The Effect of Shallow, Shaded Stream Composition on Abundance and Diversity of Benthic Assemblage in Lambir Hills National Park, Malaysia

Alan Chiu[1], **Justine Chow**[2], **Anna Ruman**[3], **Will Skinner**[4]

[1-4] Harvard University/ Cambridge, MA, USA

ABSTRACT

Interconnected water systems exhibit a wide range of of environmental conditions that may potentially shape invertebrate communities. We examined three interconnected streams in Lambir Hills National Park, Malaysia, and hypothesized that stream areas of dissimilar pH, flow rate, and salinity sustain different invertebrate populations. We collected water and invertebrate samples from the streams, ensuring collection of a minimum of three samples per stream for each of four water flow rates, with a total of 38 samples and two discarded samples. Analysis of our data showed strong negative association between stream flow rate and both abundance and diversity of stream invertebrates (ANOVA abundance f-values 0.0025 and 0.0073; diversity f-value=0.0093). However, stream salinity demonstrated strong negative association solely with invertebrate abundance (Generalized linear model, Poisson distribution, abundance p-value=0.048 and =.0018; diversity p-value=0.43). The strong statistical significance of our data indicates the ecological implications of our results and suggests associated future research objectives.

Key words: invertebrate abundance, invertebrate diversity, stream flow rate, salinity

INTRODUCTION

As recent research has shown, the ecology of freshwater rainforest streams is crucial to the health of tropical rainforests, and freshwater stream flow rate due to seasonal rainfall change profoundly impacts fish and invertebrate ecology in streams (Dudgeon, 2000). Furthermore, a study in Borneo showed that habitat alteration in the rainforest also strongly affected invertebrate life in tropical freshwater streams (Iwata, et al., 2003). Based on our interest in the ramifications of stream ecology alteration, this study will examine the effect of multiple variables on the makeup of the aquatic invertebrate community. First, we hypothesize that there will be a statistically significant difference in abundance and diversity of invertebrates collected from an individual stream as water flow rate varies. Second, we hypothesize that there will be a statistically significant difference in abundance and diversity of invertebrates collected from tributaries feeding into a larger stream as water flow rate, pH, and salinity of sample vary. These water characteristics often play a large role in determining the kinds of organisms adapted to living in stream microenvironments. For example, organisms living in faster water would benefit from possessing the ability to cling onto substrate; likewise, organisms living in areas with high salinity would need the ability to be specialized for hypertonic environments. Consequently, we examined specific factors that determine streamwater ecology. Our discussion examines the adaptations of aquatic invertebrates to stream niches and evaluates the potential impact that habitat alteration may have on tropical freshwater invertebrate communities. The goal of the present paper is to determine the effect of stream water flow rate, salinity, and pH on the relative abundance and diversity of invertebrate communities.

METHODS

We sampled a minimum of 12 one meter by one meter sample plots along Latak Waterfall stream, Nibong Waterfall stream, and Pantu Waterfall stream at Lambir Hills National Park; all these streams were wide flowing streams that run into Sungai Liam. The locations were randomly chosen from locations near to the respective waterfalls and were categorized by water flow rate (pool, glide, riffle, and rapid), with at least three of each category sampled per stream to create the statistical replication necessary to ensure data reliability. Light levels and water depth were controlled for, as we only considered sites that were less than one half meter deep and fully shaded. Weather conditions were also controlled for by sampling during a short period of time, during the post-dawn morning to noon hours of July 7-8, 2008, both days free of precipitation. At each of the locations, we took three standardized swipes with an aquatic net, alternating turns between research members in order to control for individual swiping styles, and transferred collected invertebrates to a labeled vial. A water sample was also collected and tested with pH paper and a digital salinity meter back at the laboratory. Sampled invertebrates were identified to order using hand lenses and a 20x microscope.

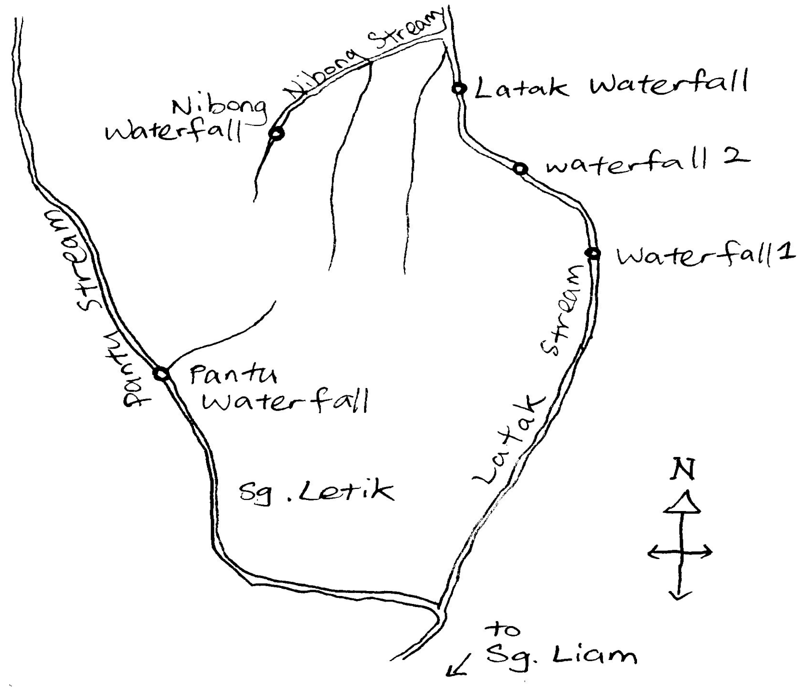

FIGURE 1: Map of Three Sampled Streams in Lambir Hills N.P.

We carried out ANOVA analyses for Heteroptera and Crustacea correlation with flow rate. Since "flow rate" is a categorical variable with four levels, statistical tests designed for quantitative input were not valid. ANOVA examines whether more variation exists between data sets rather than within the data sets. If more variation exists between rather than within data sets, the ANOVA f-value is significant ($f<.05$). In addition, we used Wilcoxon tests to determine if significant differences in salinity levels existed between the three streams. The Wilcoxon test examines whether two data sets have statistically significantly similar means, and we wished to test whether a significant difference in salinity levels existed between the three streams. Nibong and Latak continuousness ($D = 0.7348$, p-value = 0.004066), and Nibong and Pantu continuousness ($D = 0.9091$, p-value = 0.0001057) were significantly different so we can assume that our data did not follow a normal distribution; the Wilcoxon test was therefore appropriate. Furthermore, we used generalized linear models based on the Poisson distribution to examine association between salinity levels of the entire data set and Crustacea and Heteroptera abundance. Lastly, we analyzed species richness with the "vegan" R package. This package allows analysis of our entire invertebrate count data set to create a species richness data set. We then compared richness data to flow rate using ANOVA and also to salinity values using generalized linear models. Once again, ANOVA provided the ideal statistical analysis for the "flow rate" categorical variable, and generalized linear models allowed Poisson analysis of two quantitative variables.

RESULTS

After noting apparent outliers in our data set, we created parallel boxplots of salinity readings for each of the three streams (Latak, Nibong, Pantu). Two salinity outliers were identified, and these two data points (Nibong pool 1, Latak riffle 1) were excluded from our data analysis. We justify our exclusion of these two data points not only based on their identification as outliers in the boxplot analysis but also based on our concerns regarding the reliability of our digital salinity meter. The Wilcoxon tests indicated significant salinity variation between Latak and Nibong streams and between Pantu and Nibong streams but not between Latak and Pantu streams. The Wilcoxon p-value for Latak and Pantu equaled 0.14 compared to a p-value of 0.0002 for Pantu and Nibong and a p-value of 0.0012 for Latak and Nibong. Nibong Stream had significantly lower salinity measurements than the other two streams (See Figure 2). In addition, generalized linear models associating Heteroptera abundance with salinity data produced a statistically significant negative correlation (Poisson distribution, p-value= 0.048, $z = 1.975$, $df = 35$), and identical modeling of Crustacea association with salinity data also produced a significant negative correlation (Poisson distribution, p-value= 0.0018, $z = -3.123$, $df = 35$).

Our ANOVA analyses for Heteroptera and for Crustacea abundances indicated a statistically significant negative association with flow rate ($Pr(>F)=0.0073$ ($F = 4.7762$)for Heteroptera, $Pr(>F)= 0.0035$ ($F = 5.5514$) for Crustacea) (See Table 1). Lastly, our ANOVA comparison of entire data set species richness with flow rate indicated a highly significant negative association ($Pr(>F)=0.0093$, $F =4.534$), but our generalized linear model comparing species richness to salinity did not indicate a strong association (Poisson distribution, p-value=0.43, z= -0.797, df = 35).

TABLE 1: Mean Crustacea and Heteroptera Counts and Mean Shannon Index for Four Stream Flow Rates In Latak, Nibong, and Pantu Streams

Stream	Flow Rate	Mean Crustacea Count	Mean Heteroptera Count	Mean Shannon Index (Averaged Values in Parentheses)
Latak	Pool	0.33	6.67	0.528 (0.562, 0.280, 0.735)
	Glide	1.00	1.67	0.437 (0.637, 0.673, 0.0)
	Riffle	0.00	1.75	0.00
	Rapid	0.00	0.00	0.00
Nibong	Pool	5.33	2.67	0.400 (0.562, 0.637, 0.0)
	Glide	3.33	2.67	0.443 (0.693, 0.637)
	Riffle	2.00	0.67	0.231 (0.693, 0.0, 0.0)
	Rapid	0.00	0.00	0.00
Pantu	Pool	5.00	2.33	0.286 (0.859, 0.0, 0.0)
	Glide	2.33	0.00	0.00
	Riffle	0.33	2.00	0.212 (0.637, 0.0, 0.0)
	Rapid	0.00	0.66	0.00

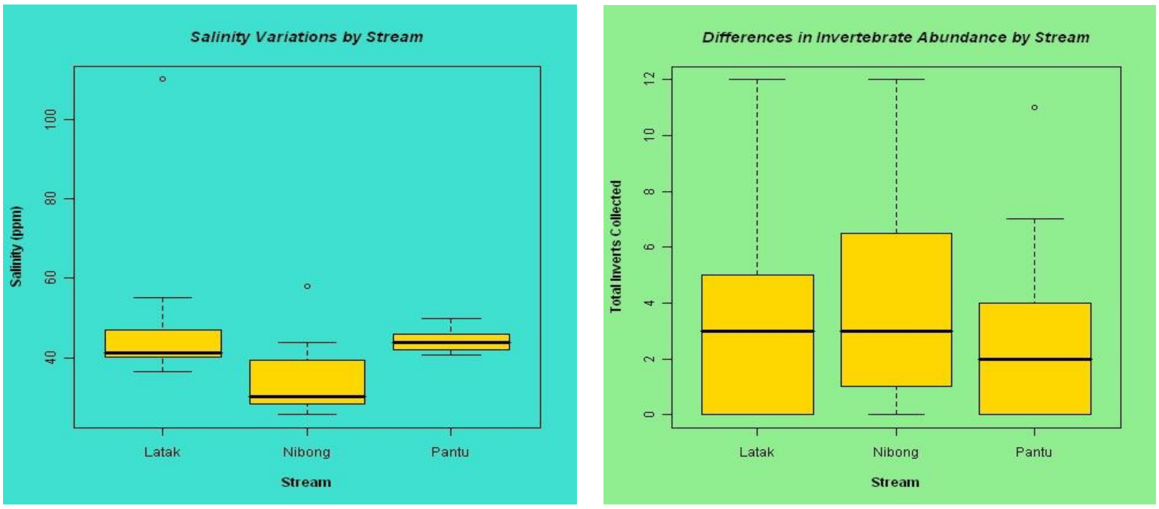

FIGURE 2: Parallel Boxplots of Salinity and Total Invertebrates Collected for Three Sampled Streams

TABLE 2: Statistical Tests, Resulting Data Output, and Concluded Associations

Test	Variables Tested	Result	Conclusion
Wilcoxon	Latak versus Nibong mean salinity	0.0012	xbar Nibong < xbar Latak
	Latak versus Pantu mean salinity	0.14	none
	Nibong versus Pantu mean salinity	0.0002	xbar Nibong < xbar Pantu
Generalized Linear Model	Heteroptera abundance with salinity	0.048	Negative association
	Crustacea abundance with salinity	0.0018	Negative association
	Species richness to salinity	0.43	none

ANOVA	Crustacea abundance with flow rate	0.0035 (F = 5.5514)	Negative association
	Heteroptera abundance with flow rate	0.0073 (F = 4.7762)	Negative association
	Species richness with flow rate	0.0093 (F =4.534)	Negative association

DISCUSSION

Based on our data analysis, we reject the null hypothesis that flow rate would not affect invertebrate abundance and composition within a single stream; we cannot reject the null hypothesis that both pH and salinity create differences in invertebrate abundance and composition between the streams, however. Flow rate did have a statistically significant negative association with invertebrate abundance and diversity due to its Pr(>F) of 0.0073 (F = 4.7762) and 0.0035 (F = 5.5514) for Heteroptera and Crustacea abundance, respectively. With respect to our second alternative hypothesis, a malfunctioning pH meter prevented digital pH measurement. We used pH paper instead, but the consequent loss of precision disallowed thorough analysis of pH association with invertebrate abundance and diversity. However, although we noted a significant difference in salinity levels of the three streams and a negative association between invertebrate abundance and salinity (Generalized linear model; p-value = 0.048 (z = 1.975, df = 35) for Heteroptera and p = 0.0018 (z = -3.123, df = 35)for Crustacea), salinity values failed to show significant association with invertebrate species diversity (Generalized linear model; z = -0.797, df = 35, p-value =0.43).

These results may have many implications with regard to how changes to freshwater salinity and water flow due to human activities such as water pollution or redirection of water sources for irrigation purposes could affect benthic invertebrate populations and their predators. However, possible confounding factors include our limited ability to collect and identify much smaller invertebrates, our inability to control for and analyze oxygen levels in the water, and the narrow range of invertebrates that could be caught with our aquatic net due to speed or net hole size. In addition, we were unable to determine tannin presence in the water—as a natural insect deterrent in plants that leaches into water, it could have a potentially strong effect on aquatic invertebrate populations. Lastly, we were unable to collect invertebrates that would be nocturnal or to determine the nocturnal distribution of our analyzed invertebrates.

Future research could augment available data by allowing comparison of dissolved oxygen levels and tannin levels with invertebrate distributions and may indicate if our results can be applied to smaller aquatic organisms that may affect larger invertebrate distribution. In addition, genetic study and phylogenetic construction of collected species may provide further insight into relationships between invertebrates occupying different niches. Identification of genetic relatedness of invertebrates occupying stream flow rate- or salinity-defined niches may allow identification of particular adaptations that allow specialization to the niche. Although our data set is not extensive enough to allow such phylogenetic analysis, we would highly recommend further investigation. Understanding the specific niches of aquatic invertebrates in tropical freshwater streams is crucial to understanding the dynamics of rain forests and consequently to effectively targeting related conservation efforts.

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LITERATURE CITED

Dudgeon, D. (2000), 'The ecology of tropical Asian rivers and streams in relation to biodiversity conservation', *ANNUAL REVIEW OF ECOLOGY AND SYSTEMATICS* **31**, 239-263.

Iwata, T.; Nakano, S. & Inoue, M. (2003), 'Impacts of past riparian deforestation on stream communities in a tropical rain forest in Borneo', *ECOLOGICAL APPLICATIONS* **13**(2), 461-473.