SUBSTRATA PREFERENCE IN FORAMINIFERA OF FOULING COMMUNITIES IN MOOREA, FRENCH POLYNESIA

MYFANWY E. ROWLANDS

Environmental Science Policy and Management, and Earth and Planetary Science, University of California, Berkeley, California 94720 USA

Abstract. Foraminifera are known to occur in fouling communities, but no extensive studies of foraminifera assemblages on these communities exist. We know little about the differences (if any) in the succession, diversity, distribution, and selective strategies of foraminifera found in fouling communities, and nothing at all has been documented about the foraminifera in fouling communities on Moorea, French Polynesia. This study examined foraminifera assemblages in fouling communities of three substrates on Moorea (cement, plastic, and metal). An experiment on the succession of foraminifera over the course of four weeks on submerged steel fouling tiles was also conducted. Hierarchical cluster analysis determined that forams in fouling communities do not show a preference for metal, plastic, or cement substrate, and that foram assemblages in fouling communities on the island are similar, regardless of their locality around Moorea. Succession followed a typical trend, but may have been accelerated by disturbance.

Keywords: Benthic foraminifera, fouling community, succession, artificial substrate, assemblage, French Polynesia.

INTRODUCTION

Marine fouling communities are dynamic systems, often developing integral roles in their surrounding environment. The epibiont biomass they represent provides habitat, as well as an important link in the local marine food web (Krohling 2006). Their man-made origin, combined with an influential role in the marine ecosystem, compels the need for an extensive scientific understanding of the fouling community system and the organisms found within. The more that is known about how a fouling community is established, composed, and affected, the better we can predict how a marine ecosystem changes in response to biotic and abiotic factors incurred by human populations.

The consistent pattern of succession in these communities culminates in a unique assemblage of organisms suited for the fouling habitat (Scheer 1945). The assemblages of common fouling organisms have been observed to correspond with substrate (Beatriz et al 2006, McGuinness & Underwood 1986, Scheer 1945), and fouling organisms are selective between artificial substrate types, favoring cement (Beatriz et al 2006). Pier pilings, docks, and the hulls of ships and boats are all very suitable environments for many varieties of organisms, such as of ascidians, bryozoans, mussels, tube building polychaetes, sea anemones, and foraminifera (Hewitt *et al.* 2002).

Foraminifera are useful bioindicators, and their presence in fouling communities may be valuable in future ecological studies of these systems. Given these applications, it is beneficial to describe the assemblages of fouling forams and what factors determine their distribution.

The composition of foraminifera in fouling communities has not been studied in depth, and we know next to nothing of the

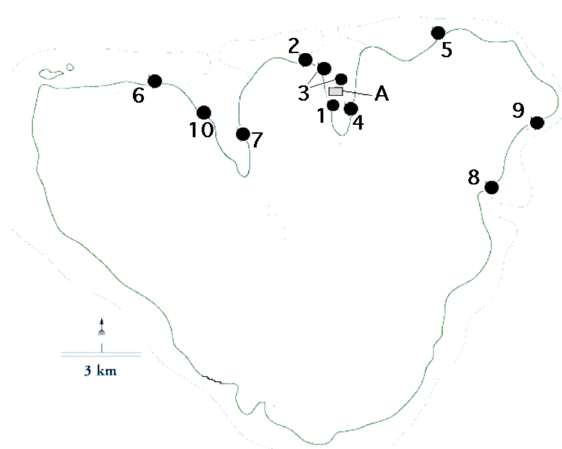

Figure 1. Sampling sites on Mo'orea, grouped into 10 localities.

foraminifera present in the fouling communities on Moorea Island, French Polynesia. Substrate is a determining factor in the distribution of benthic foraminifera (Murray 1991), but little is known about their succession. Their preference (if any) between artificial substrate is also unknown. The aim of this study is to provide data on the assemblages of foraminifera in fouling communities on Moorea, French Polynesia, and to demonstrate whether fouling forams select between three artificial substrates.

MATERIALS & METHODS

Sampling Fouling Community Sites

Twenty-nine different fouling community sites were sampled on Moorea, French Polynesia, comprising ten localities on the island (Fig. 1). A site was selected for substrate availability and stationary age (minimum one year). Examples of typical sampling sites include pier pilings, floating docks, and boat hulls. The samples were standardized for depth (6”-36”), and sampling took place on the leeward surface (the surface most protected from currents or disturbance) of the fouling site. Of the 29 samples, ten were from plastic substrate, ten from cement, and nine from metal.

The sampling method consisted of scraping the material present in a 25x25 cm quadrat into Ziploc bags, then filtering the material collected through a microsieve. Samples were treated with a solution of rose Bengal and 10% alcohol in order to to preserve and stain the protoplasm of any live foraminifera present, making differentiation between those forams that were alive or dead at the time of collection possible. Each sample was examined for thirty minutes under a dissection microscope, and all forams found during this period were identified and catalogued.

Succession experiment

A 5X4 grid of 15cm^2, hand-brushed galvanized steel tiles was constructed and placed in Cook’s Bay, 0.4 km from shore (Site A, Fig 1). The tile grid rested on a 0.75x0.75x.01m^2 metal plate, oriented semi-vertically in the water column at a depth of 0.5-1.5 meters. Five randomly selected tiles were collected at the end of each week for four weeks. Immediately after collection, the material on each tile was scraped off and filtered through a microsieve, then

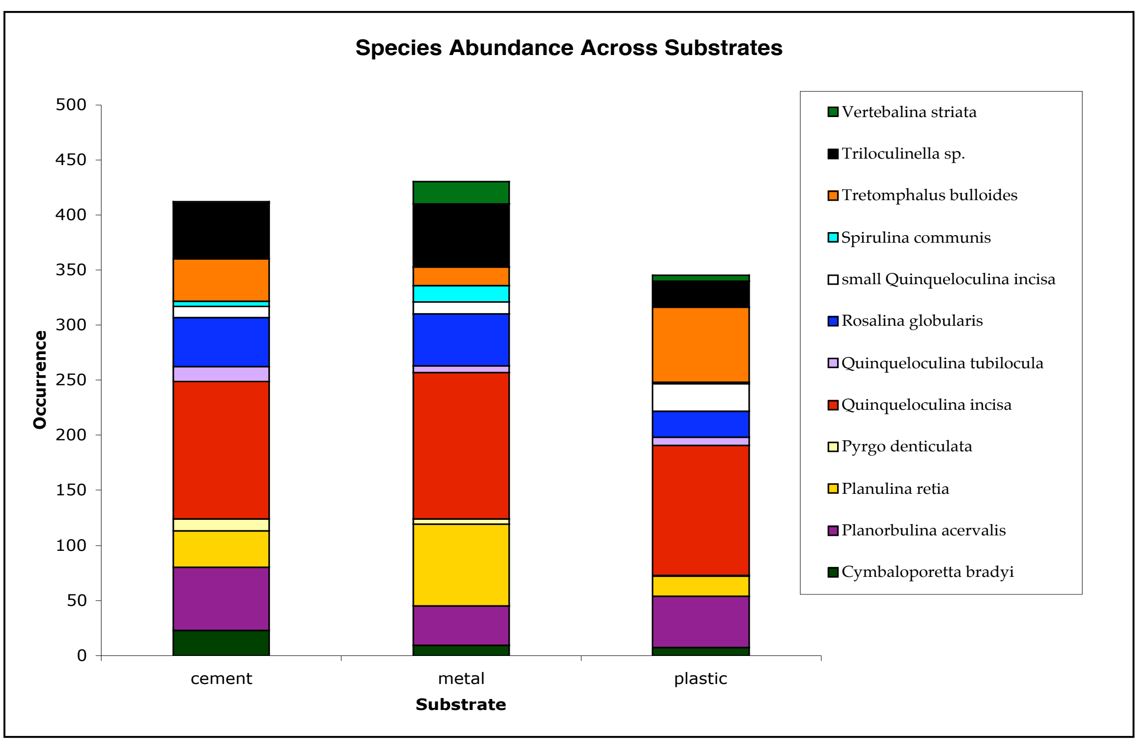

Figure 2. Distribution of the most abundant species by substrate.

examined in a Petri dish. The filtered material was examined in its entirety, and all foraminifera present were identified and catalogued.

Statistics

A hierarchical cluster multivariate statistical test was performed for the group of 29 samples, generating separate clusters for substrate and locality. A one-way ANOVA test was conducted for the Shannon diversity indexes of the samples from each substrate, followed by a Tukey-Kramer test to determine the significance between the indexes. Chi-squared tests were performed on the distribution abundances of individual species across all three substrates.

For data collected from the succession experiment, a T-test was used to determine significant differences between the species richness and abundance values for each week.

RESULTS

Fouling community sites

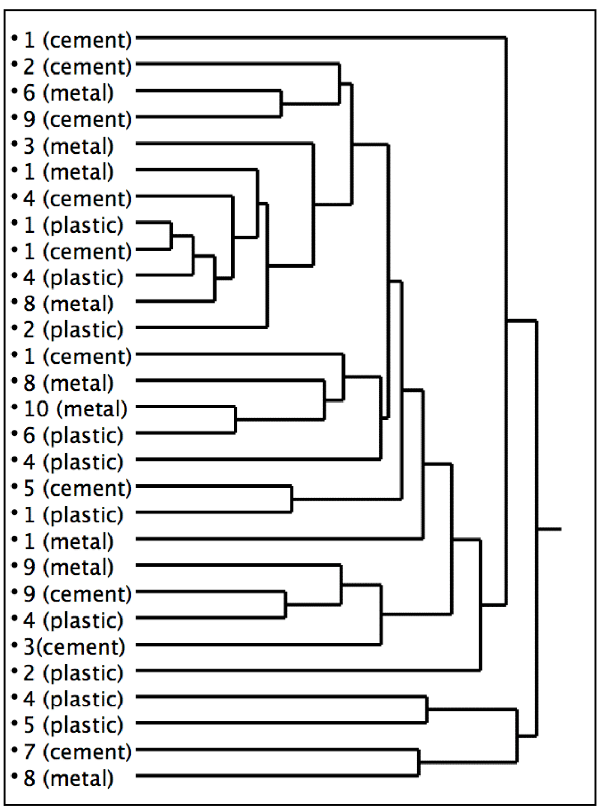

Figure 3. Hierarchical cluster by locality, substrate.

A total of 1279 foraminifera were recorded, representing 29 different species (Appendix 1). Abundance across substrate type was similar (Fig 2), and differences between species diversity indexes across substrates were not significant ($p<.52$). Chi-squared tests performed on individual species distribution across substrates found that 11 of the 29 species were disproportionately distributed (Appendix 1). Examples of the distribution of two abundant species, *C. bradyi* and *T. bulloides*, are shown (Fig 4). Hierarchical clustering of foram assemblages at each sampling site did not show a clear pattern by either locality or substrate type (Fig. 3).

Succession experiment

When the tiles were grouped by week, the succession of species richness and abundance showed a slight trend (Fig. 5), with a significant increase in values between week one and week two. There was also a significant difference in species richness and abundance between weeks one and four.

DISCUSSION

Fouling community sites

Past studies of the role of substrate in fouling communities have found that cement is preferred by the largest number of fouling organisms (Krohling et al 2006, Flavia et al 2006, McGuinness & Underwood 1987). Since the distribution of foraminifera is controlled by substrate (Murray 1991), assemblages are somewhat determined by the group of species adapted to live on a particular surface type. The overall similarity of foram assemblages on all the fouling sites sampled suggests that there is a definable group of common fouling forams on Moorea. Furthermore, the consistent composition of this assembly regardless to substrate type or locality suggests that they are not selective for either.

The ecology of the individual species and not the characteristics of the fouling community sites themselves may provide an explanation for the similar assemblages of fouling forams. The majority of the species found are common epifaunal benthic foraminifera. Because these species

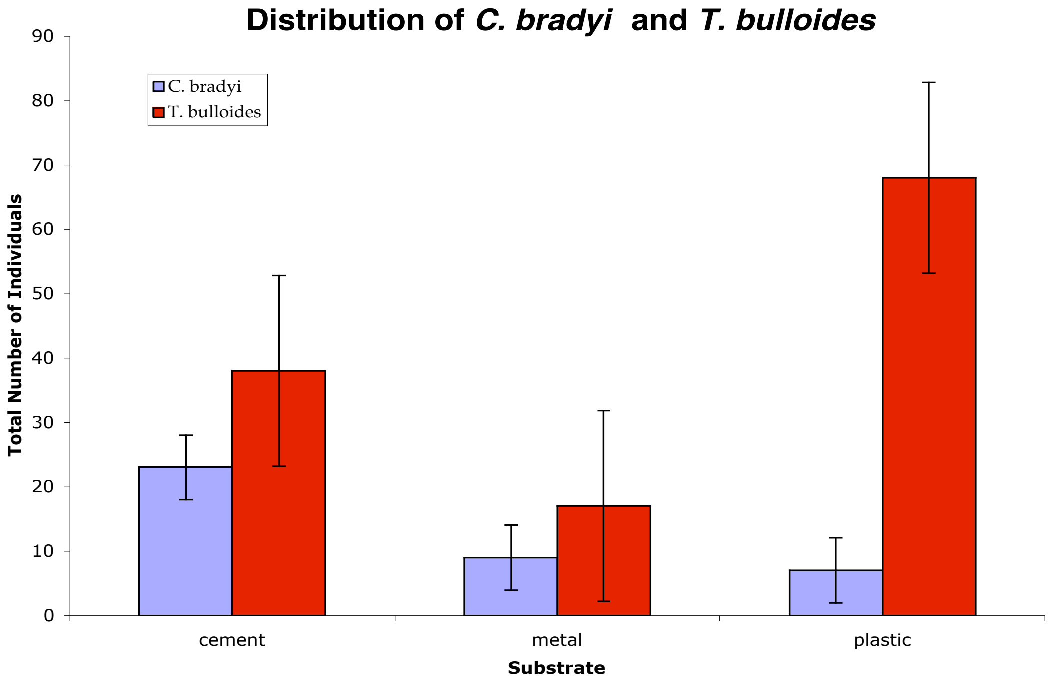

Figure 4. *T. bulloides* and *C. brayi* were observed disproportionately on plastic and cement substrate respectively.

are all able to exist as either free-living or clinging,

they have the widest range of microhabitats available to them (Murray 1991). The distribution of benthic foraminifera is influenced by the hardness of a substrate (Murray1991), but it has not been demonstrated that epifaunal benthic foraminifera select between hard substrates. Considering this, it is possible that given a hard surface for attachment, artificial substrate type does not make a difference to the overall assemblage of fouling forams.

The mechanism of attachment differs between species of epifaunal foraminifera (Lee 1991), and it may also describe the preference of one substrate over others exhibited by *C. bradyi* and *T. bulloides*. The first stage of fouling community colonization is often characterized by a homogeneous covering of macroalgae (Scheer 1945), providing favorable attachment opportunities for benthic foraminifera in a free-living life cycle phase such as *T. bulloides*, which was overwhelmingly found on younger plastic fouling sites. Conversely, cement substrate, like a calcareous surface, provides a favorable surface for boring foraminifera (Venec-Peyre 1987), such as *C. bradyi*, which was observed to prefer cement fouling sites. The preference for one substrate type over another at different periods in a foram life cycle would be an interesting area of further research.

Succession Experiment

The foraminifera documented in the tile succession were all common, abundant species found in lagoons on Moorea, indicating that the unique substrate did not have an effect on colonization.

However, the relatively low abundance found in this study did not make it possible to run statistical tests on individual species, and it was not discernable whether those few species observed exemplify the first colonizing forams of Moorea. The trend exhibited in species richness and abundance, characterized by low initial values followed by a sharp increase shortly thereafter before leveling off, is consistent with patterns in succession in fouling communities first described by Bradley Scheer in his extensive study of the

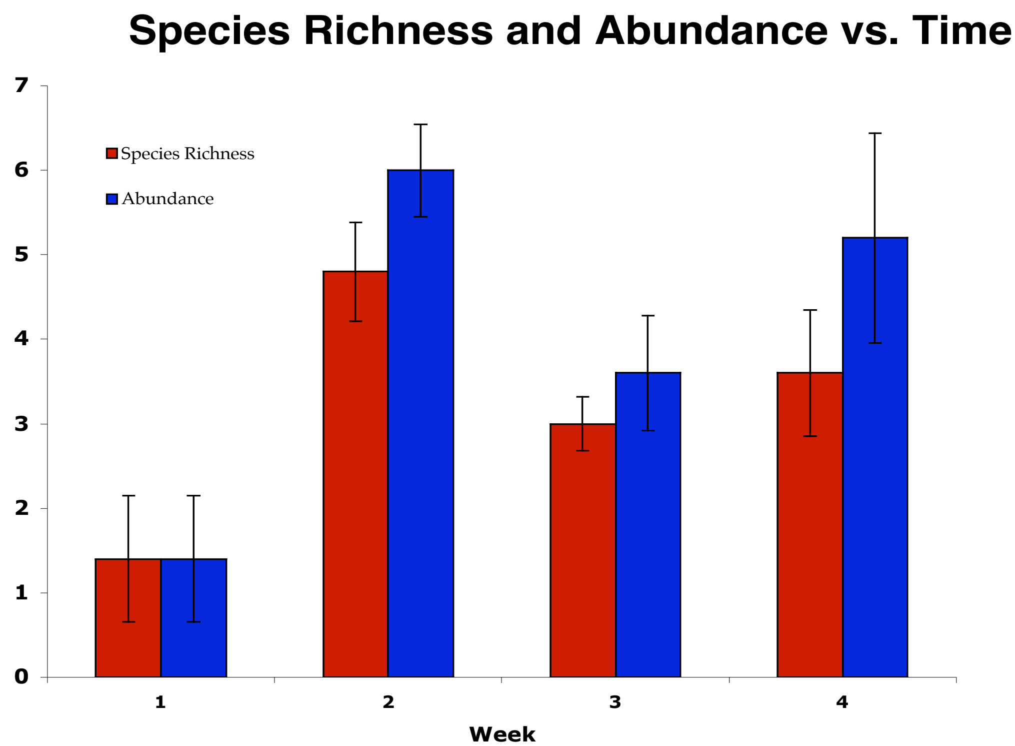

Figure 5. Succession of tile experiment.

development of marine fouling communities (*Biological Bulletin*, Vol. 3 1945) and repeated in later studies (McGuinnness & Underwood 1986). However, the rapid rate of succession observed is not consistent with documented rates. In the two studies mentioned above, the sharp increase in species abundance and diversity did not occur until after the eighth week of observation (McGuinness & Underwood 1986, Scheer 1945). Disturbance is one possible cause of the acceleration -- a large storm occurred in Cook's Bay less than 24 hours of the time the tile grid was placed. Field observations during tile placement note that there was so much material in the bay that visibility underwater became a problem. The abnormal amount of material in the water column may have settled on the tiles more readily than otherwise, accelerating succession. In light of this, a more long-term study with multiple trials would be required to define the rate of foraminiferal succession, as well as the relative abundances of initial colonizing forams.

CONCLUSION

The fouling forams on Moorea comprise a definable group, and the assembly of this group does not appear to depend upon artificial substrate type or locality around the island. Individual species of fouling forams show preference for substrate, but this does not affect the overall composition of assemblies. Succession in foraminifera can occur rapidly and may obey a normal fouling succession, but further studies of this aspect of foraminiferal ecology are needed to confirm the trend observed in this study.

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APPENDIX 1

Recorded Species Abundance and Substrate Preference

Species	Total number found	Substrate preference
Agglutinella arenata	10	
Ammodiscus sp.	15	
Amphisorus lessonii	4	
Amphistegina hemprichii	1	
Cheilochanus sp.	3	Cement
Cheilochanus minutus	3	
Cymbaloporetta bradyi	39	
Elphidium sp.	4	
Fischerinella diversa	3	
Laevidentalina sidebottomi	1	
Massilina timorensis	1	
Patellina corrugatta	2	
Peneroplis pertusus	8	
Planorbulina acervalis	140	
Planulina retia	125	Metal
Pyrgo denticulata	17	Cement
Quinquiloculina cuveriana	10	
Quinqueloculina incisa	376	
Quinqueloculina latidentella	7	
Quinqueloculina sp.	14	Plastic, cement
Quinqueloculina tubilocula	26	
Rosalina globularis	116	Metal, cement
Siphogenerina striata	4	Plastic
Juvenile Quinqueloculina incisa	46	Plastic
Juvenile Quinqueloculina tubilocula	2	
Spirilina communis	21	Metal
Tretomphalus bulloides	123	Plastic
Triloculina sp.	132	Metal
Vertebralina striata	26	Metal