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The Effect of Sedimentation Levels on *Tarebia granifera* in Freshwater Lagoons in Punta Cana, Dominican Republic

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Abstract

Punta Cana, one of the largest tourist destinations in the Caribbean, is located in the western part of the Dominican Republic on the island of Hispaniola. Increased human activity has had a negative impact on the aquatic ecosystems, significantly decreasing the number of coral reefs, mangroves and sea grasses. The decline is not only occurring in the Caribbean, but also worldwide and is attributed to human and natural causes. It is believed that the degradation of aquatic ecosystems is partially driven by increased sedimentation. Sedimentation levels directly impact the wellbeing of aquatic ecosystems. Suspended particles reduce the amount of light that penetrates the water, which reduces photosynthesis and the production of dissolved oxygen. The suspended material can clog fish gills reducing their resistance to disease, lowering growth rates and affecting egg and larval production. Increased sedimentation means a thicker layer of particles accumulates on the floor of the aquatic biome and smothers eggs and benthic macroinvertebrates. The Indigenous Eyes Ecological Reserve, situated on 1500 acres of protected land on the resort, has twelve freshwater lagoons. Since only three of them are open to swimming, it was an ideal natural setting to conduct an experiment to compare the effect of human activity on the levels of sedimentation in two lagoons – one open and one closed to swimming. We also measured the effect of sedimentation levels on the size of the *Tarebia granifera* in each of the lagoons. The data was analyzed using One-Way ANOVA.

Author's Note

C. Damienne Harfouche is a senior majoring in Sustainable Development at Columbia University and is a member nominated to serve on the Earth Institute Student Advisory Council, which will be working this year with the Office of Environmental Stewardship at Columbia University to increase student voice in sustainability initiatives on campus.

Diane Jung is a junior also majoring in Sustainable Development at Columbia University and worked as an intern in the United Nations Global Compact Korea, which works to promote voluntary corporate citizenship initiatives in the areas of human rights, labor, anti-corruption, and the environment.

This experiment was the result of fieldwork done at the Indigenous Eyes Ecological Reserve in Punta Cana, Dominican Republic through the SEE-U program, which is a five week ecosystem experience that took place in July and August 2013. We would like to thank Omar Perez-Reyes for his guidance throughout the process.

Keywords: Punta Cana, Dominican Republic, Lagoons, Sedimentation, Tarebia granifera

1. Introduction

The goal of this study was to measure the effect of anthropogenic activities on the sedimentation level in each of two freshwater lagoons – one open and the other closed to swimming – situated in the Ecological Reserve Ojos Indigenas (Indigenous Eyes) in the Punta Cana Resort. Punta Cana is the eastern tip of Hispaniola, an island shared with Haiti. We compared the effect of the sedimentation level on the size of *Tarebia granifera*, a non-native resident snail, in each lagoon.

Figure 1. Location of Punta Cana on Hispaniola Island (Galileo Travel)

Aquatic ecosystems are affected by radiant energy, water temperature, oxygen and clarity. The clarity or turbidity of water is a measure of the number of suspended particles in the water and since suspended particles absorb heat, an increased number of them cause the temperature of the water to increase. Elevated water temperatures increase the metabolic rate of the resident species, the rate of decomposition, and the water density.

Figure 2. Punta Cana resorts

Turbidity and sedimentation levels directly impact the wellbeing of an aquatic ecosystem. Suspended particles reduce the amount of light that penetrates the water, which reduces photosynthesis and the production of dissolved oxygen. The suspended material can clog the fish gills reducing their resistance to disease, lowering growth rates and affecting egg and larval production. Increased sedimentation means that a thicker layer of particles accumulates on the floor of the aquatic biome and smothers the eggs and benthic macroinvertebrates. (Minnesota Rural Water Association, Sedimentation)

Figure 3. Life outside the resorts: a family home in the country side (left) and a fisherman who supplements his income by giving boat tours (right)

Sedimentation occurs when gravity causes the suspended particles to settle at the bottom of an aquatic ecosystem. The sediment may consist of sand, clay, or silts and are transported by wind, water or ice. The size of the particles, the water temperature, the currents, and the shape of the basin affect the rate of sedimentation. Sediment particles can be naturally-occurring material or the result of anthropogenic activities such as agriculture, deforestation, and construction. Anthropogenic sediment has two aspects: 1) physical – top soil loss and land erosion; 2) chemical – the absorbed chemicals in clay and silt, such as phosphorous, pesticides, and metals. Both aspects contribute to increased levels of turbidity in the receiving waters. Bioturbation, the reworking of soils by animal and plant organisms, is a particularly important process with regard to sedimentation.


Figure 4. Inside the Indigenous Eyes Ecological Reserve, a protected area within the Punta Cana Resort: blue land crab (left) and iguana (right) are among the many species that live in the reserve

2. Questions/Hypothesis

What is the effect of human activity on the level of sediment in the freshwater lagoons in the Indigenous Eyes Reserve?

What is the effect of the level of sediments on the size of snails (*Tarebia granifera*)?

H0: We hypothesize that increased human activity in the lagoon will not result in higher levels of sediment.
H1: We hypothesize that increased human activity in the lagoon will result in higher levels of sediment.
H2: We hypothesize that increased human activity (higher levels of sediment) will result in different size of snails (*Tarebia granifera*).

3. Site Information

There are twelve freshwater lagoons in the Indigenous Eyes Reserve in Punta Cana. The reserve is situated in the lowland subtropical forest of the Dominican Republic. The lagoons are the result of emerging water from Quaternary reefal limestone aquifer, one of the three major aquifers of the Dominican Republic (Gilboa 1980). The main sources contributing to aquifers are rainfall, inflow from rivers and canals, irrigation losses and other aquifers. Only three out of twelve lagoons in the Reserve are open to the public for swimming in order to protect the lagoons and the surrounding environment from degradation as result of development. Not only are the lagoons economic resources from tourism, but they also play a crucial role in the ecosystem of Punta Cana, providing habitats for diverse species as well as flood and climate control. The primary criterion in site selection was ensuring that there is significant enough difference in level of human activity between the lagoons. Therefore, we chose the open lagoon that seemed most popular to tourists, and the closed lagoon that was most easily accessible for our twice daily collection, but also small and located deep enough in the reserve area to minimize the likelihood of human activity.

By comparing the sediment levels in the lagoon open to swimming versus the one closed to the public, we observed the impact of human activity on the number and size of the snails (*Tarebia granifera*)

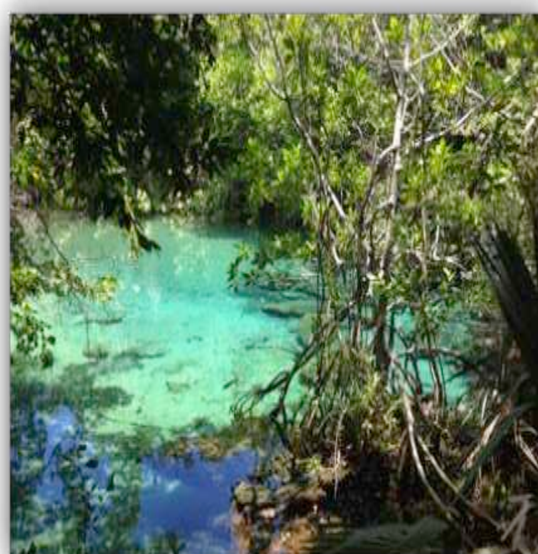


Figure 5. Laguna Turey (left) open for swimming and Laguna Yucahu (right) closed to swimming. The lagoons are within the reserve, which is a protected area on the resort

3.1 Taribia granifera

Snails are an important part of the food web and they link and influence the different trophic levels. They are able to filter food from the water and from the sediment through their gills. Snails feed across trophic levels on bacteria, algae, zooplankton, detritus (non-dissolved organic material) and dissolved organic material (CC Vaugn et al. 2008). The *Tarebia granifera* is a freshwater snail that is non-native to the Dominican Republic. Originally from Asia, it is believed that it was first introduced to the United States in 1940 when an aquatic plant dealer used improperly washed tubs to gather native plants. The range of this mollusk continues to expand due to transport by humans. The diet of the adult *Tarebia granifera* is primarily algal growth on rocks as well as various microorganisms and small particles of organic material. It has not been found to harm aquatic vegetation (Tarebia, 2007).

Figure 6. *Tarebia granifera*, the snails we collected from both lagoons. These were collected by hand by removing them from rocks and from underneath sediment

4. Methods

Figure 7. Since there was no sign at the entrance of Laguna Yucahu indicating that it was not open to swimming, we made one and blocked the entrance to ensure that the site remained undisturbed for at least the duration of the experiment

Two sites were selected for the experiment. Laguna Turey, the one open to tourists, is larger and less covered with tree canopy than Laguna Yucahu, which is closed to tourists. Out of the twelve lagoons in the Ecological Reserve, only three are open to tourists, but there were no signs indicating that the lagoon is closed. Therefore, we created a sign and blocked the entrance, to ensure that there would no human activity in the closed lagoon.

Figure 8. Diane assembling the containers to be placed at the bottom of the lagoons for sediment collection

We used plastic containers, tiles, and flagging tape to collect the accumulated sediments in two lagoons. Two plastic containers were attached on each tile with flagging tape, and placed underwater. Initially, we had planned to use tiles only and collect them with the settled sediment using Ziploc bags underwater; however, through trial and error, we realized that the sediments would float off if we moved them underwater. Therefore, in order to minimize disruption to the settled sediments, we placed the lids on the containers underwater before lifting them out of the water.

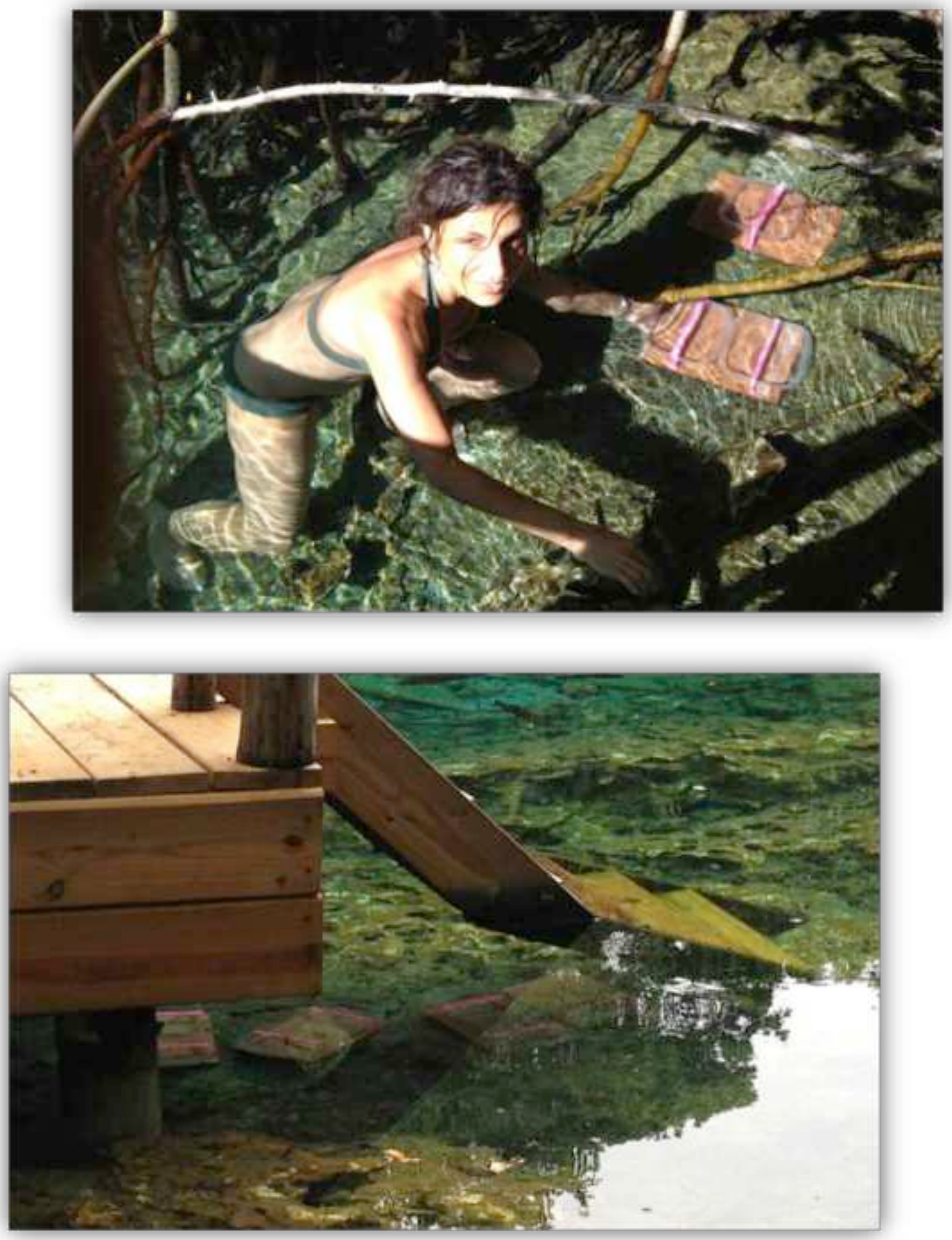


Figure 9. Top: Damienne replacing the containers in the Yucahu lagoon after removing them for our daily collection of sediments. Bottom: location of cumulative accumulation containers (placed in a different location than our daily collection containers), placed under the stairs in order to capture more sediment accumulation from swimmers tracking in matter and stirring up the sediments as they go in and out of the lagoon

We had two different types of collection: one for daily sediment accumulation and one for cumulative accumulation. For the daily accumulation of sediments we collected three containers (replicas) from each site twice a day: in the morning (normally between 8 am and 9 am) and afternoon (normally between 4pm to 5pm). For the cumulative accumulation there was only one daily collection in the morning over six days and in order to minimize sediment disruption, those containers were placed in a different part of the lagoon away from the twice daily containers.

Figure 10. Outdoor Lab (top): As soon as the containers were removed from the water we drained them using coffee filters in a funnel to trap the sediments of each container at each location. Indoor Lab (bottom): The wet coffee filters were set out to dry inside the lab and once completely dry, the sediment specimens were weighed and measurements entered on paper and into excel tables.

Once containers were removed from the water, we used coffee filters and funnels to filter them immediately at the site. The drained sediment on the filter papers were then carried to the lab and left out to dry with silica packs for a couple of days. Lastly, the completely dry filter papers with sediment accumulations were weighed on a scientific scale that measures in grams to one decimal point. Placing an unused filter on the scale and resetting it to zero deducted the weight of the filter paper.

Every day, for each site, there were three types of data: 1) three weight measurements for morning daily sediment accumulations 2) three weight measurements for afternoon daily sediment accumulations 3) one weight measurement of cumulative sediment accumulations collected in the morning.

Table 1. Sediment weight measurements in grams

Daily and Accumulated Levels of Sediments in Turey and Yucahu Cenotes							
		Turey Cenote (Open)			**Yucahu Cenote (Closed)**		
		AM Daily	PM Daily	AM Accumulated	AM Daily	PM Daily	AM Accumulated
1	7/14 Sun	0.4	0.1	0.3	0	0.1	0
		0.1	0.3		0	0	
		0.1	0.7		0.1	0.1	
2	7/15 Mon	0	0	0.8	0.1	0	0.1
		0.1	0		0	0	
		0	0.1		0	0	
3	7/16 Tues	0	0	1	0	0.1	0.2
		0.1	0		0	0	
		0	0.2		0	0	
4	7/17 Wed	1.7	0.1	1.5	0	0	0.2
		0.2	0		0.1	0.1	
		0.1	0		0.1	0	
5	7/18 Thur	0.1	0	2.1	0	0.1	0.3
		0.1	0		0.1	0	
		0.1	0		0	0.1	
6	7/19 Fri	0.2	0.2	1.5	0	0	0.3
		0.1	0.2		0	0.1	
		0.2	0.1		0	0	
7	7/20 Sat	0	0		0	0	0.2
		0.1	0		0	0	
		0.2	0.1				

There were three replicas for daily accumulations. Since those were collected twice a day (morning and afternoon), there were six measured weights for the daily accumulation in each site, plus the one cumulative accumulation collected every morning in each site; there was a total seven measured weights recorded daily for each site. While daily accumulations were collected over seven days and cumulative accumulations were collected over six days, there were a total of ninety-four weights measured for daily and cumulative accumulations in both sites. Finally, we took the average of three replicas in morning and afternoon of each day and brought down the numbers to fourteen weight measurements for the daily accumulation. In sum, there were seven averaged weights of sediment accumulations each for the morning and afternoon collection in each site and six weights of sediment accumulations for the cumulative accumulation. There were forty weights in total in the finalized data for the One-Way ANOVA Analysis.

The second part of the experiment consisted of measuring an organism, which in this case was the *Tarebia granifera*. We randomly collected the snails over the period of an hour in each of the open and closed lagoons where we had collected our sediments, and measured their lengths with calipers on site before releasing them. Thirty-one snails were captured in the open lagoon, and fifty-six snails were captured in the closed lagoon.

Figure 10. Tarebia granifera. Most of the snails we found in the lagoon that was open to swimming were the size of the tiny ones in the photograph, whereas in the closed lagoon the large ones were readily visible and easy to collect.

5. Results

We used One-Way ANOVA (Analysis of Variance) to compare our data from each lagoon. ANOVA is a statistical model that compares differences (or variances) between two or more means of certain collections of numbers. The P-value is a probability value in test statistics. When P-value is larger than 0.05, the results are considered to be insignificant, meaning that the numbers do reveal anything meaningful.

We have four One-Way ANOVA Analysis: two for the comparison between AM and PM (daily accumulation) for each site and two for comparison between the two sites for cumulative accumulations and size of snails.

Table 2.

ANOVA: AM/PM Accumulation in the Open Lagoon			
Open	*Average*	*Variance*	*P-value*
AM	0.19	0.05	0.39
PM	0.1	0.02	

P-

ANOVA: AM/PM Accumulation in the Closed Lagoon			
Open	*Average*	*Variance*	*P-value*
AM	0.02	0.0006	0.51
PM	0.03	0.0007	

Value (Open) : 0.39 > 0.05 Value (Closed): 0.51 > 0.05
* NO significant difference between sediment accumulations
in morning and afternoon for both sites

The first two One-Way ANOVA Analyses compares sediment accumulations in two different times (morning and afternoon) in each site. The P-values for each site (0.39 and 0.51) is much larger than 0.05, showing that there is no significant difference between sediment accumulations in morning and afternoon for either lagoon. The first One-Way ANOVA Analysis shows the averages and variances of sediment accumulations of the open lagoon that was measured in morning and afternoon. For the open lagoon, both averages of sediment accumulations in morning and afternoon (0.19g and 0.1g) are similar and small. Also variances of sediment weights in both morning and afternoon (0.05 and 0.02) are small, meaning that sediment accumulations were very consistent.

The second One-Way ANOVA Analysis, like the first one, shows the averages and variances in sediment accumulation for the closed lagoon. As with the open lagoon, both averages and variances of sediment accumulations in morning and afternoon (0.02g and 0.03g) were similar and small. Variances of sediment accumulations in both morning and afternoon (0.0006 and 0.0007) were much smaller for the closed lagoon than for the open lagoon, showing that sediment weights were very consistent both in the morning and afternoon.

Table 3.

ANOVA: Cumulative Accumulations in Open and Closed Lagoons			
	Average	*Variance*	*P-value*

Open	1.2	0.4	0.003
Closed	0.18	0.014	

P-value: 0.003 << 0.05
* Significant difference between cumulative accumulations in Laguna Turey (Open) and Laguna Yucahu (Closed)

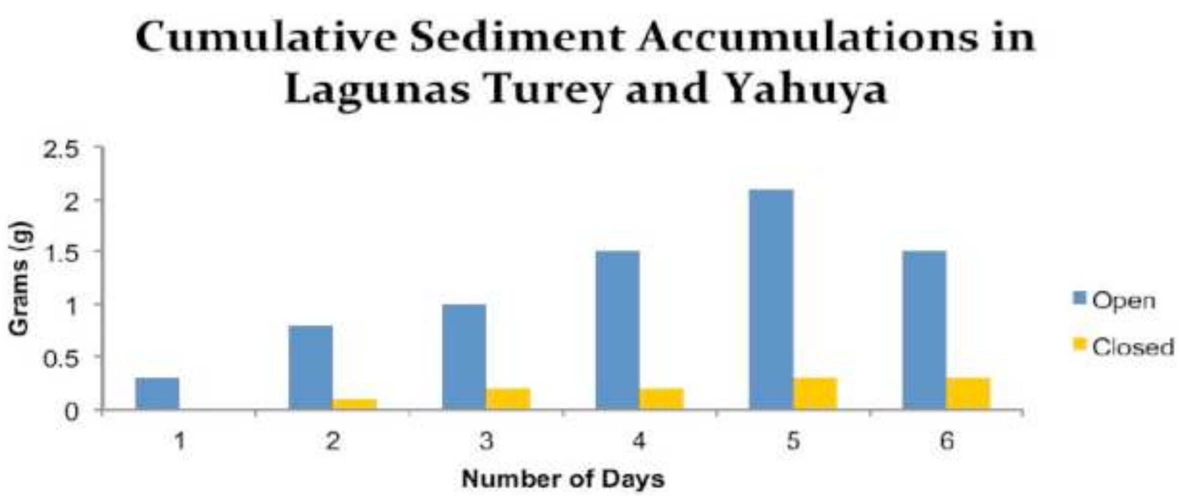


Figure 11. Comparison of cumulative accumulations between open (left) and closed (right) lagoons. The container on the left has a large quantity of fish fecal matter indicating that the swimming by people may increase the fishes' metabolic rate.

The third One-Way ANOVA Analysis, unlike the first two, compares two sites in cumulative accumulations of sediment. The P-value for this analysis (0.003) is much smaller than 0.05, implying that there is a significant difference between cumulative accumulations in the open and closed lagoons. There is a substantial difference in averages of sediment accumulations (1.2g and 0.18g) between the open and closed lagoons. There is also a significant difference in variances of sediment accumulations (0.4 and 0.014) between the two lagoons, meaning that sediment accumulations had been more consistent over six days in the closed lagoon than in the open lagoon.

Table 4.

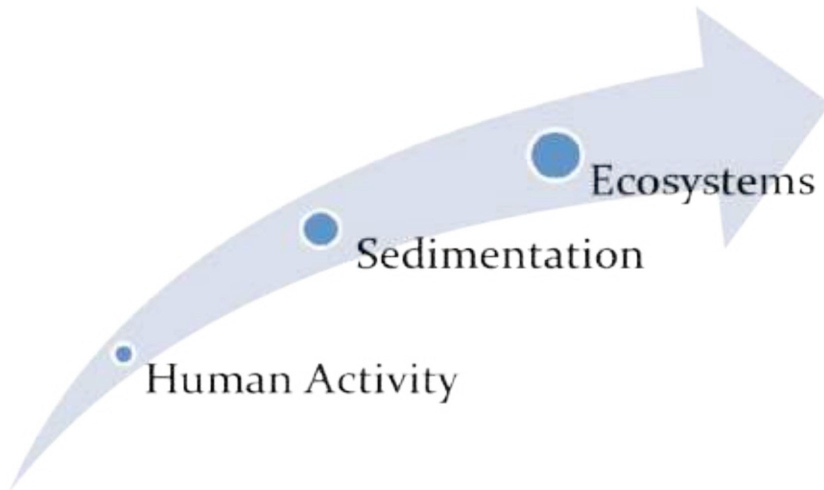
ANOVA: Size of Snails in Open and Closed Lagoons			
	Average	*Variance*	*P-Value*
Open	1.90 cm	1.15	0.00019
Closed	2.92 cm	1.49	

P-value: 0.00019 <<< 0.05
***** Significant difference in sizes of snails in
Laguna Turey (Open) and Laguna Yucahu (Closed)

The final One-Way ANOVA Analysis compares snail sizes in the open and closed lagoons. The P-value for this analysis is smallest, 0.00019, meaning that there is a significant difference in sizes of snails between the open and closed lagoons. There is a substantial difference in averages of snail sizes (1.90cm and 2.92cm) between the open and closed lagoons. Variances of snail sizes (1.15 and 1.49) for the two lagoons are similar, and they are quite large, meaning that snail sizes vary substantially in both open and closed lagoons.

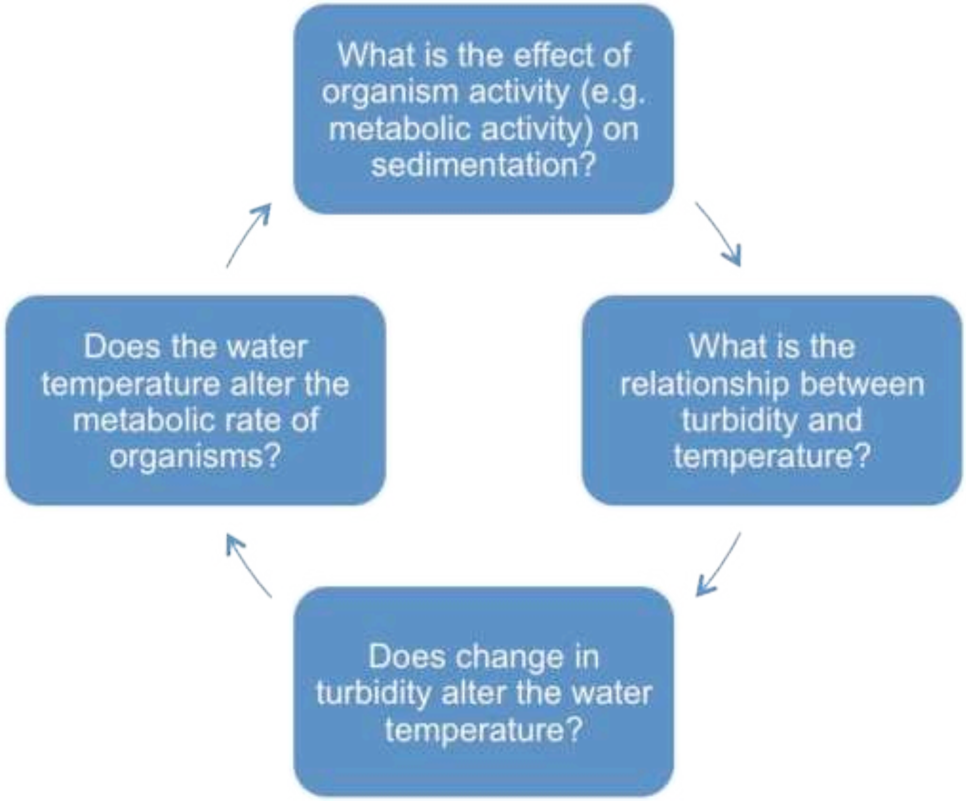
6. Discussion

The Indigenous Eyes Reserve, with natural control zones of lagoons open and closed to swimming, is an ideal setting to observe differences in sedimentation levels and sizes of organisms. The analysis of our data confirmed that there was an increased level of sedimentation as a result of anthropogenic activity in the open lagoon. According Henley et al., increases in sedimentation produce negative cascading effects on organisms in an aquatic ecosystem, causing mortality, a reduction in physiological function and avoidance of the area. Swimming in the lagoon carries in sediments, stirs up existing sediments, and adds biofilm, but in our daily collection there was evidence that human activity also had a significant impact on the metabolic activity of the organisms. In addition, we found that there was a clear difference between the two lagoons in the number and size of snails we were able to find. According to Watters, even naturalists who appreciate and try to be mindful of natural areas cannot avoid trampling. In Turey, the lagoon open for swimming, the snails were difficult to find because they were mostly very small and hidden in crevices or under sedimentation, whereas in Yucahu, the closed lagoon, the snails were a lot larger and readily accessible. We believe that trampling was a factor in the shortage of larger snails in the open lagoon. Surprisingly, natural disturbances like heavy rain and storms didn't have a noticeable effect on the levels of sediment in our daily collection. Even when storms cause destruction, natural disturbances are part of the cycle of an aquatic ecosystem and may have other benefits (NOAA).



We have seen that human activity, even as seemingly innocuous as swimming, causes a measurable increase in sedimentation. Sedimentation has a direct impact on the trophic levels and threatens the overall health of aquatic ecosystems (Henley et al., 2000). It has been documented that this extends to larger ecosystems as well. In fact, the collapse of coral reefs in certain areas of the ocean has been linked to increased sedimentation. According to NOAA, a World Resources Institute report estimates almost sixty percent of the world's reefs are threatened by anthropogenic activity. Suspended sediment, or turbidity, blocks sunlight, smothers corals and interferes with larval production and benthic macroinvertebrates.

If we were to extend our study we would want to examine the relationship between turbidity and temperature and the effect of temperature fluctuations on the metabolic activity of organisms in different trophic levels. Also, it would be worthwhile to consider other factors that can alter the level of sediments besides human activity, such as organism activity (bioturbation) or depth and amount of light in different locations in the lagoons.



7. Conclusion

While the entire process of our experiment only took a little over two weeks, we were able to gain a deeper understanding of the impact of human activities on an aquatic ecosystem. The first half of the experiment entailed the set up of procedures for on-site collections of sediment samples, while the second half of the experiment focused on the analysis of the results. In the Dominican Republic and other tropical areas that are biodiversity hotspots, tourism and related human activities have increased the threats to ecosystems, which act as the Earth's haven for a myriad of organisms. Competing lucrative interests have prevented appropriate measures to be taken to protect the fragile ecosystems in these hotspots, since short-term economic returns often seem to render the long-term environmental costs negligible. In addition to the environmental problems that are readily visible, like the decreased metabolic and growth rates of organisms described in our experiment, there are also potential problems that may surface later with much broader consequences. Since decreased metabolic and growth rates of organisms can further slow the reproduction rates, it could lead to a decrease in species diversity in the lagoons. A few strong invasive species, like Tilapia fish and Red-Eared terrapin, were observed in the lagoons and an increase in their population could threaten the diversity of native species weakening the entire ecosystem by disturbing the food chain and web.

These problems may be a sign of disturbances to larger ecological cycles and are likely to be more costly and challenging to address in the future if ignored. Thus we should not neglect seemingly trivial yet immediate changes in the ecosystem, and even small experiments, when they aggregate related data, can be the basis of impactful findings that can deepen our understanding of the natural world and motivate us to take strong actions to ensure sustainable development in order retain the future viability of ecosystem services in both our niche and the surrounding environment.

Figure 12. (clockwise starting top left) Children at play in the country side, in an urban village, and on the resort next to a mangrove

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