Aquatic Insect Diversity as an Indicator of Water Quality in the Quebrada Guacimal

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Abstract

The goal of this project was to monitor the recovery of a previously polluted Costa Rican stream. Five sites were examined on a stream near a creamery to assess water quality following the halt of waste dumping in 1993. Invertebrates were sampled above, adjacent to, and below the creamery. Results showed that diversity, evenness, and abundance of pollution-intolerant orders decreased downstream. Overall, abundance of pollution-intolerant orders was low compared to those recorded in previous studies. Numerous discharge pipes suggest local pollution in addition to discharge from the creamery. In comparison with a similar study in 1995, our results suggest water quality has decreased.

INTRODUCTION

Pollution adversely affects aquatic species' richness and diversity by altering the habitat quality of streams and rivers. Different animals have varying tolerances to a number of water quality parameters, such as dissolved oxygen concentration, pH, temperature, nutrient levels (such as phosphorus and nitrogen), and turbidity (amount of suspended solids). The physical environment is also important; the quality of the stream environment for invertebrates depends on characteristics of water flow and substrate type (the boulders, rocks, cobbles, pebbles, sand, or silt that line the streambed). Pollution to aquatic systems can occur in several forms. Toxins can kill aquatic animals, whereas pollution in the form of excess nutrients, such as phosphorus, can cause blooms of oxygen-depleting algae or bacteria.

From 1954 to 1993, Productores Monteverde (a creamery) discharged soda washes and whey from cheese-making directly into the Quebrada Guacimal, a stream that runs from the mountains of Monteverde (Gill 2000). The addition of carbon-rich discharges from the creamery was allowing bacteria populations to flourish, creating anoxic conditions (Gill 2000). Numerous studies over the past 20 years have used aquatic invertebrate communities of the Quebrada Guacimal as indicators of water quality (i.e., Adriatico and Shafer 1995, Beebe and O'Keefe 1996, Gill 2000). The orders (the taxonomic level to which insects are commonly identified) *Ephemeroptera*, *Trichoptera* and *Plecoptera* are generally considered pollution-intolerant and require high oxygen levels, while the order *Diptera* is generally tolerant of higher pollution (Mitchell and Stapp 1995, Gill 2000).

Research prior to 1993 showed that sections downstream of the creamery had low aquatic invertebrate diversity and high dipteran abundance (Gill, 2000). A study in 1995 (Pouliot et al.), two years after the creamery ceased dumping pollutants into the stream, showed high abundances of pollution-tolerant orders and high diversity, suggesting recovery from former pollution. Our goal was to evaluate the recovery status of the Quebrada Guacimal.

METHODS

We sampled five sites in the Quebrada Guacimal near the creamery, in the community of Monteverde, Puntarenas Province, Costa Rica. Sites 1, 2, and 3 were 179 m, 82 m, and 42 m, respectively, upstream of the

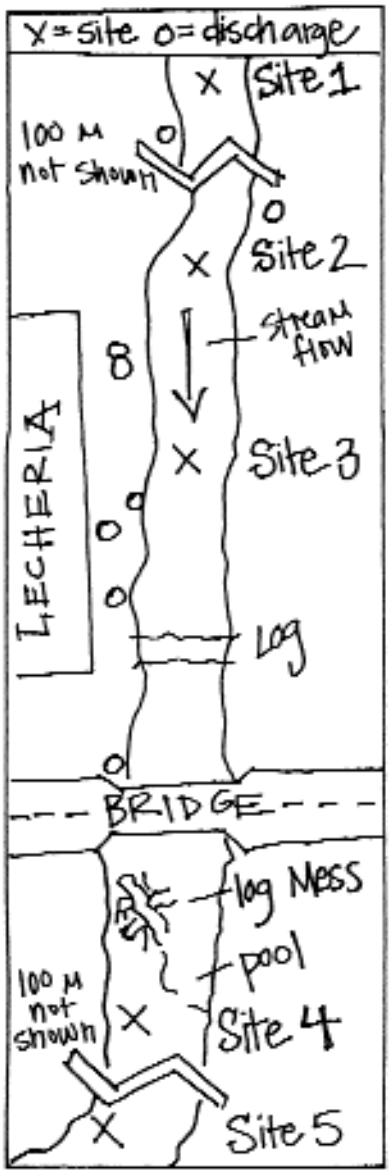

Figure 1. Map of study site showing approximate locations of sample sites and discharges along the Quebrada Guacimal, a stream in Monteverde, Costa Rica. See Methods for distances between sites and site specifications.

bridge that crosses the river below the creamery. Sites 4 and 5 were 26 m and 80 m, respectively, downstream of the bridge (Fig. 1). We selected sites with similar substrate type (medium and small cobble), depth (20-30cm), and approximate flow rate between 0.5 and 1.5 m/sec. Canopy cover was similar for all sites (ca. 60-75%), except for site 4 where cover was slightly less (40%). At each site, we took seven samples in which we turned over and rubbed all the rocks 1 m upstream of a 22 cm diameter aquatic sampling net. We classified all the invertebrates to order within each sample, then combined the samples by site. To analyze the effect of discharges on the river, we lumped the five sites into three zones: above discharges (site 1), at discharges (sites 2 & 3), and below discharges (sites 4 & 5). We calculated the Shannon-Weiner diversity index (an index commonly used to describe the diversity of a particular community) and used this value to calculate evenness (the equitability of distribution of individuals within the species) for each of the three zones.

RESULTS

Diversity, evenness, and number of orders present all decreased with distance downstream (Table 1). The proportion of dipterans (predominantly chironomids) increased downstream and dominated the lower sites (Fig. 2). Trichoptera was the most common order in the upstream zone but its abundance decreased downstream (Table 1, Fig. 2). *Ephemeropterans* and *plecopterans* were rare or absent at all sites (Table 1, Fig. 2).

DISCUSSION

Water quality appeared to decline downstream, demonstrated by a decrease in diversity, evenness, and the number of orders observed (Table 1). Decreased diversity is a standard indication of pollution (Begon et al. 1990). Abundance of the pollution-tolerant dipterans increased downstream, while abundances of pollution-intolerant orders like *Trichoptera* decreased (Fig. 2). The apparent decline in water quality downstream across similar microhabitats suggests that pollutants are entering the stream within our study area. Likely sources of these pollutants are the numerous discharging pipes we observed along the stream (Fig. 1).

The high abundances of chironomids at all sites and the near-absence of pollution-

Order	Site 1	Sites 2 & 3	Sites 4 & 5
Diptera	37	151	90
Trichoptera	56	68	7
Odonata	6	7	0
Decapoda	4	9	0
Plecoptera	3	3	1
Coleoptera	1	3	0
Leeches	0	0	2
Ephemeroptera	2	0	0
Hemiptera	0	1	0
Amphipoda	1	0	0
Total Individuals	110	242	100
Number of Orders Present	8	7	4
Shannon Diversity Index	1.25	1.01	0.41
Evenness	0.6	0.52	0.29

Table 1. Total number of individuals per order collected by kicknet from five sites on the Quebrada Guacimal.

intolerant orders imply that the overall water quality of the stream is poor. In addition, comparison with the 1995 study (Pouliot et al. 1995) suggests that overall water quality has decreased in the last 6 years. The most striking difference between our results and those of the 1995 study is the change in abundance of dipterans in the stream. Pouliot et al. (1995) found only one dipteran in their downstream study site (2% of the total individuals at that site); dipterans comprised 90% of our downstream sites and almost 35% of our upstream site (Fig. 2). The diversity along the stream is also lower than in 1995, when Pouliot et al. found that the Shannon-Weiner diversity index was 2.0 at the upstream site and 1.7 at both the discharge and downstream sites (c.f. 1.3, 1.0 and 0.4 respectively, Table 1). The fact that our results are similar to those found before the creamery ceased dumping in 1993 (Gill 2000) suggests a potential pollution problem.

Due to possible differences in sampling methods, our data may not be completely comparable to previous studies: we used round dip nets rather than flat-bottomed kicknets, so certain organisms may have escaped collection. High numbers of individuals within samples increase the likelihood that our samples are representative. Even if our data are not representative of all orders present in the study area, consistent sampling methods at all five sites allow comparisons between them.

The apparent change in water quality since 1995 cannot be attributed to pollution from the creamery alone. The 1995 study mentioned 2 discharge pipes; eight were found in our study, most likely from different sources. The substances coming from the pipes could not be identified, but several of the discharges had strong odors or oily sheens, and on one occasion a

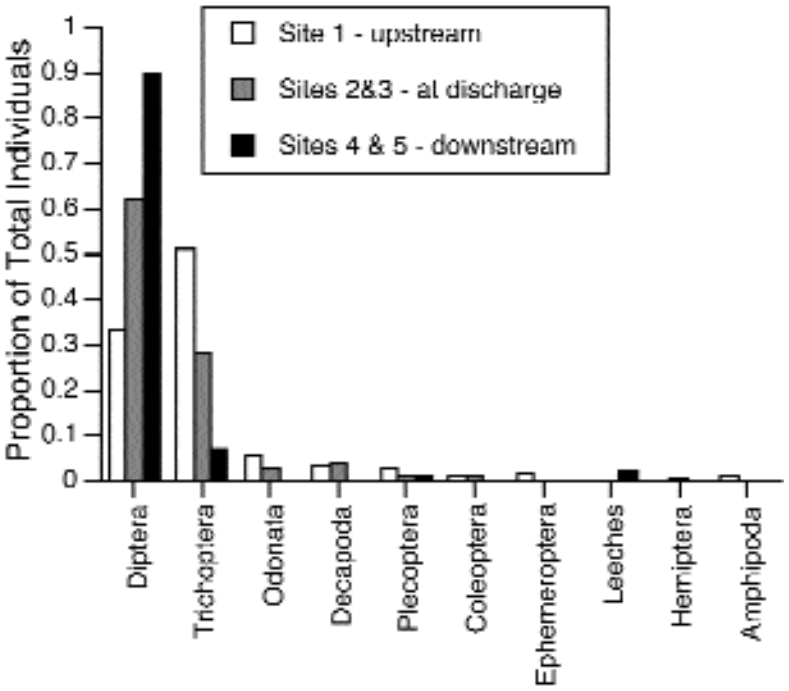

Figure 2. Proportion of individuals in invertebrate orders caught in kicknet samples from sites on the Quebrada Guacimal, Monteverde, Costa Rica.

milky white substance was observed running into the stream from a drainage ditch below the creamery. The Monteverde area has experienced a substantial increase in development in the last few years (D. Peart, pers. comm.), which may be responsible for the decrease in water quality. Additionally, the relatively low water level during this study may contribute to low water quality by concentrating pollutants.

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REFERENCES

Adriatico, M., and Shafer, L. (1995). Wastewater and freshwater ecosystems in Monteverde and San Luis Valley. In *1995 Tropical biology and conservation*. (pp. 139-158). Monteverde, CR: CIEE.

Beebe, D., and O'Keefe, K. E. (1996). Diversity, abundance, biomass, and the presence of certain families of aquatic insects as bioindicators of stream recovery from a pollution source. In *Tropical biology and conservation: Council on international educational exchange, Summer 1996*. (pp. 3-22). New York, NY: CIEE.

Begon, M., Harper, J. L., and Townsend, C. R. (1990). *Ecology: Individuals, populations and communities.* Boston, MA: Blackwell Scientific Publications.

Gill, D. E. (2000). The impact of the Monteverde lechería on the Quebrada Guacimal. In N. M. Nadkarni and N. T. Wheelwright, (Eds.), *Monteverde: Ecology and conservation of a tropical cloud forest.* (pp. 446-447). New York, NY: Oxford University Press.

Mitchell, M. K., and Stapp, W. B. (1995). *Field manual for water quality monitoring: An environmental education program for schools (ninth edition)*. Dexter, MI: Thomson-Shore, Inc..

Pouliot, N. D., Barnhorst, A. V., Levesque, V. R., and J. L. Mitchell, J. L. (1995). The Recovery of Quebrada Guacimal. In C. D. Wray, (Ed.), *Dartmouth studies in tropical ecology 1995*. (pp. 48-50). Hanover, NH: Dartmouth College.

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