A comparative assessment of water quality between two tropical streams in primary and secondary rainforest systems

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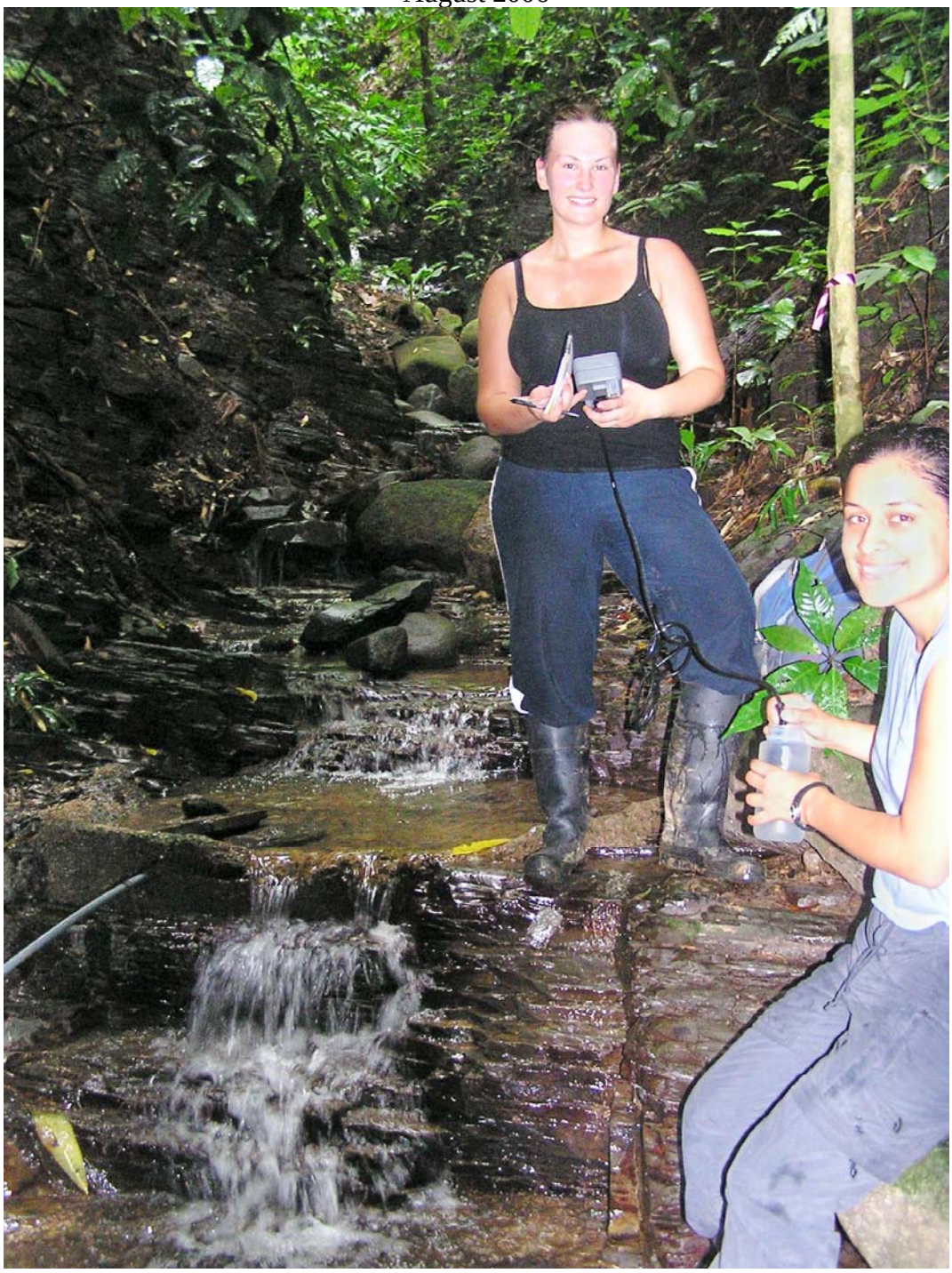

Abstract

Streams and rivers in the Dominical area, Costa Rica, are in constant use by native and domesticated animals, humans, and for land development, activities which threaten the balance of maintaining healthy stream systems. During June and July, 2006, physical properties, such as temperature, pH, and conductivity, as well as total coliforms (*E. coli* and fecal coliform) were measured and counted to determine the overall condition of the mouth of the Baru river and along two streams, one running through primary and another, through secondary rainforests. These data were collected as part of a longer term study examining the comparison among physical and biological parameters in a primary forest, at Hacienda Baru National Widlife Refuge and a secondary aquatic system, on the Firestone Center for Restoration Ecology (FCRE) property. There was also a restoration component to this study in comparing differences between a primary system and that of a secondary forest that is in the process of being restored back to its natural state. On average, surface temperatures in the stream of the secondary forest was greater than in the primary forest stream, however bacteria counts remained similar in both ecosystems. On the Firestone property, bacteria and surface temperature increased at sites sampled at the stream head (spring) downstream to sites where the stream joined with the Baru River. This trend was similar at Hacienda Baru, although not as strong, with some of the highest bacteria counts at the primary stream head. Bacteria counts increased during rain events in the stream running through the Firestone property. These data will contribute baseline water quality information during the months of June and July, mid rainy season and will become part of the longer term comparison among seasons and years.

Introduction

Streams and rivers in the southwest region of Costa Rica provide a habitat rich in nutrients and food for local wildlife. The Hacienda Baru stream as well as the streams on the Firestone Center for Restoration Ecology (FCRE) property feed into the Baru River. This river becomes an estuary in the town of Dominical. The Dominical population uses the Baru River for fishing. Estuaries are unique ecosystems that provide ideal environments for many animals. This tropical estuary is home to animals such as caiman and egrets. Estuaries are also used by wildlife as stopovers or places to raise their young (Bolsa Chica). The streams of Hacienda Baru are used by wildlife and some are used for drinking water. Wildlife such as frogs use the streams of FCRE as places to lay their eggs (Heller et al, pg. 737). Aside from the ecological importance of streams and rivers, maintaining their beauty is important for the ecotourism that is essential to the Costa Rican economy since it has become the main source of income (Daling, Tjabel pg. 38).

This study analyzes the effects of regeneration on the health of streams and rivers by testing levels of bacteria from streams in both primary and secondary growth as they feed into the Baru River. Both properties studied have a history of cattle farming, however Hacienda Baru has primary forest and has been in the process of reforestation for 27 years whereas the FCRE started roughly 15 years ago. The fact that they are in different stages of restoration can help to predict how restoration affects the health of streams and rivers. Health is measured by looking at the differences bacteria counts to determine the animal use of the habitats. Temperature is a factor that can greatly affect

the levels of bacteria in water: the hotter the water temperature, the more bacteria there should be. Hacienda Baru is believed to have a generally lower water temperature due to the canopy cover over the sites on the stream. This cover does not allow sunlight to warm the shallow stream water. *Escherichia coli* (E. coli) is always present in the intestines of warm-blooded animals and therefore is used as an indicator of fecal contamination by animals and consequently indicates the use of stream habitat by animals. Since Hacienda Baru has been in restoration for a longer period of time it has a higher abundance of animals and therefore more bacteria is expected to be in the streams in comparison to FCRE. This study will also provide insight into the change of abundance of bacteria and changes in temperature as the water starts from the stream head at both properties and flows into the Baru River. The Dominical samples are also used as indicators of completely disturbed areas and its effect on temperature as well as bacteria counts.

Methods and Materials

The research was conducted in 2006 between the Dry and Wet season of Costa Rica, from June 13 to July 21. There were two properties tested, the FCRE and Hacienda Baru. At each of these two properties, six sites were tested.

Sites:

At FCRE the sites at the top are the Terciopelo Stream Head and North Creek Falls, which feed into the Cacao River on the FCRE property. The Terciopelo Stream Head is where the water starts and flws to the Terciopelo Stream Bridge that also feeds into the Cacao River. At the Cacao River there are three sites tested: the Cacao Waterfall, at the middle of the river where two smaller streams feed into the Cacao River and at the Baru road bridge at the property border. The Cacao River passes through another property and goes to the Baru River.

The Hacienda Baru also starts from the Primary Stream Head and also goes down to the Baru Road and eventually feeds into the Baru River further down from the FCRE property. The other sites include above the camp where the Hacienda Baru campers acquire their water and down stream; Below Camp and Primary Ceibo. The second to last site sampled is on the border of Hacienda Baru and private property; it also represents the border of Primary and Secondary forest. The last site is taken under the Baru Bridge, which is under a road and is composed of entirely secondary forest. The sampling was done from the top to the bottom on both properties and therefore stepping in the water was minimized to reduce the effect of stirring it up. In addition to these sites, The Dominical Bridge and the Baru river mouth were also tested. The sites were tested during different weather patterns to ensure that the results were an accurate portrayal of the stream conditions during those months.

Site Changes:

There were a few problems encountered while sampling including some site changes. On the Hacienda Baru property the Primary Stream Head was dry for four out of the six times that the Hacienda Baru property was sampled and therefore those times the soil was disturbed. The Above Camp site was changed on the 27th of June, 2006 to 200 meters above the site that had been sampled on the 13th and 20th of June. The Below

camp site was also changed on the 13th of July to about 100 meters above the site that had been sampled the previous times.

On the Firestone property two sites were changed on the 12th of July 2006. The Mid-Cacao site was changed to around 200 meters further down the river from the original site, which was closer to the waterfall. The site was changed to include the water feeding into the Cacao River from two smaller streams. The Barn Bridge name and location were changed to Road Bridge so samples would be taken under the Baru road bridge where the coverts are.

Samples and Procedure:

To collect bacteria samples, 250mL Nalgene bottles were autoclaved in a pressure cooker before visiting the properties. At each site the bottles were opened and closed under water to prevent bacteria from the air to contaminate the samples. The EPA procedure suggests refrigerating the samples an hour after collection if they cannot be filtered, however since the samples were at remote locations they could not be refrigerated and sometimes were not filtered for up to 4 hours later.

The samples were filtered following the EPA Method 1604: Total Coliforms and *Escherichia coli* in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium). The samples were filtered using 1mL and 5mL sterile pipettes and afterwards some were adjusted to 0.5mL because of the overwhelming amount of colonies when using a larger amount. The filters were placed on agar plates to grow for 24 hours in an incubator set at 35°C. After 24 hours the plates were counted under white light for the E. Coli colonies and under UV light to count the total coliform.

Results

The Hacienda Baru property did not have higher E. coli, coliform, or total coliforms bacteria colonies than the Firestone Center for Restoration Ecology property (t-test, p-values = 0.192, 0.349, 0.256) as seen in Figures 1 and 2. The temperature at the Hacienda Baru property was lower than the temperature at the FCRE site (t-test, p-value=0.043, Figures 3 and 4). There is no correlation between an increase in temperature and an increase in bacteria colonies at Hacienda Baru (Figure 5). At the FCRE property bacteria colonies do not increase as temperature increases (Figure 6). Figure 7 shows that as the hours after a rain event increase the number of bacteria colonies does not significantly decrease on the Hacienda Baru property. On the FCRE property, figure 8 shows that bacteria colonies for coliform and total coliforms increase during rain in comparison to taking samples during dry events. However, there is generally no correlation between weather and number of colonies grown. Bacteria abundance does not change from the stream head of both properties unto the Dominical Bridge and River mouth (Figures 9 and 10).

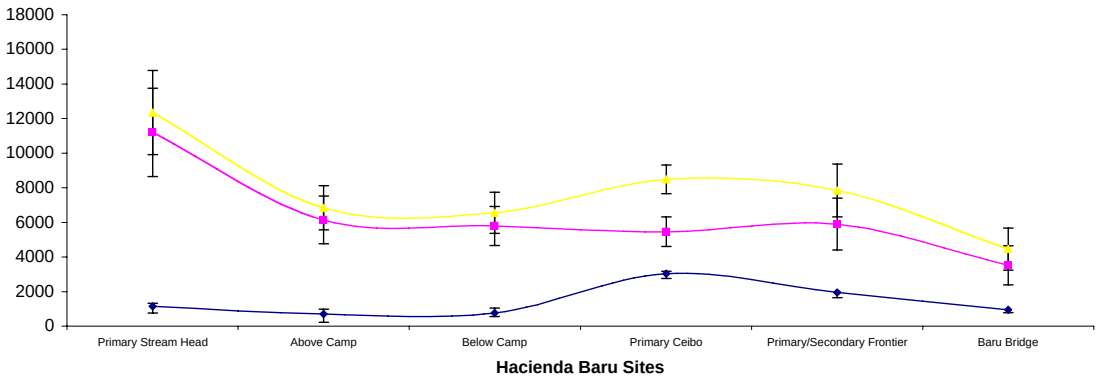

Figure 1. Bacteria colonies per 100mL at each site on the Hacienda Baru property (diamonds= E. coli, squares= other coliform, triangles= Total Coliform)

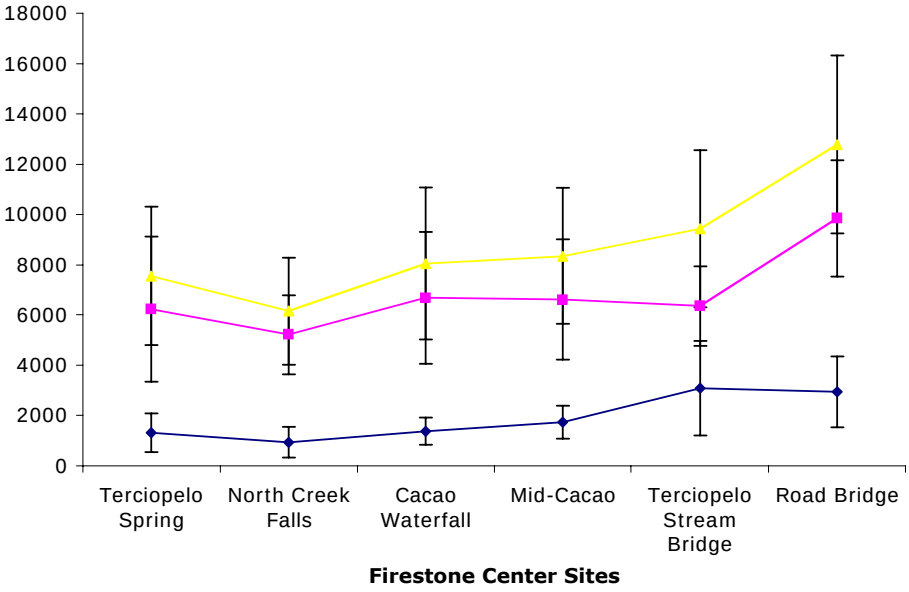

Figure 2. Bacteria colonies per 100mL at each site on the FCRE property (diamonds= E. coli, squares= other coliform, triangles= Total Coliform)

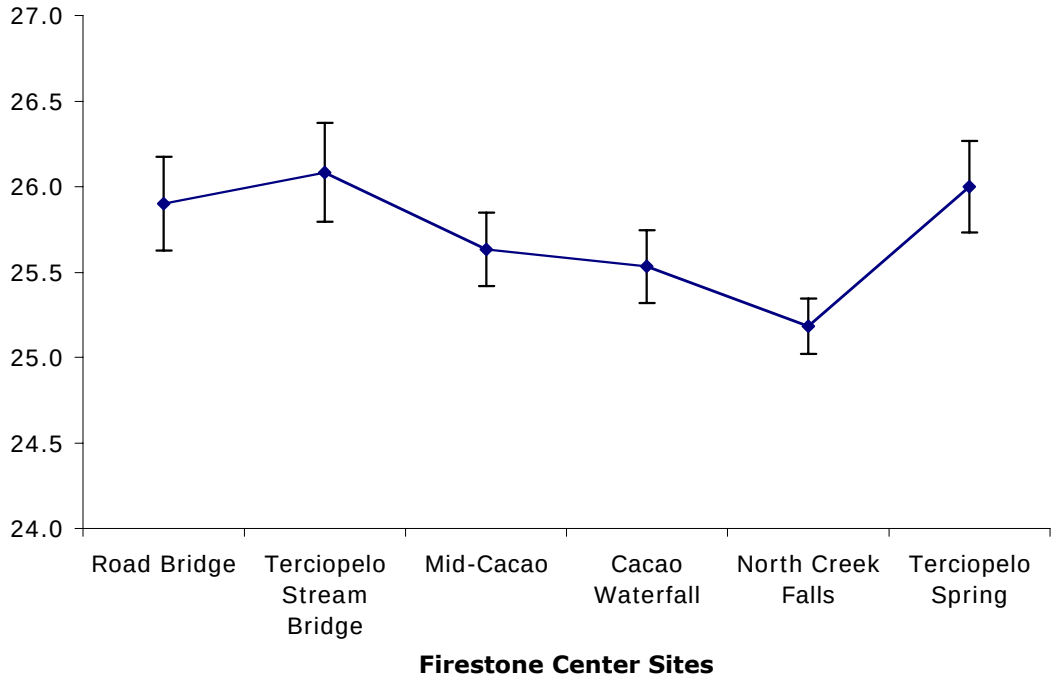

Figure 3. The average temperature at the six sites of the FCRE.

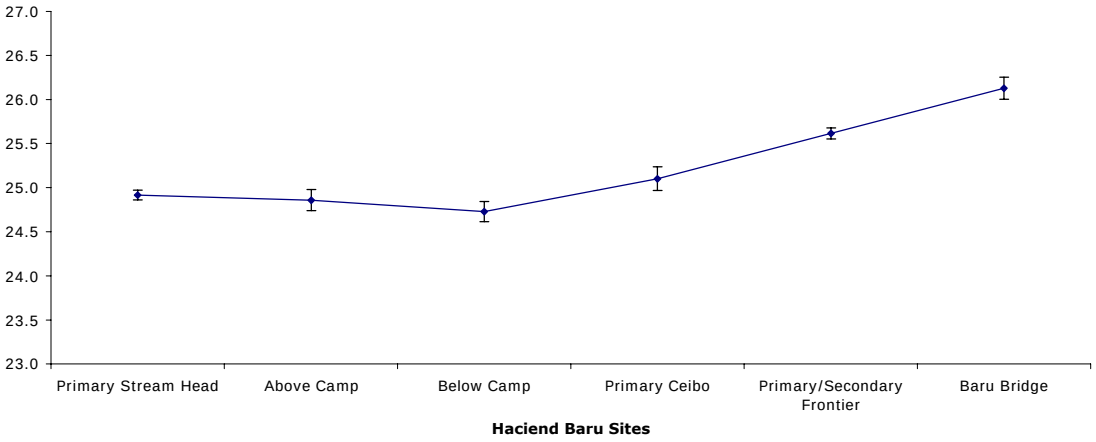

Figure 4. The mean temperature of each site at Hacienda Baru.

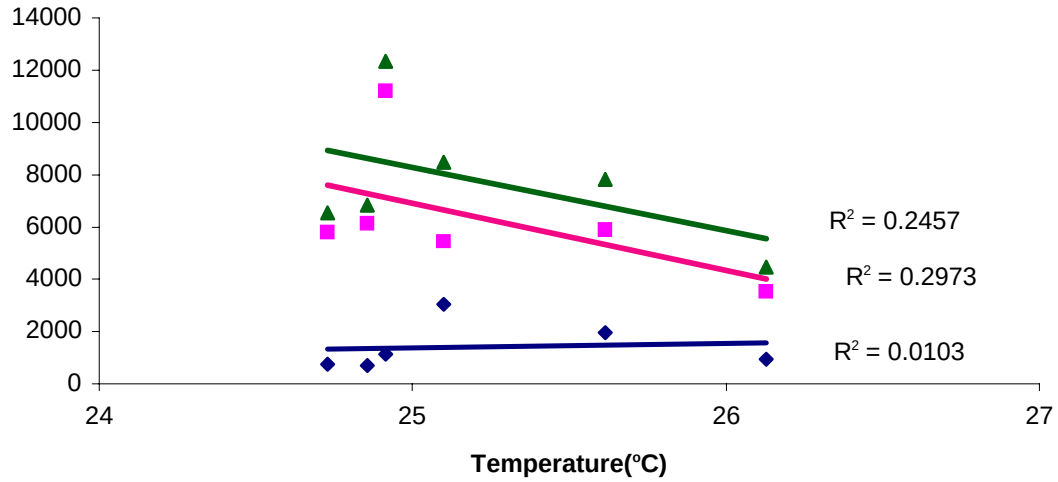

Figure 5. The number of colonies of bacteria as temperature increases at the Hacienda Baru property (diamonds= E. Coli, squares=coliform, triangles=total coliforms).

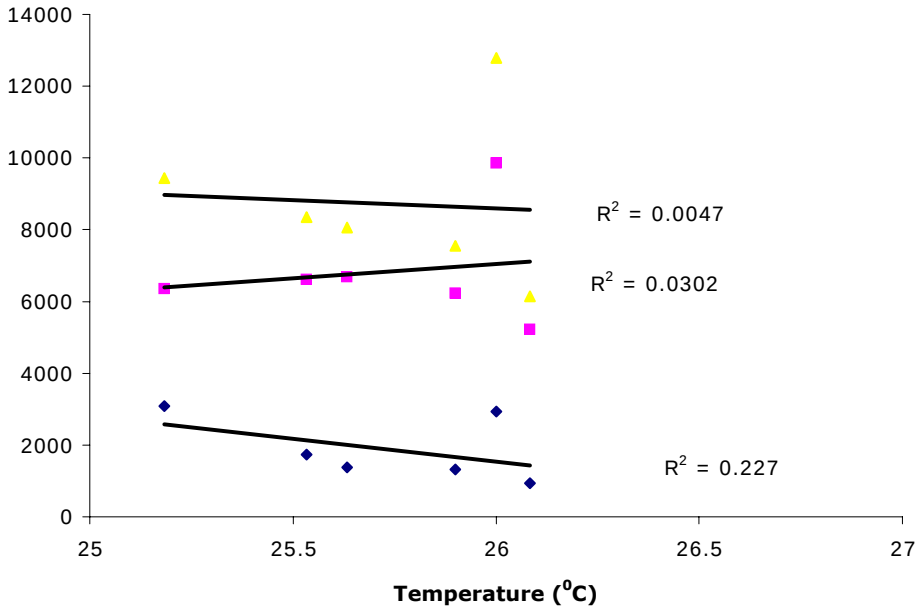

Figure 6. The number of colonies of bacteria as temperature increases at the FCRE property (diamonds= E. Coli, squares=coliform, triangles=total coliforms).

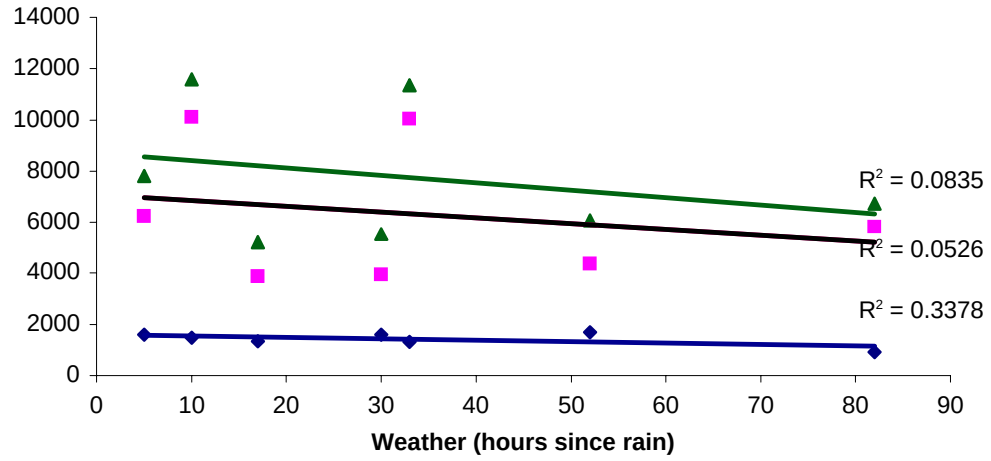

Figure 7. Bacteria colonies as the number of hours after a rain event increases at the Hacienda Baru property (diamonds=E. coli, squares=coliform, triangles=total coliforms).

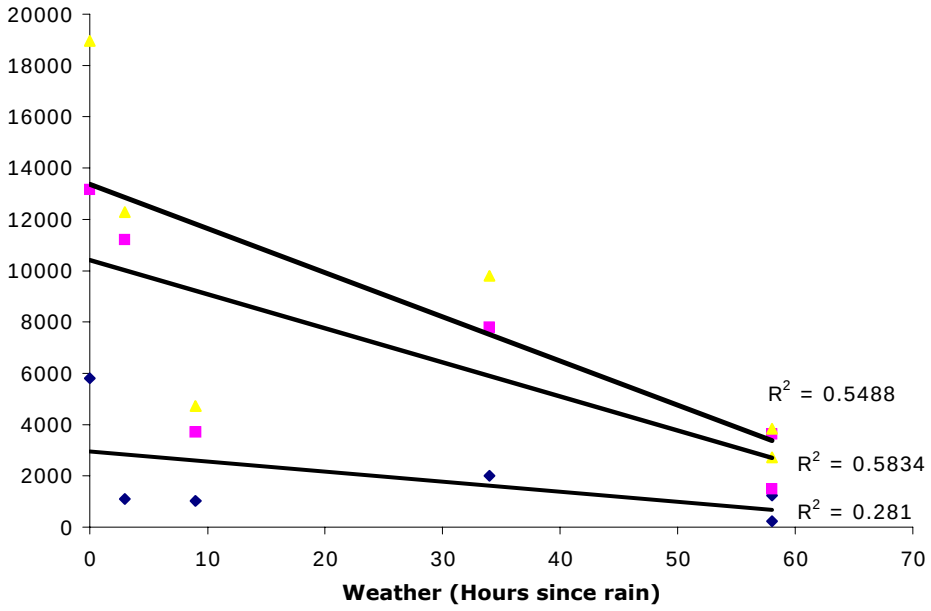

Figure 8. Bacteria colonies as the number of hours after a rain event increases at the FCRE property (diamonds=E. coli, squares=coliform, triangles=total coliforms).

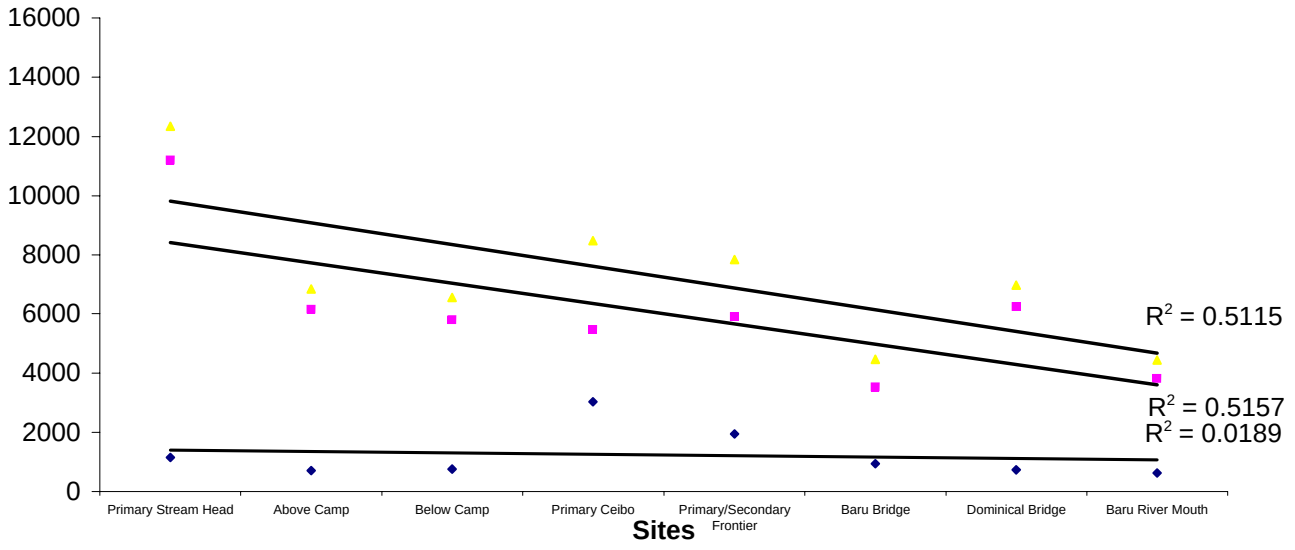

Figure 9. Bacteria abundance from the stream head on the Hacienda Baru property to the river mouth in Dominical (diamonds=E. coli, squares=coliform, triangles=total coliforms).

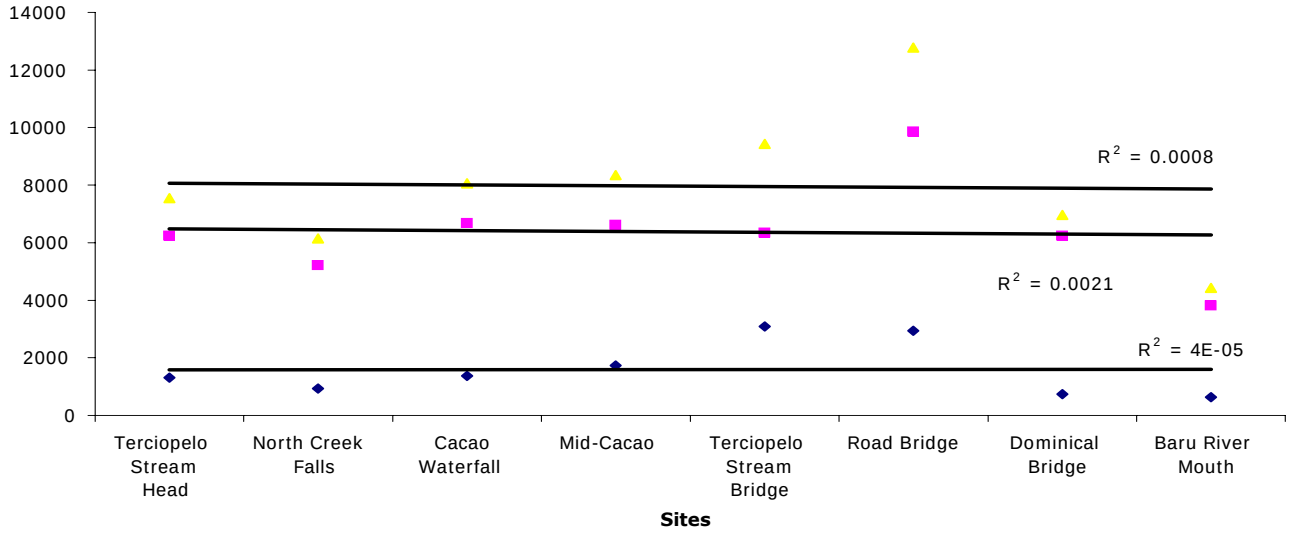

Figure 10. Bacteria abundance from the stream head on the FCRE property to the Dominical River Mouth (diamonds=E. coli, squares=coliform, triangles=total coliforms).

Discussions

Hacienda Baru did not have a higher amount of bacteria than the FCRE as had been anticipated. The hypothesis that the primary forest has more mammals contaminating the stream waters because of their use of the habitat and that this would cause it to have a higher bacteria count than the secondary forest was wrong. The

significantly higher temperature in FCRE should have allowed a higher bacteria count since bacteria thrive in warmer temperatures. Although the FCRE had higher water temperatures, the colonies of bacteria were equal to the Hacienda Baru property showing that Hacienda Baru must have another source of bacteria input that outweighs the temperature difference. Once again this could be explained by extensive animal use of the streams in comparison to FCRE. Other factors could also affect bacteria colonies at Hacienda Baru such as coliform that naturally occurs in soil, vegetation, and water. The study also shows that sites with higher temperatures did not necessarily have higher numbers of bacteria colonies. The primary stream head on Hacienda Baru had the largest number of total coliforms and had one of the coldest temperatures. The stream head is completely surrounded with loose black soil, which is said to be the richest soil and can consequently skew the data because of naturally occurring bacteria in the richer soil and vegetation. There is also no correlation between temperature and bacteria colonies on the FCRE property. Higher temperatures do not yield higher bacteria colonies primarily because the temperatures were not extremely variable within the FCRE sites. At Hacienda Baru the temperatures were also not variable within the property and therefore did not affect the yield of bacteria colonies. The Hacienda Baru site was not sampled during a rain event therefore it cannot be compared to the during rain samples of FCRE. The hours after rain are also rough estimates and the amount of rain is variable, making it difficult to find a correlation between weather and its effect on bacteria in streams. Within the FCRE property there were more bacteria colonies during a heavy rain event possibly due to runoff from the soil. However for the other samples taken, the hours after rain were estimates and the amount it rained was variable. The dominical bridge and the river mouth had similar amounts of bacteria in comparison to both the Hacienda Baru and FCRE properties which is a good indicator that the river is not being over contaminated by the cattle farms or by the people of Dominical.

Future studies should include stream sites at completely disturbed areas to get an overall picture of the streams feeding into the Baru River that affect the estuary. These sites would also be good comparisons to the secondary growth forest. A long-term study of this is necessary in order to be able to see whether conditions will change as time passes. It would also be helpful to have a comparison of healthy river mouths and the disturbed river mouth of dominical. A long term study would also be useful to acquire more samples and get a more accurate portrayal of the stream and river chemistry of both Hacienda Baru and the Firestone Center for Restoration Ecology.

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Bolsa Chica

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