Understanding the prevalence of coral disease in Curaçao as a function of C*oralliophila abbreviata* density and the disease status of nearest neighbors

Abstract

The spread of diseases, such as White Pox and White Band Disease, is becoming an increasing threat to the life of corals in recent years. By understanding the route and dispersal methods of coral diseases, effective strategies of disease treatment and prevention could be developed. Several studies have centered on the spread of coral disease in *Acropora* species in Florida and have shown that disease can spread by healthy tissue coming into contact with fragments of infected tissue from other corals and the presence of vector, such as the snail *Coralliophila abbreviata*. This project analyzed the role those dispersal methods play in the prevalence of disease in the corals of Curaçao. The frequency of disease spread via infected tissue contact was examined by observing the disease status of an individual coral colony, the distance of the colony from its nearest neighbor, and the disease status of the nearest neighbor. Though no statistically significant data resulted, the data corresponded to the trend that shorter distances between diseased colonies and their nearest neighbors increased likelihood of the neighbor’s being diseased. The role of a vector in disease dispersal was analyzed as a function of the density of the snail *Coralliophila abbreviata* and the disease status of a coral. However, the snail was not common enough in Curaçao do significantly contribute to disease outbreak.

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Introduction

Coral reefs are often considered the hub of biodiversity in marine environments, providing food and shelter for a variety of organisms. In addition to their importance to biodiversity of marine environments, coral reefs buffer shorelines from erosion by storms. The economic value of coral reefs not only lies in the food and recreation industry, but also lies in the pharmaceutical industry, providing compound that can treat diseases, such as malaria and cancer (Burke et al 2004). With global temperatures expected to increase, corals have become more susceptible to disease and coral bleaching, endangering these valuable ecosystems (Rosenberg et. al. 2007).

A variety of coral diseases exist in the ocean; some include White Band Disease, Black Band Disease, Plague Type II. Each infect coral colonies differently. Yellow Band and Black Band disease spread from a starting point on a colony until the whole colony is infected. This spread can be distinguished by its namesake, a band (Richardson 1998). Figure 1 shows a colony infected by Black Band Disease.

**Figure 1.**



**Figure 1**. is an image of Black Band Disease spreading over a *Colpophyllia natans*, colony (Richardson 1998).

Diseases can be extremely devastating to coral communities. Some diseases can wipe out a significant portion of the local coral population. 88% of *Acropora palamata* in the Florida Keys was killed by White Pox Disease between 1996 and 2002 (Sutherland et. al. 2010). In addition to their virulence, many diseases are universal and can infect several species of corals. In 1995, White Plague Disease infected 17 species of coral in the Florida Keys (Dybas 2013). Identifying the causes and pathways of coral diseases can aid the development of treatment and preventive strategies.

Within recent decades, coral diseases have been found to be caused by bacterial, viral, and fungal infections. *Aurantimonas coralicida*, a Gram negative bacteria, single-handedly caused the White Pox breakout in 2003 (Dybas 2013). Various microorganisms occupy coral tissue and mucus under normal conditions; however, environmental stress triggers pathogenic organisms to induce infections. The stresses that can induce an infection include rising temperatures, water pollution, and overfishing (Rosenberg et. al. 2007). Once a coral is infected, the disease can be transmitted various ways including coral-to-coral contact or by a vector.

Corals are sessile organisms; however diseases have been found to be contagious, typically spreading to a diseased coral’s nearest neighbors. An organism’s nearest neighbors are identified as the organisms closest to the individual of interest. The larger the distance between the individual and its nearest neighbors, the more isolated the individual is (Clark et. al. 1954). Coral disease can transmit to a healthy neighboring, colony when infected tissue fragments off of the diseased coral lands by healthy coral colonies. A diseased coral’s nearest neighbors are the most susceptible to come into contact with these fragments (Williams et. al. 2005). The spread of White Pox Disease in *Acropora palmata* on Florida reefs has been observed as a prime example of this disease transmission through nearest neighbors. Within one year, White Pox spread from one colony of *A. palmata* in Florida to the four surrounding *A. palmata* reef stations (Patterson et. al. 2002).

Another factor contributing to the spread of disease is the presence of a vector, carrying the pathogen. One vector, the coral-eating snail *Coralliophila abbreviata*, has been found to transmit disease between *Acropora palmata* individuals. Snails typically only travel between coral individuals once their host coral dies. A snail, feeding on a diseased coral until the coral dies, transports disease when it travels to a new healthy coral, intensifying the spread of the disease (Williams et. al. 2005).

Several studies have focused on the transmission of disease among acroporid corals in Florida. However, the transmission of disease in coral species of Curaçao has yet to be analyzed. Located in the Caribbean Sea as part of the “ABC” islands, Curacao is surrounded by a fringing reef, home to over 65 species of coral. In the 1980s, *Acropora* species of coral in Curaçao were devastated by White Band Disease (Bak et al 1981). To help address coral disease in Curaçao, this project analyzes two factors contributing to disease dispersal: fragmentation and the presence of a vector based on distance from nearest neighbor and the density a coral-eating snail *Coralliophila abbreviata*. It is expected that the closer the nearest neighbor is to a diseased coral, the more likely the neighbor is diseased. Conversely, the farther the nearest neighbor is from a diseased coral, the less likely that neighbor is diseased. Additionally, it is expected that diseased corals will have a high density of *Coralliophila abbreviata* feeding on the remaining healthy tissue, while healthy coral individuals will have lower snail densities. The results from this project can contribute to the development of treatment and preventive strategies of disease prevalence in Curaçao coral populations.

Materials and Methods

To test these hypotheses two sites in Curaçao were analyzed: Director’s Bay and the Spanish Waters Channel. At each site, five diseased coral colonies and five healthy coral colonies were examined. Disease status was determined by the presence of any disease sign, typically the presence of a discolored band followed by bleached polyps on a colony. Field data was recorded on underwater paper.

**Nearest-neighbor distance and disease status.** At each site, diseased coral colonies were chosen at random to be analyzed. The amount of disease coverage was recorded in increments of 25%: 0-25%, 25-50%, 50-75%, and 75-100%. The diseased coral’s nearest neighbor was determined as the closest coral colony of the same species. The distance between the colony and its nearest neighbor was measured with transect tape in centimeters. The disease status of the nearest neighbor was recorded. This process was repeated for healthy colonies. Healthy coral colonies were chosen at random and the distance from their nearest neighbors, as well as the disease status of the nearest neighbors were recorded.

**Snail density.** The same colonies that were analyzed for nearest neighbor data were also examined for the density of the snail, *Coralliophila abbreviata*. The size of colonies were measured in centimeters using measuring tape for their height and width. Next, the number of snails present were recorded.

**Data analysis.** The data was combined from each site and presented in tables. To analyze the occurrence of disease status in nearest neighbors as a factor of distance, a two-sample t-test was applied with an alpha value of 0.05. A p-value lower than 0.05 means the probability of the diseased colony’s nearest neighbor being diseased increased with decreasing distance from the diseased colony. If the p-value was greater than 0.05, there was no relationship between distance from a diseased colony’s nearest neighbor and the nearest neighbor’s disease status. To examine if the nearest neighbors of diseased colonies were more likely to be diseased, a Fisher’s Exact Test was applied. A Fisher’s Exact Test was also intended to be applied to analyze the presence of high or low snail density (the definition of high and low snail density was to be determined relative to the data collected) and the probability that the coral is diseased. An example of a Fisher’s Exact Test is in the table is below.

**Table 1**. This table represents the probability that a coral’s nearest neighbor will be diseased based on the diseased status of the nearest neighbor. This table shows the expected results that if the colony is healthy, its nearest neighbor is more likely to be healthy than diseased and if a colony is diseased its nearest neighbor is more likely to be diseased than healthy. According to this table, if the focal colony is healthy, there is an 80% chance its nearest neighbor is healthy and 20% chance the nearest neighbor is diseased, and if the focal colony is diseased, there is a 20% chance its nearest neighbor is healthy and 80% chance its nearest neighbor is diseased. If the disease status of a focal colony and its nearest neighbor’s disease status are not related, the probability in each situation will be equal, 25%.

|  |  |  |
| --- | --- | --- |
|  | Nearest Neighbor Colonies |  |
| Focal Colonies | Healthy | Diseased |
| Healthy | 80% | 20% |
| Diseased | 20% | 80% |

Results

The number of colonies analyzed was too small to make statistically significant remarks about the predictions. However, the absolute data of the small sample size did correspond to the predictions that the average distance between diseased-to-diseased colonies was smaller than the average distance between diseased-to-healthy colonies. Also, the probability of a diseased colony having a diseased neighbor was greater than the probability of having a healthy nearest neighbor.

Equal numbers of healthy colonies and diseased colonies were intended to be analyzed at both the Spanish Waters Channel and Director’s Bay. However, in total, ten diseased colonies were analyzed, five at Spanish Waters Channel and five at Director’s Bay, but only five healthy colonies were analyzed, five at Director’s Bay. In order to run the statistical tests, five of the ten diseased colonies’ data were chosen at random to be analyzed. Also, the snail *Coralliphila abbreviata* was less prevalent than expected. Only one was spotted on one of the diseased colonies. No statistical tests were run on snail density due to the rarity of the snail.

**Table 2.** Nearest neighbor and snail density data from Director’s Bay and the Spanish Waters Channel

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Focal Colony |  |  |  |  |  |  |  |
| Colony buoy number | Disease status | Colony height | Colony width | % diseased | NN  H or D | NN distance | Number of snails |
| 3 | Diseased | 77 | 75 | 25-50 | D | 40 | 0 |
| 5 | Diseased | 39 | 91 | 25-50 | H | 50 | 0 |
| 1 | Diseased | 45 | 65 | 50-75 | D | 60 | 0 |
| 4 | Diseased | 37 | 37 | 25-50 | D | 3 | 1 |
| 6 | Diseased | 70 | 80 | 25-50 | D | 75 | 0 |
| 24 | Healthy | 60 | 40 | N?A | D | 62 | 0 |
| 36 | Healthy | 55 | 77 | N/A | D | 50 | 0 |
| 44 | Healthy | 44 | 65 | N/A | H | 73 | 0 |
| 7 | Healthy | 57 | 34 | N/A | H | 120 | 0 |
| 201 | Healthy | 63 | 46 | N/A | D | 90 | 0 |

NN=nearest neighbor

H=healthy; D=diseased

N/A=non-applicable

**Table 3.** Two-Sample t-test input of distance from nearest neighbor and likelihood of neighbor’s disease status

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NN D or H | Number of Colonies | Mean | Standard Deviation | SE Mean |
| D | 4 | 44.5 | 31.2 | 16 |
| H | 4 | 63 | 18.9 | 9.4 |

NN= nearest neighbor; D=diseased; H=healthy; SE=standard error

**Table 4.** Two-Sample t-test output of distance from nearest neighbor and likelihood of neighbor’s disease status

|  |  |  |
| --- | --- | --- |
| Difference | mu(D)-mu(H) |  |
| Estimate for difference | -18.5 |  |
| 95% CI for difference | -69.1, 32.1 |  |
| T-Test for difference = 0 (vs not =): | T-Value | -1.02 |
|  | P-value | 0.367 |
|  | DF | 4 |

mu=mean; D=diseased; H=healthy;

CI=confidence interval

DF=degrees of freedom

The mean distance of diseased colonies from diseased nearest neighbors was 44.5cm, while the mean distance of diseased colonies from healthy nearest neighbors was larger at 63cm (Table 3). Despite the smaller average of distance from the diseased nearest neighbor compared to the distance from the healthy nearest neighbor, the t-test output indicates that there is no difference between disease status of the nearest neighbor and its distance from the diseased colony. The p-value was 0.367, larger than the alpha value of 0.05 (Table 4). Perhaps a larger sample size would show a statistically significant difference.

**Table 5.** Fisher’s exact test input and output of disease status of colony and nearest neighbor. Instead of percentages recorded into the table, as stated in the methods section, colony counts were recorded into the table.

|  |  |  |  |
| --- | --- | --- | --- |
| Disease status | NN H | NN D | Total |
| H | 2 | 3 | 5 |
| D | 1 | 4 | 5 |
| Total | 3 | 7 | 10 |
| Fisher’s exact test |  |  |  |
| p-value | 1 |  |  |

NN=nearest neighbor; H=healthy; D=disease

The probability of a diseased colony’s nearest neighbor also being diseased was not proven by the Fisher’s exact test. The p-value was 1, meaning that the sample size analyzed was too small to indicate a pattern (Table 4). However, the absolute values in each scenario correspond to the prediction that diseased colonies are more likely to have diseased neighbors than healthy ‘neighboring colonies. The data indicates that four of the diseased colonies’ nearest neighbors were also diseased, while only one of the diseased colonies’ nearest neighbors was healthy (Table 5). Meanwhile, the healthy colonies contradicted the prediction that healthy colonies are more likely to have healthy nearest neighbors because the number of healthy colonies with healthy nearest neighbors was only 2, while the number of healthy colonies with diseased neighbors was higher, 3 (Table 5).

The snail counts were too low to compare snail densities on diseased and healthy coral colonies (Table 2).

Discussion

The spread of disease via fragmentation of diseased tissue and the presence of a vector based on distance from nearest neighbor of *Coralliophila abbreviata* density could not be clarified by this project due to the small sample size. Though the sample size of the data could not lead to statistically significant meaning, the data did show trends in regard to fragmentation. The average distance between diseased-to-diseased colonies was smaller than the average distance between diseased-to-healthy colonies. Also, the probability of a diseased colony having a diseased neighbor was greater than the probability of having a healthy nearest neighbor. There were not enough *Coralliophila abbreviata*, snails, present in Curaçao to imply their role in the spread of disease. Thus, the presence of this snail is not likely a major cause of disease outbreak in Curaçao.

To address the spread of coral disease based on fragmentation, distance to nearest neighbor, and the presence of a vector, snail density, additional colonies could be analyzed in the future using the same parameters. If this additional data follows the trend that the closer the nearest neighbor is to a diseased colony, the more likely the neighbor will be diseased, a minimum distance from diseased colonies to healthy neighbors could be established. Coral coverage has decreased roughly 80% globally in the past 40 years. Some restoration efforts have involved growing coral colonies in nurseries and then planting them in the wild (Rinkevich 2005). With a known minimum distance from diseased colonies, nursery colonies can be planted beyond that distance to reduce their chance of getting infected.

In order to develop more accurate minimum distances, the parameters of distance from nearest neighbor and nearest neighbor disease status are not sufficient indicators. Not all coral species fragment at the same rate or pattern. Of the boulder coral species, under equal amounts of disturbance, *Montastraea annualaris* has been found to fragment more frequently than *Montastraea franksi* (Weil et al 1994). Fragmentation patterns and rates should be analyzed on a per species basis. The minimum distance a nursery colony should be planted from a diseased coral colony will then be species-specific.

Conclusion

Despite the lack of statistically significant information analyzed, trends of disease spread in Curaçao have been uncovered. The data available suggests that the closer a diseased colony is to its nearest neighbor, the more likely the nearest neighbor is also diseased. With a species-specific understanding of fragmentation patterns, minimum distances from diseased colonies to healthy colonies can be established for the future planting of healthy coral colonies from nurseries, reducing the spread of coral diseases. The presence of *Coralliophila abbreviata* as a vector of disease did not seem to be a major cause of disease outbreak in Curaçao. Thus, preventive and treatment strategies of coral disease in Curaçao should be focused on fragmentation pathways.

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Timeline

Day 1: Site One Examination

This day will be used to examine twenty-five corals at site 1, their disease status, distance from nearest neighbor, nearest neighbor’s disease status, and snail density.

The total time per coral is estimated to be eight minutes.

Finding coral to observe: 2 minutes

Identifying disease status of coral and coral’s nearest neighbor: 2 minutes

Measuring snail density on coral: 4 minutes

Total time per coral: 8 minutes

Total timer per site: 8 minutes X 25 corals = 3hrs and 20 minutes

Since the site will be available 9am-5pm, a total of 8 hours, there is enough cushion time for breaks to be taken and possible occurrences that may delay some parts of the procedure.

Day 2: Site Two Examination

This day will be used to follow the same procedure as Day 1 at site two.

Day 3: Data Organization, Analysis, and Interpretation

These tasks will most likely occur after the Curaçao trip, if not during the trip, if time permits. The data will be organized into tables. The ANCOVA test and Fisher’s Exact test will be run. The results will then be interpreted.

Budget

|  |  |
| --- | --- |
| 0.5m X 0.5m Quadrat tape | $20 |
| 35ft Measuring tape | $15.98 |
| Underwater paper | $32.25 |
| Pencil | $1.00 |
| Clipboard | $6.00 |
| Total | $75.23 |