March 2003

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ABSTRACT

I investigated the effects of pollution and elevation on the population density of freshwater crabs as well as their age structure and sex ratio. This study gives insight into freshwater crabs as bioindicator of water quality as well as provides basic demographic information. Water quality was tested and crabs were collected at three different elevations, 1350 m, 1500 m, and 1650 m, at six different streams. Using a Kruskal-Wallis statistical analysis on the total crabs, the average male size, the average female size, the number of males, and the number of females were analyzed in relation to elevational change (table 2). There was a strong correlation between the total numbers of male and female crabs with a change in elevation (figure 3). The data on the total crab abundance suggests a pattern of crabs being most densely populated in higher elevations around 1650 m above sea level.

RESUMEN

Investigué los efectos de la contaminación y la elevación en la densidad de población de cangrejos de agua dulce así como su estructura de edad y proporción de sexo. Este estudio da la penetración en cangrejos de agua dulce como bioindicator de la calidad de agua así como proporciona información demográfica básica. El agua se probó y los cangrejos se reunieron en tres elevaciones diferentes, 1350 M, 1500 M, y 1650 M, en seis corrientes diferentes. Utilizar un análisis estadístico de Kruskal Walis en los cangrejos totales, el tamaño masculino mediano, el tamaño mediano de hembra, el número de males, y del número de hembras se analizaron con relación al cambio de elevational (pospone 2). Había una correlación fuerte entre los números totales de cangrejos masculinos y femeninos con un cambio en la elevación (la figura 3). Los datos en la abundancia total del cangrejo sugieren una pauta de cangrejos es la mayoría del densamente poblado en elevaciones más altas alrededor de 1650 M sobre el nivel del mar.

INTRODUCTION

Freshwater crabs (Decopoda: Eucarida) are found all over the world across various habitats and elevations (Corvich & Throps 1991). At Monteverde, Costa Rica, they are known to occur in streams of variable water quality. River pollution in this region tends to increase at lower elevations. No studies to date have investigated density or demography of freshwater crabs in the Monteverde area in relation to elevation and water quality.

In Monteverde, streams are subject to municipal waste such as runoff from roads and agriculture, as well gray and black water from homes and businesses. These wastes change water quality parameters such as pH, dissolved oxygen, and temperature. Whether freshwater crabs are sensitive to these pollutions has not yet been documented in Monteverde.

The pH of a stream affects aquatic life, and an extreme pH (below 5 and greater than 9) is harmful to arthropod populations (Allan 1995). The pH is affected by factors such as natural and human inputs. For instance, calcium carbonate levels influence the acidity/alkalinity of the water. Natural high levels of carbonate and bicarbonate raise the alkalinity of the water. Human inputs of soaps in streams also raise the alkalinity of the water (Allan 1995). Average amounts of calcium carbonate rocks, dissolve, neutralizing the soil and river water, forming a buffer system that resists against changes in pH from 7. The pH values lower than 5 and greater than 9 are harmful to the survival of organisms and may be the result of natural causes, human influences, and chemical variations. Arthropod taxa increase in numbers as pH reaches a neutral 7 (Allan 1995).

Another important quality, which greatly affects aquatic life, is the amount of dissolved oxygen (D.O.). Most stream organisms are sensitive to oxygen levels. An unpolluted healthy stream should have a D.O. concentration of 80%. The solubility of oxygen increases nonlinearly with a drop in temperature and reduces with a decrease in elevation or fluctuates with barometric changes in weather. Organic pollutants such as municipal waste or industrial waste may significantly reduce the amount of dissolved oxygen. Microbial processes, which consume oxygen, can be concentrated in leaf and debris dams, thus reducing the levels of dissolved oxygen in the microhabitat (Hauer and Lamberti 1996).

Temperature is also a very important variable. It affects the movement of molecules, saturation constants of dissolved gases in water, metabolic rates of organisms, and a vast array of other factors pertaining to the health of aquatic life. Annual fluctuations in stream temperature is important to stream organisms regulating life variables (reproduction and growth). Many stream organisms use temperature changes as cues for emergence or spawning (Hauer & Lamberti 1996). Human inputs from cities or homes may change temperatures and thus affect the nature of the aquatic system.

At Monteverde, the pH, dissolved oxygen, and temperature of streams is likely to vary naturally with elevation since stream width, depth, and velocity should increase at lower elevations. Likewise, pollution levels should increase at lower elevations. The response of freshwater crab populations to elevational changes and water quality has not yet been studied in Monteverde. In this study, I investigate the effects of pollution and elevation on the population density of freshwater crabs as well as their age structure and sex ratio. The results give insight into freshwater crabs as bioindicators of water quality as well as provide basic demographic information.

METHODS

Study Site

Data were gathered from six different streams on the western slopes of the Cordillera de Tilarán (mountain range) around the Monteverde area at three different elevations. Santa María, Quebradas Rodríguez, Sucia, Máquina, Cuecha, and Alondra were sampled at 1350,1500, and 1650m.

Stream Quality and Characteristics

At each of the 18 sites (six at each elevation) the pH, D.O., and temperature (°C) were recorded before crabs were caught. I used an Oakton Waterproof pH Tester2 model 35624-22 to measure pH. I used the Waterproof Data Meter model WD-35615-75 to measure the D.O. and temperature (°C) of the stream. I also measured the stream elevation, width, depth, length, and velocity. I used an altimeter to measure elevation to 10 m and a metric tape to measure width, depth, and transect length. Velocity was estimated by timing how long it took a cork to float one meter.

Crabs

Once the stream quality and characters were recorded I measured an eight meter transect of stream at each elevation where I searched for crabs. I started down stream to prevent clouding the stream. All leaves and removable rocks and logs were very slowly excavated, also to prevent clouding the stream. I moved from bank to bank, capturing crabs by hand, until I concussed the entire transect. For each crab I caught, I determined its sex by the size of the telson and measured each carapace at the widest point with a Spi Caliper.

Data Analysis

Once all data were collected, I analyzed the stream quality, average male size, number of males, and number of females in relation to the three different elevations using a Kruskal-Wallis Test. I used Spearman Rank Correlations Test to investigate relationships between water quality and the average male size, average female size and the total number of crabs.

RESULTS

Water quality and elevation

Table 1 shows the results of the Kruskal-Wallis Tests for the effects of elevation on stream quality and characteristics. There was a significant effect of elevation on two parameters, pH and temperature. The pH was higher at lower elevations (figure 1) as was temperature highest at lower elevations (figure 2). Elevation was also correlated to crab density and demography in relation to the three elevations.

Crab abundance and size in relation to elevation

Table 2 shows the results of the Kruskal-Wallis Test for the effects of elevation on the number of total crabs, the average male size, the number of male crabs, and the number of female crabs. There was a significant effect of elevation on the size and number of male crabs and the total number of crabs, with larger and more males and total crabs being found at higher elevations (figure 3). There was a nearly significant effect ($H = 4.867$, $p = 0.087$) between the numbers of females living at higher elevations.

Water quality and crab abundance and demography

Table 3 summarizes the correlation of water quality parameters and stream characteristics with the total number of crabs. There is a significant, negative correlation between the total number of crabs and temperature (°C) (figure 4). Tables 4 and 5 summarize the correlation between male and female size and water quality and stream parameters. There is a significant, positive correlation between male size and stream depth (figures). There is a nearly significant ($Rho = 0.870$, $p = 0.051$), positive correlation between female size and the level of D.O.

DISCUSSION

The results of this study show that pH and temperature were both higher at lower elevations. The average pH was greater than 7 (neutral) and the average temperature was 18.5 °C at 1350 m. These values are not considered to indicate poor water quality or cause a decline in arthropod populations (Allan 1995).

However, studies on algae have shown that water quality in Monteverde decreases around 1350 m. These tests at 1350 m, included nitrogen and phosphorus concentration that relate specific species of algae to be biological indicators of low water quality (Buckman 2003 CIEE). This study found water quality at 1350 m to be contaminated in Monteverde, which may inhibit populations of freshwater crabs from sustaining healthy populations.

The results presented here indicate that males are larger and more numerous at higher elevations. The total number of crabs, likewise, increases at higher elevations, but this is mainly due to male effects, as the number of females was not significantly affected by elevation.

The consequences of males being larger and more numerous at higher elevations may increase competition. Larger males consume more food and may compete to acquire more territory. There may be greater competition among large males for the few reproductive females. However, there are possible reasons for larger populations and sizes of male crabs at higher elevations.

Larger populations and sizes of male crabs may be the response to an increase in food availability, reduced predation, reduced parasitism, cooler environments, or water quality may affect crab abundance. Male crab size and abundance is sensitive to stream characteristic and may be sensitive to water quality.

Water and stream characteristics appear to be important factors in determining male crab abundance, but not in ways obviously linked to water pollution. Cool and deep streams maintain higher crab abundance; however, pH and D.O. are not related. This may be in part due to more space and habitats to forage and roam for mates. In contrast, female abundance is nearly significantly related to D.O. Female crabs may have higher survival rates in more oxygenated streams and may prefer these conditions for reproduction. It is possible that spawning and the health of eggs are dependent D.O. levels and temperature.

I did not find a direct correlation that shows extreme fluctuations in water quality to inhibit a healthy population of crabs at 1350 m. Healthy levels of pH, D.O., and temperature, are very important factors in maintaining populations of arthropods. However, the fluctuations I found do not suggest the reasons for the drastic drop in crab populations. It is my theory, based on other detailed studies, to relate a decline in water quality with a dramatic drop in crab densities.

Acknowledgements

Thank you Karen Masters for guiding my thoughts and ideas into a quality project. I would like to greatly thank Rick for his time spent with me in the field and attending to the flurry of questions. Thank you Andrew you can always be counted on. The entire group and staff, thank you it was great!

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Table 1. Kruskal Wallis test results for effects of elevation (1350m, 1500m, and 1650m) on water quality parameters and stream characteristics.

Parameter	H corrected for ties	Tied P-value	Sample size per elevation
Width	0.92	0.631	6
Depth	0.54	0.769	6
Velocity	1.73	0.422	6
ºC	13.24	0.0013	6
pH	13.27	0.0013	6
DO	1.46	0.4818	6

Table 2. Kruskal Wallis test results for effects of elevation (1350m, 1500m, and 1650m) on total amount of crabs, average male size, number of males, and number of female crabs.

Crab abundance	H corrected for ties	Tied P-value	Sample size per elevation
# Males and Females	6.48	0.0392	6
Average M size	1.72	0.4223	6
# of Males	6.41	0.0405	6
# of females	4.87	0.0877	6

Table 3. Correlation coefficients (Rho corrected for ties, and tied P-values) for total number of crabs vs. water parameters.

Parameter	Rho corrected for ties	Tied P-value	Sample size
pH	-0.39	0.107	10
DO	0.25	0.294	10
ºC	-0.69	0.004	10
Width	0.22	0.372	10
Depth	0.30	0.221	10
Velocity	0.00	0.798	10

Table 4. Correlation coefficients (Rho corrected for ties, and tied P-value) for average male size vs. water parameters.

Parameter	Rho corrected for ties	Tied P-value	Sample size
pH	-0.27	0.427	10
DO	0.29	0.389	10
ºC	-0.31	0.356	10
Width	0.45	0.182	10
Depth	0.67	0.043	10
Velocity	-0.12	0.726	10

Table 5. Correlation coefficients (Rho corrected for ties, and tied P-value) for average female size vs. water parameters.

Parameter	Rho corrected for ties	Tied P-value	Sample size
pH	0.27	0.548	8
DO	0.87	0.051	8
ºC	0.37	0.411	8
Width	0.67	0.13	8
Depth	0.69	0.125	8
Velocity	-0.02	0.973	8

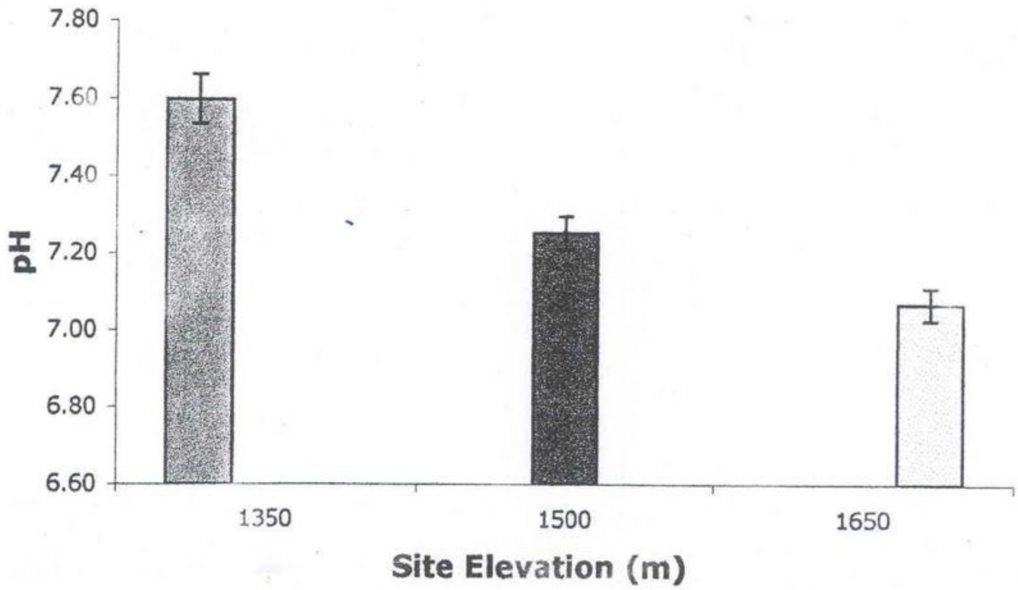

Figure 1. The mean pH (and s.e. bars) of Monteverde streams at three elevations differs significantly.

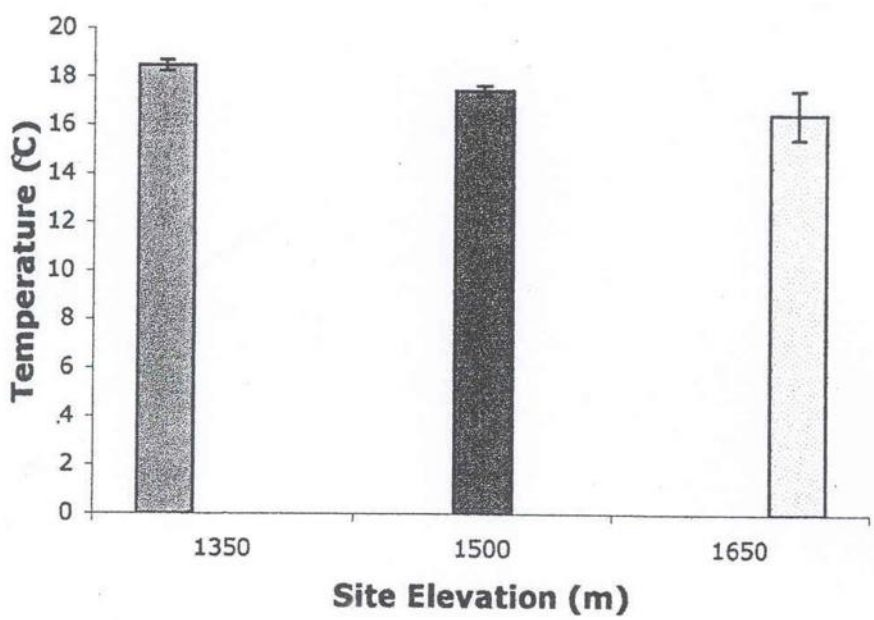

Figure 2. The mean temperature (and s.e. bars) of Monteverde streams at three elevations differs significantly.

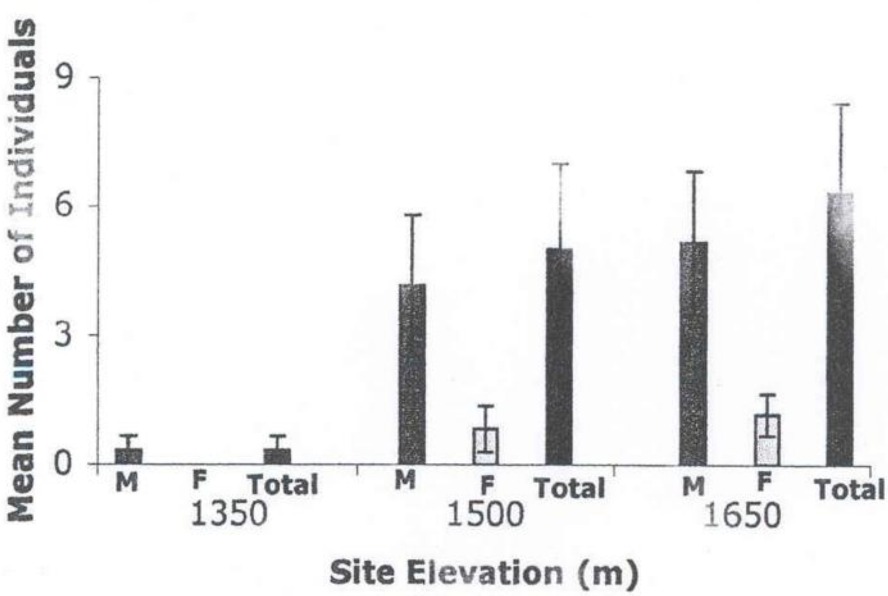

Figure 3. The mean male, female and total number of crabs (and s.e. bars) at three different elevation.

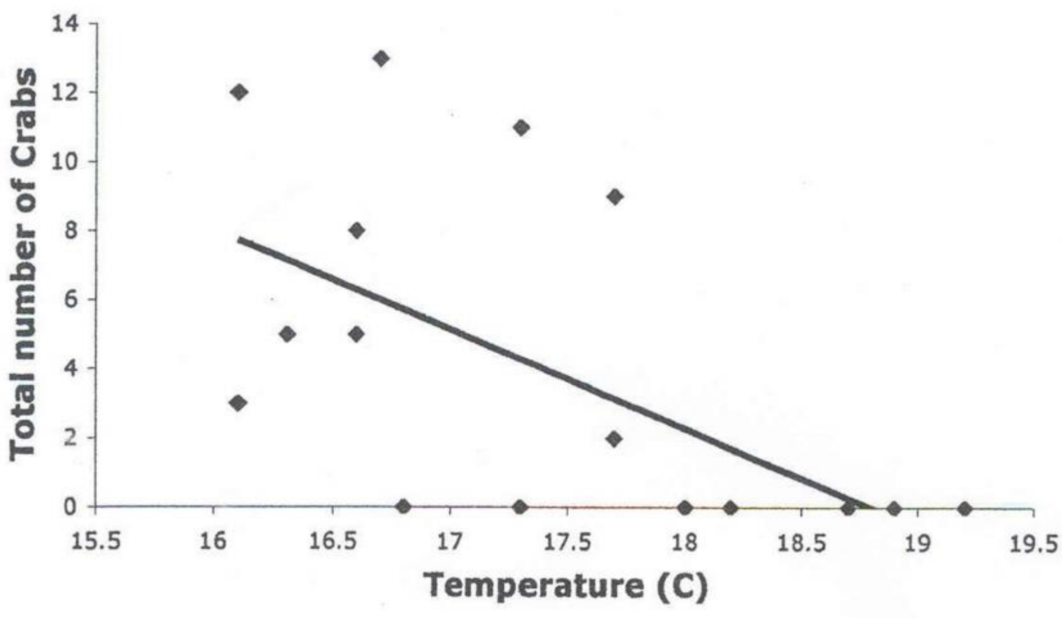

Figure 4. There is a significant, negative correlation between number of crabs in cooler water. R2 = 0.3401

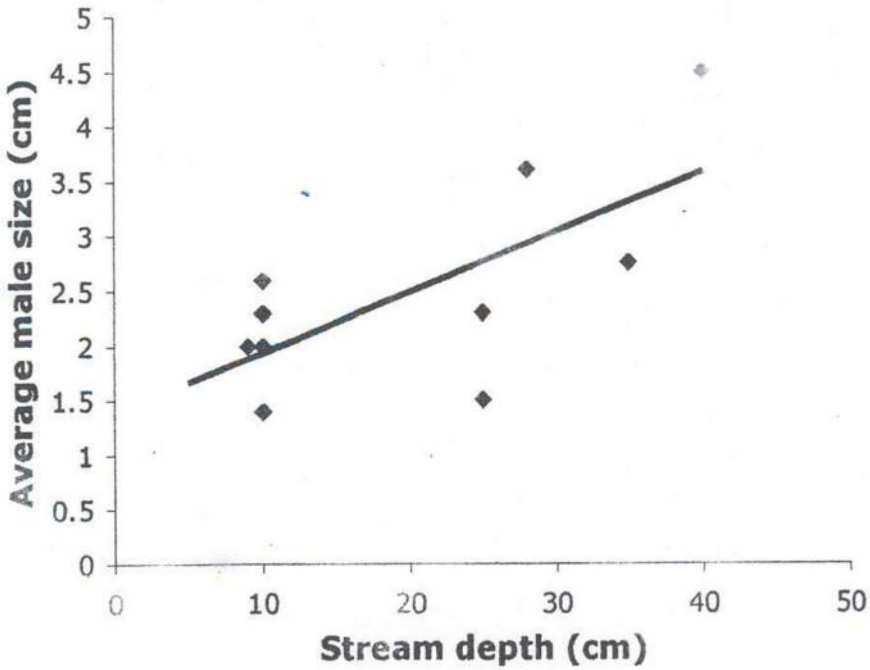

Figure 5. There is a significant correlation of larger males in deeper streams.
$R2 = 0.4691$