The evaluation of agricultural impacts upon the water quality in a university campus stream in Costa Rica.

EARTH University

Limón, Costa Rica

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Acknowledgments

When I first arrived at EARTH as a Borlaug-Ruan intern in the middle of rural Costa Rica, I had no idea what to expect. I knew very little about Costa Rica as a country, not to mention the Spanish language itself. However, in just eight weeks, I learned an incredible amount about Costa Rica, its people, and its environment. I was given the opportunity to take an initial two-week course about rural communities and rural development in the country, which allowed me to travel around the country and meet inspiring people who are making change. Not knowing much Spanish ultimately made my time at EARTH even more valuable, as I had constant exposure to native Spanish speakers as well as a formal three-week Spanish class to learn some of the complex aspects of the language. Similar to my past experiences with living/traveling abroad, flexibility was key. I was required to completely do away with my preconceptions of what I would be doing at EARTH from the moment I stepped foot on campus, but doing so was a valuable experience in independence and communication, in terms of initiating my project. Lastly, my time at EARTH has been a useful introduction to college life, as I was due to start college in the fall. I had quite a lot of independent time on campus to do personal research and writing, learning how to manage my time effectively so that I could complete my work and still having social time.

I would like to express my sincere gratitude to the people who enabled me to have such a successful, transformative experience in Costa Rica. First and foremost, thank you to Sofia Vargas as well as Ricardo Brenne, EARTH staff members who worked constantly to make sure that I was happy and healthy at EARTH. Whether it was Sofia reaching out to professors to find me a research project to dedicate myself to, or Ricardo spending a day driving me to doctor's

offices to make sure I wasn't sick with a dangerous virus, they cared about my wellbeing and success. I would also like to express my sincere gratitude to my Professor, Alex Gilman, for guiding me through my project and supporting not just my research but also my wellbeing as an intern at EARTH. Her guidance as a teacher was incredibly valuable, and she was generous enough to invite me to her home for two separate weekends and show me unique parts of Costa Rica. Last but not least, thank you so much to Crystal Harris and Ambassador Quinn, for working tirelessly to plan safe, rewarding experiences for so many students going to so many parts of the world. Quite simply, none of the important work that we do and the knowledge that we gain could be possible without their work and support.

Evaluation of water quality of a local stream and potential agricultural impacts on the EARTH University campus, Costa Rica

Abstract

The objective of this project is to evaluate the water quality of a local stream on EARTH University's Campus and to assess the potential impacts of agricultural activities. One of the largest evaluations was on EARTH bananas. EARTH bananas are marketed with the Whole Trade and Rainforest Alliance certifications for sustainable production. Water analysis was completed utilizing both standard physio-chemical analysis and by using macroinvertebrates as bioindicators for the relative health of the water using the Biological Monitoring Working Party modificado para Costa Rica (BMWP'-CR) index method. Both approaches are incorporated in Costa Rican law. Historical data and current data provide evidence that the banana packing plant and other agricultural sectors of EARTH campus are negatively impacting the local stream water quality. Potential limitations and other possible sources of water contamination are also discussed. Lastly, a survey conducted of students at EARTH was done to measure how perceptions of Costa Rica's environmental practices might or might not change when students personally witness and measure these practices, connecting to the larger issues of environmental education and differences between perceptions and realities.

Introduction

Water pollution and low water quality is a global problem that affects billions of people worldwide. Contamination comes from a variety of sources, but agriculture by-itself plays a major role. Agricultural activities discharge organic matter, pesticides and other agrochemicals, which significantly impact water quality. In addition, as the world population continues to rise, agriculture and pesticide use grows to meet the growing global need of food (Mateo-Sagasta, J., Zadeh, S. M., & Turral, H., 2017). The expanding agricultural sector and the expanding discharge of agricultural material into local water sources is a significant issue that affects all of the world, including the developing country of Costa Rica.

Costa Rica is a developing country that has a growing agriculture sector. Agriculture in the country not only feeds the growing population but also is a very important part of the economy with exports like pineapples and cocoa (OECD, 2018). However, as with the majority of the world, developing agriculture can have its consequences. When land has been developed and forests have been cut down for farming, decreases in water quality and increases in soil erosion have been measured (Umaña-Villalobos, G., & Springer, M, 2006). As a sustainably-minded country, Costa Rica has to develop strategies to mitigate the harmful effects of the growing agriculture sector. EARTH University is one such place that is working to develop these kinds of strategies.

"Escuela de Agricultura de la Región Tropical Húmeda" or EARTH University is a for-profit university in Límon, Costa Rica. The school provides education to a diverse student

body of around 450 students with a focus on environmental and ethical awareness. All students who graduate from EARTH receive a Licienciatura degree in Agricultural Engineering. While EARTH's student body is relatively small, at 420 students, the campus itself is quite large, with a total of 8,342 acres. This is because EARTH is home to an organic farm, agroforestry areas, an animal production unit and an academic crop production unit, a protected forest, archeological and wetland reserves and even a 740-acre commercial banana production and packing plant. The university makes money largely through banana production, but all commercial profits support student fellowships (EARTH Facts, 2018).

The banana production business and its packing plant export bananas to Costa Rican grocers such as Walmart and Mas o Menos and to Whole Food Markets across the US as well as European purchasers. The production of bananas and the packing plant are advertised as having "innovative, environmentally-friendly practices," and being carbon neutral. In addition. the plant has been Rainforest Alliance Certified as well as WholeTrade certified (Banana, 2018). The Rainforest Alliance is a global auditor focused on environmental protection and requires that businesses conserve biodiversity, reduce runoff, and other specific regulations for sustainability (Rainforest, 2018).

Previous studies have concluded that chemicals, such as those used to dissolve the latex generated from cutting the unripe bananas, are released into the water as a part of the banana packing process. While these chemicals are organic in nature, they can still have a significant impact on local water quality (Barz, 2009).

Exporting fruit and crops such as coffee, bananas, and pineapple are some of the largest stimulators of Costa Rica's economy (OECD) and hence, financial motivations, as in many parts

of the world, can take precedence over environmental concerns. As I have learned from conversations with Costa Rican farmers and EARTH staff, Costa Rica is a very green country but has still historically acted in favor of the economy of the country over the health of the environment (Personal Communication).

This study sought to determine how agricultural activities on campus may be impacting local stream water quality. This will be done using macroinvertebrate species as bioindicators; an accepted method of water quality assessment in Costa Rica. Also, potential sources of contamination will be evaluated and possible solutions will be proposed. The project explores the initial hypothesis that heavy rainfall events that occur frequently during the rainy season in Costa Rica help contribute to contamination and loss of macroinvertebrate species. Water quality data was evaluated on the basis of this proposal.

Method

A third-year class of Applied Ecology students evaluated the water quality in the Quebrada Henry stream which is a branch off of the river Rio Dos Novillos *(Figure 1)* and runs through the university campus to the Rio Parismina. For the study, a total of six sites were sampled. Each site was selected to evaluate the effect of nearby agricultural activities. For example, in sites 1 and 2 there is frequent plowing, seed and harvest short-term crop production such as yucca, malanga, ñampie, and maize, and long-term fruit tree plantations on the Academic farm. Site 3 is where the water treatment plant from the banana packing plant releases its wastewater into the stream, and site 4 is the location of two large concrete tanks of wastewater from agrochemical equipment washdown that utilizes photo remediation to degrade biodegradable chemicals. Site 5 and 6 are within the pastures of the Integrated Animal

Production Farm, and potential contamination comes from soil, sediment and animal wastes being washed into the stream during periods of high rain. The presence of animals near the stream is limited by the forested riparian buffer zones that is one of the innovative ways the campus reduces the impact of its agricultural activities on stream health and water quality. The study sites are marked in blue in *Figure* 2.

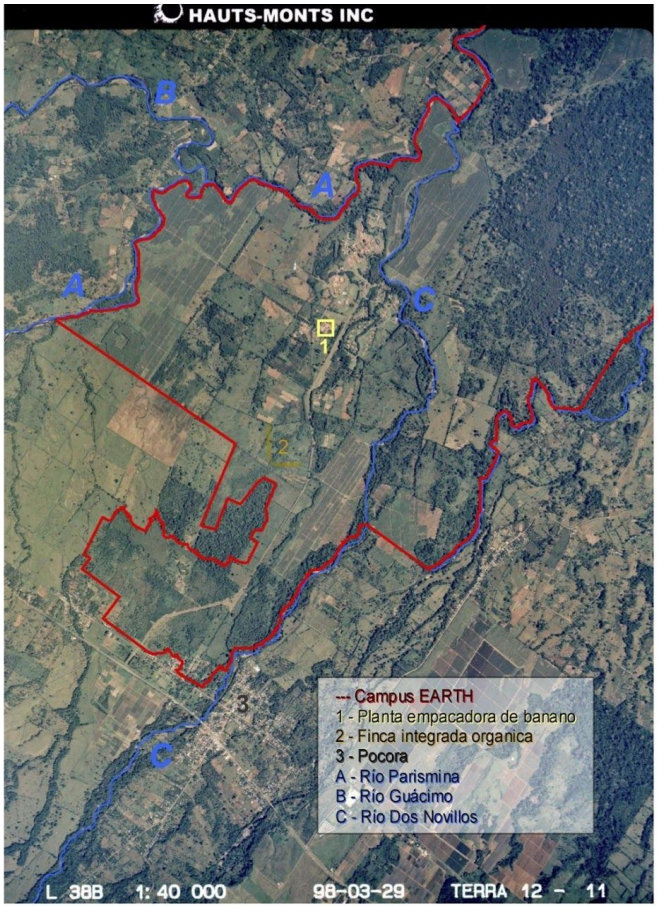

Figure 1. Satellite image of EARTH University (Barz, 2009, p. 3)

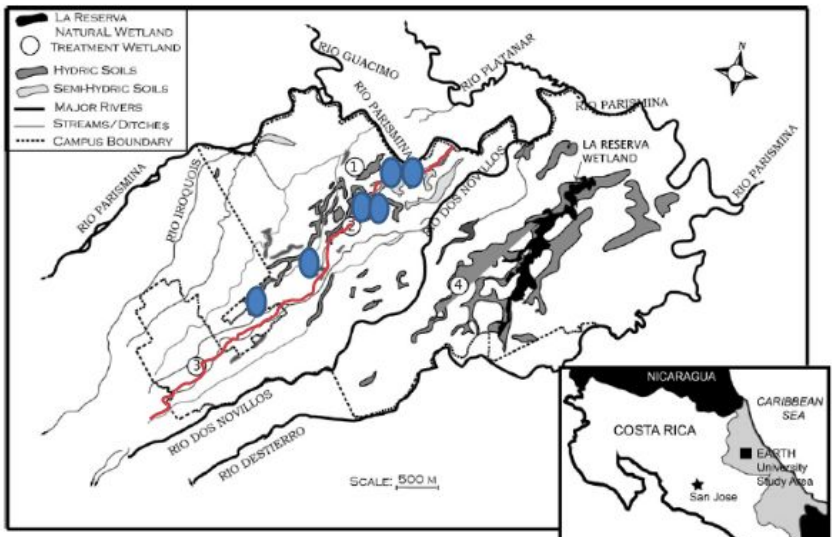

Figure 2. EARTH Hydrology ap with sampled sites indicated by blue ovals (Mitsch *et al.,* 2008).

Physicochemical analysis of the water was done by taking water samples from each site. Small, sterile bottles were used to collect water samples and taken to the soil and water lab on campus. EARTH students working on the project used a variety of analytical tools to measure the pH, water turbidity, biological oxygen demand, chemical oxygen demand, nitrates, phosphates, ammonia, and SST. These methods are valuable in determining water conditions, but on a much smaller time frame. This analysis presents the water conditions of a given day that can change drastically day by day. Days during drought, after heavy flooding, after the banana packing plant has released chemical buildup (a regular process they undergo), can all lead to very different water conditions. Macroinvertebrate analysis, however, can show a much more comprehensive image of water conditions (Springer, 2010). The species that inhabit the water change on a larger scale. Over time, repeated contamination can kill off species in a region

entirely. Therefore, changes to macroinvertebrate species better indicate that a significant problem exists.

Using bioindicators to determine water quality is a method used across several continents to conduct research, but in fact, has been specifically incorporated into Costa Rica legislation as a foundation of water quality standards. The Biological Monitoring Working Party modificado para Costa Rica, (BMWP'-CR) is a water quality index where the presence of different species of small macroinvertebrates found on the riverbed correspond to different qualities of water. Scores are assigned based on the sensitivity of species to water contaminants, where most sensitive species have the highest values (Springer, 2010). Thus, the higher the score of a given sample site, the higher the quality of water is present and the legally defined water quality standards in Costa Rica demonstrate the index values for water quality (Figure 3).

BMWP'-CR	NIVEL DE CALIDAD
>120	Aguas de calidad excelente
101-120	Aguas de calidad buena, no contaminadas o no alteradas de manera sensible
61-100	Aguas de calidad regular, contaminación moderada
36-60	Aguas de calidad mala, contaminadas
16-35	Aguas de calidad mala, muy contaminadas
<15	Aguas de calidad muy mala extremadamente contaminadas

Figure 3. BMWP'-CR water index (*Bioindicadores,* 2010)

To determine BMWP'-CR at a given site, it was necessary to collect macroinvertebrate samples. A group of twenty-five students and myself waded into the water with nets in hand,

split into groups of two or three. These nets were approximately two feet in width and three feet in length and were used in the water for a span of around ten minutes each. One person was required to hold a net inclined against the water flow while the remaining students stood directly upstream from the net and kicked up dirt, rocks, and sediment from the riverbed. Doing so brought various plant material, animals, and pollutants into the net. Afterward, tweezers were used to collect the macroinvertebrates from among the other river material and place them in sealed containers containing 70 percent alcohol (as a preservative) for each individual sample site. Samples were taken to the laboratory in EARTH for analysis. Stereoscopes were used to identify morphological characteristics of individual specimens to different families of macroinvertebrates present in each sample. Species were then tallied and organized in tables by site. For this project, data was analyzed both from current water conditions (as of July 2018) but also from March of this year, as to have both a dry season measurement (March) and a wet season measurement (July) incorporated in the study.

This research at EARTH was conducted with other EARTH students, specifically those in the third-year course, “Ecologia Aplicada” or Applied Ecology. The class focuses on teaching principles of ecology and environmental issues., The class embodies EARTH’s emphasis on experiential learning because it focuses on labs where analysis of local farms, water sources, etc takes place. The class evaluated the water quality of Quebrada Henry river and the potential impacts of agricultural activities on the EARTH campus. The data collected by the larger group was used for this research project.

In addition, a survey was conducted to assess the environmental views of EARTH students. More specifically, the survey was created so that the change in environmental views

could be measured. Both first-year EARTH students who had yet to experience much of EARTH's curriculum or see Costa Rica's environmental conditions firsthand, as well as third-year students who had had significant exposure, took the survey. For example, many of the third-year students who participated in the survey also completed the aforementioned Applied Ecology class where much of this project took place. A Google survey was created so that it could be easily distributed and accessible to interested students. The survey itself was quite short and asked (in English and in Spanish) about how students viewed the environment and environmental protection in their home countries and in Costa Rica (See Appendix A). In a sense, this survey was both a test of how public perceptions change with a deeper understanding of the complexities of environmental issues, but also how time at EARTH changes students perceptions and attitudes towards the environment over the course of several years of instruction.

Results and Discussion

In general, when water was tested downstream from the packing plant, a significant drop occurred at site 3 and 4 (*Figure 4* and *Figure 5*). In the case of the March analysis, water before the packing plant for sites 1 and 2 was measured as good quality and excellent quality respectively, while sites three and four received a zero, indicating extremely contaminated water ("extremademente contaminados" from *Figure 3*) in that area. Meanwhile, sites 5 and 6 had regular quality.

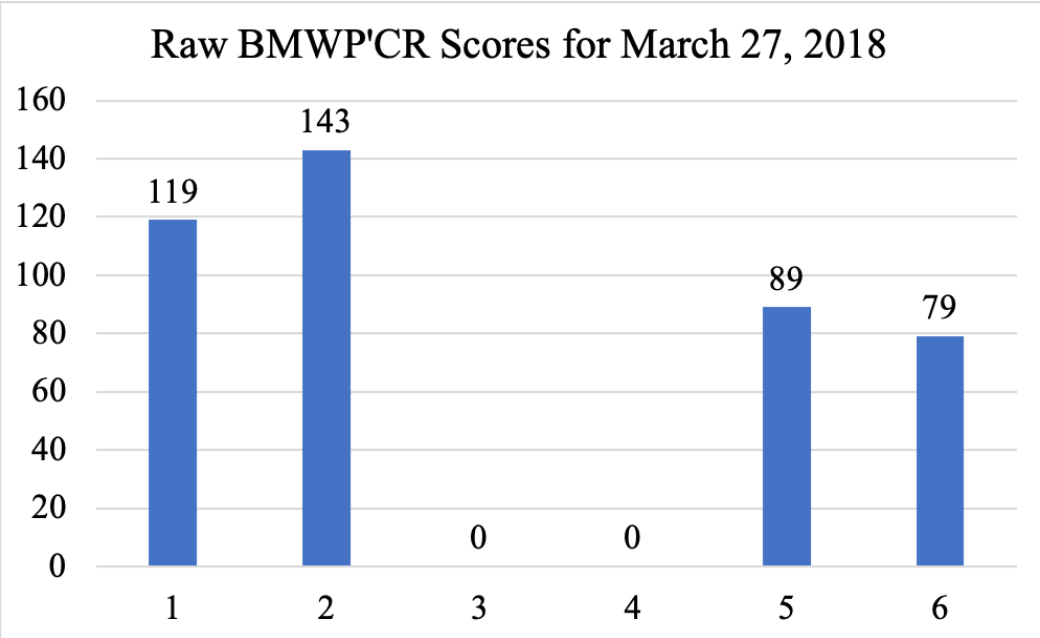

Figure 4. Results from March 27, 2018 Testing of Quebrada Henry, Campus Universidad EARTH

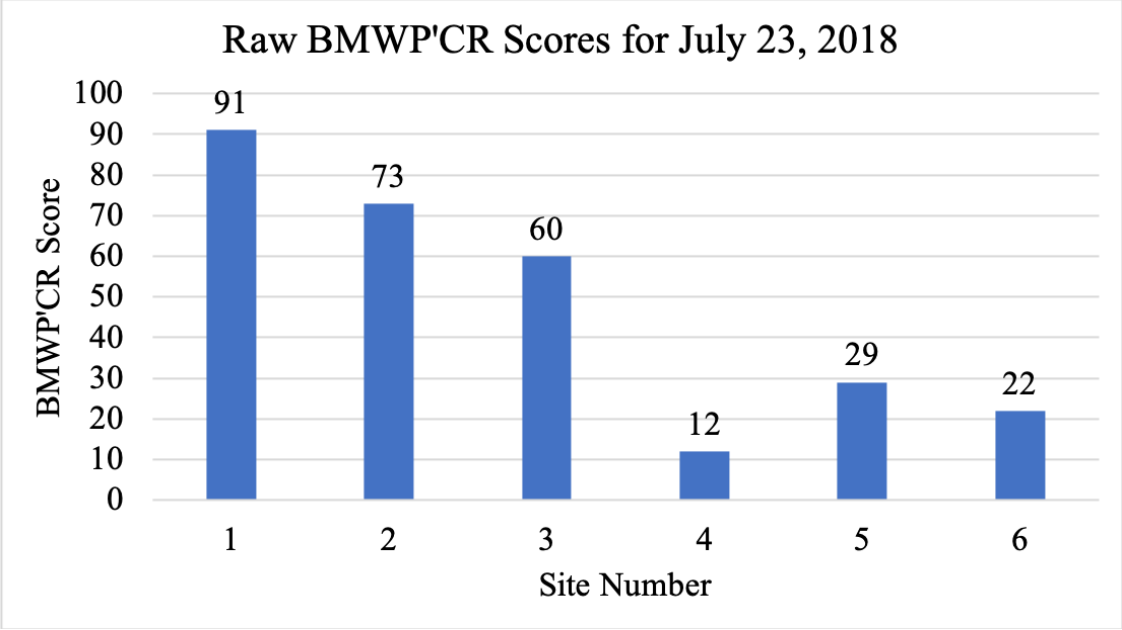

Figure 5. Results from July 23, 2018 Testing

Results from the test in July differ from the March results. Measured water quality was regular for sites 1, 2 and 3, and then dropped to extremely contaminated at site 4. Sites 5 and 6 were only slightly higher quality and were still rated as very contaminated.

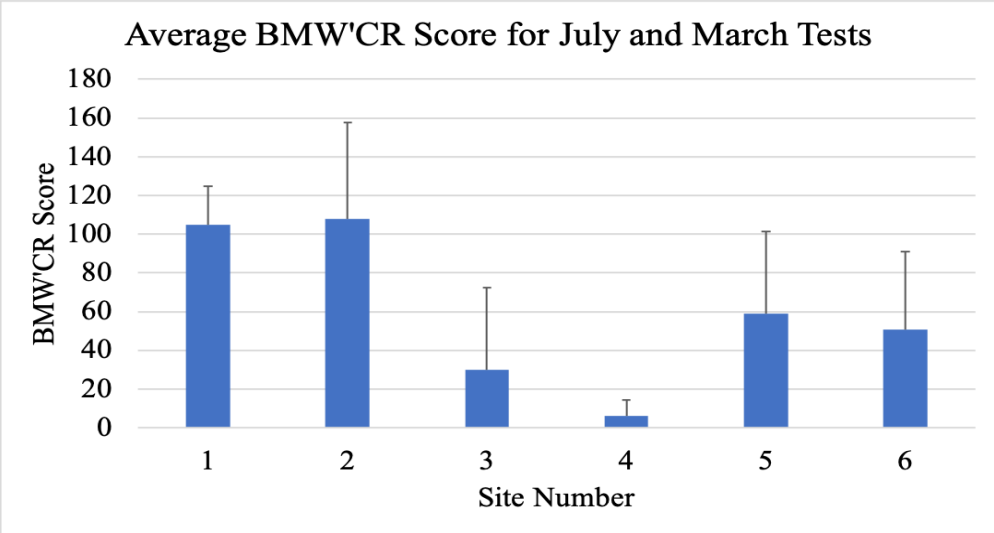

Figure 6. Average Scores for Both Tests with Standard Deviation Calculations

However, as suggested in *Figure 4* and in general in *Figure 6*, the water quality of streams can improve over time as macroinvertebrate populations recover and actively clean the water. Sites 5 and 6 in both graphs show that water quality gradually improved after the contamination zone, albeit still significantly lower quality than the first two sites near the academic farm. As previously learned from discussions at EARTH, the general stance of the banana producers is that since there is evidence to show that the chemicals that enter the water are dispersed as they flow down the river, then the producers are not directly responsible. The critical query that arises from this is what consideration should ultimately be made regarding

local water quality and ecosystems, based on information learned at EARTH in the past two months, it appears that that local contamination is still contamination. Although the river contamination may only occur on an expanse of river between 10 and 50 kilometers, EARTH and Costa Rica as a whole are places that act as role models for the future of sustainability and so they must both work diligently to remain as these role models. It is in their best interests as a sustainable institution to prevent contamination when possible, whether this is physical plastic or chemicals from agricultural practices. Chemical contamination can be avoided if EARTH invests in the proper technology and working practices to naturally disperse chemicals. For example, the technology could include more advanced water guards to prevent overflow of chemicals after heavy rainfall. Furthermore, there is also very clearly a problem with plastic pollution from the banana plantation. Each bunch of bananas that EARTH eventually exports is covered with a plastic bag for transporting from the field to farm. This plastic is eventually recycled, but yet a significant amount of plastic still ends up on EARTH property and in the local streams (Figure 7). EARTH needs to work to collect this pollution or prevent it from occurring in the first place to prevent a significant and visible amount of plastic from contaminating local streams, the ocean and other parts of the country. One potential solution could be to start a volunteer organization for EARTH students to help collect plastic and other physical pollutants in or near the campus streams.

Figure 7. Personal recording of plastic remainders caught on the river bank

The survey that was conducted of a group of EARTH students was done to gauge differences in environmental perceptions. Results, however, were mixed.

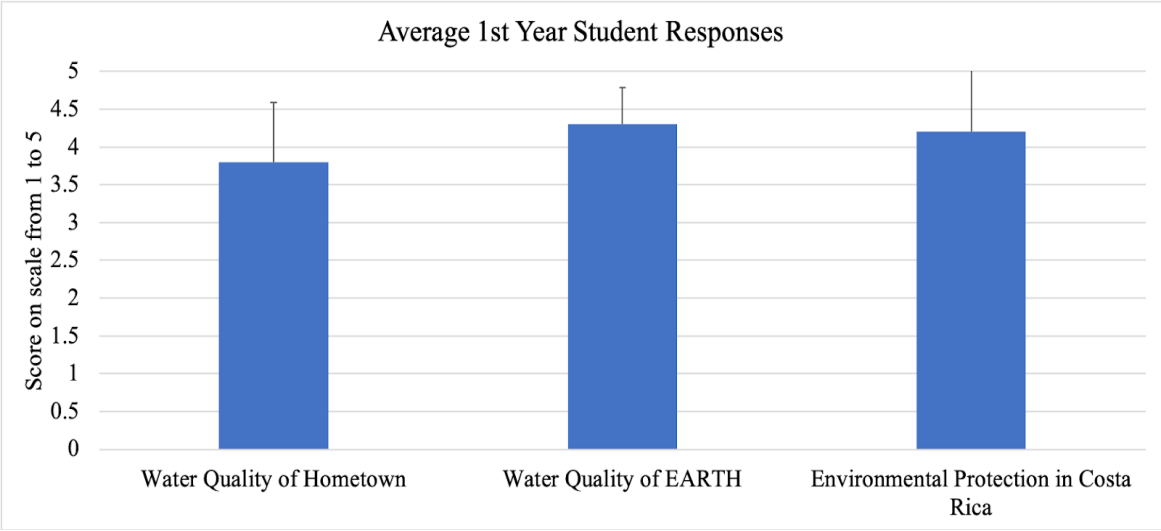

Figure 8. Average responses of 1st Year Students Survey

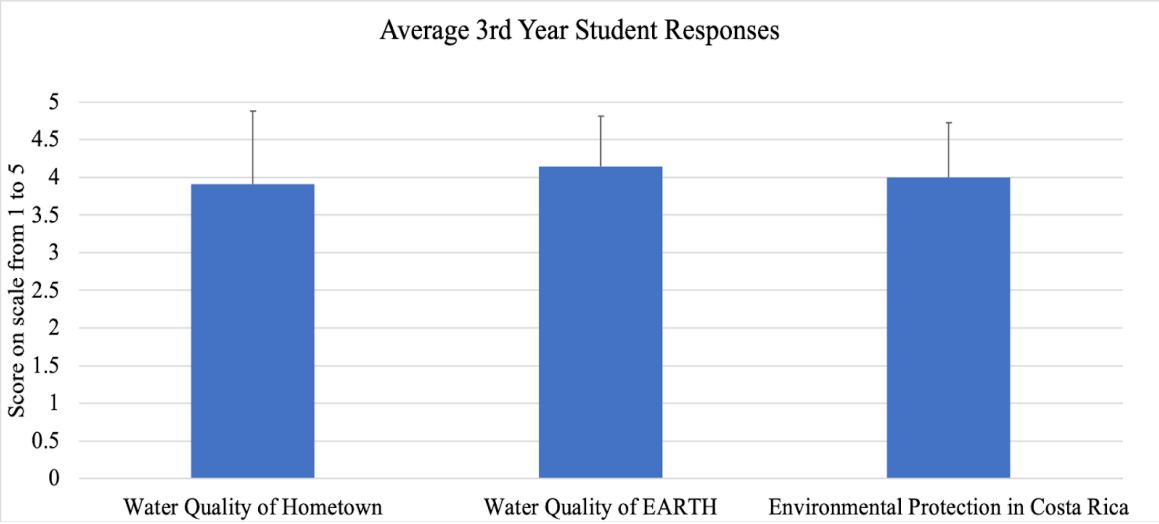

Figure 9. Average responses of 3rd Year Students Survey

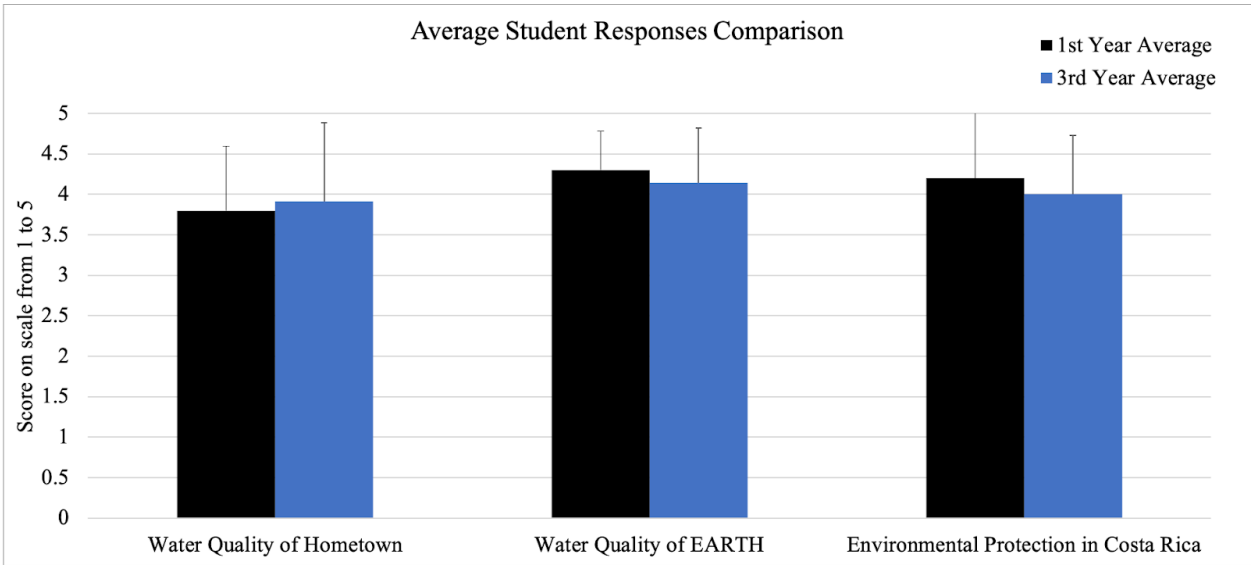

Figure 10. Average Responses Side by Side Comparison

Figure 8 and *Figure 9* showcase the responses by 1st and 3rd-year students respectively. They are displayed as averages of responses to the quantifiable survey questions. As shown by *Figure 10*, first-year students did, on average, rate environmental practices and protection in

Costa Rica higher than third-year students. However, standard deviation calculations represented by error bars in the figure show that this difference is not significant. P values for the three questions were generated as 0.5470, 0.6422 and 0.2469 respectively. For a significant difference to be present, values would need to be less than 0.05. Overall, students view Costa Rica's environmental practices favorably, often citing the strict legislation that the Costa Rican government has put in place. However, many also referenced the fact that this legislation is not always followed or enforced, which shows that many EARTH students are in fact aware of the issue of environmental perceptions not matching realities. It is important to note that while 35 third-year students responded to the survey in total, only 9 first-year students responded. A more in-depth survey, perhaps done in person, could yield more accurate and insightful data.

With respect to the issue of public perceptions and realities, businesses tend to be more economically motivated than environmentally motivated. This is a global trend but through discussion with Costa Rica scholars and residents, it was gathered that it is also a substantial trend in Costa Rica. Sustainability has become synonymous with quality in terms of advertising products, as consumers in places like Costa Rica prefer products that are not harming the planet. Businesses with truly good intentions need to be constantly mindful of how what they claim matches their actual practices. EARTH University is one such business that must be constantly diligent of the balance between intentions and impact.

For the water contamination data gathered, weather, and in particular rainfall, can be an influencing factor. Large rainfall events do effect physicochemical analysis more than bioindicator macroinvertebrate analysis such as the BMWP´CR index, but variation in rainfall conditions can influence what species are present. Initially, it was believed that high rainfall

events during the rainy season would lead to many macroinvertebrates washing downstream or digging deeper into the riverbed to prevent being washed downstream. However, this effect is not directly evident. The most contaminated sites overall (sites 3 and 4) were actually less contaminated during the rainy season, suggesting that high rainfall events may help clean the water in some instances. In general, long-term analysis with a variety of weather conditions would yield even more reliable and accurate results.

Evidence collected in this study supports the claim that the banana packing plant and/or other agricultural activities at EARTH are contaminating the local stream and are affecting the viability water life such as indicator macroinvertebrate species. It is imperative that institutions like EARTH continue to advocate and demonstrate sustainability and organic practices. In addition, EARTH has a large population of talented professors and students dedicated to sustainability. The best solutions for EARTH could come from discussions and open-mindedness between farm managers and EARTH faculty and students. Specific practices by the banana plantation and potentially other EARTH farms need to be addressed with relatively simple solutions like the aforementioned water guards. Sustainable practices will need to become the norm if humans wish to avoid severe global warming and global catastrophes but these practices will only be viable if they are enacted on their own merit. Sustainability only for the sake of business does not work. There must be a balance struck between protecting the planet and remaining financially stable for the sake of sustainability. Environmental protection must first and foremost be motivated by a core belief in preserving and protecting delicate and increasingly threatened natural systems.

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Appendix A

Below are the survey questions used to assess student's thoughts on the local environment and environmental protection. Most questions were followed by "Please justify your answer" so that both quantitative and qualitative data could be gathered.

Water Survey for EARTH Students

The purpose of this short survey is to see how EARTH students view water quality in EARTH, in Costa Rica and abroad. Thank you for taking the time to fill out this survey as it will provide me with valuable information for my research project on local water quality.

- Eli Arbogast, EARTH Intern from Ohio, USA.

What region of the world are you from? *

When will you graduate from EARTH? *

How would you rate the stream water quality of your hometown or city? *

How would you rate the stream water quality near EARTH? *

How would you rate environmental protection in general in Costa Rica *

Are there any further steps that Costa Rica needs to take to increase environmental protection? *

What is a reasonable solution to mitigate water contamination in Costa Rica? *