DISTRIBUTIONS OF FRESHWATER INVERTEBRATES IN A TIDALLY INFLUENCED STREAM

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ABSTRACT (SCF)

We examined freshwater invertebrate distributions in rocky substrate and leaf-litter habitats across a tidally induced salinity gradient in a freshwater Costa Rican stream. The diversity and abundance of invertebrates was much higher in the upstream site, which remained freshwater throughout the tidal cycle, as compared to the downstream site, which was intermittently brackish. Transplant experiments of the three major taxa (decapod crustaceans, gastropods and plecopterans from the upstream site revealed significant mortality of decapods and plecopterans to intermittent brackish water exposure. Gastropods appeared to be unaffected by elevated salinity during the course of our experiments. We conclude that saline water invasions may be one of several important factors influencing the distribution of freshwater invertebrates in ocean-flowing streams.

Key Words: tropical streams, brackish water, Plecoptera, Gastropoda, Decapoda.

INTRODUCTION (ANS)

Lower reaches of coastal rivers and streams experience intermittent periods of saline water invasion associated with tidal cycles. As a result, freshwater invertebrates in this variable environment encounter unique stresses. These stresses may present physiological and ecological challenges to freshwater invertebrate populations, resulting in habitat limitations. In this work, we considered one abiotic factor affecting invertebrates.

We examined the effects of fluctuating salinity on invertebrates found in a tropical stream. Using decopods (freshwater shrimp), gastropods and plecopterans as representative taxa, we tested the hypothesis that tidal salt water invasions limit the distribution of freshwater stream invertebrates. We predicted that invertebrate abundance and diversity would be reduced at an intermittently brackish site versus a continually freshwater site. In addition, we predicted that taxa absent from an intermittently brackish site would be more susceptibile to periods of elevated salinity.

METHODS (SCF)

We conducted our experiment on the lower reaches of the Rio Claro in Corcovado National Park, Costa Rica on February 2-3, 1994. The Rio Claro is a freshwater stream which drains into the Pacific Ocean and experiences tidal saltwater invasions in its lower reaches. Our two study sites were a tidally influenced run area at the mouth (downstream site) and a permanent freshwater run area (upstream site) ≈ 0.6km from the mouth.

We examined leaf litter and rocky substrate habitats at both sites to determine the diversity and abundance of invertebrates across the salinity gradient. Leaf litter areas (upstream and downstream) were sampled during daylight high and low tides. Sampling entailed taking five "handfuls" of leaf-pack, counting all organisms, and identifying them to order. Concurrent salinity measurements were taken at three depths (6cm from bottom, middle of water column, 6cm from top) using a hand-held refractometer (American Optics, Buffalo, NY). A regression line to calculate salinity from refractometer "brix" units was determined using tap water (assumed to be 2 ppt) and sea water (assumed to be 35 ppt) as regression points.

We sampled rocky substrates for gastropods during low tide at both upstream and downstream sites. We haphazardly selected 20 rocks of similar size at each site and counted the gastropods that were attached.

We conducted a bag enclosure experiment to determine the sensitivity of invertebrates to intermittent brackish water exposure. We deployed two treatments, upstream controls and downstream treatments, with four replicates per treatment. Each bag was constructed out of 100μm nitex mesh (allowing for exposure to ambient water) containing a small rock and four clean leaves as substrate for inoculated organisms. Each bag contained two gastropods and two decapods. Two of the four replicates per treatment also contained two plecopterans. We deployed bag enclosures at each site for ≈ 22 hrs (1.5 tidal cycles), and determined mortality of each taxa at the end. We measured salinities for each site at high and low tide.

We conducted a jar enclosure experiment to determine invertebrate sensitivity to prolonged exposure to brackish water. Our two treatments were a freshwater control (5 ppt salinity) and a brackish treatment (20 ppt salinity), with four replicates per treatment. Each 400 ml jar contained a rock for substrate, two gastropods, two decapods, and two plecopterans. Jars were sealed with parafilm and placed in a pool at the upstream site to keep jars at ambient stream temperature. Survival was monitored every 24hr for 48hr total.

All comparisons between stream locations and tidal cycles for abundance and survival data were analyzed by student t-tests.

RESULTS (PSW)

The upstream site remained freshwater throughout the tidal cycle at ≈ 5 ppt, while the downstream site was invaded by sea water during high tide, raising the salinity as high as 12 ppt (Figures 1A and 1B). In addition, the downstream site developed a halocline during high tide (Figure 1A) resulting in two very distinct vertical layers.

Over 20 times more decapods were found at the upstream site than the downstream site during both high and low tide ($t = 3.01$, $p < 0.05$ and $t = 6.17$, $p < 0.001$; Figure 2). There was no difference in abundance of gastropods between sites during either high or low tide ($t = 1.65$, $p > 0.1$ and $t = 0.62$, $p > 0.1$; Figure 2). There were > 30 times more gastropods per rock at the upstream site than the downstream site ($t = -3.59$, $p < 0.01$). Aquatic insects were much more diverse at

the upstream site where we found Coleoptera, Diptera, Plecotera, Tricoptera, and several other unidentified larvae. At the downstream site only four Dipteran larvae were found.

In the bag-enclosure experiment, plecopterans were the most intolerant of brackish water (≈12 ppt) of the three taxa with 100% mortality at the down stream site. Decapods appeared intolerant, suffering 75% higher mortality at the downstream site ($t = 3.97$, $p < 0.01$). The gastropods were quite tolerant. with 100% survival at the downstream site. All three taxa had 100% survival at the upstream site.

In the jar-enclosure experiment, there was 100% mortality of decapods and plecopterans within 24 hours in both our control and treatment jars. This may have been due to contamination of the jars with residual mayonnaise and soap. The gastropods demonstrated a high tolerance for both contaminants and high salinity with 100% survival over 48 hours in both treatments.

DISCUSSION (ANS)

At high tide, there was an influx of salt water, producing salinity levels as great as 20 ppt near the mouth of the river. Salinity decreased greatly as one moved up the stream and up the water column, a phenomenon known as a "salt wedge". Increased salt concentrations present physiological challenges (i.e. osmoregulation) for freshwater organisms making brackish waters potentially harsh environments.

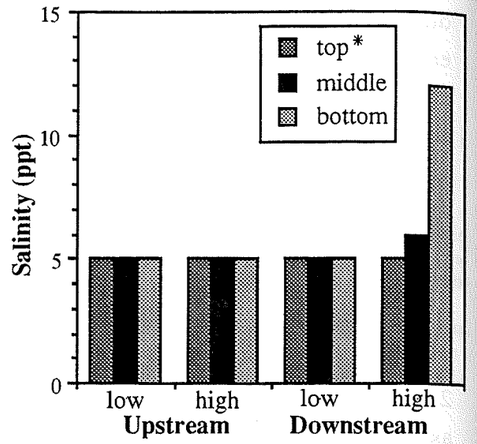

Figure 1. Salinity of water column at upstream and downstream bag-enclosure sites on Rio Claro at high and low tide. Tap water = 2 ppt, sea water = 35 ppt.

* Top, middle, and bottom refer to position in water column from which salinity was measured and were estimated by sight.

Although physical characteristics between sites varied, we were able to find leaf packs in both areas that were potentially inhabitable by invertebrates. However, the species composition of aquatic invertebrates was very different at the upstream and downstream sites. Decapods were diverse and abundant at the upstream site and rare at the downstream site. Similarly, aquatic insects were more diverse, and tended to be more abundant at upstream sites than downstream sites.

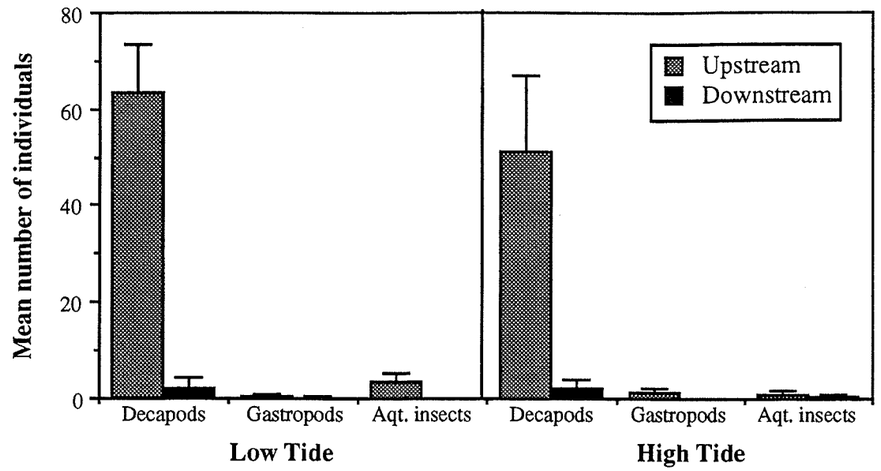

Figure 2. Abundances of decapods, gastropods, and aquatic insects at upstream and downstream sites on Rio Claro during high and low tide.

Gastropods also showed a preference for rocky substrates found at the upstream site, although these individuals had a greater tolerance of high salinity in both bag enclosures and jar experiments than other invertebrates. Patterns of natural abundance, and transplant experiments, were consistant with the hypothesis that the physiological capacity for osmoregulation in brackish water limits the downstream distribution of decapods and plecopterans in the Rio Claro. However, we cannot exclude some alternative hypotheses. For example, higher predation risk near the river mouth or abiotic effects of higher temperature and increased sediment load may incluence invertebrate distribution. Our transplant experiments suggest that one of these alternatives is a more likely explanation for patterns of gastropod abundance.

During sampling, we observed an interesting pattern of decapod distribution at our downstream site. During high tide, decapods were abundant in the upper third of the water column, while absent from the benthos. During low tide, when salinity and depth decreased, shrimp were more evenly abundant in the water column. Even during high tide, salinity in the upper portion remains approximately 5 ppt, suggesting that decapods vertically migrate to a freshwater refuge. The few decapods counted in leaf packs were likely "snagged" from the upper portion of the water column when retrieving samples from the benthos. The possiblity of shrimp utilizing a freshwater refuge requires urther study along with other variables such as temperature and sediment load that may affect habitat selection of freshwater invertebrates.