# Habitat Characteristics of *Lingula reevii* in Kāneohe bay, Oahu, Hawaii (2011)

Cover photo*:* *L. reevii* siphon burrows in Kāneohe Bay.


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## Abstract:

Kaneohe Bay is the only area in the state of Hawaii where the NOAA Species of Concern *Lingula reevii* is found. Due to their limited habitat range it is important to understand what factors structure high density locations. From field observations, the parameters that were chosen for analysis include: flow intensity, turbidity, abundance of burrows, *Holaphila hawaiiana*, *Lyngbya spp.*, and *Spyridia spp.* percent coverage. Quadrat surveys at Fringing Reef A and the Sandbar were conducted in the bay to assess *L. reevii* habitat. T-test results illustrated that only abundance of holes and *H. hawaiiana* seagrass coverage had a significant difference between high and low abundance sites. However, *H. hawaiiana* significance was only found at the Sandbar so it questionable whether it is a primary factor in structuring the optimal *L. reevii* habitat. In conclusion, the objective of this study was to characterize abiotic and biotic factors that determine the locations of high *L. reevii* abundance.

## Introduction:

*Lingula reevii,* is a rare inarticulated brachiopod, that has only been found in three locations; Japan (Emig 1997), Indonesia (Cals and Emig 1979) and Hawai'i (Worcester 1969). Based on studies in Kaneohe Bay, Oahu, Hawai'i, NOAA National Marine Fisheries Service has deemed *L. reevii* a Species of Concern (SOC) because of the severe decrease in the abundance observed over the last decades (Hunter *et al.* 2008). In Hawaii, this brachiopod species has only been found in shallow, sandy reef flats in Kaneohe Bay, Oahu (NOAA SOC). In the bay, *L. reevii* density has declined from 500 individuals per square meter in 1960 (Worcester 1969) to less than 1 in the years 2007-2009 (Hunter *et al.* 2007, 2008, 2009). The most recent study done in Kaneohe Bay in 2010 found that the densities had increased for the first time since 2004 (Hunter *et al.* 2010). Unfortunately, no environmental factors that they tested were found to have facilitated this unexpected abundance increase.

*Lingula reevii* is characterized by: elongated, bilaterally symmetrical valves that are either a blue-green or emerald color. The signature characteristic that identifies the presence of *L. reevii* in the sediment is the three siphon holes on the surface of the benthos (Emig 1987). Their lophophores filter and direct particles from the water column to their mouth. In 1997, Emig and his colleagues analyzed *L. reevii* gut contents and found mainly diatoms, peridinians, foraminifera, filamentous algae, rotifers, polychaetes, oligochaetes, copepods, and organic detritus. Due to the fact that *L. reevii* is a filter feeder, it is believed that they will be most abundant in areas with higher water flow. The soft sediment that they live in will need to range within certain depth and grain size for them to efficiently burrow and survive. In the summer of 2009 field research found a correlation between fine sand and high abundance and a positive correlation with sediment depth and high abundance (Hunter *et al.* 2009). Turbidity of the water is also a crucial parameter thought to determine the optimal habitat for *L. reevii.*

In Kaneohe Bay, it has been found that there are high densities of *L. reevii* at Fringing Reef A and the Sandbar (Hunter *et al.* 2010). It is important to study and determine the parameters that are thought to facilitate these high population densities. *Lingula reevii* is a SOC, but there has not been much previous research that gives insight to the forces that determines why certain sites have high abundance. Therefore, it is an area of interest to study the species ecological preferences and the interspecific associations. It has been observed that in the areas where *L. reevii* chose to burrow there are certain plant species that make up the community structure. *Halophila hawaiiana*, *Lyngbya spp*. and *Spyridia spp.* are commonly found in the areas surrounding the organism, thus they were thought to be a primary focus in understanding the habitat of *L. reevii*. In addition, turbidity and flow were abiotic factors of interest for a comparison between areas of high and no *L. reevii* abundance. The objective of the study presented in this paper was to determine the factors that structure the optimal habitat for *L. reevii.* From field observations, it was hypothesized that there would be certain biotic and abiotic correlations (e.g., abundance of burrows, *H. hawaiiana* percent coverage) that are the driving forces structuring the distribution and abundance of *L. reevii*.

**Materials & Methods:**

During a period of two weeks, between July 25- August 6, surveys of *Lingula reevii* habitats analyzing biotic and abiotic factors were conducted in Kaneohe Bay, O'ahu. Survey sites were chosen based on data from previous Biology 403 *L. reevii* research, which identified high and no abundance sites (Hunter *et al.* 2010). In this research, the surveyed sites were Fringing Reef A (FRA) and the Sandbar (SB). Two areas within each site were chosen, in which one consisted of high abundance of *L. reevii*, and the other no abundance. Locations in the field were: 21.43342N 157.76501W (FRA high abundance), 21.43333N 157.76607W (FRA low abundance), 21.46472N 157.81076W (SB high abundance), and 21.46481N 157.81026W (SB low abundance); these points were found from previous research (Hunter *et al.* 2010).

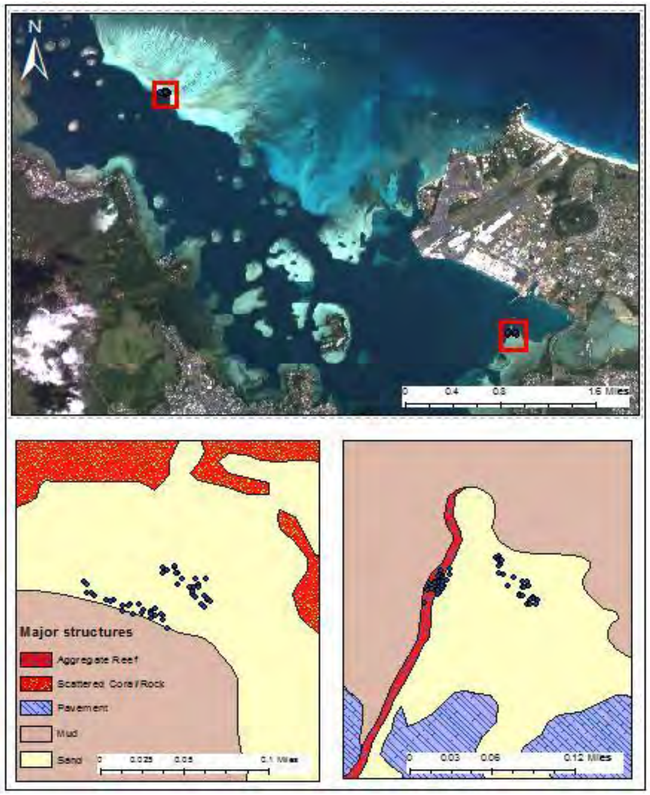


Figure 1. Survey sites in Kaneohe Bay (chosen based on previous research) illustrating *L. reevii* high and no abundance areas.

Upon detection of *L. reevii*, a quadrat of 1 $m^2$ was placed in a manner that aligned the organism in the center. Snorkeling surveyors then marked down GPS coordinates for the location. The quadrat was analyzed based on: number of burrows (> 1cm diameter), percent coverage of *Lyngbya spp., Halophila hawaiiana*, and *Spyridia spp.* Each high and no abundance sites were examined equally, with the same quadrat sample size (n= 30).

**BRAUN-BLANQUET COVER CLASSES**

| Cover Class | Percent Cover | Midpoint |
|---|---|---|
| 1 | <1% | 0.5% |
| 2 | 1-5% | 3.0% |
| 3 | 5-25% | 15.0% |
| 4 | 25-50% | 37.5% |
| 5 | 50-75% | 62.5% |
| 6 | >75% | 87.5% |

Figure 2. Braun-Blanquet Cover Classes used to help eliminate bias in our %-cover estimates.

Surveyors counted burrows by simply looking in the quadrat: to verify and decrease error, counts were compared between at least 2 surveyors. Lastly, percent coverage was examined and quantified by Braun-Blanquet Cover Classes (Figure 2). If the species (stated above) was present, surveyors were asked to estimate coverage and assign ordinal data in the closest vicinity. In areas of no abundance the quadrat locations were chosen randomly to avoid bias; the same methods for parameter measurements were utilized.

Plaster balls (n=24) and sediment traps (n=24) were placed within the first six quadrats surveyed at each site. In order to be consistent, the same ratio of 5:1 (plaster:water) was used when making plaster balls. A molding tray was used which produced spherical plaster balls of approximately 3 cm in diameter. Prior to weighing and assigning an ID, each ball was examined for any apparent defects such as cracks or deformations. The plaster ball was then put in the metal mesh, which was held together and attached to the stake by zip ties. Likewise, sediment traps made of 50 ml falcon tubes were attached to metal stakes by zip ties. At each site, plaster balls (n=6) and sediment traps (n=6) were placed within quadrats. The quadrats selected were marked with GPS for relocating the parameter tools at a later point. Time was recorded as soon as the plaster balls and sediment traps had been submerged under water. Within the range of a few hours, plaster balls were collected after 48 hours, and sediment traps approximately a week later.

Flow intensity was indirectly estimated by the difference in initial and final plaster ball weight, and by comparing the means utilizing t-test analysis. In addition, a control was set up, with a plaster ball submerged in water of zero flow, in order to assess the natural degradation rate. The weight loss calculated from the control ball was later added to the final weight of the field plaster balls to cancel out the variable of plaster ball degradation leaving only weight loss from flow.

Sediment traps were analyzed by measuring the dry weight of the sand captured in the 50 ml falcon tubes. This method was used to indirectly measure the water column's turbidity within the surveyed sites. First, water was decanted from the falcon tubes and the full contents of the tubes were emptied into filters; the tubes were continuously rinsed to ensure complete collection of sediment. An unequal variance t-test was conducted to determine if there was any statistically significant relationship between turbidity and *L. reevii* abundance.

Data gathered throughout the research project was analyzed and visualized in the computer program ArcGIS, utilizing Geographic Information System (GIS) applications. ArcGIS was used to illustrate the spatial distribution of the high and no abundant site within Fringing Reef A and the Sandbar. Tools, such as dot density, were used to correlate the significant parameters that characterize quadrats with the GPS points on the map.

**Results:**

The results illustrate that *Halophila hawaiiana* percent coverage and abundance of burrows were the only parameters that were significantly different between sites in Kaneohe Bay: Fringing Reef A and the Sandbar (Table 1). The parameters that did not show a significant difference between high and no abundance sites include: plaster ball weight loss, sediment trap collection weight and *Lyngbya spp.* and *Spyridia spp.* percent coverage. An ANOVA test was conducted to determine if the data from both sites could be compiled; the test verified that the variances were not significantly different so a compiled t-test was run. Trends in Figure 3 for *Lyngbya spp*. and *Spyridia spp*. percent coverage illustrate similarities between means while *H. hawaiiana* percent coverage is visibly different between the sites. The t-test verifies this significant difference producing a p-value < 0.001 (Table 1). Figure 2 visibly displays the means for abundance of burrows, sediment collection weight and plaster ball weight loss for all four study sites. It is evident that sediment collection weight and plaster ball weight loss do not have a significant mean difference between the high and low sites in either Fringing Reef A or the Sandbar (P > 0.05). The average abundance of burrows in the graph clearly shows a significant difference between sites supported by a p-value < 0.001 (df = 108) (Table 1).

Abundance of burrows was significant between high and no abundance sites within Fringing Reef A and the Sandbar as well as overall with data collaboration between the high and no abundance locations (P<0.001; df = 108). For all t-tests analyzing abundance of burrows (within Sandbar, within Fringing Reef A and high and low locations overall) the p-value < 0.001 verifying the significance of the data. The GIS dot density map (Figure 5) visually displays the spatial relationship between the high and no abundance sites within Fringing Reef A and the Sandbar.

*Halophila hawaiiana* percent coverage was significantly different within the Sandbar high and no abundance site locations. The t-tests conducted for the Sandbar site resulted in a p-value < 0.001 (df = 53) verifying the significance of the data. Although, within Fringing Reef A all quadrats assessed resulted in zero percent *H. hawaiiana* coverage. Trends in Figure 3 clearly show a distinct difference between

*H. hawaiiana* percent coverage between high and no abundance sites within the Sandbar. The GIS dot density map (Figure 6) spatially displays *H. hawaiiana* percent coverage within the Sandbar survey site.

**Table 1.** Statistical values generated from t-test conducted within Fringing Reef A and Sandbar high and no abundance sites as well as overall t-test values from high and low abundance locations.

| VARIABLE | LOCATION | MEAN | VARIANCE |
|---|---|---|---|
| Hole Abundance | Sandbar High | 16.33 | 44.92 |
| | Sandbar No | 29.70 | 88.98 |
| | Fringing Reef A High | 22.03 | 44.86 |
| | Fringing Reef A No | 29.37 | 104.72 |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | $5.84 \times 10^{-8}$ | |
| | Comparison within Fringing Reef A | $1.77 \times 10^{-3}$ | |
| | Comparison between High and No Abundance Overall | $1.43 \times 10^{-9}$ | |
| | **LOCATION** | **MEAN** | **VARIANCE** |
| Plaster Ball Weight Loss | Sandbar High | 13.25 | 4.25 |
| | Sandbar No | 15.18 | 1.48 |
| | Fringing Reef A High | 11.31 | 6.10 |
| | Fringing Reef A No | 12.24 | 0.83 |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | 0.12 | |
| | Comparison within Fringing Reef A | 0.42 | |
| | Comparison between High and No Abundance Overall | 0.15 | |
| | **LOCATION** | **MEAN** | **VARIANCE** |
| Sediment Trap Collection Weight | Sandbar High | 1.41 | 0.07 |
| | Sandbar No | 1.38 | 0.10 |
| | Fringing Reef A High | 2.84 | 5.01 |
| | Fringing Reef A No | 1.20 | $7.7 \times 10^{-4}$ |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | 0.92 | |
| | Comparison within Fringing Reef A | 0.18 | |
| | Comparison between High and | | |

| | | | |
|---|---|---|---|
| | No Abundance Overall | 0.14 | |
| | **LOCATION** | **MEAN** | **VARIANCE** |
| *Lyngbya* Percent Coverage | Sandbar High | 0.13 | 0.31 |
| | Sandbar No | 0.60 | 7.69 |
| | Fringing Reef A High | 3.42 | 61.59 |
| | Fringing Reef A No | 6.15 | 95.95 |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | 0.37 | |
| | Comparison within Fringing Reef A | 0.24 | |
| | Comparison between High and No Abundance Overall | 0.20 | |
| | **LOCATION** | **MEAN** | **VARIANCE** |
| *H. hawaiiana* Percent Coverage | Sandbar High | 16.22 | 145.22 |
| | Sandbar No | 65.00 | 273.71 |
| | Fringing Reef A High | 0 | 0 |
| | Fringing Reef A No | 0 | 0 |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | $3.43 \times 10^{-18}$ | |
| | Comparison within Fringing Reef A | NA | |
| | Comparison between High and No Abundance Overall | $2.20 \times 10^{-6}$ | |
| | **LOCATION** | **MEAN** | **VARIANCE** |
| *Spyridia* Percent Coverage | Sandbar High | 2.03 | 14.17 |
| | Sandbar No | 3.23 | 30.17 |
| | Fringing Reef A High | 0.17 | 0.32 |
| | Fringing Reef A No | 3.48 | 67.61 |
| | | | |
| | **T-TEST** | **P-VALUE** | |
| | Comparison within Sandbar | 0.35 | |
| | Comparison within Fringing Reef A | 0.04 | |
| | Comparison between High and No Abundance Overall | 0.02 | |

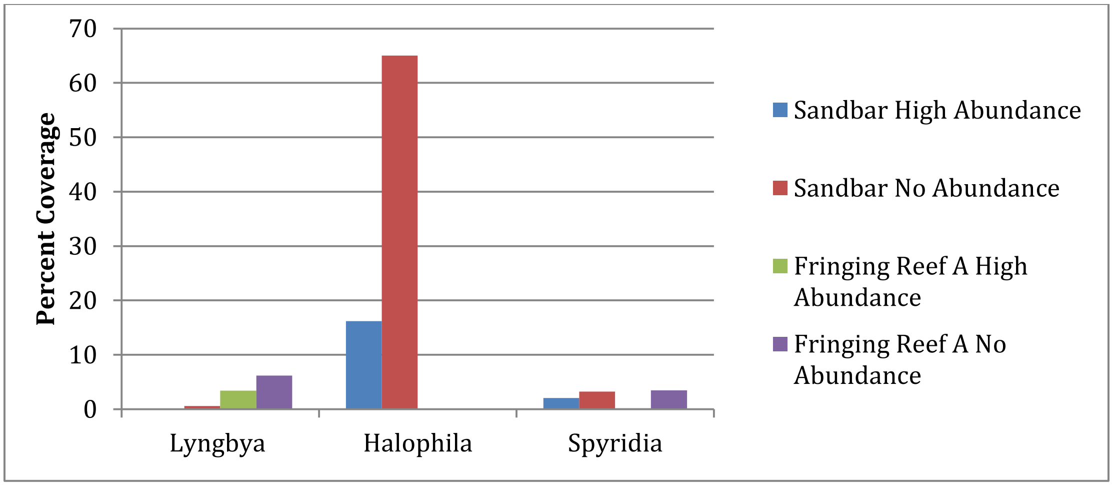


**Figure 3.** Percent cover of *Lyngbya spp., H. hawaiiana,* and *Spyridia spp.* within high and no abundance areas of *L. reevii* at the Sandbar and Fringing Reef A.

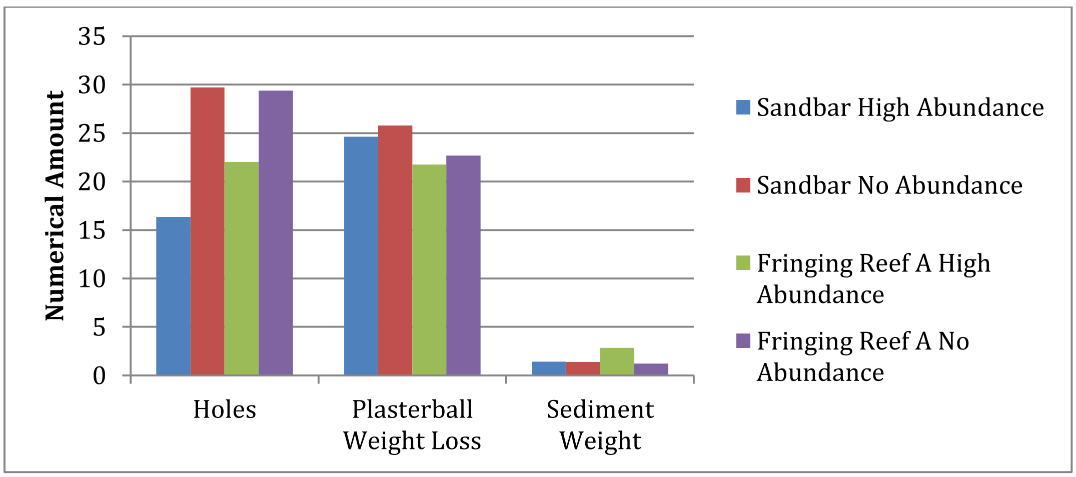


**Figure 4.** Abundance of burrows, plaster ball weight loss and sediment weight from traps within high and no abundance areas of *L. reevii* at Sandbar and Fringing Reef A.

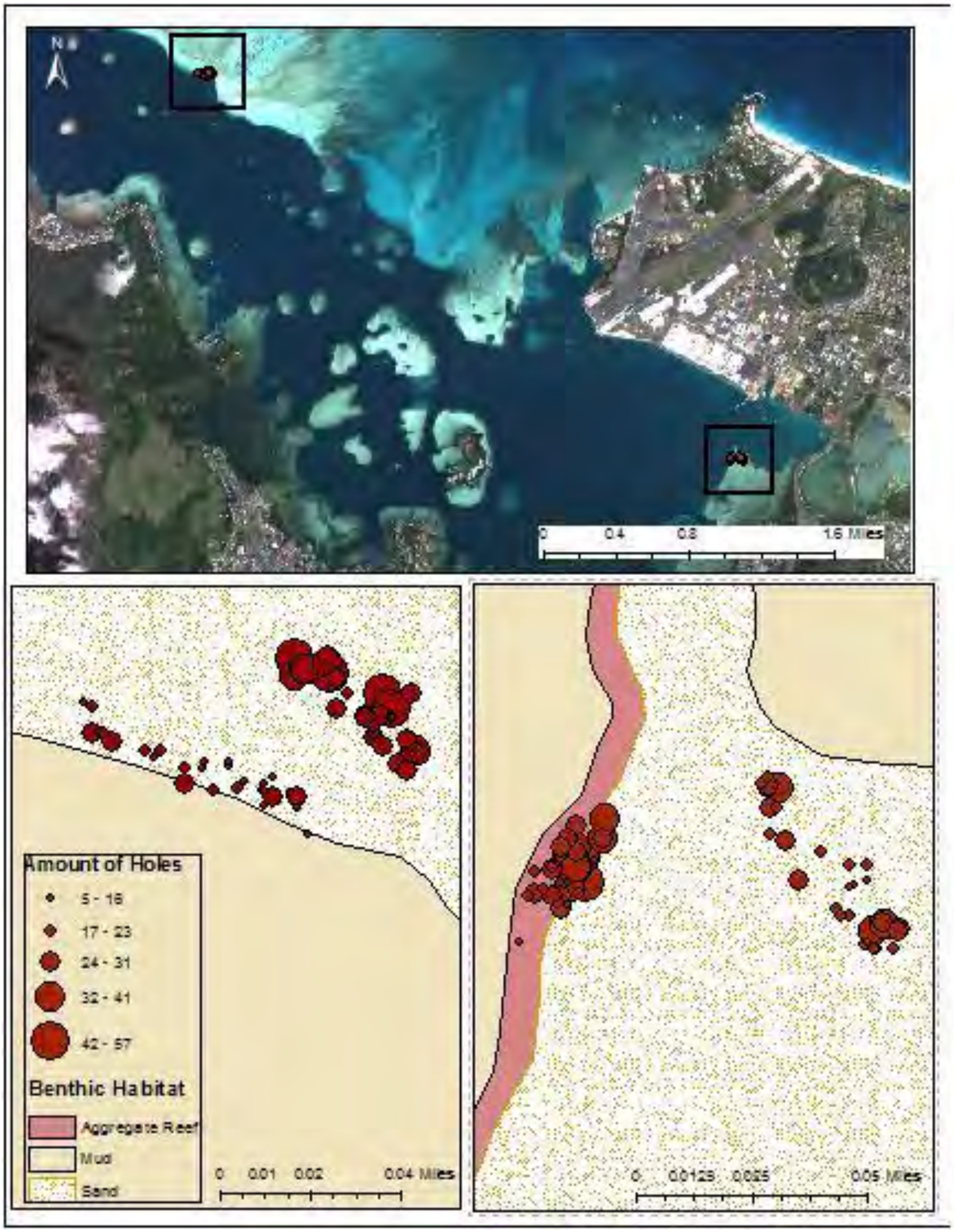


**Figure 5.** Abundance of burrows within Fringing Reef A and Sandbar for high and no abundance areas.

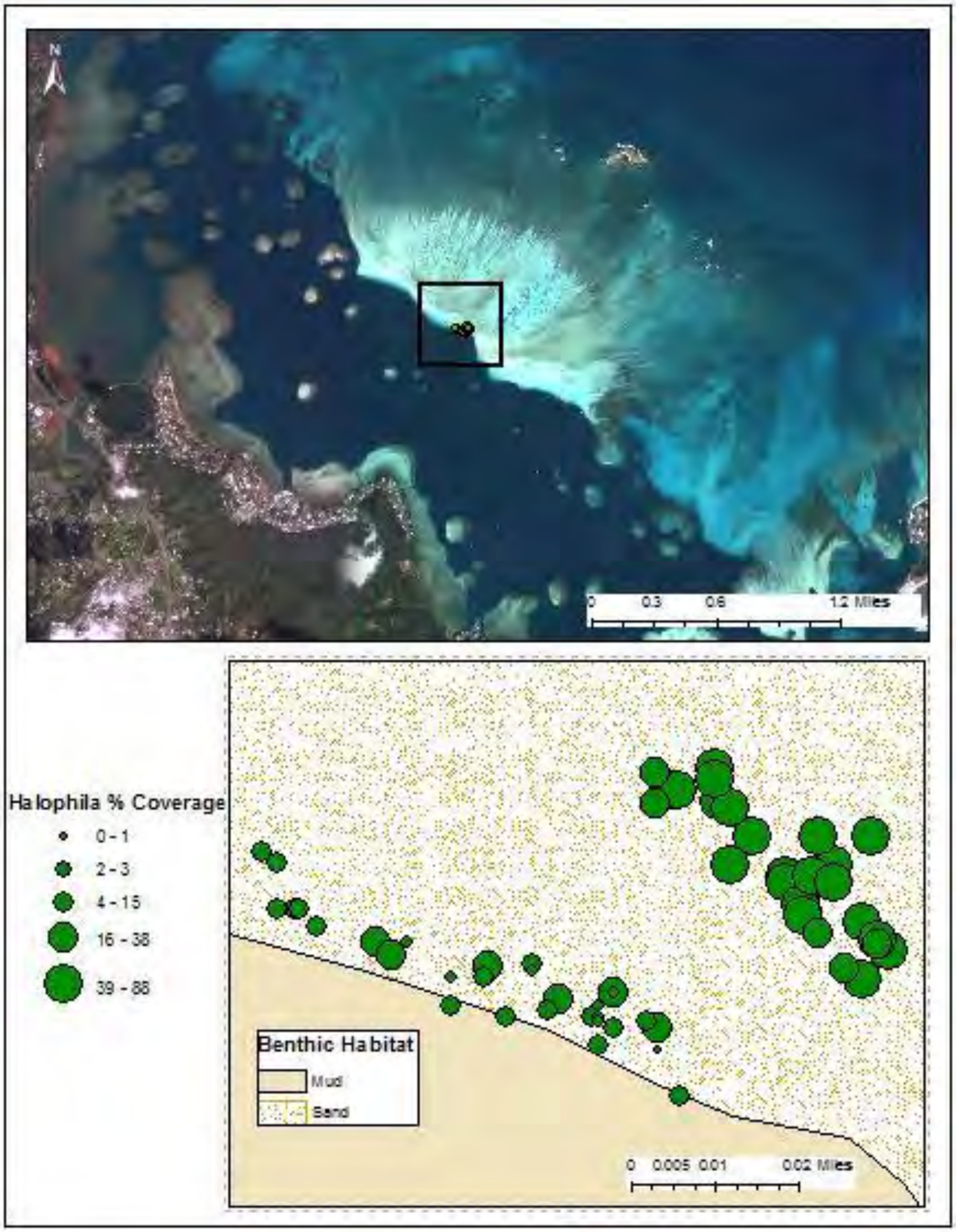


**Figure 6.** Percent cover of *H. hawaiiana* within Sandbar survey site for high and no abundance areas of *L. reevii*.

**Discussion:**

Kaneohe Bay is the only area in the state of Hawaii where the SOC *Lingula reevii* is found. Due to this species' minute habitat range inquiries are formed based on the characteristics that determine where *L. reevii* will inhabit with high densities. Field observations have directed this study's interests toward parameters including: turbidity, flow intensity, abundance of burrows, *Halophila hawaiiana*, *Lyngbya spp.,* and *Sypridia spp.* percent coverage.

Fringing Reef A and the Sandbar did not show a significant difference between sites for flow intensity, turbidity, *Lynbya spp.* percent coverage and *Spyridia spp.* percent coverage. However, there was a significant difference for abundance of burrows within the sites and overall (combined data from both Fringing Reef A and the Sandbar) and *H. hawaiiana* percent coverage within the Sandbar. The significant differences of these parameters illustrate that abundance of burrows and *H. hawaiiana* coverage could possibly be an environmental characteristic that determines the optimal habitat for *L. reevii*.

Known areas not inhabited by *L. reevii*, have notably more burrows within the 1 $m^2$ quadrats than the quadrats that have the organism in the high abundance sites (Figure 4). This could possibly be due to the fact that *L. reevii* settle in areas with less competition or their settlement could deter other organisms from settling in close proximity to them. Abundance of burrows was shown to be a significant parameter differing between areas of high and no abundance overall and within the sites at Fringing Reef A and the Sandbar. This potentially implies that abundance of burrows does have a role in determining and/or shaping *L. reevii* habitat and therefore *L. reevii* abundance.

Further studies increasing the quadrat sample size at these study sites, and expansion to other sites in Kāne'ohe Bay will need to be done to strengthen this plausible relationship between hole and *L. reevii* abundance.

*Halophila hawaiiana,* an endemic Hawaiian seagrass, is commonly found in sandy areas surrounding reefs, bays or fishponds ("*Halophila hawaiiana*"). *Halophila hawaiiana* percent coverage at the Sandbar was significantly higher in the areas where *L. reevii* is not found. In correspondence with the increase of *H. hawaiiana* cover there was a decrease in water depth. A previous study (Hunter *et al*. 2009) had discovered an increase in *L. reevii* abundance with increased depths at the Sandbar. Due to this parallel in parameters, it cannot be determined if *H. hawaiiana* has an explicit effect on the abundance when water depth is also a known variable that has been previously determined to characterize *L. reevii's* optimal environment. Also, quadrats placed at Fringing Reef A were mostly lacking *H. hawaiiana* in both high and no abundance areas. This illustrates that overall *H. hawaiiana* does not have a significant role in shaping the optimal environment for *L. reevii*.

The parameters that did not show a significant difference between high and no abundance sites included flow intensity, turbidity and algal cover (*Lyngbya spp.* and *Spyridia spp*.). Due to the close proximity of high and no abundance areas within each study site it is highly understandable that flow intensity and turbidity would not significantly differ. Algal coverage for both *Lyngbya spp.* and *Spyridia spp*. was shown to have no significantly affect on the abundance of *L. reevii*. In the field, it was observed that both algae had an average of less than 5% coverage in quadrats for both sites. These measurements show that the algae *Lyngbya spp.* and *Spyridia spp.* are not prominent species in the area and do not have substantial effect on influencing the habitat. A possible reasoning for these species lack of effect on the habitat could be due to their patchy distribution and displacement during disturbances within the bay.

The critical issue with this study design was the exceptionally small sample size for the parameter measurements. Due to limited field collection time, sample size ranged from six to 30 depending on the type of parameter that was collected. In general, t-tests work much more efficiently with a higher sample size; there is too much room for error with sample sizes as low as six. Also, only two sites were evaluated in this study, Fringing Reef A and the Sandbar. Many more known *L. reevii* sites in Kaneohe Bay must be incorporated in future studies to better assess the optimal habitat conditions for high *L. reevii* abundance.

NOAA deemed *Lingula reevii* a Species of Concern; understanding the structure of the organism's habitat would help in future conservation efforts related to *L. reevii* and the overall Kaneohe Bay benthic community. The study from the previous Biology 403 class in 2010 analyzed the parameters of salinity, sand depth, temperature, water depth, sediment composition, and algal coverage revealing that there was no linear relationship for any of these environmental factors (Hunter *et al.* 2010). However, the study in 2009 contradicts the findings in 2010 by discovering a positive correlation for sediment depth and water depth with *L. reevii* abundance. Therefore, further studies should continue to analyze and expand beyond the parameters from 2010 and this study to determine the optimal habitat for *L. reevii*. This study provides evidence that abundance of burrows and *H. hawaiiana* could potentially have a role in structuring the organism's benthic habitat, but there should be more surveys to expand sample size. In addition, a deeper understanding of reproductive periodicity and larval behavior could enhance the understanding of *L. reevii* placement in the benthic community. It is apparent from this study and previous ones that the optimal habitat parameters are not well understood and as a Species of Concern it should be an area of importance to further diagnose *Lingula reevii's* high abundance locations.

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