

Invertebrate Abundance and Rate of Decomposition in Beach Wrack of *Zostera marina* and *Fucus distichus*

Jacqui Levy, Megan Dethier, Alex Lowe

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Contact information:

Jacqui Levy

Jacqui2@uw.edu

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Abstract

Beach ecosystems rely on the supply of off-site primary production in the form of stranded algae, or beach wrack. As beach wrack washes up on shore, it is colonized by a host of microbes, detritivores and herbivores, which supply the beach ecosystem food web. This study seeks to understand how nutrients are transferred from seaweed throughout the food web by looking at how mass loss changes in beach wrack as larger invertebrates are included or excluded from the system. We found more total colonizers of beach wrack in treatments that included larger invertebrates. The community structure of colonizers shifted with site, and in treatments that included large amphipods there was more mass loss of algae due to herbivory. In wrack with more ephyridae larvae, mass loss was more uniform between treatments. This shows that the community dynamics of beach wrack colonizers affect how it is degraded, and that the presence of large herbivores like amphipods contributes to the degradation of wrack and thus its integration into the beach ecosystem food web.

Introduction

Beach wrack is the tangle of seaweed and sea grass that is transported from coastal ecosystems to sandy and rocky shores around the world (Heerhartz et al. in press). The arrival of beach wrack on the shore represents a movement of nutrients from the nearshore environment to the marine-terrestrial ecotone (Mews et al. 2006). As beach wrack decays due to microbes and detritivores, the drying and rewetting cycles of the tides, and herbivory, nutrients are released into the surrounding sediment (Dugan et al. 2011, Lavery et al. 2013). The flux of beach wrack is a bottom-up control for beach ecosystems, as it provides food for herbivores, like amphipods, which in turn provide

food for migratory or resident shorebirds and small mammals (Orr et al. 2005, Dugan et al. 2003, Dugan et al. 2010). This input provides structure and habitat for an environment that would otherwise lack enough autochthonous input to support a food web.

The ecosystem function of beach wrack on wave-exposed sandy shores is well studied. Species richness and abundance are positively correlated with the amount of wrack, and there is a higher species diversity and abundance of invertebrates as well as feeding shorebirds when beach wrack is abundant (Dugan et al. 2003, Ince et al. 2007). Where there is more beach wrack there is more inorganic and organic nitrogen in the sediment (Dugan et al. 2003). There is evidence that beach wrack not only provides nutrients but can also contribute to the formation of sand dunes by slowing sand movement and trapping moisture for seedlings (Dugan et al. 2009). Sandy beaches that have lost their beach wrack through anthropogenic influences may turn into unvegetated sand (Dugan et al. 2009).

The role of beach wrack is less studied for sheltered pebble-sand beaches. The composition of fresh wrack on such beaches depends on wave exposure and substrate size, with larger substrates tending to trap more wrack (Orr et al. in 2005). The wrack species present are determined by the algae and sea grass in the local nearshore environment (Ruiz-Delgado et al. 2014). If the beach has armoring structures, the composition of the wrack is altered and there is less wrack (Heerhartz et al. in press). Algae in beach wrack are decomposed or eaten at different rates, with *Nereocystis luetkeana* losing weight rapidly, *Phyllospadix* spp less rapidly, and *Fucus* spp losing mass very gradually (Mews et al. 2006). It is not clear how mass is lost in beach wrack,

whether it is through herbivory by amphipods, microbial decay, or other factors. My study aims to distinguish how the mass of wrack species *Nereocystis luetkeana*, *Fucus distichus*, and *Zostera marina* changed when amphipods and other large herbivores were excluded from the wrack. I hypothesize that the mass loss of *Fucus distichus* and *Zostera marina* can be explained by the abundance of amphipods and the dynamics of the colonizer communities in the beach wrack.

Methods

Tubes with fresh beach wrack were set up at Point Caution and Friday Harbor Labs, San Juan Island. Point Caution is a small, crescent shaped coarse sand and gravel beach bounded at either end by bedrock that faces north and is in the University of Washington's biological preserve. Terrestrial bushes and trees hang over into the wrack line. The beach selected on the Friday Harbor Labs campus, near Lab 12, is a south-facing cobble beach that is bounded on either end by bedrock, has a cement armoring structure just beyond the wrack line. The terrestrial plants are sparse and include low shrubs behind the concrete armoring structure. Both beaches are only moderately wave exposed.

I collected fresh subtidal *Zostera marina* blades and fresh intertidal *Fucus distichus* from the harbor in front of Friday Harbor Labs, and fresh *Nereocystis luetkeana* blades from Turn Rock. All plants were kept in running sea water and then blotted two to three times, weighed, and placed into 16 centimeter long pvc tubes that were 6 centimeters in diameter. The ends of each tube were covered with either ½ centimeter plastic mesh for a large mesh treatment, or 250 microns nitex for small mesh treatment. There were five of replicates of each mesh treatment for *Z. marina*, *F. distichus* and for

N. luetkeana. One large and small mesh treatment tube for each wrack species were attached to a rebar stake and pounded into the sediment at the wrack line. In the first experiment at Point Caution, wrack tubes were left out for twenty-two days, and then placed in plastic bags and frozen overnight. Before sorting, the wrack was thawed at room temperature for twenty-four hours and then the algae in each tube were washed over a 200 micron sieve to catch any invertebrates that had colonized the tubes. Invertebrates in the sieve were collected in plastic jars to be sorted later. The algae were set in bags of sea water overnight to completely rehydrate. After the algae were rehydrated, they were blotted several times until their moisture level was similar to pre-experiment levels, and then weighed.

The second experiment was set out on the beach near Lab 12 in Friday Harbor Labs one week after the experiment at Point Caution, and it ran for seventeen days.

A count was taken of individuals of each order or class of arthropod present identifiable under a dissecting scope. The data on arthropods and the weight differences of each of the treatments were calculated and graphed in excel. Statistical methods included 2-way ANOVA tests and t-tests and were computed using JMP.

Results

When wrack tubes were collected, it was found that *N. luetkeana* had been completely decomposed, and so the results of these treatments were not calculated. Furthermore, because the treatments for each of the study sites were left out for different amounts of time, the data were analyzed separately.

Colonizers in the tubes were separated into five categories: amphipods, ephyridae, ephyridae larvae, annelids, gastropods, and coleoptera. Nematodes were

also counted, but it was unclear if these were from the sea water used to rinse the algae and so these results were omitted. At Point Caution, amphipods were counted in both *F.distichus* and *Z. marina* large mesh sizes, but not in the small sizes. Ephydriidae larvae were counted throughout the treatments, and ephydriidae were present in all but *Z. marina*, small mesh treatment. Annelids were found in all treatments but *F.distichus* large mesh sizes, and there were no gastropods and coleoptera found in treatments at Point Caution (Table 1).

Table 1. Average colonizers per small and mesh treatment size at Point Caution for *F. distichus* and *Z. marina*.

	Amphipods	Ephydriidae larvae	Ephydriidae	Annelids	Gastropods	Coleoptera	TotalAvg. colonizers
<i>F. distichus</i> , large mesh	4.4	330.2	1.6	0	0	0	336.2
<i>F. distichus</i> , small mesh	0	245.25	2.75	3	0	0	251
<i>Z. marina</i> , large mesh	7.8	101	4	0.2	0	0	113
<i>Z. marina</i> , small mesh	0	61.25	0	1.25	0	0	62.5

At Friday Harbor Labs, amphipods were counted in all mesh sizes for both wrack species. Ephydriidae larvae were present in all treatments except *Z. marina*, small mesh, and ephydriidae were present in the large mesh treatments except the small mesh treatments. Annelids were found in all treatments except *Z.marina* large mesh sizes, gastropods in all except *Z. marina*, large mesh and coleoptera found only in *F. distichus* (Table 2).

Table 2. Average colonizers per small and mesh treatment size at Friday Harbor Labs for *F. distichus* and *Z. marina*.

	Amphipods	Ephydridae larvae	Ephydridae	Annelids	Gastropods	Coleoptera	Total Avg. colonizers
<i>F. distichus,</i> large mesh	281	40	28	29.6	0.2	1.6	370.8
<i>F. distichus,</i> small mesh	28.8	2.8	0	4	0.2	0.6	35.8
<i>Z. marina,</i> large mesh	127.8	76.4	2	0	0	0	206.2
<i>Z. marina,</i> small mesh	49	0	0	26.75	0.25	0	76

An analysis of total colonizers (amphipods, ephydridae, ephydridae larvae, annelids, gastropods, and coleoptera) for Point Caution showed there was no significant effect on algae genera (Two-way ANOVA; $p=0.1316$), but there was a significant effect on mesh size (Two-way ANOVA; $p=0.0015$). There was a significant interaction with algae genera and mesh size (Two-way ANOVA; $p= 0.0242$). The Friday Harbor Laboratory site showed a significant effect of algae genera (Two-way ANOVA; $p=0.0098$), a non-significant effect on mesh size (Two-way ANOVA; $p=0.9074$), and an interaction with algae genera and mesh size (Two-way ANOVA; $p= 0.2126$). At Point Caution there were more colonizers in both of the *F.distichus* mesh size treatments than in both of the mesh size treatments for *Z. marina*. For algae genera at Point Caution there were more total colonizers in the large mesh treatments than the small mesh treatments. At Friday Harbor Laboratories, *F. distichus* had more total colonizers than *Z. marina* in the large mesh treatment but not in the small treatment. In each algae genera at Friday Harbor Laboratories there were more total colonizers in the large mesh treatments than the small mesh (Figure 1).

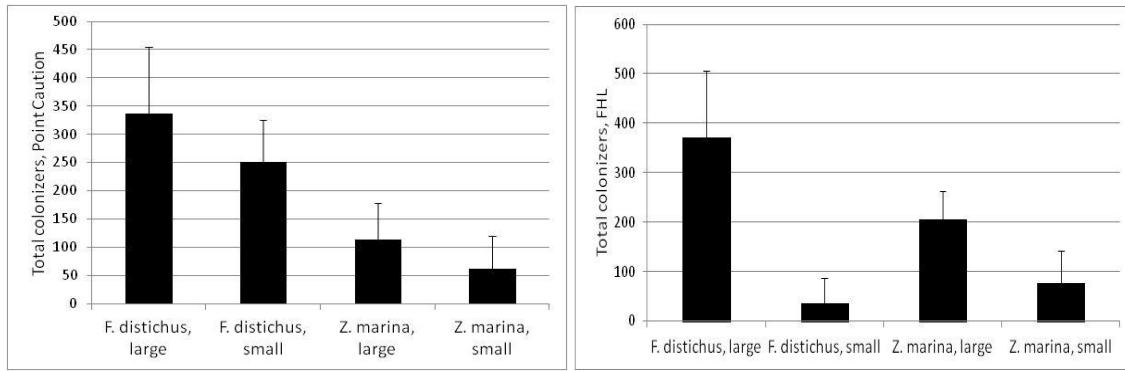


Figure 1. Average total colonizers at Point Caution, left, and Friday Harbor Labs, right, for each genus of algae with small and large mesh size treatments.

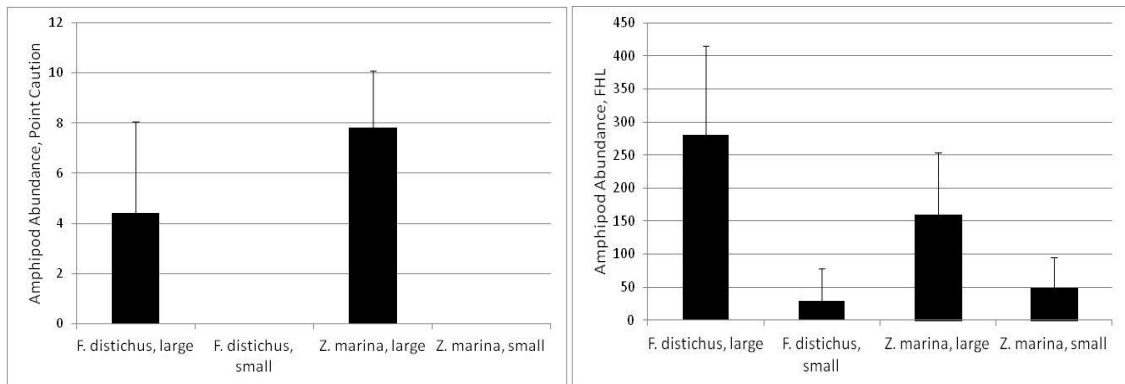


Figure 2. Amphipod abundance at Point Caution, left, and Friday Harbor Labs, right, for each genus of algae with small and large mesh size treatments. The large mesh sizes for both algae genera show a greater abundance of amphipods.

Amphipod abundance was not significantly different between tubes with different algae but was significantly different between mesh types (Two-way ANOVA; Point Caution: $p=0.1176$ and <0.0001 , respectively; FHL: $p=0.1501$ and 0.0018 , respectively). There was not a significant interaction between algae genera and mesh size at either site (Two-way ANOVA; Point Caution: $p=0.1176$, FHL: $p=0.0667$). Amphipod abundance was higher in the large mesh sizes for both *Z. marina* and *F. distichus* at both sites (Figure 2).

Average percent change in mass was significantly different between tubes with different algae genera at Point Caution (Two-way ANOVA; Point Caution: $p < 0.0001$),

and at Friday Harbor Labs (Two-way ANOVA; FHL: $p < 0.0001$). At Point Caution, the effect of mesh size was not significant (Two-way ANOVA; $p = 0.1253$), but it was significant at Friday Harbor Labs (Two-way ANOVA; $p < 0.0001$). There was a significant interaction for Point Caution between mesh size and algae genus which indicates that the effect of mesh sizes were different between algae genera (Two-way ANOVA; $p = 0.0182$). At Point Caution, there was a non-significant effect of mesh size on percent mass change for *F. distichus* (t-test, $p = 0.5755$), and a significant effect of mesh size on percent mass change for *Z. marina* (t-test, $p = 0.0116$). There was a significant difference in percent change in mass between genera, with *F. distichus* losing more mass than *Z. marina* at both sites. At Point Caution, the large mesh treatment *Z. marina* lost more than the small mesh treatment, but the small *F. distichus* lost slightly more than the *Z. marina*. At Friday Harbor Labs, both the large mesh sizes for both algae genera lost more mass than the small mesh sizes for each algae genera (Figure 3).

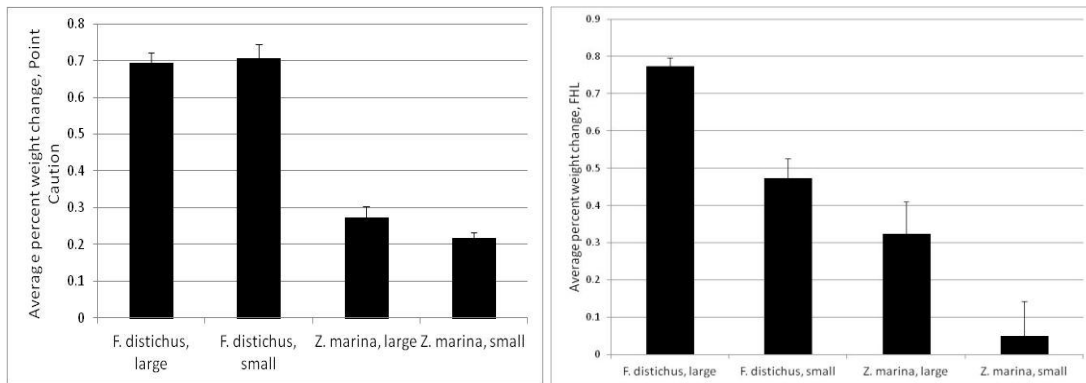


Figure 3. Average percent weight change at Point Caution, left, and Friday Harbor Labs, right, for each algae genera with small and large mesh size treatments.

Discussion

My findings indicate that the inclusion of larger invertebrates changes the community structure of *F. distichus* and *Z. marina* beach wrack. At both sites, the larger

mesh size treatments had more total colonizers than in the small mesh treatments. At Point Caution the bulk of the total colonizers consisted of ephyridae larvae, while at Friday Harbor Labs there were far more amphipods than ephyridae larvae. And at both sites amphipod abundance was higher in the larger mesh sizes for both *Z. marina* and *F. distichus*.

At the Friday Harbor Labs site, the wrack with the larger mesh size treatment lost more mass than the smaller mesh treatment. The larger mesh size also had more colonizers. As the dominant colonizers at this site were amphipods, this could indicate that some mass loss was due to herbivory. However, at the Point Caution site, the *F. distichus* small treatment lost about as much mass as the *F. distichus* large treatment, even though there were more amphipods in the larger mesh treatment. The community structure at this site was different, as the dominant colonizer in all mesh sizes was the ephyridae larvae. This could indicate that the ephyridae larvae contributed to the mass loss in *F. distichus* rather than the amphipods. *Z. marina* at this site had more mass loss in the larger mesh treatments, and also had more amphipods in the larger mesh treatment. Since the dominant colonizer at this site was the ephyridae larvae, it is likely that this affected the mass loss in *Z. marina* as well as the presence of amphipods. The experiment at Point Caution ran for five days longer than the experiment at Friday Harbor Labs which may have caused the variation in community dynamics.

At both sites, *F. distichus* showed greater mass loss than *Z. marina*, which is in contrast to a study that found *Z. marina* loses mass more rapidly than *F. distichus* (Mews et al. 2006). However the 2006 study looked at beach wrack over 24 hours rather than 2-3

weeks. In addition this study did not look at the invertebrate communities in the collected beach wrack, which would have influenced the degradation amount of the wrack.

My study contributes to the understanding of how nutrients in nearshore seaweeds get transported to the beach ecosystem. It is likely that if there is more wrack decay, as in most of the large mesh treatments, there are more nutrients being leached into the sediment and the intertidal zone, since the presence of beach wrack is correlated with more nitrogen in sediment, which supports more flies and amphipods, which feed other organisms (Dugan et al. 2003). These nutrients from the decaying seaweeds have a bottom-up effect on the ecosystem, as they support both terrestrial and intertidal primary producers, as well as detritivores and herbivores like amphipods (Dugan et al. 2003). Thus, beach wrack supports a beach food web that may not exist without this transfer of nutrients from nearshore primary production, and amphipods play a role in this nutrient transfer.

It is important to understand these ecosystem functions, since beach ecosystems are fragile and constantly affected by human activity like development and pollution (Dugan et al. 2010, Heerhartz et al. in press). Anthropogenic climate change is a new yet daunting threat, and the impacts to the beach ecosystem from sea level rise and increased erosion from storms are likely to be significant (Dugan et al. 2010, Revell et al. 2011). Understanding how beach wrack acts as a nutrient transfer that supplies the food web is important to be able to adequately apply management and development strategies for coastlines. More research is necessary to understand how wrack is integrated into the ecosystem for cobble beaches in the Salish Sea, how nitrogen and carbon become

integrated into the cobble beach environment from nearshore primary production, and how this helps form the food web in the marine-terrestrial ecotone.

This present study found that beach wrack composed of *Z. marina* and *F. distichus* is decayed more by the presence of amphipods. Many other species can be found in beach wrack, but the role of amphipods in their decomposition was not tested. Wrack tube experiments should be replicated on several similar beaches throughout San Juan Island, perhaps over a shorter period of time, so that the mass loss and community composition of *N. luetkeana* and other algae can be measured.

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