THE EFFECTS OF GEOTHERMAL AND ANTHROPOGENIC PHOSPHORUS INPUTS ON TROPICAL MACROINVERTEBRATE COMMUNITIES

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Abstract: At La Selva Biological Station in Costa Rica, some streams receive geothermal groundwater enriched with phosphorus from the Barva Volcano. Others receive anthropogenic inputs from pastures. We sought to understand how macroinvertebrate abundance and diversity varies with non-geothermal, geothermal, and anthropogenic phosphorus inputs. We collected and morphotyped macroinvertebrates from each stream. There was no difference in average abundance or diversity per sample among the streams. We were unable to detect differences among streams because patchiness in macroinvertebrate distributions resulted in high variance among samples. Our results suggest that macroinvertebrate abundance and diversity in streams at La Selva may be strongly influenced by factors other than P inputs.

Key Words: La Selva Biological Station, nutrient inputs, soluble reactive phosphorus, detrital food web

INTRODUCTION

Phosphorus (P) is frequently a limiting nutrient in stream systems (Ramirez et al. 2003). Phosphorus is also a major component of industrial and agricultural runoff, as well as of natural inputs from geothermal groundwater (Pringle 1991). Phosphorus inputs can increase the abundance and diversity of macroinvertebrates by increasing detrital decomposition rates and autochthonous primary production, both of which provide carbon to macroinvertebrates (Ramirez et al. 2003, Hedin et al. 1995).

At La Selva Biological Station, several streams differ in soluble reactive phosphorus concentrations (SRP) and geomorphology (Ramirez and Pringle 2004; Triska et al. 2004). Despite the differences in SRP and geomorphology among streams, invertebrate communities do not differ among streams when all substrates are included in sampling protocols (Ramirez et al. 2006). However, since invertebrates have patchy distributions over different substrates, sampling all substrates may mask important substrate-specific differences in P responses of invertebrate communities. By focusing on cobble, we controlled for differences in substrate.

Because human disturbances are common in aquatic systems, we sought to compare the relative effects of anthropogenic and natural nutrient inputs on biotic communities. Specifically, we

wanted to know how P inputs from a cattle pasture and geothermal groundwater might affect the macroinvertebrate communities in streams. Ramirez et al. (2002) hypothesized that greater SRP would support higher macroinvertebrate abundances, resulting in more trophic levels and higher diversity. We predicted that since P is often limiting in stream ecosystems, streams with higher SRP would have both higher abundances and diversity of invertebrates.

METHODS

Study System: Our study was conducted at La Selva Biological Station, which includes 1536-ha of lowland tropical rainforest on the Caribbean slope of Costa Rica (10° 26′ N, 84° 01′ W). Depending on their location, some streams at La Selva receive groundwater inputs from the Barva Volcano that are rich in SRP from newly weathered rock (Pringle 1991). Additionally, there are pastures near the margins of La Selva, which provide anthropogenic P inputs into the adjacent streams.

Sampling Sites: We chose three streams based on their different P inputs. Two of them, Piper and Surá, have been extensively studied by Catherine Pringle and collaborators on the University of Georgia STREAMS Project. Piper (SRP = 12 μg/L[1]) is a non-geothermal stream in secondary forest on the west side of La Selva (Fig. 1). Surá (SRP = 227 μg/L[1]) is on the east side of La Selva (Fig. 1), surrounded by old growth forest. Thirty-three percent of the water in Surá comes from geothermal inputs (Genereux and Pringle 1997). The third stream, the Sábalo-Esquina (SRP = 26 μg/L[1]), runs through a cattle pasture that borders La Selva to the east (Fig. 1). The Sábalo-Esquina riparian zone contains some large trees and moderate undergrowth along both sides, but pasture is within 5 m of the eastern stream edge.

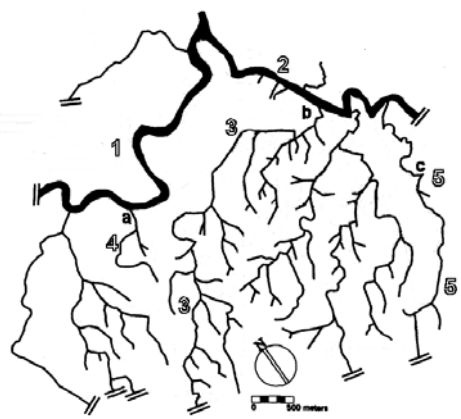

Figure 1. Streams at La Selva Biological Station. 1 = Río Sarapiquí, 2 = Río Puerto Viejo, 3 = Surá, 4 = Piper, 5 = Sábalo-Esquina. Chemical and macroinvertebrate samples were taken from Surá, Piper, and Sábalo-Esquina streams at the points indicated by letters a-c. Piper is a natural, non-geothermal stream in secondary growth forest. The Surá is a geothermal stream located surrounded by old growth forest. The Sábalo-

[1] SRP values for the Piper and Surá streams were taken from Ramirez and Pringle (2004). The SRP values for the Sábalo-Esquina stream was taken from Triska et al. (2004).

Esquina is adjacent to a large pastured area that borders La Selva. Figure is adapted from Genereaux and Pringle (1997).

Sampling methods: We sampled macroinvertebrates in two 10 m sections of predominantly cobble substrate in each stream. Within each sampling area, we collected invertebrates at approximately 2 m increments at haphazard points. For each sample, we agitated the substrate and washed all rocks in a 30 cm x 30 cm square immediately upstream of a D-frame net. We morphotyped all macroinvertebrates in each sample under a microscope.

Statistical Analysis: To test how mean invertebrate abundance and diversity per sample differed among streams, we used two one-way ANOVAs. We calculated diversity using the Shannon-Weiner diversity index[2]. We also examined patterns of overall invertebrate diversity on cobble substrate in the streams.

RESULTS

We found 78 distinct macroinvertebrate morphotypes in 12 orders. Streams did not differ in average invertebrate abundance ($F_{2,27}$ =0.725, P=0.49, Fig. 2A) or diversity ($F_{2,26}$ = 0.985 P=0.39, Fig. 2B), per sample. The lack of difference among streams may be a result of macroinvertebrate patchiness and subsequently high variance among samples. Therefore, we also

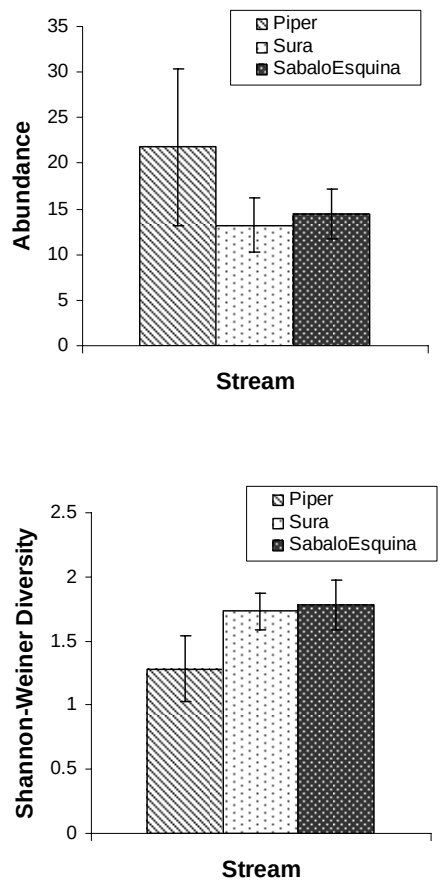

Figure 2. Average abundance (number per sample, all taxa combined) and diversity (Shannon-Weiner index) of macroinvertebrates in 0.30 x 0.30 m samples in three tropical streams at La Selva Research Station, Costa Rica. Samples were collected haphazardly at 2 m intervals on cobble substrate. Error bars represent ± 1 SE, n = 10 samples per stream.

examined overall diversity and abundance in each stream. Overall diversity was greater in the

[2] $H = \sum_{i=1}^{S} p_i \ln p_i$, where "H" is Shannon-Weiner diversity, "S" is species richness, and "p_i" is the proportion of species "i" in the total number of macroinvertebrates.

agricultural stream, Sábalo-Esquina, than in the geothermal stream, Surá, and both had higher overall diversity than the non-geothermal stream, Piper (Table 1).

Table 1. Soluble reactive phosphorus concentrations (SRP) and macroinvertebrate abundance and diversity for three streams at La Selva Biological Research Station, Costa Rica. Diversity (H) was calculated using the Shannon-Weiner index[2].

	Sábalo-Esquina	Surá	Piper
SRP (µg/L)	26	227	12
Abundance	146	132	219
Diversity (H)	3.40	3.35	2.13

DISCUSSION

Contrary to our predictions, we found a higher abundance of macroinvertebrates in the non-geothermal stream. This may be because factors other than P are affecting macroinvertebrate communities. For example, in La Selva streams, invertebrate abundance has been shown to be strongly correlated with the number of days since the last large storm (Ramirez and Pringle 2004).

The geothermal and non-geothermal streams both have detritus-based food webs (Rosemond et al. 2002); however, in the pasture stream, energy input to the food web may be partly from primary production, because of high light conditions and low detritus inputs. Although SRP should increase carbon availability in both detritus-based and primary production-based food webs, SRP may influence each food web differently.

We found that macroinvertebrate diversity was higher in streams with higher SRP (as predicted), but these streams had lower overall macroinvertebrate abundances, contradictory to our prediction. Ramirez et al. (2002) hypothesized that higher SRP increases carbon availability, which can maintain more macroinvertebrate trophic levels and higher diversity. However this argument is apparently based on a positive relationship between P inputs and invertebrate abundances. The argument does not hold for our results, because macroinvertebrate abundance and diversity exhibit opposite trends with higher SRP; according to the logic of Ramirez et al. (2002) they would exhibit the same pattern.

Studies of stream invertebrate communities have demonstrated how single nutrients such as P alter the biotic communities of stream systems (Ramirez et al. 2003; Ramirez and Pringle 2004; Ramirez et al. 2006). However, our results suggest that macroinvertebrate abundances and diversity in streams at La Selva Biological Station may be strongly influenced by factors other than P inputs. For example, high

discharge rates during floods can alter invertebrate communities. Thus, invertebrate abundances and diversity may depend strongly on the time since flooding, which may differ among streams with different catchment areas (Ramirez and Pringle 2004). Unfortunately, time series data on discharge rates for the three streams in our study were not available to explore these relationships.

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