Community effects of an invasive bryozoan, *Watersipora subtorquata*, in the Monterey harbor

A Senior Thesis

Submitted by

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ABSTRACT: Invasive species are a conservation concern because they often change the ecological communities they invade. Invasive species can compete with or prey on native species, or alter the structure of the habitat (ecosystem engineers). The invasive bryozoan *Watersipora subtorquata,* is abundant in the Monterey harbor and has been sighted in kelp forests in the Monterey Bay. We examined whether there is evidence that *Watersipora* has affected the "fouling community", i.e. sessile invertebrates and algae that inhabit man-made structures, by studying the differences between photoquadrats with various levels of *Watersipora* cover. *Corynactis californica* negatively responded to increasing abundance (percent cover) of *Watersipora*, while *Membranipora fusca* positively responded. *Diplosoma listerianum* had high percent cover when there was high cover of *Watersipora* and when *Watersipora* was low or absent, but *D. listerianum* was much less abundant at moderate levels of *Watersipora*. Our results suggest that *Watersipora* influences this fouling community because of the differences between the communities with different levels of *Watersipora*. However, experimental manipulations of the community would be necessary to confirm that *Watersipora* is the cause of these differences. It will be interesting to following changes in *Watersipora* abundance and its interactions with other species, both in the Monterey harbor and in the kelp forests, to see how *Watersipora* affects the native community.

INTRODUCTION

Invasive species are a conservation concern because they sometimes alter ecosystems and can result in extinctions of native species. Invasive species are believed to be a main cause of global declines in biodiversity (Sala et al 2000). However, some researchers have argued that invasion may just be correlated with other processes that reduce biodiversity (i.e. habitat destruction) and may not be the direct cause of extinctions (Gurevitch and Padilla 2004). Moreover, invasive species can colonize ecosystems and not contribute to the local extinction of native species. Whether or not invasive species have been the direct cause of extinctions, invasive species have had impacts in many systems. Known effects of invasive species include shifts in the community composition (Brown and Gurevitch 2004) and negative interactions with native species including competition and predation (references in Crooks 2002, Fritts and Rodda 1998). There are also examples of invasive species that act as ecosystem engineers by modifying the physical structure of the environment increasing species richness or abundances of certain species (Castilla et al 2004, Crooks 1998).

Watersipora subtorquata (d'Orbigny, 1852) (hereafter *Watersipora*) is an invasive bryozoan that has been in the Monterey Bay since at least 1994 (http://www.exoticsguide.org/species_pages/w_subtorquata.html) (Figure 1). In a study by the California Department of Fish and Game (2002), *Watersipora* was the most commonly encountered introduced species and was found at all sites surveyed. In Monterey Harbor, *Watersipora* grows patchily in extensive reefs several centimeters thick on the wooden pilings on wharf #2 outside the seawall (Figure). On the concrete, flat-sided pilings within the seawall, *Watersipora* grows flat on the pilings and does not extend outward into large reefs and there appears to be a higher diversity of sessile invertebrate species. Mobile invertebrates and fish are often seen in the folds of *Watersipora* colonies, so it is of particular interest because it may provide habitat to other invasive species or native ones.

Figure 1. *Watersipora* in its crustose form and erect form, shown with the invasive tunicate *Diplosoma listerianum*.

Watersipora has been sighted in the kelp forest at Hopkins Marine Reserve (Lonhart and Watanabe pers. comm.). At Hopkins, *Watersipora* has patchy distribution from shallow areas to the edge of the kelp forest (~10 – 11-m depth) and may vary considerably in abundance between seasons (Watanabe pers. comm.) *Watersipora* is not thought to disperse far because it has a short larval duration of less than one day (http://www.exoticsguide.org/species_pages/w_subtorquata.html). However, colonies have been observed in the Monterey harbor detached from any substrate but still alive (Lonhart pers. comm.), and this might facilitate dispersal. As an invasive species, *Watersipora* is a conservation issue for kelp forests. With the sightings of *Watersipora* in kelp forests and the large colonies in Monterey harbor, it is important to know just what effect it might have on the native communities that inhabit shallow rocky reef and kelp forest ecosystems along the coast of central California. We wanted to know to what extent the *Watersipora* invasion has affected the fouling community in Monterey harbor. Our research questions are: 1) How is *Watersipora* distributed on the pilings of Monterey harbor? 2) Are there patterns in community structure on the pilings of the harbor in the absence of *Watersipora*? And 3) Does the community on these pilings differ as a function of *Watersipora* cover?

METHODS

Watersipora is a sessile colonial bryozoan that feeds on plankton and grows by spreading over the surface of the substratum it inhabits. Larvae settle quickly, within one day. *Watersipora's* native range is unknown. Its' invasive range is very broad, and includes southern Australia and New Zealand, the Mediterranean, and California and Oregon. There is no documentation of predators of *Watersipora* in the literature.

Monterey harbor is on the northern side of the Monterey Peninsula. The area inside the harbor is protected from storms and waves by seawalls (Figure 2). Monterey harbor is a commercial and recreational port that receives vessels from throughout the west coast of north America. *Watersipora* invaded southern California in the mid-1900s and spread north (Sellheim et al 2010) and was present in Monterey harbor by 1994 ((http://www.exoticsguide.org/species_pages/w_subtorquata.html). The main vector of *Watersipora* dispersal over long distances has probably been by growing on boat hulls ((http://www.exoticsguide.org/species_pages/w_subtorquata.html).

General approach.

To answer our three questions we surveyed six pilings on the northern side of tier A in the Monterey Harbor (36°36'14.79''N, 121°53'30.46''W) (Figure 2). The pilings surveyed are 4.6-m deep; 3-m apart, and have four flat, 0.5-m wide sides with beveled edges. These six pilings were representative of the area near the harbor entrance.

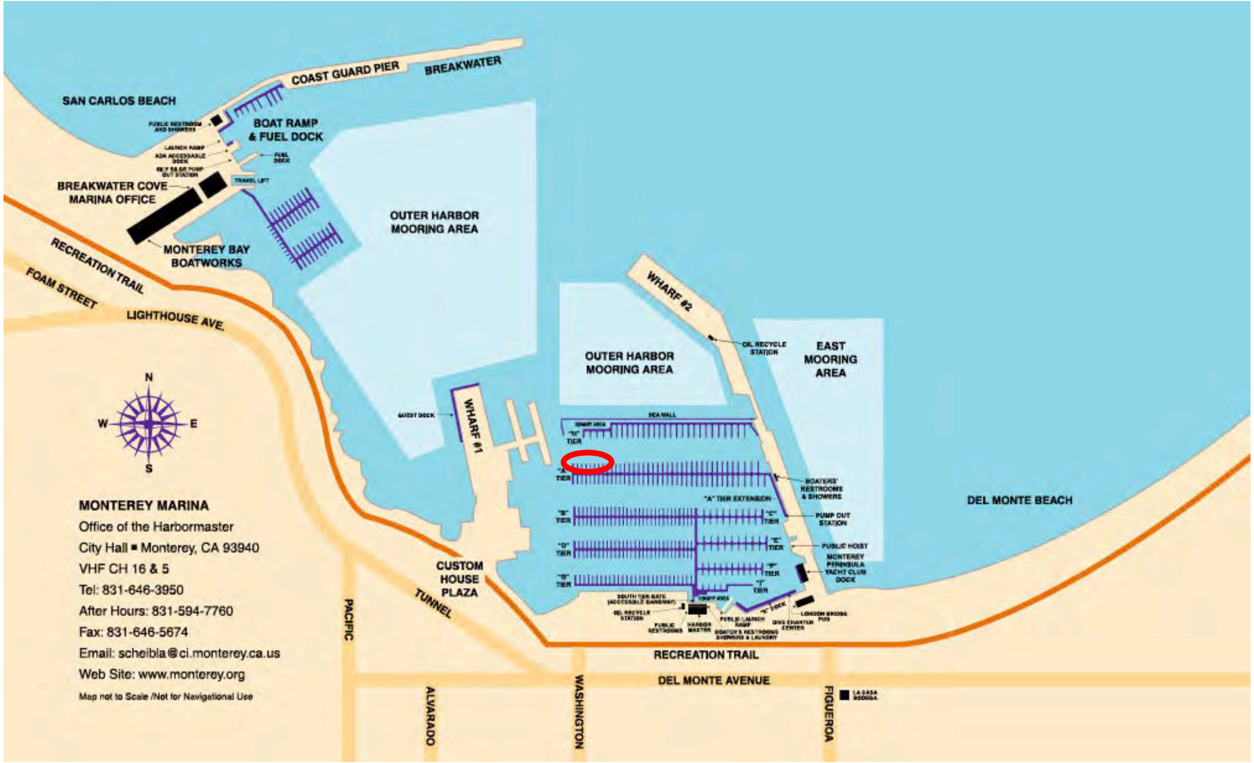

Figure 2. Map of the Monterey Harbor and location of the six pilings we surveyed on A tier (red oval).

To quantify the abundance of *Watersipora* and other sessile species in the fouling community on the pilings, we estimated their percent cover. Percent cover was estimated from digital photoquadrats. All photos were taken on March 18, 2010 at low tide. We used a pvc frame attached to an underwater housing (Subal 300D) to take digital photographs 0.5-m (lens to subject) from the piling, capturing 0.025-m^2 of the piling. To estimate percent cover of the piling community we used a point sampling technique and overlaid a grid with 50 uniformly distributed points over each photoquadrat (Figure 3). We decided to use 50 points by comparing the percent covers obtained for two photoquadrats using either 25, 50, or 100 points. We decided to use 50 points because the percent cover estimates were very similar to those obtained with 100 points (Figure 4), and the process was much faster. We stretched the grid over the whole digital image and viewed each point at 50% zoom in Adobe Photoshop Elements. Any point where the image was out of focus, shadowy, or could not be identified was recorded as "unknown." We included only the top layer of sessile organisms in our percent cover estimate, so each photoquadrat had a maximum value of 100% cover. Points lying over mobile invertebrates (e.g. shrimp, hermit crabs) were removed from the analysis because we were interested in what was attached to the pilings. To sample the mobile invertebrate community, we counted all identifiable mobile invertebrates in the digital images, including all individuals at least half-way within the photoquadrat. A table of categories used for percent cover estimates with example photos can be found in the appendix (Table A1).

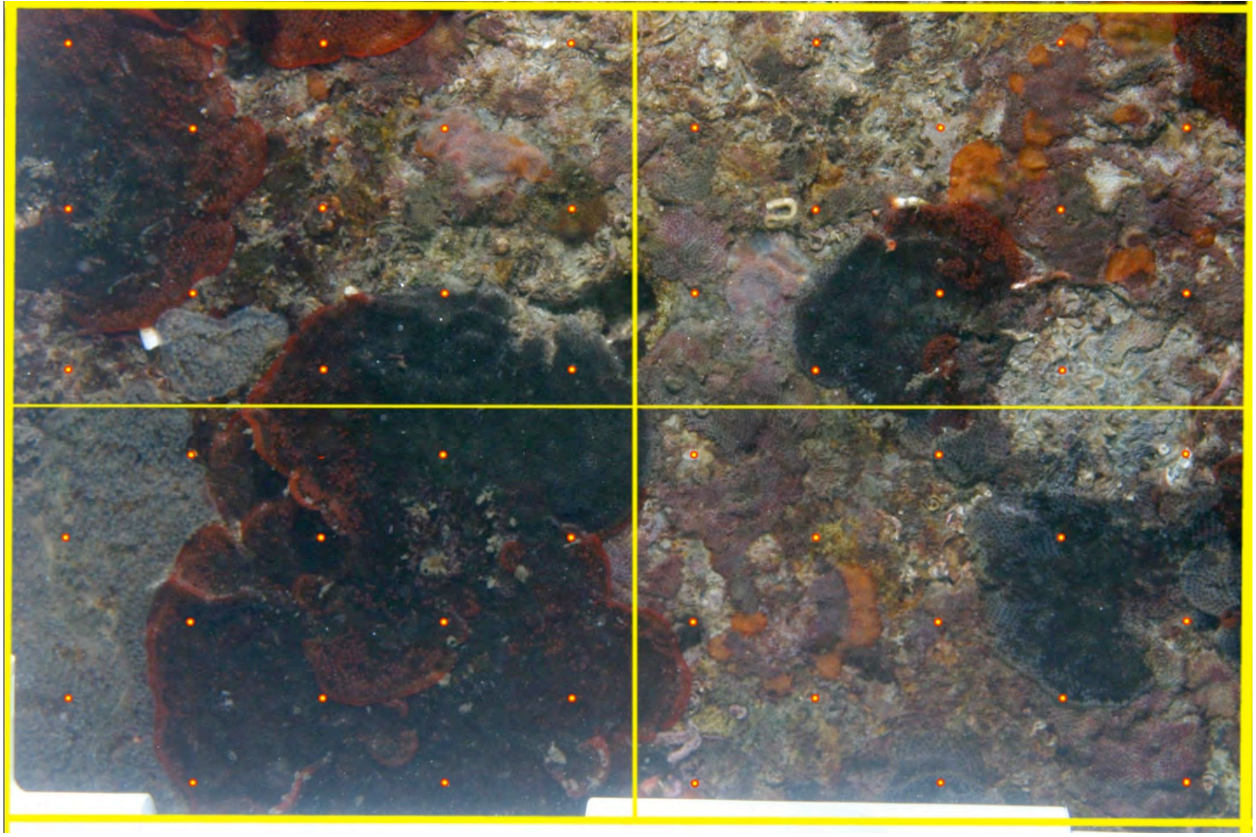

Figure 3. An example of a photoquadrat with 50 point grid overlaid.

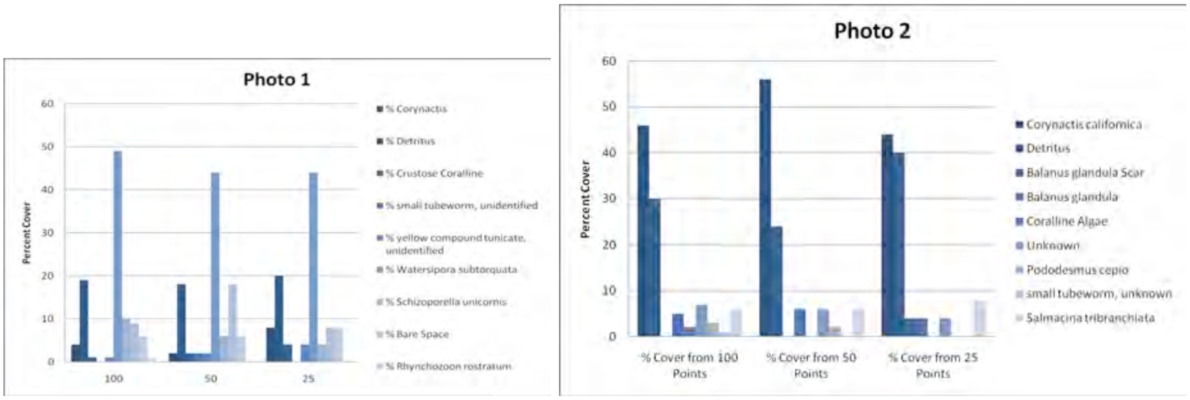

Figure 4. Comparing percent cover estimates using 25, 50, and 100 points for two photoquadrats.

Where does Watersipora occur within our study site?

To answer this question, we compared the relative percent cover of *Watersipora* at two depths on all four sides (north, south, east and west-facing) of each of the six pilings sampled. We used these comparisons to test the hypotheses that the percent cover of *Watersipora* differed significantly among the six piling, between the two depths, and among the four sides (orientations) of the pilings. We took photos at locations 4-m (below the surface) on each of the six piling, and at fixed locations (permanent cables wrapped around the pilings) from 2 to 3-m (below the surface) on each piling and at north, south, and west sides of the pilings.

To determine if there were significant differences in percent cover in *Watersipora* between the two depths and among the four sides (orientations) of the pilings, we performed a two-way ANOVA with each photoquadrat as the unit of replication. Percent cover estimates were log-transformed to meet the assumptions of normality and homogeneity of variances. Depth and orientation were treated as fixed factors. We also tested for an interaction effect between depth and orientation (i.e. does the effect of depth differ among the four orientations?).

Are there patterns in community structure in the absence of Watersipora?

To answer this question, we tested the hypothesis that the native community varied significantly between the two depths and among the four sides (orientations) of the pilings across the six pilings. Only quadrats that had no *Watersipora* were used for this analysis. We used a multivariate analysis (the statistical package "Primer") to characterize the fouling community in each quadrat. This analysis determines the relative abundance of all of the species that constitute the community in each quadrat and compares those communities among all of the quadrats sampled. We then used a multivariate analysis of variance (PERMANOVA) to test for significant differences among those communities by treatment level (depth and orientation) and to identify which species characterize communities of each treatment level and which contribute most to the differences among the treatment levels.

Does the community differ as a function of Watersipora cover?

To answer this question, we tested the hypothesis that the native fouling community differed significantly among quadrats with three levels of percent cover of *Watersipora*: none/low, moderate and high. We combined quadrates with none and low (≤ 5%) percent cover of *Watersipora* because initial comparison indicated no difference between these two levels. We categorized the percent cover of *Watersipora* into three categories of abundance (Table 1). We used the same multivariate analysis that we used to test the hypothesis of differences in community structure in the absence of *Watersipora* (above). We combined percent cover of live and dead *Watersipora* for the multivariate analysis. We also tested for a difference in community structure across the six pilings and the interaction effect between pilings and *Watersipora* levels to determine if any effect of *Watersipora* abundance varied among the pilings.

Table 1. Categories of *Watersipora* percent cover and sample sizes.

Percent Cover	Level	Number of photoquadrats
≤ 5% Cover	None/Low	39
≤ 10% Cover	Moderate	5
> 11% Cover	High	4

RESULTS

Where does Watersipora occur within our study site?

There was no pattern in percent cover of *Watersipora* across the faces of the pilings, i.e. orientation (ANOVA: df = 3, p = 0.354). Although percent cover varied from 42 percent cover on the east facing sides to 8 percent on the north facing sides (Figure 5), the variability among quadrats across the replicated pilings was too great to detect a significant difference. Nor was there a significant difference in percent cover of *Watersipora* between the two depths sampled (ANOVA: df = 1, p = 0.7207). The mean percent cover of *Watersipora* at 2 – 3 m and 4 m depth was 0.30 % +/- 0.10 % and 0.25 % +/- 0.10 %, respectively. Although piling 1 had an average percent cover sixteen times greater than that on piling 4 (Figure 6), the variation among quadrats on that piling (range = 32 to 0 percent cover) was so great that no significant differences were detected among pilings.

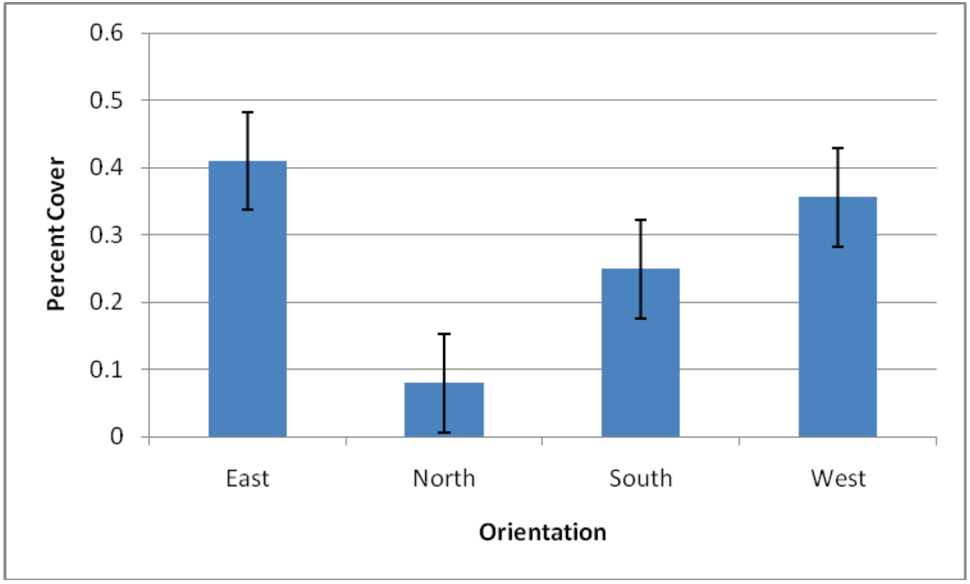

Figure 5. Average percent cover of live *Watersipora* on each face of the pilings. ANOVA: df = 3, p = 0.3546

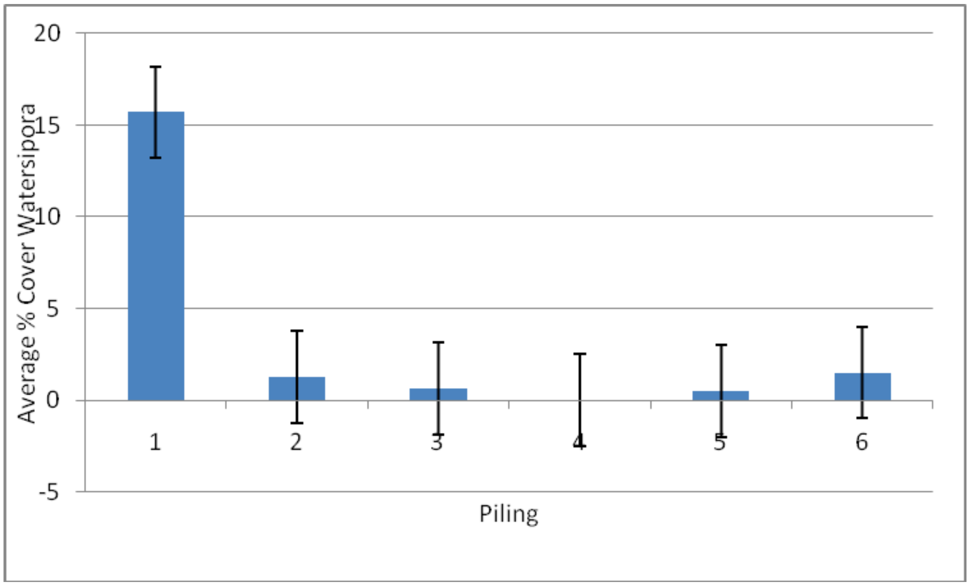

Figure 6. Average percent cover of *Watersipora* on each piling.

Are there patterns in community structure in the absence of Watersipora?

In the absence of *Watersipora* there was a significant difference in the community across pilings (PERMANOVA: df = 5, p = 0.008 Table 2). However, there was no significant difference in community structure between the two depths (PERMANOVA: df = 1, p = 0.062), across orientations (ANOVA: df = 3, p = 0.333), and there was no significant interaction between depth and orientation (ANOVA: df = 3, p = 0.995) (Table 3).

Table 2. Results of PERMANOVA test for the differences in community structure in the absence of *Watersipora* between pilings. These tests used only the quadrats without *Watersipora*.

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Pilings	5	15252	3050.5	1.8784	0.008	998
Res	26	42223	1623.9			
Total	31	57475				

Table 3. Results of the ANOVA tests for differences in community structure in the absence of *Watersipora* between depths and among orientation and the interaction of orientation and depth

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Depth	1	4339.3	4339.3	2.326	0.062	998
Orientation	3	6368.3	2122.8	1.1379	0.333	998
dexOr	3	1641.7	547.24	0.29334	0.995	996
Res	24	44774	1865.6			
Total	31	57475				

Does the community differ as a function of Watersipora cover?

As without *Watersipora*, there was a significant difference in overall community structure across pilings (ANOVA: df = 5, p = 0.007) in quadrats with *Watersipora*. There was also significant difference in community structure across three levels of *Watersipora* percent cover (none/low, moderate, and high) (ANOVA: df = 2, p = 0.045).

Where *Watersipora* was absent or at low levels, detritus (31%) and bare space (18%) were the most abundant (percent cover) species in the community, followed by the anemone *Corynactis californica* and the tunicate *Diplosoma listerina* (Figure 7).These four species were also the largest contributors to the community: detritus (46%), bare space (19%), *Corynactis californica* (9%), and *Diplosoma listerina* (7%) (Figure 8).

Detritus (42%), bare space (20%), and *Corynactis californica* (3.67 individuals/quadrat) were the most abundant species in the community with moderate cover of *Watersipora* (Figure 7). Detritus was the most significant contributor to the community (65%), followed by bare space (20%), and *C. californica* (2%) (Figure 8).

At the high *Watersipora* percent cover community, bare space (17%) and *Diplosoma listerianum* (18%) were the most abundant followed by detritus (14%) and *Membranipora fusca* (9%) (Figure 7). Bare space (44%) was the largest contributor to the characterization of this community, and *D. listerianum* (23%), detritus (20%), and *M. fusca* (9%) also contributed to the community (Figure 8).

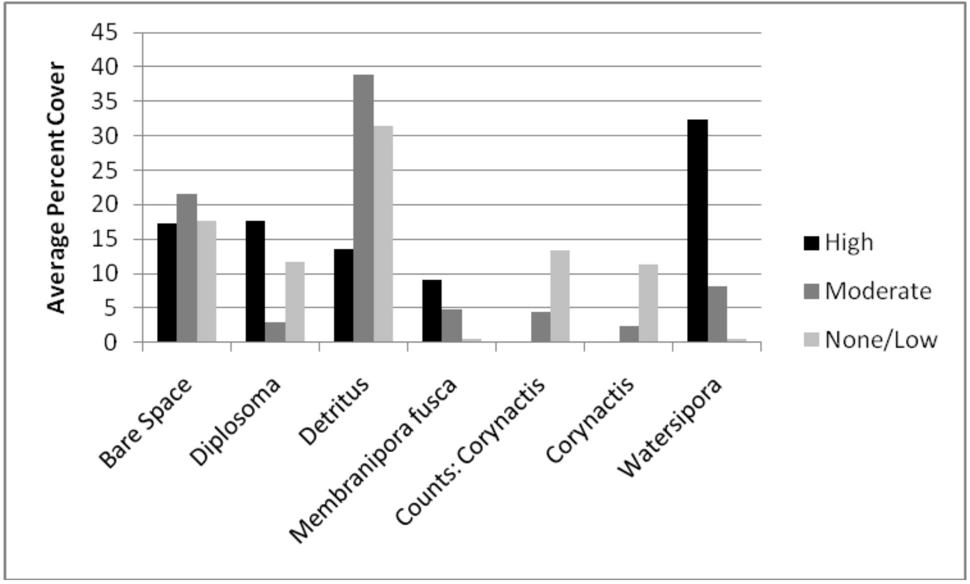

Figure 7. Average percent cover of important species at high, moderate, and none/low levels of *Watersipora*.

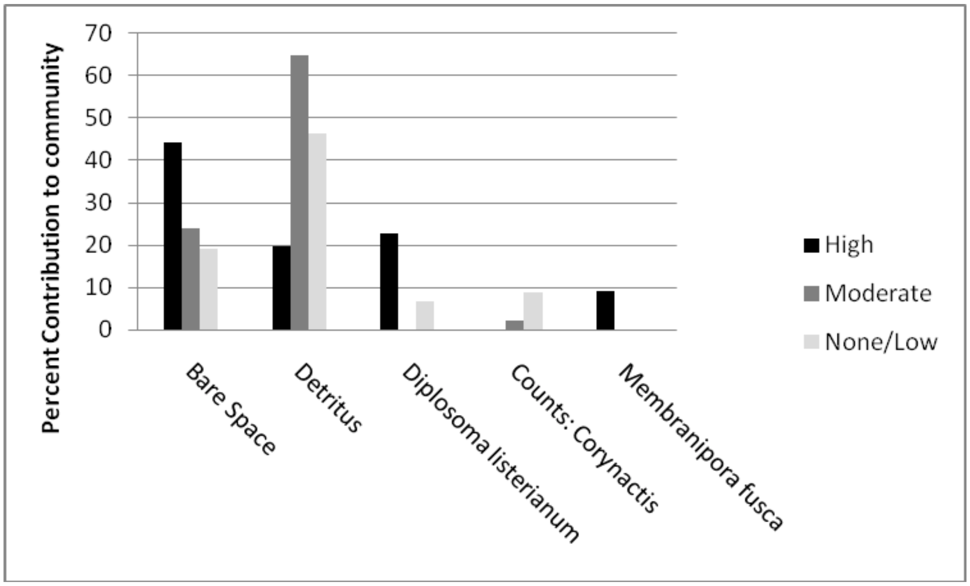

Figure 8. Percent contributions, generated by the mulitivariate analysis, of percent cover categories at high, moderate, and none/low levels of *Watersipora* cover.

Comparing the communities at the three *Watersipora* levels, the high and none/low communities were the most different from each other (average dissimilarity = 65%) (Table A2). Important contributors to the differnces between the high and none/low communities were detritus (17%), *Diplosoma listerianum* (16%), *Corynactis californica* (11%), bare space (10%), and *Membranipora fusca* (7%). Abundance of *C. californica* and detritus decrease from none/low to high *Watersipora* communities, while *D. listerianum* and *M. fusca* increase in abundance between the two levels (Figure 7)

The high and moderate *Watersipora* communities had an average dissimilarity of 56% and detritus (33%), *Diplosoma listerianum* (19%), and bare space (10%) were the most important contributors to the dissimilarity (Table A3).

The moderate and none/low *Waterispora* communities had an average dissimilarity of 53% and detritus (14%) was the most important contributor to the dissimilarity (Table A4).

DISCUSSION

I have identifed some significant relationships between *Watersipora* and various attributes of the community which may be evidence of *Watersipora's* impact on the fouling community. Many species were in too low abundance to see any relationship between *Watersipora* levels, but *Corynactis californica*, *Diplosoma listerianum,* and *Membranipora fusca* were abundant and differed across the levels of *Watersipora* abundances so I have drawn some conclusions about possible interactions between these species and *Watersipora*.

Corynactis californica abundance declined with increasing *Watersipora* abundance, and was absent at high *Watersipora* levels (Figure 7). This result agrees with a study of *Watersipora* on the offshore oil platforms in the Santa Barbara Channel where cover of *C. californica* was inversely related to cover of *Watersipora* (Page et al 2006). As Page et al concluded, *Watersipora* may outcompete *C. californica* for space.

Diplosoma listerianum seems to be influenced only by moderate levels of *Watersipora*, and was more abundant at both high and none/low levels. In fact it sometimes grew on top of *Watersipora* and in the folds of the colony. *Diplosoma* and detritus were the only groups observed on top of *Watersipora*. *D. listerianum* co-occurs with *Watersipora* in southern Australia (Sams and Keough 2007), so *D. listerianum* may have already had more time to adapt to the presence of *Watersipora* than native sessile invertebrates, which may be why it is able to grow over *Watersipora* unlike the native tunicates and sponges. Selheim et al (2010) conducted an experiment to determine the effect of *Watersipora* (and a *Watersipora* strucutral mimic) on the sessile epifaunal community in the harbor in Bodega Bay, and *D. listerianum* was the only species in common with our study. In Selheim et al's study, *D. listerianum* did not differ significantly between *Watersipora*, *Watersipora* mimics, and control treatments. It is important to understand the interactions between these two invasives because *Watersipora*, already present in kelp forests, could facilitate the invasion of *D. listerianum* or other invasive species to kelp forests.

Membranipora fusca was more abundant in high *Waterispora* communities (Figure 7), although it never occurred on top of *Watersipora* as *Diplosoma listerianum* and detritus did. *M. fusca* may be better able to compete with *Watersipora* as an neighbor compared to native invertebrates.

Availability of space is an important factor for the success of invasive species (Stachowicz et al 2002, Glasby et al 2007) and is often a limiting resource in fouling communities (Stachowicz et al 2002). This could mean that competition for space between invasive and native sessile invertebrates is the most important biotic interaction in this system (Selheim et al 2010). However, bare space was relatively abundant in many of our photoquadrats and it was an important contributor to the communities at all *Watersipora* levels (Figures 7 and 8). Higher abundance of *Watersipora* does not appear to limit the amount of bare space, so bare space may be just as available to native sessile invertebrates where *Watersipora* is 11 - ~30% cover as it is when *Watersipora* is absent. Native sessile invertebrates may not be intensely competing with *Watersipora* for space.

Predation may be an important biotic interaction at this site. The seastar *Pisaster giganteus* and *Pateria miniata* are common on the pilings in Monterey harbor and may contribute significantly to generating availible space by feeding on sessile invertebrates. Additionally, seastars crawling over *Watersipora* colonies may prevent the colonies growing upright (outwards from the piling surface) or may cause erect portions fo the colony to break off. *Watersipora* is very fragile and breaks easily at light touch. However, no direct physical effect of seastars on *Watersipora* has been studied or witnessed.

Although I have seen some interesting patterns between *Watersipora* and the fouling community on these pilings, this study is observational and does not allow us to say that *Watersipora* is causing these patterns. An experimental study, such as removing *Watersipora,* is needed to fully asses whether *Watersipora* has an effect on native sessile invertebrates in this area.

In future research, we plan to examine the fouling community on these six pilings over time. This will indicate if there are seasonal patterns in *Watersipora* abundance, and will provide information on *Watersipora's* growth rate. Studying the same quadrats on the pilings over time may also give us clues to interactions between species. It would also be valuable to conduct studies like this on *Watersipora* in the Monterey kelp forests, to see how *Watersipora* is effecting natural kelp forest communities.

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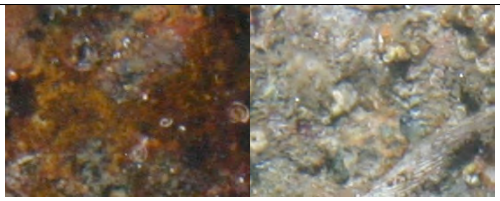
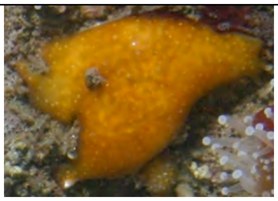
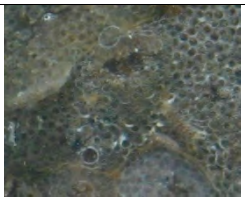
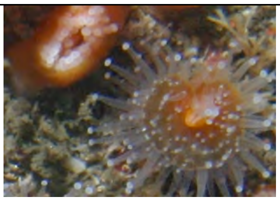
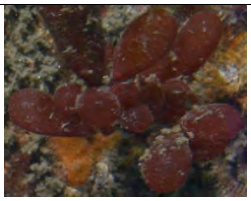
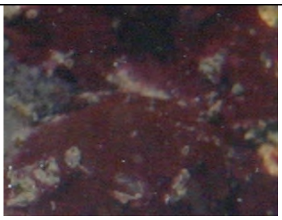
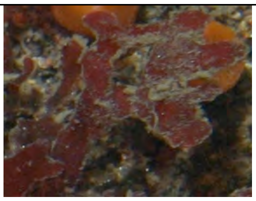
APPENDIX

Table A1. Percent cover categories and example images.

Category	**Example Image**
Unknown	
Detritus	
Bare Space	
Watersipora	
Dead *Watersipora*	
Other Dead Bryozoan	
Rhynochozoan rostratum	

Membranipora fusca	
Unknown grey, flat bryozoan	
Costazia costazi xx actually unknown sponge	
Bugula neritia	
Diplosoma listerianum	
Unknown Yellow compound tunicate	
Botylloides violaceus	

Unknown Yellow/brown solitary tunicate	
Unknown smaller white solitary tunicate	
Corynactis californica	
Unknown small pale anemone	
Botryocladia pseudodichotoma	
Encrusting Red Algae	
Unknown Erect Red Algae	

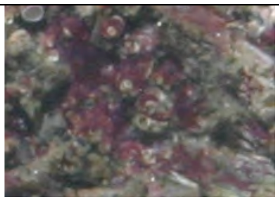
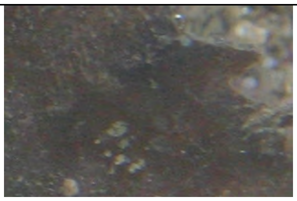
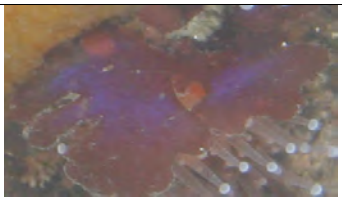
Crustose coralline algae	
Brown Algae	
Fauchea laciniata	
Serpula columbiana	
Salmacina tribranchiata	
Unknown yellow thing with white lines	
Hermissenda crassicornis eggs	

Table A2. Results of the PERMANOVA analysis comparing the high and none/low *Waterispora* communities.

Groups H & N/L

Average dissimilarity = 65.12

	Group H	Group N/L				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritus	13.5	30.76	11.16	1.44	17.13	17.13
Diplosoma listerianum	17.57	11.53	10.16	1.28	15.61	32.74
Counts: Corynactis	0	13.79	6.97	0.87	10.7	43.44
Bare Space	17.29	17.73	6.72	1.12	10.32	53.76
Corynactis	0	11.55	5.86	0.89	9	62.75
Membranipora fusca	9	0.38	4.8	1.11	7.37	70.12
Red Algae Encrusting	0.5	6.28	3.32	0.61	5.1	75.22
Counts: Unknown small pale anemone	0	4.97	2.79	0.74	4.29	79.51
Botryocladia speudodichotoma	0.5	4.24	2.58	0.4	3.97	83.47
Unknown	1.5	4.35	2.51	0.78	3.85	87.32
Dead Other Bryozoan	2.5	1.51	1.65	1.01	2.53	89.85
Rhynochozoan rostratum	0.53	2.64	1.57	0.48	2.41	92.27

Table A3. Results of the PERMANOVA analysis comparing high and moderate *Watersipora* communities.

Groups H & M

Average dissimilarity = 55.42

	Group H	Group M				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritus	13.5	41.92	18.28	1.98	32.98	32.98
Diplosoma listerianum	17.57	5.4	10.43	1.23	18.82	51.8
Bare Space	17.29	20.01	5.56	1.27	10.03	61.83
Membranipora fusca	9	4.42	5.38	1.18	9.7	71.53
Counts: Corynactis	0	3.67	2.27	0.92	4.1	75.63
Dead Other Bryozoan	2.5	2.69	1.99	1.16	3.58	79.21
Rhynochozoan rostratum	0.53	2.42	1.58	0.87	2.86	82.07
Unknown	1.5	2.5	1.56	1	2.82	84.89
Yellowish unknown compound tunicate	1.03	1.67	1.46	0.77	2.63	87.52
smaller white solitary tunicate	0	2.02	1.22	0.55	2.21	89.73
Corynactis	0	2	1.22	0.86	2.19	91.93

Table A4. Resluts of the PERMANOVA analysis comparing moderate and none/low *Watersipora* communities.

Groups M & N/L

Average dissimilarity = 53.06

	Group M	Group N/L				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Detritus	41.92	30.76	7.69	1.34	14.49	14.49
Bare Space	20.01	17.73	6.94	1.23	13.07	27.56
Diplosoma listerianum	5.4	11.53	6.37	0.88	12.01	39.57
Counts: Corynactis	3.67	13.79	6.11	1	11.51	51.08
Corynactis	2	11.55	5.07	0.95	9.56	60.65
Red Algae Encrusting	0	6.28	2.88	0.58	5.43	66.08
Counts: Unknown small pale anemone	0.83	4.97	2.45	0.79	4.61	70.69
Unknown	2.5	4.35	2.31	0.86	4.36	75.04
Membranipora fusca	4.42	0.38	2.22	0.71	4.18	79.23
Botryocladia speudodichotoma	0	4.24	2.14	0.38	4.03	83.25
Rhynochozoan rostratum	2.42	2.64	1.92	0.71	3.62	86.87
Dead Other Bryozoan	2.69	1.51	1.53	0.96	2.89	89.75
smaller white solitary tunicate	2.02	0.74	1.15	0.66	2.17	91.92