

# HETEROGENEITY IN ALGAL COMMUNITIES AMONG INTERTIDAL, CONGLOMERATE-PLATFORM EMBAYMENTS AT MOTU TIAHURA, MO'OREA, FRENCH POLYNEISIA

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**Abstract.** Studies on intertidal patch ecology focus on the characteristics of Type II tide pools, while few investigate the ecological characteristics of embayments. Within this framework, macroalgal community structure among the embayments at Motu Tiahura, Mo'orea, French Polynesia was examined, and compared to the adjacent back reef. It was hypothesized that the embayments would contain a lesser diversity and abundance of species than the back reef due to their differing physical and biological parameters. Significant variation was revealed in the macroalgal species composition and abundance between the embayments and the back reef, while only indicating significant variation in macroalgal abundance among the embayments. Total macroalgal diversity and biomass was found to be greater within the back reef. One significant correlation was found between percent cover of sand and the biomass of *Halimeda distorta*, indicating further research is needed to examine the influence of settlement patterns and seasonal change.

**Key words:** *macroalgae; community structure; embayment; Motu Tiahura, French Polynesia*

## INTRODUCTION

The study of intertidal species is essential to investigating the effects of climate change, as the "poleward range edges of intertidal biota" have expanded "faster than most recorded shifts of terrestrial species" (Helmuth et al. 2006). Animals and algae that reside within the rocky intertidal zone are directly exposed to both oceanic and atmospheric systems and could therefore "serve as early warning systems for the impacts of climate change" (Helmuth et al. 2006). Most studies to date of intertidal species distribution have focused on the existence of a vertical zonation, yet several note that the heterogeneity in intertidal species assemblages along a small-scale, horizontal gradient is an important aspect of marine ecology in need of further study (Araujo et al. 2005, Underwood 1981, Chapman and Underwood 1998). In addition, quantitative data from small-scale, circumscribed, or semi-circumscribed environments are needed for ecological modeling systems in order to predict regional, landscape, and global scale ecosystem attributes (Rastetter et al. 1992, Wiens and Milne 1998).

In the tropics, algal distribution in particular is essential to understanding patterns of coral reef degradation (Payri 1987). The presence of algae in coral reef ecosystems can be used to evaluate reef health as it can indicate a decrease in live coral cover, a

reduction in herbivorous fishes, or the eutrophication of local waters (Andrefouet et al. 2004, McClanahan 2002). As many high island coral reef ecosystems "have progressively shifted from a coral-dominated system to an algal-dominated one" (Stiger and Payri 1999), these are ideal areas to study the algal response to physical and anthropogenic forces.

Past ecological studies on the "dynamics of marine organisms in patchy intertidal habitats" apply two categorical frameworks, entitled Type I and Type II patches, in order to better understand organismal distribution among these domains (Underwood and Skilleter 1996). Type I patches can be described as "areas of empty space surrounded by a matrix of organisms" while Type II patches are considered "isolated patches of a new habitat" (Underwood and Skilleter 1996). While much of the intertidal literature focuses on the macroalgae within Type II pools (Astles 1993), few investigate the characteristics of small embayments.

The intertidal embayments at Motu Tiahura, Mo'orea are an ideal site to test the distinctness and applicability of the Type I and II categories. The embayments are erosional features of a CaCo<sub>3</sub> conglomerate platform situated along the northwestern edge of Tiahura, and face approximately 0.05 km<sup>2</sup> of back reef environment. As each embayment experiences a constant tidal influence

(Waljeski 2003), these “patches” are continuously connected to the matrix of organisms within the back reef environment. Furthermore, as these habitats experience a host of variable physical parameters such as size, substrate cover, and their degree of connectivity to the back reef, the biological abundance within each embayment is also expected to vary. Macroalgal community composition can be used as a metric to measure the biological variability among the embayments, and the variation that exists between the embayments and the adjacent back reef.

Macroalgal species of particular interest in French Polynesia are *Turbinaria ornata*, and the genera *Halimeda*. *T. ornata* has experienced an increase in its biomass and distribution throughout French Polynesia since the 1980s (Payri 1987, Martinez et al. 2007). Along with *Sargassum sociale* it characterizes the outer reef flats (Payri 2000), but uniquely colonizes new areas by forming algal rafts (Martinez et al. 2007). As the spread of *T. ornata* throughout the Societies has also been linked to its subsequent invasion in the Tuamotus (Martinez et al. 2007), understanding its distribution within the harsh conditions of the intertidal zone is critical. The distribution of the genera *Halimeda* and coralline algae are also of importance as they contribute to sand production and reef building respectively, and their rates of calcification have been reduced due to ocean acidification (Kleypas and Yares 2009).

The purpose of this study is to reveal the species composition and abundance of macroalgae within the embayments, and to test whether the embayments represent areas of unique macroalgal community assemblages. There were several hypotheses tested. The first hypothesis tests whether there is significant variation in species composition and abundance among the embayments. The second hypothesis tests whether there is significant variation in species composition and abundance of each macroalgal species between the embayments and the back reef. Once the macroalgal community patterns were established, another goal of this study is to discover possible correlations between macroalgal community structure and the physical parameters of the back reef and embayments, or grazer presence within these sites. It was predicted that the embayments would differ from each other and the back reef

in their macroalgal species diversity and relative abundance, due to differences in the physical parameters between the two sites. It was also predicted that the embayments would display a lesser diversity of macroalgal species than the back reef in proportion to their degree of connectivity to the back reef. Additionally, I hypothesize that the macroalgal community structure will vary with grazer presence and available substrate.

## METHODS

### Study sites

The embayments at Motu Tiahura in Mo'orea, French Polynesia were selected for study due to an initial observation of variation in algal species between them, despite their close proximity and similar orientation to the adjacent back reef. All of my study sites were located on the northwestern edge of Motu Tiahura's conglomerate platform, GPS points 17°29'13.14"S, 149°54'45.13"W (Fig. 1). The eight embayments I sampled were chosen for their similar geomorphology such that each embayment has one distinct opening to the adjacent back reef (Fig. 2), and is otherwise isolated from the back reef or other embayments. The embayments represent a total area of 73.99 m<sup>2</sup>. The back reef, as defined for this study, is an area of approximately 0.05 km<sup>2</sup> that stretches between the conglomerate platform and the algal ridge and was surveyed as a control to show what the macroalgal species composition and abundance might be like without the influence of the physical characteristics of the embayments.



FIG. 1. Satellite Image of Motu Tiahura at Mo'orea, French Polynesia (Google Earth Pro, 2010). Motu Tiahura is located in the upper left corner. Google Earth Pro, 2010. Data SIO, NOAA, U.S. Navy, NGA, GEBCO Image © 2010 GeoEye, Europa Technologies, and Tetrametrics Consulting

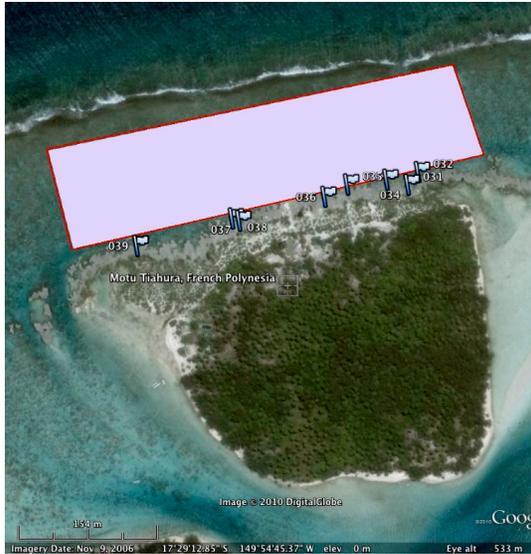


FIG. 2. Satellite Image of the embayment locations (marked by flags) on the conglomerate platform, and the back reef (denoted by the white rectangle) at Motu Tiahura, Mo'orea, French Polynesia. Google Earth Pro, 2010. Image © 2010 DigitalGlobe.

### *Methods and Rationale*

#### *Macroalgal Biomass*

In order to better accommodate both statistical tests and figure visualizations, percent cover was converted to algal biomass. Algal biomass was assessed using an adaptation of the methods employed by Andrefouet et al. (2004) and Payri (1987). Seven 0.5 m<sup>2</sup> quadrats were surveyed for total macroalgal percent cover. The biomass within each quadrat was collected and wet weight was assessed. A linear correlation between percent cover (%) and algal wet weight (gm<sup>-2</sup>) was then determined. The equation for the trend line was used to transform mean percent cover per species within the embayments to mean biomass per species. After dividing the percent cover by four for the back reef 1.0 m<sup>2</sup> quadrats, this process was repeated.

#### *Macroalgal Identification*

Algal species present within the embayments and back reef were first photographed (Appendix B), collected from the back reef, and identified using Payri's *Algae of French Polynesia* (2000). Cyanobacteria, filamentous, and encrusting algae and were not included in this study.

### *Macroalgal Species Composition and Abundance*

In order to test the variation in macroalgal species composition and abundance among the embayments, as well as between the embayments and the back reef, quadrat sampling was chosen in order to determine characteristics within the same sample, and standardize all of the data within a given area. Within each embayment, macroalgal species composition and percent cover was assessed using 0.5m<sup>2</sup> quadrats in order to meet the goal of a 100 percent survey as closely as possible, totaling 65m<sup>2</sup>. The quadrat size was selected in order to accommodate the varying size and shape of the embayments. Within the back reef, macroalgal species composition and percent cover was sampled using four continuous 1m<sup>2</sup> quadrats. Each 4m<sup>2</sup> site was paired with an embayment yielding a total of eight sites (32 m<sup>2</sup>) sampled within the back reef. Quadrat sampling began 5 meters NW (towards the algal ridge) of each embayment in order to assess species composition and abundance not under the influence of the embayment boundaries, or the edge between the embayments and the back reef.

The variation in species abundance between the embayments and the back reef was tested using a two-way Analysis of Variance (ANOVA) of the mean biomass per species, per location. A Tukey-Kramer test was then used to determine which species significantly varied. In order to test the variation in species abundance among the embayments, a two-way ANOVA was performed for all of the species across the embayments and in order to see which species were responsible for the variation, a one-way ANOVA test was performed for each species. Simpson's Diversity Index (S.D.I.) values were calculated for each back reef and embayment site in order to express the both the algal species richness and abundance of each location with one value. The back reef and embayment diversity values were then evaluated for significant variation using the non-parametric Wilcoxon test. Additionally, species richness values were evaluated.

### *Physical Parameters*

#### *Embayment Characteristics*

In order to characterize each of the embayments, and discover potential

relationships, a series of physical parameters were collected including area, temperature, pH, salinity, substrate cover, and the width of the opening to the back reef. In addition, GPS waypoints, and photographs of each embayment (Appendix A) were taken. Each photograph was taken with a 0.5 m<sup>2</sup> quadrat within an embayment and its area was determined using ImageJ. Due to wave action, depth at high and low tide varied greatly within a matter of seconds and was determined to be too erratic to contribute to this study.

#### *Temperature, pH, Salinity*

Temperature, pH, and salinity were measured within embayments three times throughout the study with the respective meters. Within the back reef, three samples of temperature, pH, and salinity were taken along an east to west transect. Temperature, pH, and salinity, were tested for significant variation between the embayments and the back reef with t-tests. As the variation in temperature, pH, and salinity among the embayments was not noteworthy, it was not tested for significance.

#### *Substrate Cover*

Substrate was divided into the four categories of rock, sand, coral rubble, and live coral and percent cover was sampled using a 0.5m<sup>2</sup> quadrat during the macroalgal survey of the embayments. Substrate cover was sampled with a 1m<sup>2</sup> quadrat during the macroalgal survey of the back reef.

I performed an arcsine transformation on substrate percent cover and tested for significant variation among the embayments with a one-way ANOVA per substrate type, and between the back reef and embayments with a t-test for each substrate type.

#### *Biological Parameters*

##### *Grazer Presence*

Grazer presence within the broad categories of swimming fish, bottom dwelling fish, and gastropods in the families Littorinidae, and Neritidae were recorded within each quadrat. Within the embayments, an additional count of littornids, and neritids on the edges of each embayment and up to the water line were taken. The presence of grazers

within each embayment was tested for significant variation using a  $\chi^2$  test for each grazer type.

#### *Turbinaria ornata dispersal*

In order to better understand *T. ornata*'s colonization of the embayments, a count of attached and floating thalli was conducted. A 600 m<sup>2</sup> belt transect was laid from west to east both across the embayments, and parallel to the embayments in the back reef.

## RESULTS

### *Macroalgal Biomass*

There was a linear correlation between the percent cover of 0.5 m<sup>2</sup> quadrats and macroalgal wet weight ( $R^2$ : 0.90, p-value: < 0.0010, D.F.: 6) (Fig 3A). A second linear correlation was made between percent cover of 1.0 m<sup>2</sup> quadrats and macroalgal wet weight ( $R^2$ : 0.90, p-value: < 0.0010, D.F.: 6) (Fig 3B).

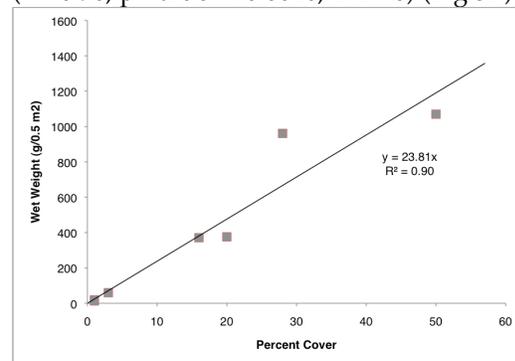


FIG 3A. 0.5 m<sup>2</sup> percent cover plotted against algal wet weight.

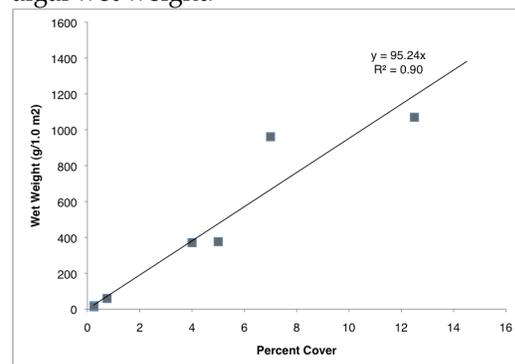


FIG 3B. 1.0 m<sup>2</sup> percent cover plotted against algal wet weight.

### *Macroalgal Identification*

Ten species of macroalgae were identified for this study (Table 1).

TABLE 1. Taxonomic identification of macroalgal species present within the back reef and embayments. Back reef has been abbreviated to Br and embayment has been abbreviated to Em.

Location	Macroalgal Species
Br	<i>Actinotrichia fragilis</i>
Br/Em	<i>Amansia rhodantha</i>
Em	<i>Boodlea kaeneana</i>
Em	<i>Caulerpa racemosa</i>
Br/Em	<i>Caulerpa serrulata</i>
Br	<i>Halimeda discoidea</i>
Br/Em	<i>Halimeda distorta</i>
Em	<i>Halimeda incrassata</i>
Br/Em	<i>Halimeda opunita</i>
Br/Em	<i>Turbinaria ornata</i>

#### Macroalgal Species Composition and Abundance

There was significant variation in the biomass of macroalgal species between the back reef and embayments (Fig. 4) (F: 8.08, p-value: <0.001, D.F.: 9, 140). The species that significantly varied between these two locations were *Amansia rhodantha*, *Halimeda distorta*, *Halimeda opunita*, and *Turbinaria ornata*. *Caulerpa serrulata* did appear in the back reef, but in a relative abundance too small (0.002) to be displayed. The greatest difference in relative biomass was illustrated by *T. ornata*, as it comprises 38% of the relative macroalgal biomass within the back reef, and 71% of the relative biomass within the embayments. *T. ornata* and *H. distorta* constituted the two most dominant species in both locations. Additionally, there was a significant difference in the overall mean macroalgal biomass per m<sup>2</sup> between the back reef and the embayments (t: -6.24, p-value: < 0.0001, D.F.: 8.14). The back reef contained almost eight times the amount of biomass per m<sup>2</sup> than the embayments. With regard to species composition, *Boodlea kaeneana*, *Halimeda incrassata*, and *Caulerpa racemosa* appeared only in the embayments, while *Actinotrichia fragilis* appeared only in the back reef. The mean S.D.I. value (1-D) for the back reef was 0.65, and 0.42 for the embayments. In addition, S.D.I. values varied significantly

between the back reef and the embayments ( $\chi^2$ :3.98, p=0.046, D.F.: 1).

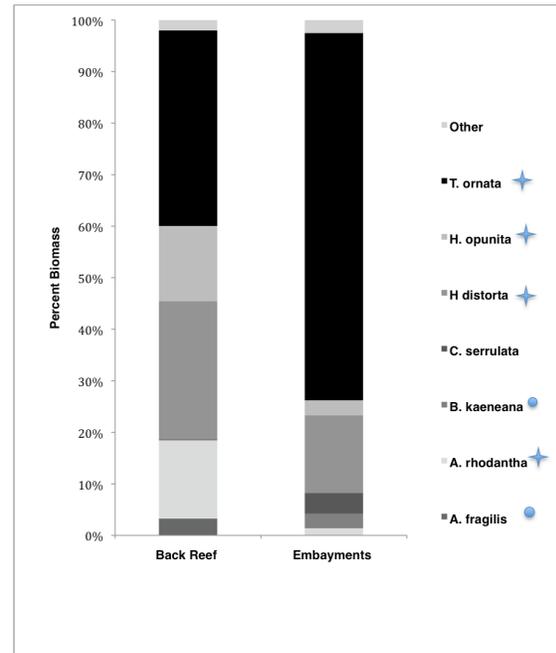


FIG 4. Percent biomass by macroalgal species and location. In order to ease figure visualization, species with differences in relative abundance that were 2% or less between the back reef and embayments were not displayed, and include *C. racemosa* (0.02), *H. discoidea* (0.02), and *H. incrassata* (0.01). \* indicates the species that significantly vary between the two sites. ● indicates the species that only occur in one location.

In six out of eight sites, *T. ornata*'s relative abundance was greater within the embayments than within the back reef (Fig. 5). For example, there was no correlation in its relative abundance within each back reef and embayment-paired site ( $R^2 = 0.0042$ , p-value: <0.89, DF: 7).

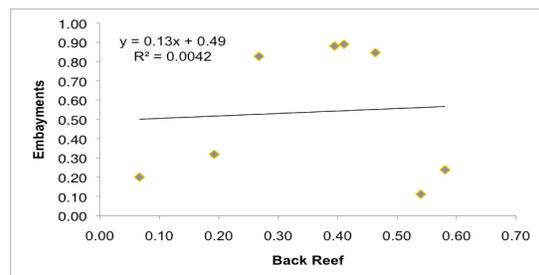


FIG 5. The relative abundance of *T. ornata* in the back reef plotted against its abundance in the embayments. Each point represents a paired back reef and embayment site.

Among the embayments, there was significant variation in the biomass of macroalgal species (F: 4.79, p-value: <0.001, D.F.: 8, 56). Each macroalgal species significantly varied across the embayments (Table 2). Additionally, there was a notable difference in species composition (Table 2). Only two of the embayments contained the same combination of species, but these species

Table 3. Temperature, pH, Salinity by location

Location	T (°C)	pH	Salinity (ppt)
Back Reef	25.5	9.0	35.0
Embayments	26.3	9.1	36.4
t	2.95	1.78	2.38
p-value	<0.98	<0.95	<0.96
D.F.	4.84	15	3.82

TABLE 2. Relative biomass of algal species per embayment with one-way ANOVA results.

EM location	<i>A. rhodantha</i>	<i>B. kaeneana</i>	<i>C. racemosa</i>	<i>C. serrulata</i>	<i>H. discoidea</i>	<i>H. distorta</i>	<i>H. incrassata</i>	<i>H. opunita</i>	<i>T. ornata</i>
West	0.00	0.00	0.00	0.00	<b>0.02</b>	<b>0.14</b>	0.00	0.00	<b>0.85</b>
	<b>0.17</b>	<b>0.03</b>	0.00	<b>0.19</b>	0.00	<b>0.25</b>	<b>0.11</b>	0.00	<b>0.24</b>
	0.00	0.00	0.00	<b>0.20</b>	0.00	0.00	0.00	<b>0.60</b>	<b>0.20</b>
	0.00	0.00	0.00	<b>0.03</b>	0.00	<b>0.08</b>	0.00	0.00	<b>0.89</b>
	0.00	0.00	0.00	<b>0.36</b>	0.00	<b>0.32</b>	0.00	0.00	<b>0.32</b>
	0.00	<b>0.07</b>	<b>0.04</b>	0.00	0.00	0.00	0.00	0.00	<b>0.88</b>
East	<b>0.03</b>	0.00	0.00	0.00	0.00	<b>0.78</b>	0.00	<b>0.08</b>	<b>0.11</b>
	0.00	0.00	0.00	<b>0.02</b>	0.00	<b>0.04</b>	0.00	<b>0.12</b>	<b>0.83</b>
F	1.8*10 <sup>4</sup>	1.2* 10 <sup>5</sup>	10 <sup>40</sup>	1.4* 10 <sup>3</sup>	12.0	3.0*10 <sup>3</sup>	10 <sup>40</sup>	10 <sup>40</sup>	5.2*10 <sup>3</sup>
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
D.F.	(7, 250)	(7, 250)	(7, 250)	(7, 250)	(7, 250)	(7, 250)	(7, 250)	(7, 250)	(7, 250)

did not occur in the same abundance. Although five out of the eight embayments exhibited a species richness value of 3, none contained the same three species, or any of the shared species in the same relative biomass (Table 2). However, S.D.I. values did not vary significantly among the embayments ( $\chi^2$ :7.00, p-value:0.43, D.F.:7).

### Physical Parameters

#### Embayment Characteristics

There was no significant correlation between species richness and the width of the opening of each embayment to the adjoining back reef ( $R^2 = 0.0013$ , p-value: 0.94, D.F.: 7). Additionally, there was no significant correlation between the S.D.I. values and the area of each embayment ( $R^2 = 0.18$ , p-value: 0.29, D.F.: 7).

#### Temperature, pH, Salinity

There was no significant variation in temperature, pH, or salinity between the back reef and the embayments (Table 3). Additionally, there was no notable difference in temperature (range: 25.8-26.8 °C, n=24), pH (range: 9.0-9.2, n=24), and salinity (35.7-37.3 ppt, n=24) among the embayments (See Appendix A).

### Substrate Cover

The percent cover of live coral varied significantly between the back reef and the embayments (t: -2.55, p -value: <0.02, D.F.: 6.02) (Fig. 6). However, I was not able to identify a relationship between percent cover of live coral and the biomass of *T. ornata* or *H. distorta*.

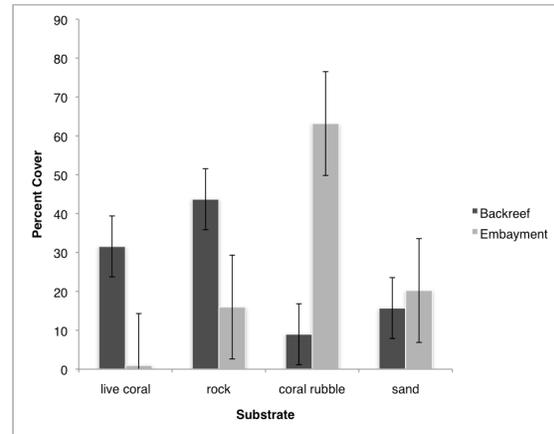


FIG. 6. Substrate percent cover between the embayments and the back reef. Error bars represent standard error.

There was significant variation in the percent cover of coral rubble and sand among the embayments (Table 4). Coral rubble was the dominant substrate in six of the eight embayments (Fig. 7). No correlation between

the percent cover of coral rubble and the biomass of *T. ornata* or *H. distorta* (Table 5) was found. Additionally, there was no correlation between the percent cover of sand and the biomass of *T. ornata*, however, a significant correlation between the percent cover of sand and the biomass of *H. distorta* was found (Table 5).

TABLE 4. The one-way ANOVA results for the variation in substrate cover among the embayments. \* indicates significance.

Substrate Type	F	p-value	D.F.
Live Coral	.079	<.60	(7, 189)
Rock	1.65	<.12	(7, 189)
Coral Rubble	12.6	<.001*	(7, 189)
Sand	21.60	<.001*	(7, 189)

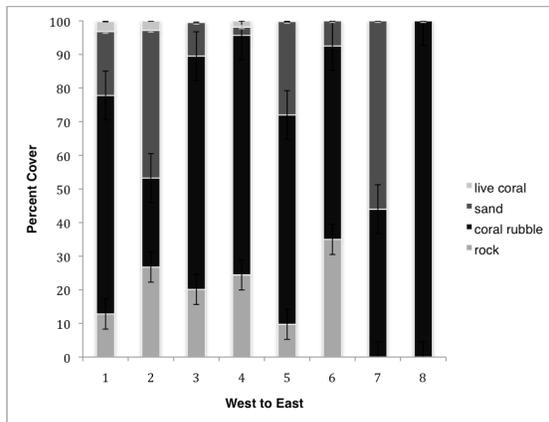


FIG. 7. Substrate percent cover per embayment location, along a gradient from west to east. Error bars represent standard error.

TABLE 5. R<sup>2</sup> results for the relationship between substrate cover and the biomass of *T. ornata* & *H. distorta*. \* indicates significance.

Substrate	<i>T. ornata</i>	<i>H. distorta</i>
Coral Rubble	R <sup>2</sup> =0.024, p-value:<0.71 DF: 7	R <sup>2</sup> =0.25, p-value:<0.21 DF: 7
Sand	R <sup>2</sup> =0.025, p-value: <0.20 DF: 7	R <sup>2</sup> =0.69, p-value: <0.01* DF: 7

## Biological Parameters

### Grazer Presence

There was significant variation in the presence of Littorinidae ( $\chi^2:474.98$ ,  $p=0.05$ , D.F.: 6), and Neritidae ( $\chi^2:136.41$ ,  $p=0.05$ , D.F.: 6) among the embayments (Fig. 8), however, this variation did not correlate to total macroalgal biomass (Littorinidae:  $R^2=0.01$ , p-value: <0.28, DF: 6; Neritidae:  $R^2=0.22$ , p-value: <0.28, DF: 6). Swimming fish did not vary significantly among the embayments ( $\chi^2:10.67$ ,  $p=0.05$ , D.F.: 6), and bottom dwelling fish were never observed within the embayments, or the back reef. Additionally, there were too few grazers observed within the back reef sites for analysis.

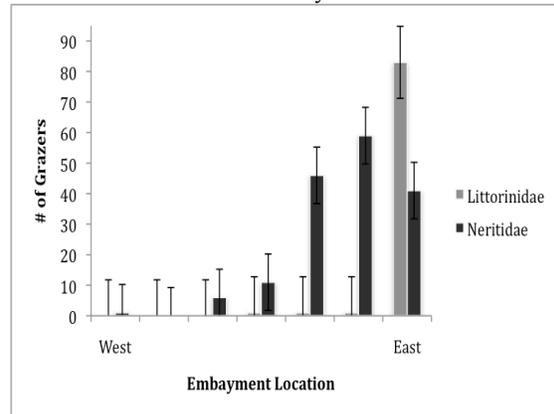


FIG. 8. Number of grazers per embayment location, swimming fish not included. Error bars represent standard error.

### *Turbinaria ornata* dispersal

There was a notable difference in the number of attached *T. ornata* thalli between the back reef and embayments (Fig. 9). The back reef contained almost twice as much attached thalli as the embayments. Additionally, there was no correlation between the number of attached thalli in the back reef and the embayments ( $R^2=0.35$ , p-value: <0.12, DF: 7). There were too few floating thalli within each location for analysis.

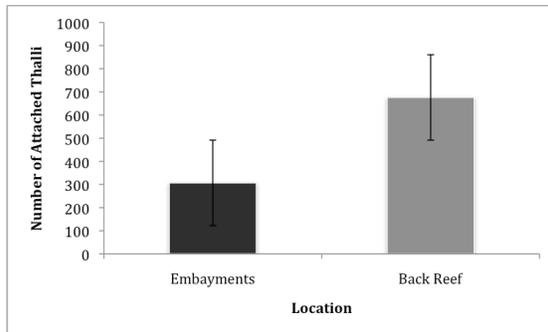


FIG. 9. The number of attached *T. ornata* thalli per location.

## DISCUSSION

### *Macroalgal Community Composition*

The results of my research indicate that significant macroalgal variability exists between the back reef and the embayments. For example, according to their S.D.I. values, the back reef exhibits both more macroalgal diversity than the embayments. In addition, the back reef contains more macroalgal biomass than the embayments. These results are in agreement with Tilman et al.'s observations that the biomass of a given community increases with diversity (1997). The absence of statistically significant differences in temperature, salinity, or pH between the embayments and the back reef suggests that these parameters did not explain the differences I found in macroalgal species composition and abundance in these locations. This notion is not in agreement with Vroom et al.'s findings that the biological variability in lagoons can be attributed to differences in temperature (2005), or Kautsky and Kautsky's discovery that algal species diversity in the Baltic Sea was influenced by salinity (1989). The absence of significant variation in temperature and salinity can possibly be due to the relatively short sampling period, which did not account for seasonal change. Or, perhaps the back reef's greater overall macroalgal biomass and diversity can be attributed to its closer proximity to Mo'orea's barrier reef, but is in need of further comparisons between the back reef, fore reef, and algal ridge.

This study also demonstrates that while the embayments contain macroalgal assemblages with distinctly diverse characteristics, they may not be different enough to be considered divergent patches.

Each embayment did significantly vary in macroalgal species biomass, and only two of the eight embayments contained the same combination of species (in differing relative abundance), however, the lack of variability reflected in their S.D.I. values indicates that while species abundance can be used to distinguish each embayment, species richness cannot. These results are in consistent with Stirling and Wilsey's findings that species richness, abundance, and diversity are not always positively correlated (2001). Furthermore, the lack of correlation between the area of each embayment and its S.D.I. value suggests that the size of the embayment has no bearing on its macroalgal diversity potential. One possible explanation for this can be found in Anderson's study on the *Effects of patch size on colonization in estuaries*, which states that, "the succession of organisms through time was, overall, more important in structuring the assemblages than was the size of the patch being colonized" (1998). Also related is the lack of a correlation between the width of the opening to the back reef and species richness, which can perhaps be explained by succession, but requires the further investigation of seasonal settlement patterns. As in the comparison between the back reef and embayments, the range in pH, temperature, and salinity among the embayments was notably small, and an unlikely source of influence on the macroalgal community within the time frame that this study was conducted.

### *Substrate Cover*

My analysis indicates only one relationship between substrate percent cover and macroalgal species abundance. The positive correlation between the abundance of *H. distorta*, and percent cover of sand among the embayments is in accord with Naim's observation that the genera *Halimeda* is able to colonize "sandy surfaces" (1987). The lack of relationships between substrate percent cover and the rest of the macroalgal species surveyed is in contrast to literature findings that substrate type may influence attachment. According to Stiger and Payri, there is "a limiting effect of the substrate against the settlement of *T. ornata* with time" (2004). Moreover, species such as *H. incrustata* are "strictly sand growing," while *H. opunita* populations on the Tiahura reef complex are able to occupy a wider range of substrates

including rock, live, and dead coral (Naim 1987).

#### *Grazer Presence*

This study reveals that grazer presence among the embayments had no influence on total macroalgal biomass. The lack of a correlation between gastropod counts and macroalgal biomass is in agreement with Vroom et al.'s results, which state "macroalgal abundance cannot be explained by grazing pressure regimes" (2005). However, the lack of grazers observed within the back reef reduced the possibility for analysis among sites, and is potentially due to flawed observational methods. Due to the common occurrence of the live coral substrate type within the back reef, grazer presence might have been better accounted for with a timed survey of a given area, as live coral has many crevices that can be more thoroughly investigated by free diving along a depth gradient.

#### *Turbinaria ornata*

My results regarding *T. ornata*'s dominance in both the back reef and embayments is consistent with literature findings. For example, in 2008, Stewart found that in French Polynesia "[t]he macroalga *Turbinaria ornata* comprises the majority of the increasing algal biomass on the barrier reefs surrounding these islands, and its distribution is increasing throughout this region." In concurrence, Bittick et al. observed that in Mo'orea *T. ornata* "is a dominant component of the back reef habitat" (2009). There are several possible reasons for *T. ornata*'s ubiquitous distribution including its resistance to herbivores (Bittick et al. 2009), and its ability to float over long distances and successfully colonize new areas (Stiger and Payri 1999). Once within the barrier reef of Mo'orea, it would be a relatively short distance for *T. ornata* to secondarily colonize the back reef, and then the embayments. However, the data on floating *T. ornata* thalli in this study is not extensive enough to support this. This portion of the study could be improved by sampling line transects for floating and attached thalli after storms, large swells, and over several seasons. Additionally, the effects of current direction and strength can be examined for their influence of *T. ornata*'s dispersal.

#### CONCLUSION

In conclusion, while the embayments significantly vary in macroalgal abundance, their lack of variation in S.D.I. values indicate that they may not be considered biologically distinct patches when compared to each other. However, they are significantly diverse in both macroalgal species composition and abundance when compared to the back reef and can therefore be considered biologically unique habitat patches within this context. As predicted, the back reef contains a greater diversity of macroalgal species than the embayments. When considered within the context of the aforementioned Type I and Type II patch categories, the embayments at Motu Tiahura call for the creation of a novel patch type whose definition more accurately describes their relationship to the back reef. This Type III patch can then be defined as an area consisting of a matrix of organisms that is continuously connected to a larger and more diverse matrix of organisms.

As few correlations were found between macroalgal variability and the physical and biological parameters measured, I was unable to identify most of the potentially influential factors. Temperature, and salinity data would benefit from an increase in the sampling period as the literature suggests these abiotic factors can influence macroalgal community structure, while the lack of a correlation between diversity and patch size is supported. Species richness within each embayment was not governed by its degree of connectivity to the back reef. A singular correlation between *H. distorta* and the percent cover of sand among the embayments begs a further look into the morphology of this species' holdfast. As other studies suggest that macroalgae do exhibit substrate preferences, an increase in the number of embayment and back reef sites sampled is necessary to further examine this relationship. Although the lack of a correlation between macroalgal biomass and grazer presence is confirmed in the literature, an observational method better adapted to the back reef environment is suggested for additional research. By increasing the sampling period and frequency of *T. ornata* thalli data, and coupling this information with seasonal surveys of macroalgal settlement patterns, the biological parameters that influence macroalgal community structure can be better investigated in future studies.

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## APPENDIX A

APPENDIX A. Mean temperature, pH, and salinity by location.

Embayment	T (°C)	pH	Salinity (ppt)
1	26.5	9.1	36.0
2	26.8	9.0	37.3
3	26.5	9.0	36.3
4	26.2	9.2	35.7
5	25.8	9.2	36.0
6	26.6	9.0	36.0
7	25.9	9.1	36.3
8	25.9	9.1	37.3