Tide Pools: a Study of the Island Biogeography Theory

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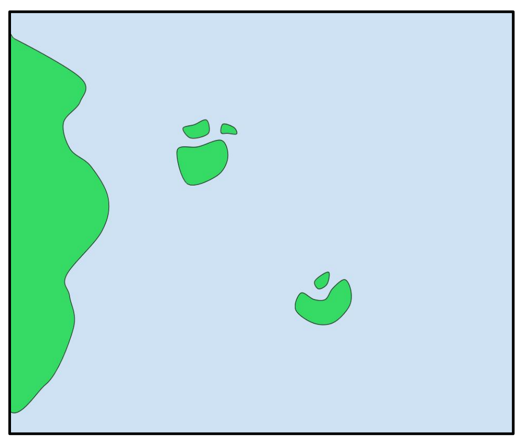
Abstract

The purpose of this study was to test the theory of island biogeography through the observation of tide pools. We hypothesized that 1) larger pools would have greater species richness and 2) greater biodiversity. We found there was a significant correlation between tide pool size and species richness, However there is not a significant correlation between tide pool size and biodiversity, and thus our second hypothesis was not supported.

Introduction

The Achotines Laboratory is located in Los Santos, Panama on the Azuero Peninsula, situated near a rocky intertidal coastline. The tide pools create fragmented ecosystems, varying in size and distance from the ocean. In this field study we chose to view these tide pools as individual islands in order to test the theory of island biogeography. This theory describes the relationship between the biodiversity of an island and its size and proximity to the main colonization source (Kricher, 1997). Pioneered by Alfred Russel Wallace, this theory asserts that "larger islands closer to the mainland will have a higher species richness… than small islands more distant from the mainland" (Kricher, 347-348). Shown in a species area graph, there is a clear positive correlation between the area of an isolated habitat and the number of species present (Lovejoy, 215). Our goal was to determine if this positive correlation applies to tide pools as well.



This experiment was designed to determine if these tide pools function as islands, with differing levels of biodiversity (the relationship between number of species and the distribution of of individual organisms across the species) and species richness (number of distinct species) based on size. The null hypothesis for this study was the tide pools' biodiversity and species richness is not predicated on size. Based on past studies on island biogeography and our own observations, we hypothesized that 1) the larger tide pools would have greater species richness than the smaller islands, and 2) the larger tide pools would have greater biodiversity than the smaller islands.

Materials and Methods

To begin, we designated an area containing the tide pools we wanted to study. We chose pools with close proximity to each other, and of relatively same heights. In addition, we chose pools with different lengths, widths, and depths. We recorded the tide pools during low tide over the course of two days to ensure a relatively consistent water level. When studying each tide pool, we counted the number of individual organisms, noted the number of species in each pool, and recorded this information in a data table. We then measured length and width using a tape measure, depth using a PVC pipe marked with centimeters, and temperature using a thermometer. We documented each pool with an iPhone camera. Over two days we recorded data for a total of 14 tide pools (see raw data in Fig. 1).

During our analysis we focused on calculating species richness and biodiversity as it correlates to pool size. We analyzed species richness by creating a linear regression test and graph by plotting the size of a tide pool against the number of species present in that tide pool (see Fig. 3). We used the program InStat to analyze the data and create the graphs. We then moved on to biodiversity. For each pool we used the following equation available through an online calculation https://www.alyoung.com/labs/biodiversity_calculator.html to calculate a Shannon's index (equation: $-\Sigma P_n (\ln P_n)$), a measure of diversity that considers the number of different species as well as the distribution of organisms across the species (see Fig. 2). We then used that number to relate tide pool size and biodiversity, once again using InStat to run a linear regression test and create a graph. When calculating size, we realized that because of the irregular shapes of the pool, using surface area or volume as calculations of size would be an inaccurate and inefficient measurement of the pools. Because of this, we added the length, width, and depth measurements together to give a holistic yet reasonable assessment of size.

Species	Pool 1	Pool 2	Pool 3	Pool 4	Pool 5	Pool 6	Pool 7	Pool 8	Pool 9	Pool 10	Pool 11	Pool 12	Pool 13	Pool 14
Sea Urchins	9	2	0	0	0	0	3	16	1	0	0	0	0	0
Keyhole Limpets	20	8	13	0	0	0	28	47	10	1	0	0	4	6
Sea slugs	7	0	0	0	0	0	1	13	4	0	0	0	0	0
Goby	5	0	1	0	0	0	7	18	2	0	0	0	1	2
Banded Goby	1	0	2	0	0	0	2	3	2	0	0	0	0	2
Round Snail	61	28	3	36	33	27	170	92	22	0	20	218	3	106
Conch Snail	7	2	2	14	0	0	3	8	1	0	0	0	0	0
White Conch Snail	0	0	3	5	27	4	1	0	4	0	1	25	0	7
Oysters	12	0	4	0	0	0	1	17	2	0	4	0	0	43
Hermit Crabs	2	0	0	0	0	0	0	2	0	0	0	0	0	4
Chitons	0	0	3	0	0	0	0	2	0	1	0	0	1	11
Mystery Tentacles	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Speckled Mollusk	0	0	0	1	1	0	0	0	0	0	0	1	0	3
Ridged Mollusk	0	0	0	0	1	0	0	0	2	0	0	2	0	0
Purple Mollusk	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Zig-zag snail	0	0	0	0	0	0	4	179	33	0	3	10	10	67
Wrasse	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Crab	0	0	0	0	0	0	2	3	0	0	2	0	0	0
Black Conch	0	0	0	0	0	0	1	2	0	1	0	0	0	0
White Colony	1	1	1	0	0	0	0	1	1	0	1	1	1	1
Green Colony	1	0	0	0	0	0	1	1	1	0	0	0	0	0
Red Colony	1	1	1	0	0	0	1	1	1	1	0	1	1	1
Pink Algae	1	3	3	0	0	0	0	1	3	2	0	0	1	0
Temperature (F)	86	90	85	96	97	97	96	87	88	93	86	94	89	95
Depth (cm)	59	23	45	5	6	2	26	101	42	6	11	9	10	27
Length (cm)	205	73	53	62	69	23	197	553	94	44	57	231	44	245
Width (cm)	89	33	38	34	19	22	147	153	52	16	42	59	23	165
Size Number	**353**	**129**	**136**	**101**	**94**	**47**	**370**	**807**	**188**	**66**	**110**	**299**	**77**	**437**

Data

Fig. 1: Raw Data

This table contains every species we encountered along with the number of individuals from these species in each pool. We have also included general measurements like temperature, depth, length, width, and our calculated size .

Number of Organisms (Biodiversity)	**128**	**45**	**38**	**56**	**62**	**32**	**226**	**406**	**89**	**6**	**31**	**258**	**22**	**253**
Number of Species (Species Richness)	12	6	11	4	4	3	15	16	14	4	6	7	7	12
Shannon's Index	1.596	0.9831	1.793	1.386	1.386	1	0.9028	1.789	1.786	1.099	1.609	1.609	1.386	1.172

Fig. 2: Biodiversity and Species Richness Calculations

This table contains the calculations that we later used to help us plot graphs. This table contains the total number of individuals per pool, the total number of species per pool, and the Shannon's index for each pool

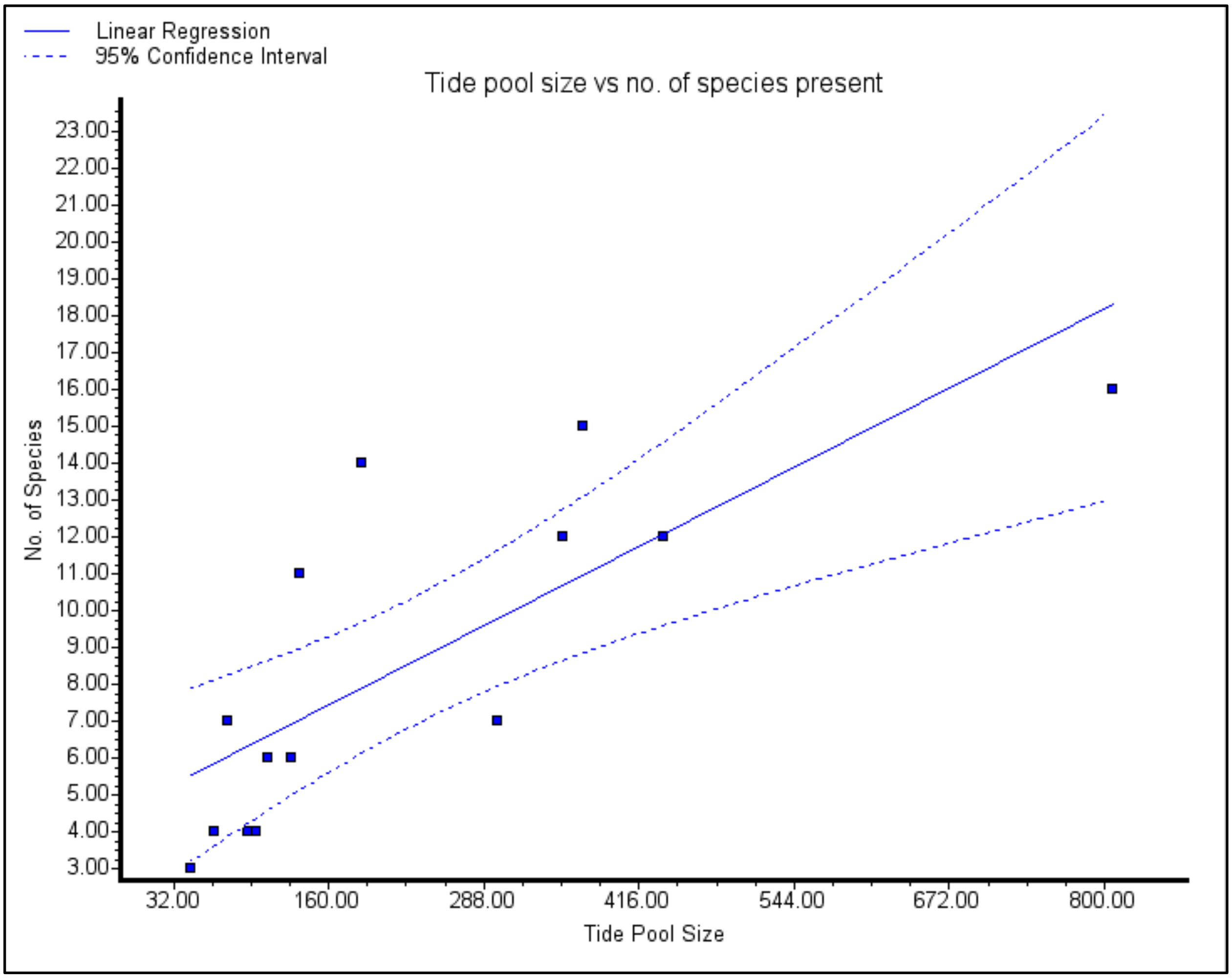


Fig. 3: Tide Pool Size vs. No. of Species

This graph depicts species richness. Our measurement of size is on the x-axis, the number of species present in each pool is on the y-axis.

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Correlation coefficient (r) = 0.7736.  r squared = 0.5985

Standard deviation of residuals from line (Sy.x) = 2.990


Test: Is the slope significantly different from zero?

The P value is 0.0012, considered very significant.
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Fig. 4: Correlation Coefficient and P Value of Tide Pool Size vs. No. of Species

This diagram shows the program InStat's calculations of the correlation coefficient and P value of the graph displayed in Fig. 3. The r squared value is 0.5985, meaning the points strongly adhere to the line of best fit. The P value is 0.0012, meaning there is a strong relationship between tide pool size and number of species.

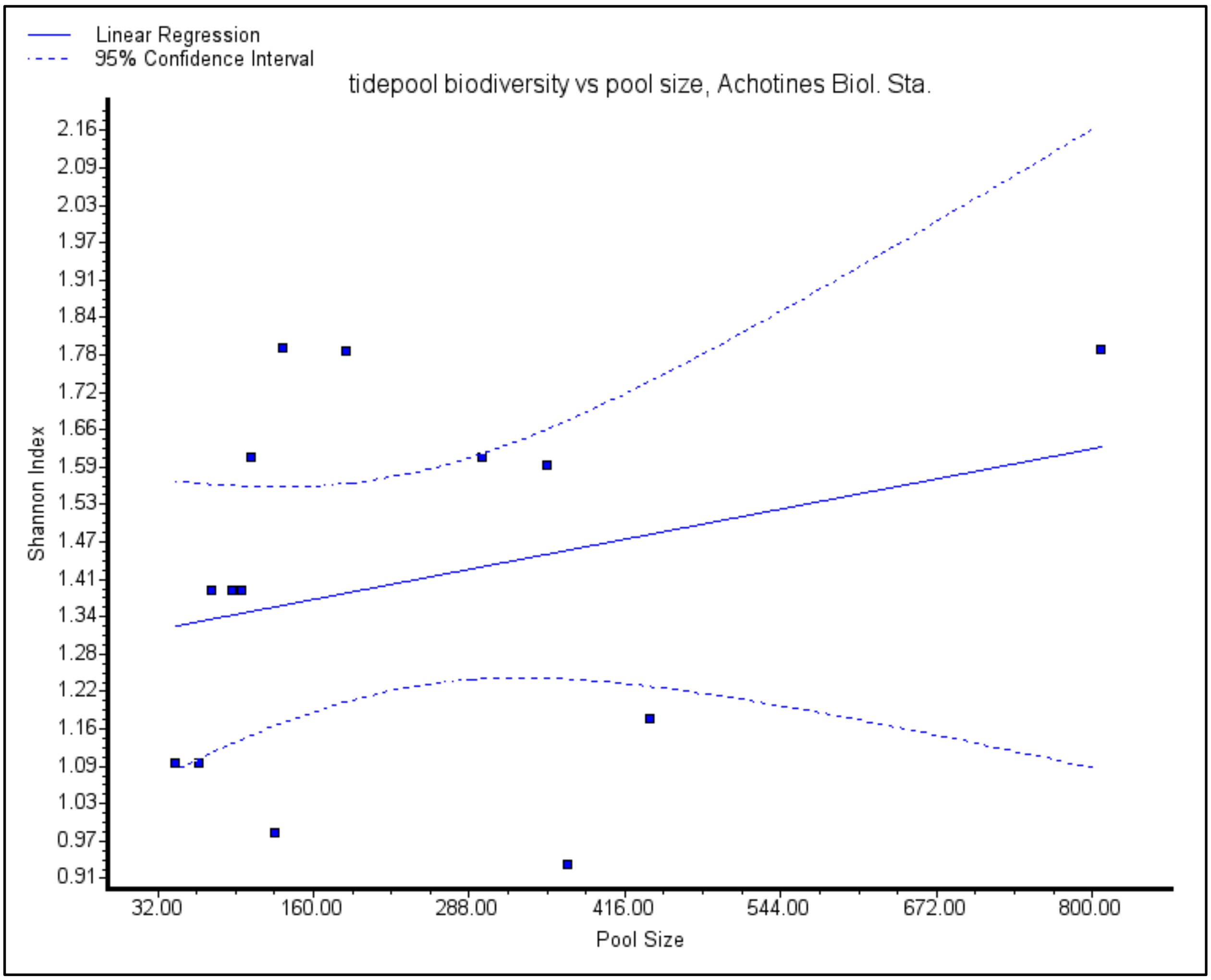

Fig. 5: Tide Pool Size vs. Biodiversity (Shannon's Index)

This graph depicts biodiversity. The x-axis is our measurement of pool size, and the y-axis are our calculated Shannon's Indices values.

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Correlation coefficient (r) = 0.2696.  r squared = 0.07270

Standard deviation of residuals from line (Sy.x) = 0.3059


Test: Is the slope significantly different from zero?

The P value is 0.3512, considered not significant.
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Fig. 6: Correlation Coefficient and P Value of Tide Pool Size vs. Biodiversity

This diagram shows the program InStat's calculations of the correlation coefficient and P value of the graph displayed in Fig. 5. The r squared value is 0.07270, which means the points don't particularly adhere to the line of best fit. The P value is 0.3512, which is greater than 0.05 meaning the relationship between tide pool size and biodiversity is not significant.

Over two days we studied 14 tide pools. We found 23 different species within the tidepools. According to our form of measurement, the tidepools ranged in size from 47-807 cm. The total number of individuals within each pool ranged from 6-406 individuals.

The species-area relationship graph shows that as the size of the tide pool increases, the number of species present within that pool increases. The p value is 0.0012, which indicates there is significant correlation between the two data sets.

When plotting tide pool size against the Shannon's index values to quantify biodiversity, the graph appeared to have a slight upward trend, yet the insignificant r squared value (0.07270) shows the points didn't adhere to the line of best fit. Furthermore, the P value of 0.3512 (greater than 0.05) indicates there is not a significant correlation between the two data sets.

Discussion

Based on our findings, we accept our first hypothesis that larger tide pools have greater species richness, but we reject our second hypothesis that larger tide pools have greater biodiversity. The hypothesized relationship between tide pool size and species richness is supported by the noticeable positive correlation in the graph (Fig. 3), the r squared value of

0.5985, and the P value of 0.0012. These figures indicate there is a statistically significant correlation between pool size and species richness, and thus we accept our first hypothesis. These results are further evidence proving the island biogeography theory.

The hypothesized relationship between tide pool size and biodiversity is countered by the data points' weak connection to the line of best fit (Fig. 5), and the P value of 0.3152. These figures indicate there is not a statistically significant correlation between pool size and biodiversity, and thus we reject our second hypothesis. Although we can make solid conclusions about our hypotheses based on data, we question the accuracy of our data. We wonder if we had studied more pools and had more data points, if our data would be more significant. In addition, there were several sources of error in our procedure.

Some of these sources of error included our inability to see and count all the organisms in the pools (human limitations), inaccurate measurements of the pools, inconsistent water levels or tide pool volume due to evaporation, and our possible bias in selecting pools that could support/counter our hypothesis. Additionally, we question if our way of sizing the pools was truly accurate, and if not, if that influenced our findings at all. Adding the lengths, widths, and depths together isn't the most accurate depiction of size, but given time and material constraints, we found this method sufficient. If we were to continue this study in a future experiment, we would eliminate chances of human error, such as finding a more reliable form of measurement.

Conclusion

This study is relevant to our understanding of tide pools and organism immigration patterns. This study supports the idea that tide pools function according to the island biogeography model, with larger pools containing a higher number of distinct species.

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