

HABITAT PREFERENCE OF LIMPETS (SIPHONARIA) AND INTERSPECIFIC COMPETITION WITH BROWN ALGAE AND BARNACLES IN THE INTERTIDAL ZONE IN MOOREA, FRENCH POLYNESIA

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Abstract. Competition for resources plays an integral role in determining how and where species interact and reside. Competition can refer to interspecific, where individuals from different species compete, or intraspecific, where individuals from the same species compete. Individuals may compete over resources such as food, space, and nutrients. The individual that can outcompete will likely gain the resource, although other factors can influence an individual's ability to compete. Habitat preference may interfere with an individual's ability to use valuable resources. *Siphonaria sp.* is a limpet found along the intertidal rocks of Moorea, French Polynesia, interacting with brown algae and barnacles. This study looked at the ability of limpets to colonize plots previously occupied with barnacles or brown algae. Manipulations were done to see if limpets would move into areas previously occupied on their own and limpets were moved into these areas to determine if they would stay. The results suggest there were only significant differences in the number of limpets in the cleared squares before or after the experiment when the limpets were moved into those squares. When left untouched, the results suggest there was no difference in the number of limpets in the cleared squares before or after the experiment, as well as no difference after the experiment between the cleared squares and the controls. This study explores community ecology along the intertidal zone by observing interactions between limpets, brown algae, and barnacles.

Key words: mollusca; Siphonaria; intertidal zone; Moorea, French Polynesia; community ecology

INTRODUCTION

A fundamental goal of community ecology is to observe interactions among organisms and determine their effects within and between species (Strong 1983). Since interactions between individuals and different species are a constant occurrence, community ecology is integral to our understanding of organisms and their environments. Community ecology can apply to varying scales, so it is vital to define specific scales to guide a research project.

Density-dependence and other biotic factors, intraspecific or interspecific, are essential in understanding how individuals establish territory (Elton and Miller 1954). Competition suggests that a species found in a

FIG. 1. Location of study site on Moorea, French Polynesia. Base map courtesy of the Geospatial Innovation Facility, University of California, Berkeley.



particular zone may be able to colonize a different zone "in the absence of related species normally found there" (Elton and

Miller 1954). The lower limit of distribution of intertidal organisms is primarily determined by biotic factors such as competition for space or predation while the upper limit is probably influenced more by physical factors (Connell 1961).

Limpets are marine gastropod molluscs. Because of their dependence on water, limpets are restricted to certain critical levels of the intertidal (Wolcott 1973). Some limpet species, such as *Lottia gigantea*, have been observed pushing other limpets out of their home range, typically a circular region the limpet patrols (Stimson 1970).

Some limpet species have been observed returning their "home scars" over a period of time. For example, *Littoralia prosobranchis* are believed to return to their home, created by their shells wearing away at the rock (Coo et al. 1969). *Siphonaria normalis* and *Siphonaria japonica* are limpets that consistently return to their "home scars" with the movement of the tide (Ohgushi 1954, Cook 1969). Cook (1969) observed limpets that were moved to an area they had previously been were able to return to their "home", while limpets moved to areas they had not previously seen were unable to return to their "home". Cook (1969) acknowledged "insufficient observations were made" in determining if the areas were unknown to the limpets. Cook (1969) also suggests unknown territories may have a detrimental effect on the limpets, interfering with their ability to return to their scar. Limpets return to their "scars" while the rock is wet and maintain their scar for a period of time (Garrity and Levings 1983).

In Moorea, French Polynesia, there are clear layers of stratification on intertidal rocks, with a brown alga occupying the lower region, *Siphonaria sp.* found along the border of brown alga and the water level, and barnacles above the limpets (Payri et al. 2000).

The overall goal of the present study was to test whether competition is structuring communities of *Siphonaria sp.*, barnacles, and brown alga. Experiments were performed to address the following questions. (1) If the barnacles are removed, will *Siphonaria sp.* colonize the cleared area? My hypothesis was that the *Siphonaria sp.* will not move into the newly cleared patches. (2) If the barnacles are

removed and *Siphonaria sp.* are placed in the clearing, will they stay? My hypothesis was that the *Siphonaria sp.* will stay in the newly cleared areas. (3) If the brown algae are removed, will *Siphonaria sp.* colonize the cleared area? My hypothesis was that the *Siphonaria sp.* will not move into the newly cleared patches. (4) If the brown algae are removed and *Siphonaria sp.* are placed in the clearing, will they stay? My hypothesis was that the *Siphonaria sp.* will stay in the newly cleared areas.

METHODS

Study site

Limpets were observed and collected at the UC Berkeley Gump Station (Fig. 1), in Cook's Bay in Moorea, French Polynesia (-17° 29' 25.728"S, -149° 49' 33.3474"W) from November 7 to November 19 2013. This site was chosen from preliminary studies that found limpets, brown algae, and barnacles all residing on the same rock. I identified *Siphonaria sp.* using specimen number BMOO-07569 from the Moorea BioCode Project (2013).

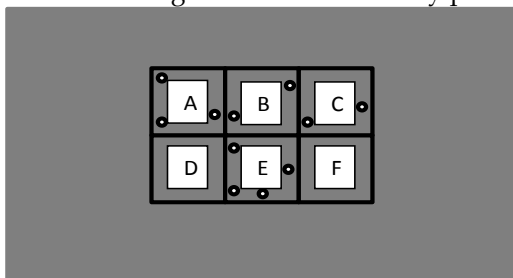
Barnacle removal and limpets not manipulated

To observe whether *Siphonaria sp.* colonize areas previously occupied by barnacles, 5x5 cm squares of barnacles were removed (Fig. 2, D and F), with a 5x5 cm square of undisturbed barnacles left between as a control (E). Rocks were chosen that were large enough to fit 10x15 cm plots and had limpets, brown algae, and barnacles. Six plots were placed over three rocks. One cleared square was observed (D or F) and the number of limpets that colonized was recorded every 24 hours from November 7-November 15. The number of limpets in every square (A, B, C, D, E, F) was recorded every 24 hours. An ANOVA test was used to test if the cleared squares were statistically different at the end of the treatment from the beginning of the treatment. Then, an ANOVA test was done to test if the cleared squares (D or F) were statistically different than the control squares (E).

Barnacle removal and limpet addition

To observe whether *Siphonaria sp.* would stay in areas previously occupied by barnacles, two limpets were added to the other square (Fig. 2, D or F) and the number of limpets in each square (A-F) was recorded every 24 hours from November 15-November 19. A Welch two sample t-test was used to test if the cleared squares that had two limpets added were statistically different at the end of the treatment from the beginning of the treatment.

FIG. 2. Diagram of barnacle study plot.



Algae removal and limpets not manipulated

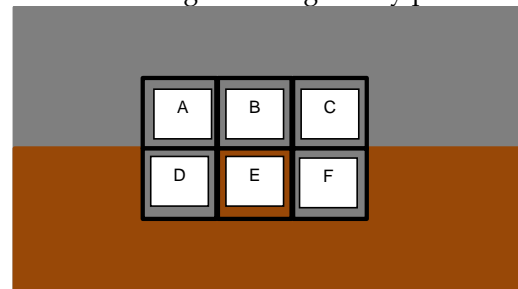
To observe whether *Siphonaria sp.*, limpets, colonize cleared areas previously occupied by brown algae, I removed a total of 12-10x10 cm squares of brown algae (Fig. 3, D and F) along the limpet and algae border along the grouping of rocks with 10x10 cm squares of brown algae between the cleared areas to act as controls (E). The six plots were distributed over five rocks. The number of limpets in each square (A-F) was recorded every 24 hours from November 7-November 15. An ANOVA test was used to test if the cleared squares (D or F) were statistically different at the end of the treatment from the beginning of the treatment. Then, an ANOVA test was done to test if the cleared squares (D or F) were statistically different than the control squares (E).

Algae removal and limpet addition

To observe whether *Siphonaria sp.* would stay in areas previously occupied by brown algae, I attached 2 marked limpets,

marked with superglue and blue flagging tape, to the bottom of one of the cleared squares (Fig. 3, D or F). I observed limpet response every 24 hours, by recording the number of limpets in each square, from November 15-November 19. There were six plots, with no more than two plots per rock. The 12-10x10 cm squares of cleared rock (D and F) were separated by 10x10 cm squares of brown algae to act as a control (E). This mirrors the natural occurrence and observed interaction of brown algae and *Siphonaria sp.* (J. Hughes, personal observation). An ANOVA test was used to test to if the cleared squares that had two limpets added (D or F) were statistically different at the end of the treatment from the beginning of the treatment.

FIG. 3. Diagram of alga study plot.



Statistical methods

All statistical analyses were carried out using R (R Development Core Team, version 3.0.2, 2013). The statistical testing used was analysis of variance (ANOVA) and Welch two sample t-test.

RESULTS

Barnacle Removal and Limpets Not Manipulated

A Shapiro-Wilk normality test was done to test if number of limpets in the cleared squares at the beginning and end of the experiment were normally distributed. Since it was not normal ($W = 0.7396$, $p < 0.05$), a Fligner-Killeen test of homogeneity of variances was done ($X^2 = 0.2558$, $p > 0.05$). The results (Fig. 4) indicate there is no statistical difference between the limpet abundance in cleared squares after ten days of observations (ANOVA, $F_{1,22} = 0.097$, $p = 0.758$).

To compare the cleared squares with the controls, a Fligner-Killeen test of homogeneity

of variances was done ($X^2=0.5506$, $p>0.05$). An ANOVA was done to look at the number of limpets in the control squares and cleared squares at the end of the experiment in relation to time ($p=0.8423$), time as a function of treatment ($p=0.8423$), and treatment ($p=0.0846$). These results (Fig. 5) indicate there is no statistical difference between the limpet abundance in the control and cleared squares at the end of the experiment.

Barnacle removal and limpet addition

A Shapiro-Wilk normality test was done to test if the number of limpets in the cleared squares at the beginning and end of the experiment were normally distributed. Since the data was normally distributed ($W=0.9$, $p=0.1585$), a Welch two sample t-test was performed and the results (Fig. 6) indicate there is a significant difference between limpet abundance in the cleared squares when the limpets were moved compared to five days after the manipulation ($t_{13.831}=3.5733$, $p=0.00311$).

FIG.4. Non-manipulated limpet abundance over time (no barnacles). 0=beginning of treatment, 1=end of treatment.

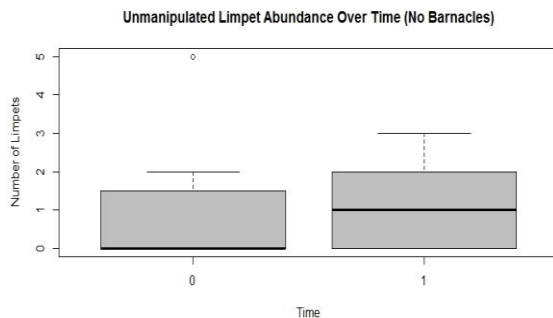


FIG. 5. Non-manipulated limpet abundance over time (no barnacles) and control. 0=control, 1=cleared area.

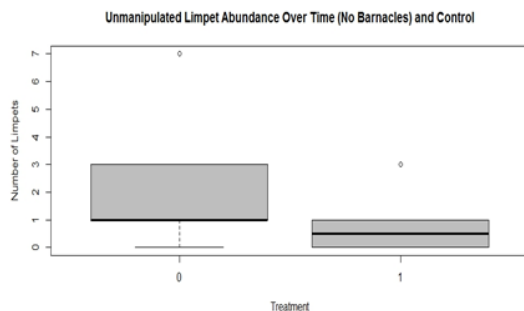
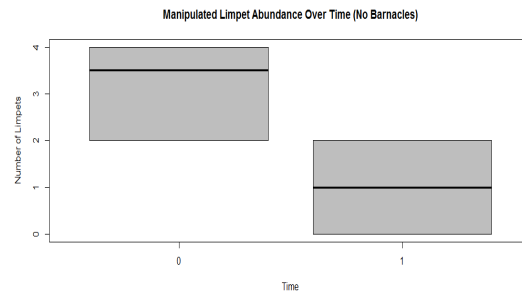


FIG. 6. Manipulated limpet abundance over time (no barnacles). 0=beginning of treatment, 1=end of treatment.



Algae removal and limpets not manipulated

A Shapiro-Wilk normality test was done to test if the number of limpets in the cleared squares at the beginning and end of the experiment were normally distributed. The data did not appear normal ($W = 0.4601$, $p<0.05$), so a Fligner-Killeen test of homogeneity of variances was done ($X^2=0.9572$, $p>0.05$). The results (Fig. 7) indicate there is no statistical difference between the limpet abundance in cleared squares after ten days of observations (ANOVA, $F_{1,22}=0.78$, $p=0.387$).

To compare the cleared squares with the controls, an ANOVA was done to look at the number of limpets in the control squares and cleared squares at the end of the experiment in relation to time ($p=0.685$), time as a function of treatment ($p=0.685$), and treatment ($p=1.000$). These results (Fig. 8) indicate there is no statistical difference between the limpet abundance in the control and cleared squares at the end of the experiment.

Algae removal and limpet addition

A Shapiro-Wilk normality test was done to test if the number of limpets that were moved into cleared squares at the beginning and end of the treatment were normally distributed. Since the data was not normally distributed ($W=0.8014$, $p=0.009719$), a Fligner-Killeen test of homogeneity of variances was

performed ($X^2=0$, $p>0.05$). The results (Fig. 9) indicate that there is a statistical difference between the limpet abundance in cleared squares after five days of observations (ANOVA, $F_{1,10}=72$, $p=0.000007$).

FIG. 7. Non-manipulated limpet abundance over time (no algae). 0=beginning of treatment, 1=end of treatment.

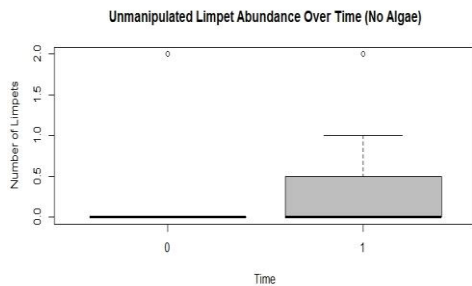


FIG. 8. Non-manipulated limpet abundance over time (no algae) and control. 0=control, 1=cleared area.

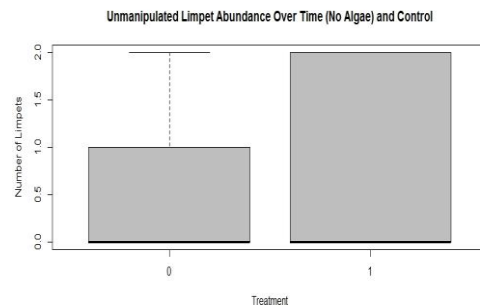
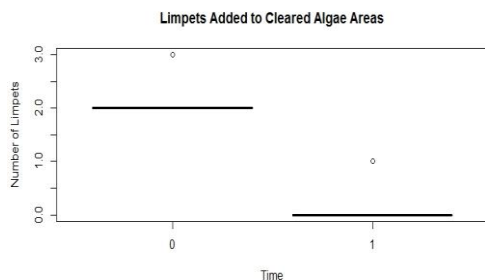


FIG. 9. Manipulated limpet abundance over time (no algae). 0=beginning of treatment, 1=end of treatment.



DISCUSSION

Limpet density in barnacle removal experiment

The density of limpets on cleared rock previously covered by barnacles suggest that limpet density is not strongly influenced by the presence or absence of barnacles. Since limpets and barnacles were seen interacting, limpets moving over barnacles, it may be interesting to observe what resources the two share that may be influencing habitat selection.

Limpet habitat preference in cleared barnacles

Limpet distribution on cleared rock previously covered by barnacles may suggest limpets would occupy niches occupied by other organisms if the population of limpets was able to establish early on. If "home scars" are influencing the distribution, and therefore path limpets follow, settlement experiments may lend insight onto how barnacles and limpets are distributed.

Limpet density in algae removal experiment

This experiment suggests limpet density is not simply controlled by the substrate by which the limpets are adhering to. For example, limpets may prefer a certain area on the rocks for the amount of water exposure throughout the day. Experiments looking at the habitat range of limpets may help to better understand how their boundaries are created and maintained.

Limpet habitat preference in cleared algae

This experiment suggests limpets may have habitat preference or other factors are influencing where the limpets move to. For example, the one limpet that still had a tag at the end of the treatment and had been moved into the cleared plot previously covered by brown algae moved out of the square plot and was observed with other limpets above the algae. Experiments that track where the limpets go and if they are able to make a new "home scar" could offer new insight.

Other studies suggest limpets, barnacles, and algae play an integral role in the abundance and distribution of the other factors. For example, "barnacle cover is ... directly related to limpet density" (Branch 1976). One study found an increase in the number of small limpets increased the microalga abundance, but limpets did not show the same pattern (Marshall and Keough 1994).

Understanding habitat preference and competition between species is an essential aspect of community ecology. A better understanding of how species interact may suggest how changes will affect these same species.

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