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FRESHWATER RUNOFF EFFECTS ON THE DIVERSITY AND COLONIZATION OF CORAL RUBBLE-INHABITING CRUSTACEAN MICROCOMMUNITIES

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Abstract. A large cause of degradation of coral reefs is increased sedimentation and eutrophication caused by human modification of freshwater input into the marine environment. Effective tools must be used to monitor the effects of freshwater input before long-term damage is done to the fringing reef zone. One powerful tool is the use of bioindicators. This study attempts to identify possible bioindicators in coral rubble-inhabiting crustacean micro communities. Coral rubble was collected from 5 stream sites with paired controls and crustaceans were counted from each site. This study found that there were significant differences between stream and control sites in percent algal cover of rubble as well as 3 crustacean species (*Thalamita admete*, *Alpheus parvirostris*, *Psuamis cavipes*). *Cuapetes* sp. density also showed a significant negative correlation with pH levels. A colonization experiment was performed with no significant difference between stream and control sites.

Key words: coral rubble, bioindicator, freshwater input, *Thalamita admete*, *Alpheus parvirostris*, *Psuamis cavipes*, *Cuapetes* sp., algal cover, eutrophication

INTRODUCTION

One of the greatest causes of degradation of coral reefs is increased sedimentation and eutrophication caused by the human modification of freshwater inputs into the marine system. As humans continue to develop coastal zones, additional nutrients and sediment enter streams and eventually the coastal marine zone. The increased turbidity and sediment load from stream runoff can decrease the overall photosynthesis of corals and has a potentially lethal effect (Rogers 1990). Increased eutrophication caused by stream runoff has been shown to cause shifts in species dominance by creating blooms of phytoplankton and benthic algae and can decrease densities of other marine organisms (Snelgrove and Lewis 1989). Destruction of coral reefs and their associated marine organisms leads to a decline in overall marine biodiversity and has a direct effect on humans by causing the decline of tropical fisheries (Dahl 1985). It is therefore imperative to monitor the effects of sedimentation and eutrophication on the marine system to stop the decline of this important ecosystem.

One powerful way of monitoring the effect of streams on the coastal zone is the use of bioindicators. Bioindicators provide an

early warning of pollution or degradation on an ecosystem before the entire system can be lost. They are particularly useful because they only assess the pollutants that have negative effects on marine organisms and can be used to measure the long-lasting, cumulative impacts that may be missed when using just physical or chemical measures (Linton and Warner 2003). Macroinvertebrates have been used previously as bioindicators in a variety of systems and have shown to be great tools in the assessment of overall health of the marine coastal zone. Polychaetes and crustacean communities have been found to work as bioindicators and have been used to assess the health of marine communities (Frouin 2000, Takada et al 2008).

Possible sources of bioindicators in the shallow water marine environment are the crustaceans that compose the motile cryptofauna assemblages associated with coral rubble microhabitats. They are a poorly studied group of organisms that play an important part in the shallow water marine environment. The coral rubble cryptofauna are mainly composed of gastropod mollusks, polychaetes, and these microcrustaceans, which are an important source of food for fish living in the coral reef, and have been shown to be significant grazers

of algae in the reef system (Klumpp et al. 1988). Coral rubble-inhabiting organisms are also an important component of biodiversity in coral reefs and have been studied as model systems for cryptic speciation in the marine environment (Mathews 2006).

Mo'orea, French Polynesia has a complete barrier reef and a relatively intact coral community in both the fringing and barrier reefs. It is a high volcanic island roughly 1.2 million years old and is part of the Society Island chain. It has two large erosional bays on the northern coast, Cook's and Opunohu. There are a number of ephemeral streams that flow into and deposit sediment in both Cook's and Opunohu bay. These bays are an important source of tourism, so monitoring the effect of stream output can protect economic interests. In a previous study on marine alga, Harbaugh 2000 showed that these streams had no effect on the total species richness, but did find that eutrophication increased one alga species, *Padina* sp.

This study sought to test the following hypotheses: (1) Stream input into Cook's and Opunohu bay alters the marine environment directly in front of the stream input either by increasing sediment and/or nutrient input; (2) this sedimentation and eutrophication will have an effect on coral rubble-inhabiting crustacean communities by: causing a decline in species richness, changing the microcommunity composition of the coral rubble, and causing a decline in the total number of individual organisms living in the rubble, thus altering the density and diversity of coral rubble-inhabiting crustaceans; (3) these factors will also change the patterns of colonization of these coral rubble pieces. The general goal was to find species that are sensitive to one or more of the factors of stream input and use them as bioindicators of overall health of the bays.

METHODS

Study Site

The island of Mo'orea (S17° 30', W149° 50') is located in the Society Island archipelago of French Polynesia. It is a high volcanic island that was formed approximately 1.2 million years ago. Both a fringing and barrier reef surround the island with a sandy-bottomed lagoon separating them. Two large bays, Opunohu Bay and Cook's Bay, are located on the north side of the island. A number of small, ephemeral streams empty

out into these bays as well as a permanent stream at the base of each bay.

Coral rubble was collected from 20 October to 11 November 2009 from a total of six stream sites, four in Cook's Bay and two in Opunohu Bay. Stream sites were located on both sides of Cook's Bay and on the east side of Opunohu Bay. The sites were selected based on the availability of coral rubble in front of each stream mouth; some sites were omitted because no coral rubble was available to analyze. Figure 1 shows the location of stream sites in Cook's and Opunohu bays

Control sites were selected 50 m from each stream site. A distance of 50 m was chosen because previous studies determined that effects of streams were localized within 50 m of the stream output (Harbaugh 2000). In most cases the control had a similar orientation and substrate composition as the stream sites. A coin was flipped to determine whether to select a control site north or south of the stream site.



FIG. 1. Map showing locations of stream sites in Opunohu (top) and Cook's (bottom) bays. Gump Station is noted with a star.

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At each site a total of five coral rubble pieces were collected to sample the crustacean communities. At each stream site a transect tape was used to measure 15 m from the center of the stream source. Rubble was collected between 10 and 15 m from the stream source along a 10 m transect parallel to the shore. Each control site was 50 m north or south of the stream sites and rubble was collected using the same method as the one used at the stream sites. All rubble collected was found between .5 and 1.5 m depth.

Rubble pieces were selected through visual inspection and omitted if they were determined to be unsuitable for organisms to live in. Each rubble piece was placed in a separate plastic tray and remained separated until it was analyzed. Some sensitive animals (e.g. fish) were released on site to avoid killing them. Stream width, depth of collection, substrate type (sand, dead coral, etc.), and other environmental factors were all noted on site.

At two stream sites and corresponding control sites, wire mesh trays were placed with defaunated coral rubble pieces to compare colonization patterns. Three trays measured 50x 50x 20cm with 2x2cm wire mesh, and one tray measured 45 x 45x 20cm with 2x2cm wire mesh. Each wire mesh tray contained 10 pieces of coral rubble that had been dried in the sun for a total of two weeks to defaunate them. They were placed 10 m from the center of the stream source and the shore for stream sites and controls respectively. All trays remained for 14 days before they were collected and analyzed. All 10 rubble pieces were analyzed and crustaceans were collected from each. Stream sites were chosen because of their proximity to the station to aid in the ease of deployment and collection of the trays.

Water samples were taken at each stream and control site on November 9, 2009 after approximately 24hrs of intermittent rain. Measures were taken .5 m from shore. All water samples were taken within two hours of each other and were kept to be analyzed at UC Berkeley.

Lab Work

After collection, plastic trays with rubble were brought to the lab to be quantified. Rubble was placed into a bucket with seawater to measure total displacement volume as a proxy for total size. Total algal cover was visualized and placed within four

general categories of percent cover (0-25, 25-50, 50-75, 75-100%). The types of algae covering the rubble were also noted.

After quantification, the rubble was broken apart with a hammer so that all decapods and stomatopods could be collected. Rubble was broken apart until no interstices remained and each organism was placed in plastic tubs and cups to be identified and counted. The organisms were identified to species or genus levels when possible using the best identification resource available (BioCode marine invertebrate identification guide). BioCode researchers were consulted for organisms that were particularly difficult to identify or new to Mo'orea. Organisms that have not been previously identified in Mo'orea were identified to family level. A total of over 1400 individual crustaceans were collected and a total of over 40 species were identified.

Water collections were analyzed at UC Berkeley on December 4, 2009. Turbidity measures were taken using a Hach 2100P Turbidometer. Conductivity and salinity measures were taken using a YSI 30 salinity, conductivity, and temperature meter. Conductivity measures were adjusted for the temperature of the water sample. pH was measured using a pH Testr 2.

Statistical Analyses

Streams vs. Control

One-way analysis of variance (ANOVA) tests were used to test differences between stream and control sites for total number of individuals, total number of species, and for differences between 12 individual species (*Galathea mauritiana*, *Thalamita admete*, *Chlorodiella* sp., *Cuapetes* sp., *Alpheus parvirostris*, *Xanthias lamarcki*, *Calcinus seurati*, *Liomera bella*, *Psuamis cavipes*, *Alpheus paracrinatus*, *Athanas dijiboutensis*, *Menaethius monocerus*) all of which occurred more than once per site on average. One-way ANOVA tests were also run to analyze whether displacement volume or algal cover of rubble differed between sites and controls which could have a possible effect on the number and types of crustaceans collected. All ANOVA analyses were run with a block for sites, to attempt to eliminate variance due to differences between sites. Linear regression analyses were performed to determine whether there was a significant relationship between number of individuals, species, and

the 12 individual species above and characteristics of the coral rubble such as displacement volume or percent algal cover.

Water Testing Data

One-way ANOVA tests were run to look for differences between streams and controls in turbidity levels, conductivity/salinity levels, and pH. Linear regression analyses were used to determine whether a significant relationship existed between total number of individuals and species and the 12 individual species listed above and water testing data.

Colonization Study

One-way ANOVA tests were run to examine possible differences in colonization in the total number of individuals, species, and all individual species found in the colonized rubble. A linear regression analysis was performed to test the relationship between total number of individuals collected and the date collected to test for effects of rainfall during the collection period.

RESULTS

Streams vs. Control

One-way ANOVA tests showed no significant difference between streams and controls for total number of individuals, total number of species, and for 9 of 12 individual species analyzed (*Galathea mauritiana*, *Chlorodiella* sp., *Cuapetes* sp., *Xanthias lamarcki*, *Calcinus seurati*, *Liomera bella*, *Alpheus paracrinitus*, *Athanus dijiboutensis*, *Menaethius monocerus*) ($p > 0.05$). There were significant differences in 3 of 9 individual species analyzed (Figure 2-3). Analysis for *Thalamita admete* showed significantly more individuals collected at stream sites than controls ($p = 0.0492$, $df = 1$, $F \text{ ratio} = 4.0907$). *Alpheus parvirostris* showed significantly more individuals at control sites than streams ($p = 0.0450$, $df = 1$, $F \text{ ratio} = 4.2583$). Similarly, there were significantly more *Psuamis cavipes* at control sites than stream sites ($p = 0.0161$, $df = 1$, $F \text{ ratio} = 6.2658$).

One-way ANOVA tests showed no significant difference between stream sites and controls for displacement volume ($p > 0.05$). There was, however, significantly more algal coverage at stream sites than controls (Figure 5).

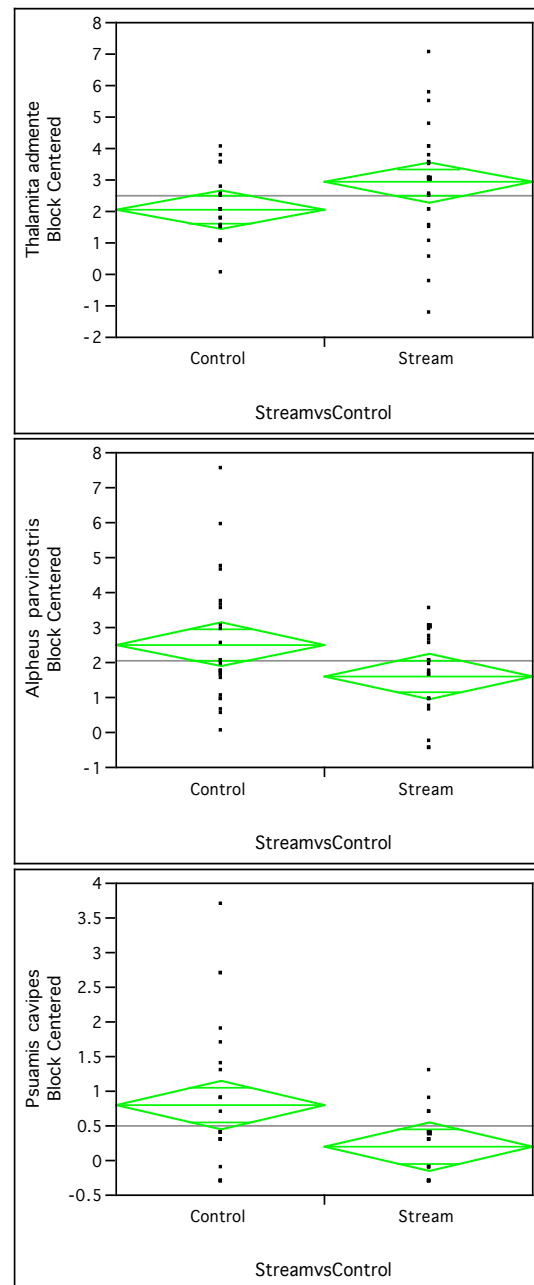


FIG. 2-4. Differences between control and stream sites in three crustacean species. FIG. 2. (Top) *Thalamita admete* has significantly higher density at stream compared to control sites. FIG. 3 (Middle) *Alpheus parvirostris* has significantly higher density at control compared to stream sites. FIG. 4 (Bottom) *Psuamis cavipes* has significantly higher density at control compared to stream sites.

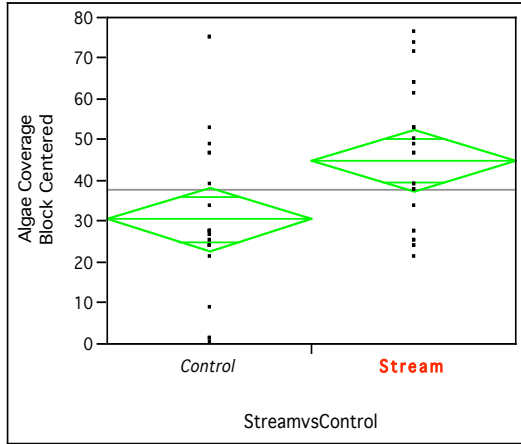


FIG. 5. Difference in percent algal cover on each rubble piece between stream and control sites showing a significantly higher amount of algal cover on stream sites than control ($p=0.0095$, $df=1$, F ratio= 7.3508).

Linear regression analyses showed that *Thalamita admete* showed a near significant increase in number as percent algal cover increased (Figure 6). *Alpheus parvirostris* and *Pseudis cavipes* showed no significant relationship with percent algal cover ($p \gg 0.05$).

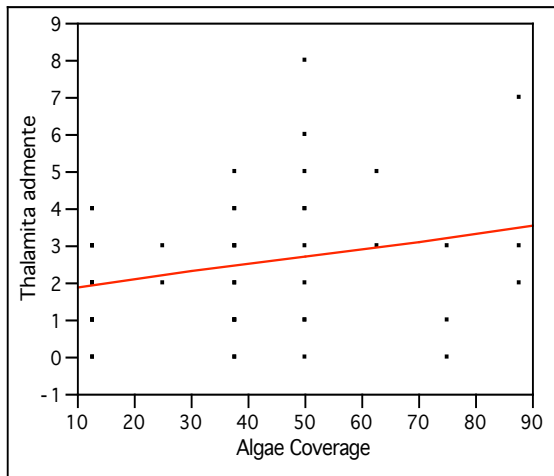


FIG. 6 Near-significant positive linear relationship between the total amount of *Thalamita admete* collected and percent algal coverage of each coral rubble piece ($p=0.0773$, $df=1$, F ratio= 3.2581).

Water Testing Data

The results from water testing are summarized in Table 1. No significant difference was found between stream sites and controls in any water testing factor. Linear regression analysis showed that there was a significant negative relationship between pH level and the number of *Cuapetes* sp. found at each site (Figure 7). No significant relationship was found in any other analysis of water testing data.

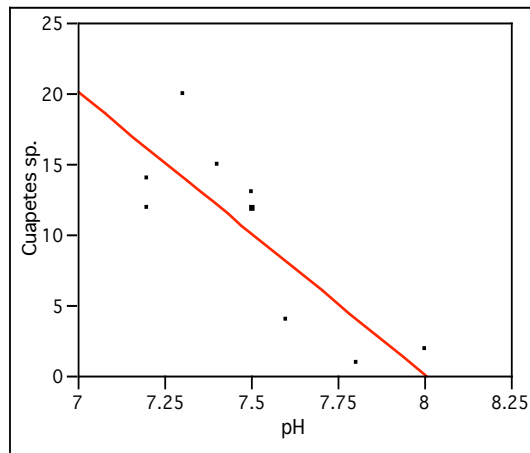


FIG. 7. Graph showing response of the number of *Cuapetes* sp. per site to increasing pH levels. A significant negative relationship exists between number of *Cuapetes* sp. and pH level ($p=0.0103$, $df=1$, F ratio= 13.5310).

Colonization Study

The results from the colonization study are summarized in Table 2. One-way ANOVA analysis found no significant difference between streams and controls in number of individuals, number of species, and total number of any species found in colonization's studies. Linear regression analysis showed there was a near significant relationship between date collected and the number of individuals found in each rubble tray (Figure 8).

TABLE 1: Results from water turbidity, conductivity/salinity, and pH tests.

Site	Turbidity(Avg NTU)	Conductivity (mS)	Salinity (ppT)	pH
Cook1	11.83	48.85	32.1	7.4
Cont1	1.61	53.8	35.6	8
Cook2	8.18	38.1	29.2	7.2
Cont2	1.48	45.18	35.1	7.3
Cook3	19.5	3.64	1.9	7.5
Cont3	1.37	45.01	34.7	7.2
Cook4	97.48	1.89	1.2	7.5
Cont4*	NA	NA	NA	NA
Op1	1.23	45.23	35.4	7.8
Opcont1	0.845	46.2	36.3	7.6

*Note: Cont4 samples lost during transport to UC Berkeley.

TABLE 2: Summary of total number of species and individuals collected for the colonization study at stream sites and controls with date collected included.

Site (date collected)	Cook1(11/8)	Cont1 (11/9)	Cook2 (11/10)	Cont2(11/11)
<i>Galathea mauritiana</i>	49	50	31	14
<i>Thalamita admete</i>	33	16	23	12
<i>Cuapetes sp.</i>	5	6	4	4
<i>Calcinus seurati</i>	3	6	1	0
<i>Alpheus paracrinitus</i>	2	1	3	2
<i>Athanus dijiboutensis</i>	2	0	7	6
<i>Pilodius areolatus</i>	2	0	0	1
<i>Alpheus parvirostris</i>	1	0	1	0
<i>Gonodactylus childi</i>	1	1	0	0
<i>Raoulserenea sp.</i>	1	0	0	0
<i>Saron marmoratus</i>	1	0	0	0
<i>Alpheus pacificus</i>	0	0	1	0
<i>Athanus parvus</i>	0	1	0	0
<i>Chlorodiella sp.</i>	0	3	5	6
<i>Phylladiorynchus sp.</i>	0	0	2	0
<i>Xanthias lamarcki</i>	0	0	1	0
# of Individuals	100	84	79	45
# of species	11	8	11	7

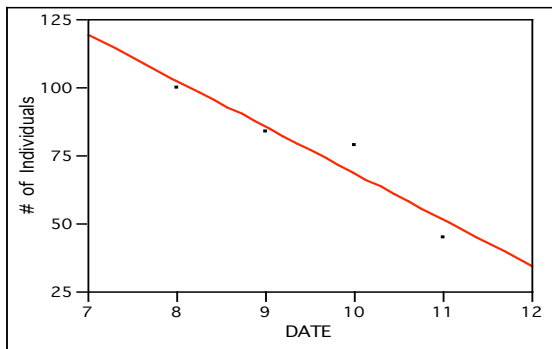


FIG. 8. Near- significant linear relationship between total number of individuals collected and the date collected in November ($p=0.0514$, $df=1$, F ratio=17.9503). Note: significant rainfall began on the 9th.

DISCUSSION

Stream vs. Control

One-way ANOVA analyses showed that stream and control sites had no statistically significant differences in total number of species, total number of individuals, or 9 of the 12 individual species analyzed (*Galathea mauritiana*, *Chlorodiella sp.*, *Cuapetes sp.*, *Xanthias lamarcki*, *Calcinus seurati*, *Liomera bella*, *Alpheus paracrinitus*, *Athanus dijiboutensis*, *Menaethius monocerus*). The lack of significant differences between could be explained by a

few reasons. First, stream and control site may not differ in sedimentation, chemical, and/or nutrient input in any discernable way. Also, coral-rubble crustacean density and diversity may not be sensitive to the sedimentation, chemical, and/or nutrient input differences in levels that these stream and control site fluctuate. These factors, as well as flaws in experimental design, would account for the lack of difference between these sites. The lack of differences between provides evidence that coral rubble inhabiting crustacean community diversity and density are not viable bioindicators for the effects of freshwater input.

Algal coverage, however, was significantly higher at stream sites than controls. Although algal coverage was not a difference that I originally attempted to measure, it highlights the same principles that I was attempting to test. The increase in percent algal coverage may reflect an increased amount of nutrient runoff from stream input causing eutrophication of the surrounding marine environment. Previous studies have shown that increased eutrophication caused by terrestrial runoff causes increased macro algal coverage in the fringing reef environment (Wittenberg and Hunte 1992). My results contradict a similar study by Harbaugh (2000) that found no difference between streams and controls in total percent algal coverage. The different sites may explain this contradiction or methods of assessing algal coverage used by our studies, the fact that I only examined algal coverage on a coral rubble substrate, and/or reflect an actual change in the algal coverage in front of streams in the past 9 years. It is important to monitor increased amounts of algal coverage caused by eutrophication because it has been shown to decrease coral larval recruitment and decrease species diversity in coral reef communities (Wittenberg and Hunte 1992, Littler et al. 1993). Algal coverage of coral rubble may be a viable bioindicator for assessing stream eutrophication in the fringing reefs of Mo'orea.

Along with algal cover, 3 individual species had significant differences in density between streams and controls. The first, a portunid crab called *Thalamita admete*, had significantly more individuals at stream sites than controls, which is the opposite response to stream sites that I hypothesized. This response to stream sites may be partially explained by the significant increase of algal

coverage found between streams and controls. From personal observations while collecting I found that *Thalamita admete* was most often found on the outside of coral rubble pieces and not deep in the interstices of the rubble. These personal observations are coupled with life history data that *T. admete*, a member of the family Portunidae, is an active carnivorous predator with swimmer legs for quick swimming movement in the open water which would be more useful in an open environment on the outside of rubble than in the interstices (Choy 1986). Algal cover, therefore, may provide an environment that promotes higher densities of *T. admete* either for shelter, food, or other ecological reasons. Linear regression analysis shows that *T. admete* density is positively correlated with percent algal coverage and although not quite statistically significant ($p=0.077$), it provides added evidence that algal coverage may explain the increased densities at stream sites. This result may provide an indirect indicator of possible eutrophication caused by stream input; increased algal caused by nutrient input increases the densities *T. admete*. Therefore *T. admete* densities may be used as an indirect indicator of possible eutrophication, but the densities respond by increasing in stream sites, opposite to what I had hypothesized.

Another species, an alpheid shrimp called *Alpheus parvirostris*, showed an opposite response to stream sites with a significant decrease in density compared to controls. This species responded to some factor of stream input by having significantly decreased number of individuals compared to controls. In this case, linear regression analysis shows that algal cover does not affect the density of *A. parvirostris* ($p=0.9$). Personal observations while collecting revealed that these shrimp live deep in the interstices of the coral rubble. This agrees with life history data that *A. parvirostris*, along with other snapping shrimp in the family Alpheidae, use their large chela (claw) to defend their burrows in the coral rubble (Conover and Miller 1978). These shrimp do not gain the benefit of increased algal cover and show a negative response in density to stream input. They respond to stream input as I hypothesized and their relative densities may be used as a bioindicator to monitor the fringing reef's response to stream input.

The last species, a xanthid crab called *Psuammis cavipes*, also had a significant decrease in density at stream sites compared to controls ($p=0.0161$). From personal observation, this

crab was also found deeper in the interstices of coral rubble with not many found around the outside. Linear regression analysis also showed it had no significant relationship with algal cover ($p=0.15$) so it does not benefit from increased algal coverage caused by stream input. Decreased densities of *P. cavipes* at stream inputs may be caused by chemical or sediment input into the fringing reef. *P. cavipes* may also be a possible candidate as a bioindicator for the effects of stream input into the fringing reef.

Water Testing Data

There was no significant difference between streams and controls in any of the water testing factors (turbidity, conductivity/salinity, pH). This lack of significant difference is probably due to the ephemeral nature of the streams and the amount of rainfall at the time of water collection. Although water samples were collected at a time with the most rainfall in the weeks in Mo'orea, it was before the tropical storms of the rainy season and only a two of the stream sites, Cook3 and Cook4, had any significant input of fresh water into the marine environment. This is reflected in their salinity levels, 1.9 and 1.2 ppt respectively (See Table 1). All other stream sites had very little to no freshwater input and this is reflected in the water testing data. In order to accurately test a relationship between water testing data and coral rubble crustacean communities, water samples need to be taken during a period of heavy rainfall when there is significant freshwater input into the fringing reef.

Similarly, linear regression analyses of the correlation between water testing data and total number of individuals, species, and individual species all were found to be not significant except between the shrimp *Cuapetes* sp. and pH levels. As shown in Figure 6, *Cuapetes* sp. had a significant negative relationship with pH levels across sites. Although there was no significant difference between sites and controls in pH levels, this relationship shows a biological response to the marine environment becoming more basic. Again, more rigorous water testing at a time with more significant stream input would show the effects of pH more clearly. *Cuapetes* sp. may prove to be a bioindicator for the environment becoming increasingly basic. A simple lab experiment studying the effects of water that is increasingly basic on the health

of *Cuapetes* sp. would shed light on the validity of this bioindicator.

Colonization Data

Colonization data showed no significant differences between sites and controls for any of the total number of species analyzed. There was high variance both among and between sites, and having only 4 replicate sites eliminated any possibility of finding significance between stream and control sites. A future study with many more replicates and possibly a long time for the trays to be set out, longer than 2 weeks, would further illuminate the effects (if any) by freshwater input on the colonization rate of these coral rubble pieces. Previous studies have used defaunated coral rubble colonization as a possible bioindicator of lagoon health across a terrestrial-sediment gradient (Takada et al. 2008). This experiment was interesting, however, in demonstrating the primary stages of colonization of these coral rubble pieces. The newly colonized rubble was primarily composed of *Galathea mauritiana* and *Thalamita admete*, a squat lobster and crab species that from personal observation while collecting primarily live on the outside of coral rubble.

There was, surprisingly, a near significant negative relationship between the date coral rubble was collected and the total density of crabs collected ($p=0.0514$). All trays of coral rubble were left out for 2 weeks, but their deployment and collection was staggered on successive days. This relationship may be related to the increasing amount of rainfall during this period (November 9th was the date when water samples were taken). This relationship could also, however, be due to statistical error caused by the few number of replicates (4 sites). Further replicates of this study, coupled with more precise weather data would be necessary to confirm this relationship and test the strength of significance.

Conclusions

Although many analyses on the differences between stream and control sites were not significant, considerable progress has been made in the search for a bioindicator to monitor freshwater input into the fringing reef environment. Percent algal cover was found to be significantly higher in streams sites and controls, possibly a response to eutrophication caused by stream input.

Three possible crustacean bioindicators have been found with differing densities between streams and controls. One (*Thalamita admete*) is most likely linked to increased algal cover caused by eutrophication, but 2 others (*Alpheus parvirostris* and *Psuamis cavipes*) have decreased densities caused by some sort of chemical or physical disturbance caused by stream output. *Cuapetes* sp. also may be a bioindicator to monitor the effects of pH levels in the marine environment. Further studies with more accurate water testing data (chemical and turbidity levels) would clarify the relationship between the possible bioindicators and stream input into the fringing reef. These coral rubble-inhabiting crustaceans join others found in previous studies as possible candidates for effective bioindicators for monitoring the health of the coastal zone (Takada et al. 2008, Erdmann and Caldwell 1997). These bioindicators could be used as part of a larger monitoring program to ensure effective management of the coastal zone (Linton and Warner 2003). Effective monitoring can help protect coral reef habitats, one of the most important ecosystems for maintaining marine biodiversity on Earth.

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LITERATURE CITED

- Choy S. C. 1986. Natural diet and feeding habits of the crabs *Liocarcinus puber* and *L. holsatus* (Decapoda, Brachyura, Portunidae). *Marine Ecology Progress Series* 31:87-99.
- Conover M. R. and Miller D. E. 1978. The importance of the large chela in the territorial and pairing behaviour of the snapping shrimp, *Alpheus heterochaelis*. *Marine and Freshwater Behaviour and Physiology* 5:185-192.
- Dahl, A. L. (1985). Status and conservation of South Pacific coral reefs. *Proc. 5th int. Coral Reef Congr.* 6:509-513
- Erdmann MV, Caldwell RL (1997). Stomatopod crustaceans as bioindicators of marine pollution stress on coral reefs. *Proc 8th International Coral Reef Symposium* 2:1521-1526
- Frouin, P (2000). Effects of anthropogenic disturbances of tropical soft-bottom benthic communities. *Marine Ecology Progress Series* 192:39-53.
- Harbaugh, DT (2000) The Use of Algae to Indicate Eutrophication in the Streams of Cook's and Opunohu Bays, Mo'orea, French Polynesia. Pp.172-182 in *Biology and Geomorphology of Tropical Islands: Student Papers 2000*. University of California, Berkeley.
- Clump DW, McKinnon AD, Mundy CN (1988) Motile cryptofauna of a coral reef: abundance, distribution and trophic potential *Marine Ecology Progress Series* 45:95-108.
- Linton, DM and Warner GF (2003) Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. *Ocean and Coastal Management* 46:261-276.
- Littler M. M., Littler D. S., and Lapointe B. E. 1993. Modification of tropical reef community structure due to cultural eutrophication: the southwest coast of Martinique. *Proceedings of the Seventh International Coral Reefs Symposium, Guam, 1992* 1:335-343.
- Mathews, LM (2006) Cryptic biodiversity and phylogeographical patterns in a snapping shrimp species complex. *Molecular Ecology* 15:4049-4063.
- Rogers, CS (1990) Responses of coral reefs and reef organisms to sedimentation. *Marine Ecology Progress Series* 62:185-202.

- Snelgrove, PVR and Lewis, JB Response of a coral-associated crustacean community to eutrophication *Marine Biology* **101**:249-257.
- Takada Y, Abe O, Shibuno T (2008) Cryptic assemblages in coral-rubble interstices along a terrestrial-sediment gradient. *Coral Reefs* **27**:665-675.
- Wittenberg M. and Hunte W. 1992. Effects of eutrophication and sedimentation on juvenile corals I. Abundance, mortality and community structure. *Marine Biology* **112**:131-138.

APPENDIX A

Quick-guide to common coral rubble-inhabiting crustaceans. Photo is provided when available along with short description of distinct features. All photos courtesy of Artour Anker.

Actaeodes hirutissimus- xanthid crab with wide-set eyes on carapace, grey/brown color. Distinctive ridges on carapace. May have algal growth on body/legs



Alpheus barbatus- one enlarged claw, clear with mottled orange coloration, hair-like projections (setae) from smaller claw (distinct feature). Previously undocumented in Mo'orea

Alpheus obesomanus- one grossly enlarged claw (distinctive feature), clear with some yellow coloration in abdomen, green eggs if present, distinctly larger than other alpheid shrimp

Alpheus pancrinitus- one enlarged claw with bulge at tip (*A. gracilis* has no bulge), orange/brown horizontal striping across tail, yellow eggs if present



Alpheus parvirostris- one enlarged claw, blue horizontal striping on tail, soft brown claws white tips on claws (distinctive feature).



Atergatis floridus- smooth, rounded carapace. Cream colored on carapace with brown mottling. Brown legs with white tips.



Athanus dijiboutensis- distinctively small (~1cm). absence of enlarged claw, white horizontal stripes down back until tail. Sometimes very faint or only present on tail.

Athanus soror- solid color from purple to yellow to soft green. Usually found associated with cushion star host.

Calcinus seurati- hermit crab, light colored with black and white striped legs. Sometimes blue tint around eyes.



Chlorodiella sp.- *C. barbata* or *C. crispipleopa*?
C. crispipleopa has more hair-like projections on legs. Very hard to distinguish between species so I lumped them together. Large color variation grey-green-brown color morphs. Banded legs, black tips on claws.



Cuapetes sp.- completely clear coloration. Large eyes on top of head. Elongated front claws (distinctive feature).



Galathea mauritiana- “squat lobster” Distinctive body form with very large claws compared to body size. Tail used to “scoot” backwards. Color varies from grey-green-blue-even reddish varieties.



Gnathophyllum americanus- “bumblebee shrimp” distinctive yellow and black striping (variable width). Elongated front claws.



Liomera bella- small xanthid crab, red to purple in coloration, smooth appearance but closer inspection shows some ridging on carapace. White tips on legs.



Liomera tristis- distinctive smooth, white carapace. White eyes. Red claws and “peppermint striped” legs.

Phylladiorynchus sp.- “squat lobster” similar to *Galathea mauritiana* except much smaller claws relative to body. Color usually cream/white/light grey. Generally very small.

Pilodius pugil- black and white banding on legs with black and white banding. Similar to *Chlorodiella* sp. except has distinctive reddish ridges on tops of claws.

Platypoda anaglypta- smooth, round carapace. Eyes wide set apart and distinctly white. Body and legs all brown color



Psuamis cavipes- whitish coloration with paired ridges running down edges and middle of carapace. Soft scalloped edging on carapace. Numerous hair-like projections on legs and claws.



Thalamita admete- portunid crab with distinctive features: “swimmer legs”, thin claws, v-shaped carapace. White line on tips of claws. Tan coloration.



Xanthias lamarcki- very typical xanthid crab, robust claws with stocky carapace. Black tips on claws. Variable color from brown to grey, but always white pattern on claws and edge of carapace.