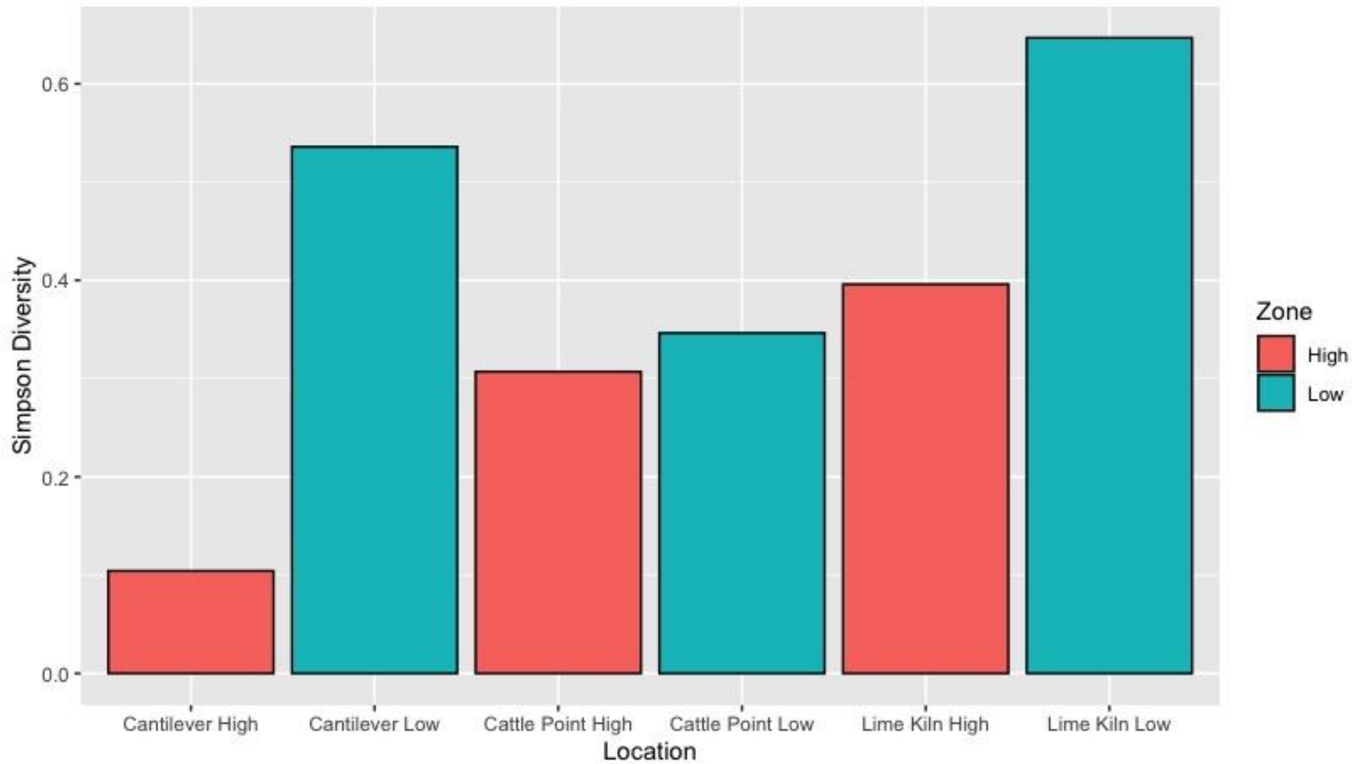

Figure 5: Mean Simpson diversity for Algae across Fucus growth zones at each site, colors represent different zonal height

**Discussion**

The assemblages we examined at the upper and lower limits of the rockweed *Fucus distichus* in the intertidal differed significantly in both composition and diversity across the three different sites. These findings support our hypothesis that the assemblage composition of invertebrates and algae would vary across the vertical distribution of *F. distichus* and that this pattern would be consistent across the intertidal, even at different sites. The differences in assemblages suggest that a forced 'squeeze' in *F. distichus* distribution can either result in increased abiotic stresses for the invertebrates that no longer have canopy in the form of rockweed cover or result in increased competition and predation along the intertidal if these invertebrates are forced to shift alongside the rockweed.

Past studies have already shown that the vertical distribution that *F. distichus* encompasses and the many services it provides for understory invertebrates and algae causes rockweed to play a key role in shaping the composition of intertidal assemblages across a large portion of the intertidal (Cowles 1922). Species richness does not necessarily differ in the presence of a rockweed canopy but abundance and diversity decreases significantly when *Fucus* is removed (Lilley and Schiel 2006, Wikström and Kautsky 2007). The ability of *F. distichus* to grow along a steep gradient of tidal height contributes to the diversity of these intertidal assemblages – its persistence across a large vertical range allows the vertical distribution of invertebrate and algae assemblages to also be expanded (Bulleri et al. 2002). Currently we see that there is high variance both in composition and diversity in the assemblages across the upper and lower limits of the *Fucus* zone – this may suggest that the disappearance of *F. distichus* at the upper and lower limits of this distribution could lead to a homogenization of these assemblages and an overall loss in biodiversity in the intertidal.

Study after study has shown that removal of rockweeds and other canopy-forming seaweeds have a detrimental effect on the overall biodiversity and primary production of intertidal communities. We examined the additional nuance of how this change could impact understory assemblages differently due to variation in composition and diversity of assemblages across the vertical distribution of *F. distichus*. The difference in assemblage composition and diversity across a small area of steep vertical distribution suggests that the intertidal community could become more vulnerable to the large-scale shifts in canopy that is projected to occur in the future. One factor that we did not analyze in this study was the difference in functional morphology across the invertebrates we assessed. Community ecology can oftentimes be hard to quantify because it becomes easy to ignore the influence of bio-physiology when drawing conclusions and forming predictions about broad ecological patterns. Further studies should aim to incorporate specific functional and morphological traits alongside broad ecological trends to better model the effects that these global shifts will cause.

## Works Cited


Bulleri, F., L. Benedetti-Cecchi, S. Acunto, F. Cinelli, and S. J. Hawkins. 2002. The influence of canopy algae on vertical patterns of distribution of low-shore assemblages on rocky coasts in the northwest Mediterranean. Journal of Experimental Marine Biology and Ecology 267:89–106.

Cowles, H. C. 1922. Vertical Distribution of Fucus. Botanical Gazette 73:334–335.

Edgar, G. J., N. S. Barrett, A. J. Morton, and C. R. Samson. 2004. Effects of algal canopy clearance on plant, fish and macroinvertebrate communities on eastern Tasmanian reefs. Journal of Experimental Marine Biology and Ecology 312:67–87.

Helmuth, B., C. D. G. Harley, P. M. Halpin, M. O'Donnell, G. E. Hofmann, and C. A. Blanchette. 2002. Climate change and latitudinal patterns of intertidal thermal stress. (Reports). Science 298:1015+.

Ingólfsson, A. 2008. The invasion of the intertidal canopy-forming alga Fucus serratus L. to southwestern Iceland: Possible community effects. Estuarine, Coastal and Shelf Science 77:484–490.

Jenkins, S. R., S. J. Hawkins, and T. A. Norton. 1999. Direct and indirect effects of a macroalgal canopy and limpet grazing in structuring a sheltered inter-tidal community. Marine Ecology Progress Series 188:81–92.

Jueterbock, A., I. Smolina, J. A. Coyer, and G. Hoarau. 2016. The fate of the Arctic seaweed Fucus distichus under climate change: an ecological niche modeling approach. Ecology and Evolution 6:1712–1724.

Lilley, S. A., and D. R. Schiel. 2006. Community effects following the deletion of a habitat-forming alga from rocky marine shores. Oecologia 148:672–681.

Martínez, B., F. Arenas, M. Rubal, S. Burgués, R. Esteban, I. García-Plazaola, F. L. Figueroa, R. Pereira, L. Saldaña, I. Sousa-Pinto, A. Trilla, and R. M. Viejo. 2012. Physical factors driving intertidal macroalgae distribution: physiological stress of a dominant fucoid at its southern limit. Oecologia 170:341–353.

Martins, G., C. Harley, J. Faria, M. Vale, S. Hawkins, A. Neto, and F. Arenas. 2019. Direct and indirect effects of climate change squeeze the local distribution of a habitat-forming seaweed. Marine Ecology Progress Series 626:43–52.

Nicastro, K. R., G. I. Zardi, S. Teixeira, J. Neiva, E. A. Serrão, and G. A. Pearson. 2013. Shift happens: trailing edge contraction associated with recent warming trends threatens a distinct genetic lineage in the marine macroalga Fucus vesiculosus. BMC Biology 11:6.

Tanaka, K., S. Taino, H. Haraguchi, G. Prendergast, and M. Hiraoka. 2012. Warming off southwestern Japan linked to distributional shifts of subtidal canopy-forming seaweeds. Ecology and Evolution 2:2854–2865.

Wikström, S. A., and L. Kautsky. 2007. Structure and diversity of invertebrate communities in the presence and absence of canopy-forming Fucus vesiculosus in the Baltic Sea. Estuarine, Coastal and Shelf Science 72:168–176.