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The Christmas Tree Worm (Spirobranchus giganteus) as a Potential Bioindicator of Coral Reef Health

Gabriella Petrocelly

ABSTRACT

Coral bleaching events pose a serious threat to the conditions of coral reef ecosystems and can be attributed to the continual rise of global sea temperatures. Symbiotic relationships between corals and inhabiting marine organisms may provide insight into environmental conditions and detrimental bleaching events in coral reef ecosystems. This study investigates whether the tube-building polychaete Spirobranchus giganteus, otherwise known as the Christmas tree worm, may be used as an ecological bioindicator to assess coral reef health. Due to the symbiotic relationship between S. giganteus and its host coral, the study hypothesizes that coral health will have a direct effect on the abundance of settled S. giganteus. Research takes place over a two-month period on the island of Moorea, French Polynesia, with three study sites located at Temae Public Beach, Gump Station, and the Hilton reefs. The results demonstrate the increase of S. giganteus abundance on host coral to correlate positively with the percentage of live Porites coral cover ($p < 0.01$, $R2 = 0.055$). This suggests that S. giganteus could be used as a potential bioindicator of coral reef health and may be useful in detecting major coral bleaching events in Moorea.

Major, Year, Departmental: Marine Science, Summer 2021, Earth and Planetary Sciences

INTRODUCTION

Coral reef ecosystems are among the most diverse and productive marine habitats. Interactions between coral and inhabiting marine species provide insight into the ecological and evolutionary effects organisms have on each other. Long-term interactions between coexisting species have given rise to many symbioses in which relationships among organisms lead to mutualism. Such interactions, like that between coral and algae, can prove beneficial for both species and vital for survival, as well as for the functioning of coral reef ecosystems.[1] As climates change due to the rapid increase of global temperatures and carbon dioxide emissions, it has become increasingly important to identify potential symbioses of marine species and coral reef ecosystems. Further, understanding organismal interactions in reef systems may help design buffers for ecological change and preserve necessary processes, such as coral structural growth and recovery.[1]

The tube-building Spirobranchus giganteus, otherwise known as the Christmas tree worm, can be found throughout tropical and sub-tropical reef regions and is an obligate associate of live coral.[2,3] The planktonic S. giganteus larvae are positively phototactic,

meaning that it is directionally responsive to light, and free-living in the water column.[2] Once settled, S. giganteus begins to construct a calcareous tube on the surface of the host coral. Over time, the calcareous tube becomes covered by coral growth.[4,5] In addition, coral settlement by S. giganteus larvae distribute non-randomly as larvae show settlement preference for various coral species.[2]

It appears that S. giganteus and the host coral have developed a mutualistic relationship.[1] The host coral provides support and protection for the worm and, in return, S. giganteus enhances water circulation for coral feeding. According to observations found by DeVanier et al. (1986), S. giganteus also provides refuge for coral polyps adjacent to worm tubes from predation by the sea star Acanthaster planci. Coral polyps that are subject to predation from A. planci show evidence of regrowth from those found living beneath the worms' branchial crowns.[1]

The exact nature of the relationship between S. giganteus and its host coral is still unknown, but their symbiosis is common and easily observed. For these reasons, S. giganteus may serve as a potential bioindicator for detecting environmental changes in coral reef ecosystems.[6] Bioindicator species are sensitive to changes in their environment and, thus, can identify and monitor potential stressors, such as those in coral bleaching events.[6,7] In unpublished data, Linkem (2003) observed a higher proportion of worms on the coral genus Porites than other related coral types on the island of Moorea, French Polynesia. Thus, observations made between the coexistence of Porites and S. giganteus may further the understanding of the coral obligate associate and its ability to detect environmental stressors.

This project aims to understand the symbiotic relationship between S. giganteus and its host coral Porites. Field surveys will determine spatial patterns of abundance of S. giganteus and whether its abundance is associated with coral health. This study will also explore a potential positive feedback loop in which larvae choose to settle on coral with previously colonized worms. Finally, test will be administered to find whether the various color morphologies of S. giganteus are associated with coral reef health. In addition to providing information on the symbiotic nature of the relationship between S. giganteus and its coral host, the study will examine the extent to which S. giganteus might serve as an ecological bioindicator for coral reef health.

METHODS

Study site

The study was carried out over two months, October-November 2019, at three sites on Moorea, French Polynesia (Fig. 1). Pilot surveys showed a variation in abundance of S. giganteus and Porites populations both within and among study sites. Final sites were

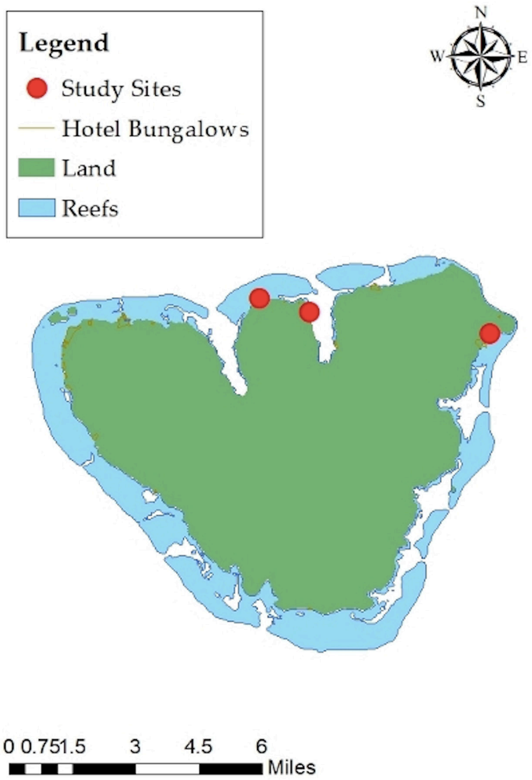

Figure 1: Map of Moorea and surrounding reefs with points indicating sites sampled in this study. *Site 1: Temae Public Beach (17°29’56.36”S, 149°45’42.51”W), Site 2: Gump Station (17°29’25.67”S, 149°49’34.92”W), Site 3: Hilton (17°29’8.15”S, 149°50’39.76”W).*

chosen to represent diverse coral habitats on Moorea (Temae reef, Gump Station reef, Hilton reef).

Coral head sampling

To sample coral heads, transects were conducted at each of the three study sites. At each site, five transects were surveyed 20 meters in length and oriented perpendicular to the shore at Temae, Gump Station, and the Hilton reefs. Transects were spaced 50 meters apart to keep a consistent survey of the coral reef habitat. Any coral heads identified within a 2-meter on either side of the transect were recorded and numbered. Each coral head was then assessed to determine if it was living or dead Porites. When live coral was present, the percentage of overall live coral was recorded since multiple genera of coral inhabit some coral heads. Consequently, the percentage of live Porites, the percentage of other live coral, and the percentage of dead coral (for a total of 100% cover) were recorded. The percentage of Turbinaria ornate, is also noted. The number of giant clams, Tridacna maxima are also documented. Coral head circumference was measured following observations of S. giganteus (described next) to avoid disturbing the worms.

S. giganteus

On each coral head encountered during my surveys, S. giganteus abundance was recorded. Worm presence was recognized by visual evidence of calcareous tube or fully emerged appendages. The number of abandoned worm tubes was also counted and recognized as empty holes on the coral heads. During transect surveys, S. giganteus color was recorded for each exposed worm. Color was categorized as white, orange, red, brown, purple, blue, or yellow. If S. giganteus retracted back into its tube, the worm would have to resurface to note the coloration.

Statistical Analysis

Statistical analysis was conducted in R as implemented in R Studio version 1.2.1335 with tidyverse, ggplot2, and tidyr packages.8,9 To test the main hypothesis, ggplot linear model method with the tidyverse package was used. To determine worm density, ggplot was used once again to construct a histogram showing log of S. giganteus density and coral count. Additionally, a chi-square test was used to test the null hypothesis that S. giganteus color morphology showed an even distribution (i.e., even number of observations among the different color categories). Alpha was set equal to 0.05 in all analyses. Lastly, the tidyr package in R studio was used to make a ggplot bar diagram indicating worm color morphologies among sites.

RESULTS

Coral head sampling

The study observed a total of 165 Porites coral heads and 558 S. giganteus. A scatterplot (Fig. 2) shows the log of the total number of S. giganteus as the response variable and percent live Porites as the explanatory variable among the three different surveyed sites (Temae Public Beach, Gump Station, and Hilton). This scatterplot indicates a positive correlation for Temae Public Beach and a negative correlation at the Hilton reefs. At the Gump Station reef, however, there is no correlation found. Yet, for both the Gump Station and Hilton reefs, very few worms are observed. A linear regression test reveals a striking difference between the number of S. giganteus at Temae when compared to Gump Station and Hilton sites. A linear regression of S. giganteus and percent of live Porites is significant at Temae Public Beach ($p < 0.01$, $R2 = 0.055$). Additionally, a regression

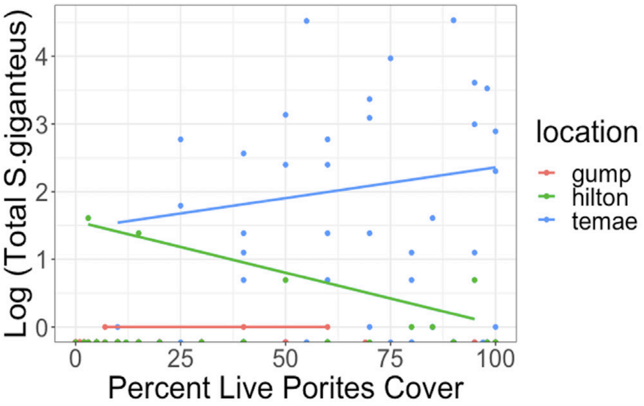

Figure 2: Log (Total S. giganteus) vs. Percent Live Porites Cover. *A scatterplot with linear regression lines associated with sites (Temae Public Beach, Gump Station, Hilton). Trendline for Temae site indicates a positive correlation between percent live Porites and the number of S. giganteus.*

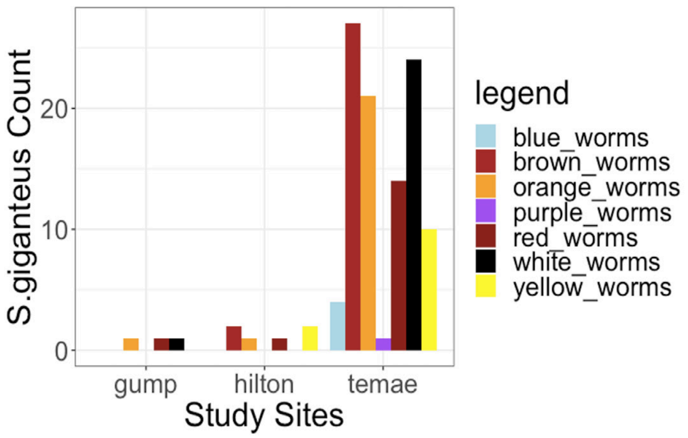

Figure 3: S. giganteus Count vs. Study Sites. Brown and orange worm colors appeared to be the most frequent at Temae. *Very few worms were observed at Gump Station and Hilton sites.*

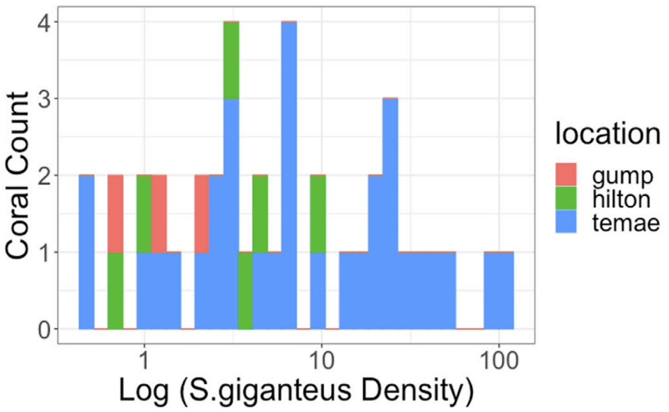

Figure 4: Coral Count vs. Log (S. giganteus Density). *Histogram of worm density and Porites coral count with the representation of study sites (Temae Public Beach, Gump Station, Hilton).*

analysis of percent dead coral and number of S. giganteus is also significant ($p < 0.05$)

S. giganteus

Brown S. giganteus are the most abundant with 151 observed individuals. Orange worms are the second most abundant with 143 individuals while blue and purple are the least abundant (Fig. 3). A chi-square test indicates no correlation between worm color morphology and the percentage of Porites coral heads ($p = 0.3499$).

A histogram (Fig. 4) demonstrating the log of worm density and coral headcount displays a positive feedback loop of worms settling on coral heads. There is a high frequency of worms settling on Porites coral heads with a log S. giganteus density of around 1 to 10 worms. In addition, a regression analysis shows a significant correlation between total S. giganteus and coral head circumference ($p = 0.001$).

DISCUSSION

Study observations conducted at Temae Public Beach, Gump Station, and Hilton reefs on Moorea suggest that the abundance of S. giganteus on Porites populations may be a good indicator of coral head health. Results from Temae Public Beach demonstrated a large number of S. giganteus and a high percentage of live Porites coral cover. However, the Hilton reef suggests a negative correlation between observed S. giganteus and live Porites percentage. Given this, we must also consider the sparse number of S. giganteus at both Gump Station and Hilton reefs. Overall, Temae Public Beach provides a trend line showing a stronger relationship with the increase of S. giganteus with an increase of live Porites percentage.

In a previous study, Ben-Tzvi et al. (2008) discovered coral colonies in the Gulf of Aqaba, Red Sea, nearly dead and covered with algae besides small areas of living coral tissue with neighboring S. giganteus. They suggest that S. giganteus populations on host coral may also decrease coral susceptibility to bleaching, sustaining the coral reef health. Findings made by Ben-Tzvi et al. further support the study's hypothesis and the proposed relationship between S. giganteus and the host coral. In addition, the lifespan of host corals is related to the longer life of S. giganteus.[11]

Although statistical analysis shows significant differences in the number of S. giganteus and the percentage of live Porites among sites, more research is needed to further understand the relationship between S. giganteus and the host coral. From the observations of my own and others, there are records of S. giganteus living on coral rubble.[5,12] Future studies may examine the implications, if any, of S. giganteus on dead or diseased coral.

When noting worm color morphology, colors such as brown and orange were more common than others among sites; however, differences are not statistically significant. Consequently, S. giganteus color morphology appears to distribute evenly and does not differ based on the percentage of live Porites. Thus, there is no evidence of an association between S. giganteus color and coral health. Spirobranchus giganteus color morphology distribution on host coral may instead be explained by worm phenotypic plasticity and mortality.[13]

Results of worm distribution on Porites coral heads suggest a positive feedback loop of S. giganteus settlement. This means that once one worm has settled on the host coral head, another worm is likely to follow and settle on the same coral as larvae. A probable cause of this positive feedback loop may be the response of S. giganteus larvae to water-borne chemicals during the planktonic phase emitted by successfully colonized adult worms.[2,14] Previous research has also attributed the similarity of the planktonic larvae distribution to the adult S. giganteus distribution on the host coral.15 However, there are points of low S. giganteus density on coral heads which could reflect a limitation on how many S. giganteus the host coral can support before they become detrimental to its health. More research is needed to understand the abiotic processes that influence the positive feedback loop involving worm larvae settlement.

Coral bleaching poses a major threat to the health of coral reef ecosystems.[16] The rise of global sea temperature due to anthropogenic disturbances cause photosynthesizing symbiotic zooxanthellae living on the host coral to decline in density leaving the coral "bleached".[16,17,18] Global sea-surface temperatures have, on average, increased by 0.7 degrees Celsius in the last century and have resulted in more frequent and intense bleaching events.[16] Moreover, climate-change models predict a continual increase in tropical temperatures for the next century.[16] Major bleaching events in Moorea, French Polynesia, have occurred every 2-5 years since 1991.[16] The most attributing factor to these bleaching events is associated with elevated sea temperatures.[17] Symbiotic relationships in coral reef ecosystems demonstrate high levels of coevolution and are [consequently] essential to the survival of both interacting species.[1] The response of one species to environmental stressors may directly impact the health of the other.

Spirobranchus giganteus could be a useful indicator of changes in the environment that lead to major bleaching events in Moorea. As climate change threatens the health of coral reefs, symbiotic S giganteus are also impacted by these changes, furthering the loss of reef formation and function.[19] By surveying the density of S. giganteus populations on host corals, researchers may be able to foresee major bleaching events caused by climate change. Additionally, S. giganteus could monitor and assess coral reef recovery. Although more research is necessary on this topic, S. giganteus may be a significant tool to further the management and conservation of coral reef ecosystems.

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APPENDIX A

Worm color morphologies: 1) White, 2) Orange, 3) Blue, 4) Yellow, 5) Red, 6) Brown, 7) Purple. For this study, I was able to identify S. giganteus by their various color morphs, exposed operculum, and spiral arrangement of radioles (Song 2006, Perry et al. 2018). S. giganteus was also identified by the Biology and Geomorphology of Tropical Islands past literature.

APPENDIX B

Start and end coordinates for each transect conducted at Temae Public Beach, Gump Station, and the Hilton reefs. Coordinates were taken with Garmin G73 GPS. Site Transect number Start Latitude Start Longitude End Latitude End Longitude Temae 1

17°29’58.05”S 149°45’24.83”W 17°29’57.42”S 149°45’24.83”W Gump 1 17°29’25.11”S 149°49’32.20”W 17°29’25.25”S 149°49’32.95”W Hilton 1 17°28’56.45”S 149°50’41.99”W 17°28’57.05”S 149°50’42.09”W Temae 2 17°29’58.68”S 149°45’27.04”W 17°29’58.10”S 149°45’27.34”W Gump 2 17°29’23.51”S 149°49’32.11”W 17°29’23.60”S 149°49’32.75”W Hilton 2 17°28’56.09”S 149°50’40.33”W 17°28’56.73”S 149°50’40.52”W Temae 3 17°30’0.63”S 149°45’28.34”W 17°30’0.13”S 149°45’28.72”W Gump 3 17°29’21.84”S 149°49’32.77”W 17°29’21.87”S 149°49’33.45”W Hilton 3 17°28’57.14”S 149°50’43.78”W 17°28’57.83”S 149°50’43.82”W Temae 4 17°30’1.23”S 149°45’30.11”W 17°30’0.64”S 149°45’30.38”W Gump 4 17°29’20.22”S 149°49’32.59”W 17°29’20.27”S 149°49’33.19”W Hilton 4 17°28’57.76”S 149°50’45.28”W 17°28’58.36”S 149°50’45.45”W Temae 5 17°30’2.09”S 149°45’31.76”W 17°30’1.36”S 149°45’31.97”W Gump 5 17°29’18.83”S 149°49’32.11”W 17°29’18.85”S 149°49’32.72”W Hilton 5 17°28’55.63”S 149°50’39.01”W 17°28’56.27”S 149°50’39.13”W

Note: Coordinates are in degrees minutes seconds format.