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Title

Water Quality Analysis and Policy Recomendation for the Guacimal Watershed

Introduction

Urban development and watershed management of riparian habitats have been an ongoing issue in the Guacimal watershed. Located in NW Costa Rica the Gaucimal and San Luis rivers are on the pacific slope of the Tilaran region flowing into the Nicoya Gulf (Quesada-Román, 2022). The Gaucimal is a large system with three main tributaries: the San Luis, Veracruz, and Acapulco rivers (Quesada-Román, 2022) (Figure 1). This study focuses on the Guacimal and San Luis rivers' water quality based on biological and chemical surveys of the rivers. Subsequently, this paper will outline policy recommendations to address water quality related to the urban development and watershed management of riparian habitats in the montane region of Monteverde and downstream areas.

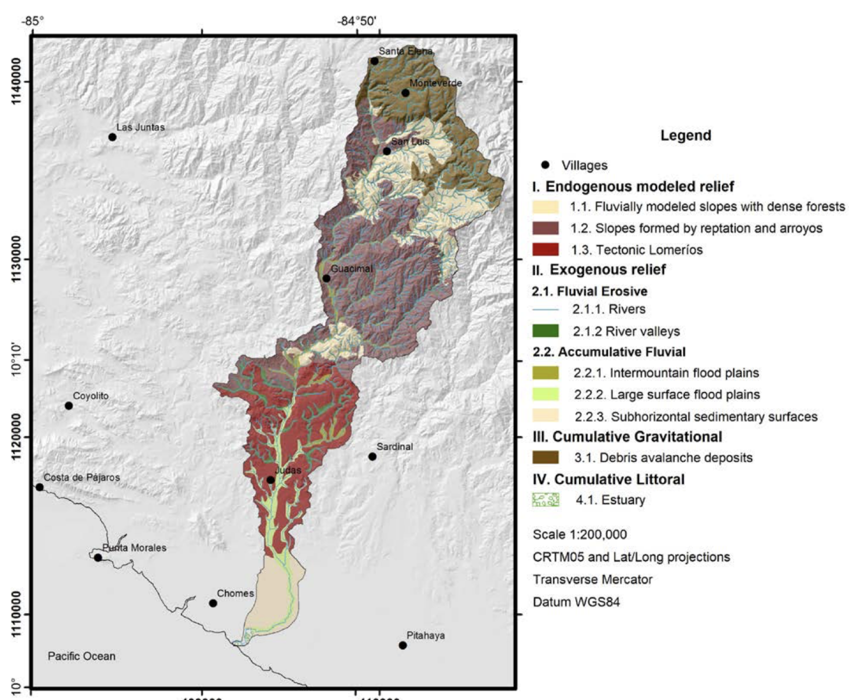

Figure 1. Guacimal Watershed

Water is a vital resource for the ecosystem and the community in Monteverde, where water is sourced from springs and rivers (Rhodes et al., 2004). The consequences of upstream activities are shown in water quality in downstream areas. The Gaucimal river has the propensity to be moderately contaminated as it receives grey water from Monteverde's urban development. On the other hand, the San Luis river tends to be more pristine as the riparian area has less development. Humans have been altering the environment in Monteverde and downstream riparian areas due to changing land use practices resulting in degraded water quality (Burnett, 2009). Land use change in the Monteverde region is characterized by agricultural development, deforestation, cattle, and coffee production. These changes have had effects on the downstream riparian areas. Agriculture impacts the environment through decreased riparian vegetation, increased sediment, and chemical and nutrient runoff (Burnett, 2009). Cattle pasture and coffee farms are two main agricultural activities in the Monteverde region. Burnett notes "Cattle pastures impact aquatic ecosystems through erosion, accounting for 84% of Costa Rica's erosion" (2009). The runoff from cattle land erosion goes into streams, typically causing stream health issues like high nutrient loading. The effects of poor water health should be seen by biological indicators.

The focus of this water quality analysis is based on macroinvertebrates found in the two rivers. Macroinvertebrate surveying in rivers is a useful method to understand long-term water quality because they are affected by intermittent pollution that may not be present at the time of sampling (Burnett, 2009). They also represent water quality degradation occurring at local or regional scales (Herman & Nejadhashemi, 2015). In the case of San Luis and Guacimal, this means how upstream influences affect the downstream water quality. For this study, we will be measuring the Biological Monitoring Working Party (BMWP) as an index of water quality.

This policy paper addresses the water quality in the Guacimal watershed, with a focus on how land uses change and urban development have effects on water quality. Based on results from a biological survey in the Guacimal and San Luis rivers, it was found that the rivers are both moderately contaminated. With information gained from the field and outside research, this paper articulates three policy recommendations to improve water quality in the watershed to protect the environment and all living organisms as well as keep in mind future conditions. Specifically, I recommend a greywater treatment plant, terracing of agricultural and pasture land, and stabilizing riverbanks with vegetation cover. Water quality must be managed in the Gaucimal watershed as it goes downstream, as many riparian players are dependent on safe clean water.

Methods

To measure water quality, students traveled down to the lower San Luis valley to look at the Guacimals and San Luis Rivers, at approximately 10.218045 N, -84.849253 W. The team ran physical, chemical, and biological surveys at each river. The physical surveys took into account: human activity, types of vegetation, the types of shores, types of alterations, the percent canopy cover, the types of soil - texture & color, watercolor, water odor, water appearance, inorganic material in the water, and organic matter in the water. Each criterion was measured and noted on a physical survey booklet. The chemical survey had students measure temperature, pH, conductivity, and turbidity. This was also written down for further study. Finally, the biological survey was a macroinvertebrate survey. To do this four students were given ten minutes per river to collect macroinvertebrates that were found on rocks. The students were instructed to pick out all the macroinvertebrates they could find at one river at a time and collect them into a colander individually. After ten minutes were up students came back together and combined their macroinvertebrates into a jar that was labeled with the river they were found in (Figure 2).

Figure 2. Study Group Examinging Macroinvertabrates at Guacimal River

To understand the water quality of the Guacimal and San Luis rivers students brought the macroinvertebrates into the lab to identify their family to get an estimate of the water quality. To go into more detail, the macroinvertebrates were examined under microscopes to account for their family. references like the number of tails, limbs, worm species, head shape, and body shape were all taken into account to determine what the family was. Each family is given a number on a scale of 0-10 based on the quality of water they need to survive. For context, 10 is the highest indicator or the highest quality water, the opposite holds for a family that scores 0 (Springer, 2010). After all of the families were accounted for, the scores of each family (not individuals) were added together. This number is the biological monitoring working party (BMWP) for water quality. The BMWP is an index specifically designed for using macroinvertebrates to determine water quality in Costa Rica (Burnett, 2009). The index is based on the presence of the families found and their assigned tolerance values (Springer, 2010). The range is from less than 15 which represents extremely contaminated water up to over 150 which means excellent water quality. BMWP index is also an estimation of contamination levels.

Results

The BMWP aquired from macroinvertebrate collection as well chemical surveys from the San Luis and Gaucimal rivers suggests that there is a slight difference in water quality. This paper will focus mainly on results from the macroinvertebrate collection of the two rivers.

The San Luis river had 11 families of macroinvertebrates, the average water quality among the families averages 6.45 on a scale of one to ten. Added up together the San Luis river's macroinvertebrate BMWP measured 71 (Table 1), which indicates moderate contamination (Springer, 2010). Three families had scores of 8 (Leptophlebiidae, Glossosomatidae, and Leptoceridae), while three families had scores of 5 (Elmidae, Helicopsychidae, and Baetidae). I found that San Luis had a more even distribution of scores from macroinvertebrates indexes.

The Guacimal river had 14 families of macroinvertebrates, the average water quality score was 5.5. The BMWP of the Guacimal river was 77 (Table 1), which also indicated moderate contamination (Springer, 2010). Species were scored as high as 10 (Perlidae), and as low as 1 (Oligochaeta). The most common family found in the Guacimal river was the Leptophlebiidae. The distribution of scores from macroinvertebrate families was not as even as those in the San Luis river.

Moving on, the chemical survey measured several factors, though the only valid results were pH and temperature. The temperature of the San Luis river measured 73º F, while the temperature of the Guacimal river was 77.7º F (Table 1). The pH of the San Luis river registered as 8.43, and the Guacimal river pH was 8.52 (Table 1).

	San Luis River	Guacimal River
BMWP	71	77
pH	8.43	8.52
Temp	73º F	77.7º F
Water Color	Clear	Clear
Canopy Cover	33%	0%
Most prevalient Human activity	Industry	Industry

Table 1. Results from Biological, Chemical, and Physical Surveys

Discussion

Results indicate that the Guacimal river is in better condition than the San Luis river due to the Gucimal receiving a 77 BMWP score, and the San Luis river receiving a 71 BMWP score. Though both of these scores indicate moderate contamination and their difference is negligible. There were low-tolerant macroinvertebrates at both rivers, the highest being the Perilidae which was found once at the Guacimal. Overall there was little variation in water quality between the two rivers.

According to the results of BMWP the Guacimal river had better water quality. Though I think there are clear biases in our results and methodology that limited us to get a full understanding of the two rivers. In terms of the biological survey, students should have conducted it multiple times in different locations along the river to get more conclusive results. Additionally, students conducted the biological survey in the Guacimal river slightly downstream from where the two streams met, therefore results aren't fully representative of the actual water quality of the river.

A study done by Anna Burrnett in streams in San Luis measured indicators of water quality, including the BMWP of rivers whose riparian areas were indicative of different land uses- like coffee farms, pasture, and forest land (Burnett, 2009). Additionally, her study was more in-depth and measured more markers like nitrogen, phosphorus, and dissolved oxygen. I believe these measures could be beneficial in understanding the water quality of riparian areas due to urban development and watershed management. Dissolved oxygen is especially important because it affects the diversity and abundance of aquatic invertebrates, it is one of the more important abiotic factors influencing water quality (Burnett, 2009).

Policy Recommendations

Water quality affects not only our environment but also communities of people that rely on its resources. For instance, downstream riparian areas in the Guacimal watershed drink the water that we release into our waterways, so all of our grey water that is sent downstream is included in that. Based on what we learned about the water quality in the Guacimal and San Luis Rivers I propose a set of policy recommendations be enacted to improve the effects of urban development and watershed management in riparian habitats to have healthier rivers and streams in the Guacimal watershed.

To improve water quality in the Guacimal watershed, a water treatment center should be implemented so the water flowing from Monteverde, San Luis, and Santa Elena is treated before going downstream. The water treatment plant should be located in San Luis in the proximity where the Guacimal and San Luis rivers join. This way grey water from upstream urban areas doesn't contaminate downstream riparian areas. This is important to the human and ecological health of the Guacimal Watershed. Grey water has negative effects on overall health as harsh chemicals can be found. Urban areas like Santa Elena are prone to release a lot of harmful grey water due to the high load of tourists and development. When grey water is released into the Guacimal watershed its nutrients become pollutants in the waterways (Grey Water Action, N.A.). This could create unhealthy conditions for marine organisms and humans who consume the water.

Terracing agricultural and pasture land is another advantage to improving water quality in downstream riparian areas. As noted before, erosion from pasture land makes up 84% of erosion in Costa Rica (Burnett, 2009). The erosion that is runoff into the Guacimal watershed contains nutrients like nitrogen and phosphorus, as well as bacteria from decaying organic matter. These contaminants are very harmful to the environment and can cause eutrophic conditions. Terraces can help to mitigate erosion and the effects of erosion from pasture and agricultural land. Terracing can limit solid erosion by slowing and reducing the energy of runoff (Al-Kaisi, Hanna, 2001). This is also an important practice, especially in sloping elevation, which classifies the montane region in and around Monteverde. A terracing system is an effective option in considering the slowing down of erosion into waterways as well as letting water seep into the ground (Al-Kaisi, Hanna, 2001). To reap the benefits of terracing, policy should suggest pasture and agricultural land, especially in high elevations, should implement terraces into their land so high amounts of runoff from erosion won't go into waterways.

Finally, the montane region around and in Monteverde should work on stabilizing river banks to limit erosion entering waterways from the banks themselves. Naturally, streams erode but human impacts have accelerated this natural process (Abernethy & Ruterfurd, 1999). Sedimentation is a problem in streams and affects the water quality due to high nutrient loading and high turbidity, therefore sources of bank erosion should be mitigated. Stabilizing banks in riparian areas entails enhancing lateral channel stability by vegetation in riparian zones (Abernethy & Ruterfurd, 1999). A system for doing this is using native plants- shrubs, trees, macrophytes, and grasses- around river banks. Different types of vegetation affect erosional processes differently, so it is extremely important to assess the dominant erosion process accurately so that appropriate species can be selected for stability (Abernethy & Ruterfurd, 1999) All in all, riverbank stabilization from planting vegetation in riparian areas will help in decreasing erosion and degrading water quality in the Guacimal watershed.

To conclude, water quality affects all living things in the Guacimal watershed so the quality of the water should be maintained. The Guacimal and San Luis rivers are in a moderate contamination condition based on the BMWP of macroinvertebrates. With that knowledge, this study suggests a grey water treatment plant be installed before the meeting of the two rivers, terracing in agriculture and pasture land, especially in montane regions, and finally, riparian stream banks should be stabilized with specific vegetation. In the future, as development continues in the Guacimal watershed climate change will be an impending issue. In the future water will become a coveted resource that needs to be protected, we can do our part now by protecting the quality of the water in the Gaucimal watershed.

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