FACTORS DETERMINING DISTRIBUTION OF THREE FRESHWATER ORGANISMS IN STREAMS OF CORCOVADO NATIONAL PARK

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Abstract: Both species interactions and abiotic factors may determine the abundance and distribution of aquatic organisms. We hypothesized that predation and physical factors such as depth and substrate type determined the microhabitat use of shrimp, guppies (*Brachyraphis terrabensis*), and the redfin fish (*Hyphessobyron savagei*) in streams in Corcovado National Park, Costa Rica. We predicted that physical factors keep redfins from inhabiting shallow pools in spite of abundant potential prey, and that the presence of these predatory fish keep guppies and shrimp out of deep pools. Field surveys indic ated that (1) shrimp and redfins rarely co-occurred and (2) shrimp and guppies were significantly more abundant in shallow pools while redfins were significantly more abundant in deep pools. Guppies living in pools with redfins were larger than guppies living in shallow pools and future studies might examine this size gradient. Shrimp prefered open sandy areas to rock and leaf covered areas, perhaps because of local effects of water flow. Predation experiments were inconclusive,but improved enclosures could test whether redfins directly influence the distribution of shrimp and guppies in these streams.

INTRODUCTION

Species interactions and abiotic factors may influence microhabitat use by aquatic organisms. In the dry season, streams in Corcovado National Park, Costa Rica are broken into a series of discrete pools seperated by riffles or underground flow. Freshwater shrimp (Decapoda) and a guppy species, (*Brachyraphis terrabensis* , Pociliidae) predominantly occurred in shallow pools, riffles or the shallows of deep pools, while a larger fish species, *Hyphessobyron savagei* (Characidae), referred to as the redfin, was common in deep pools. Predatory fish influence guppy distribution in tropical streams in Trinidad (Frasier and Gilliam 1992, Frasier et al. 1993). Angelfish in Corcovado induce predator avoidance behavior in shrimp within laboratory aquaria(Goodwin and Williams 1997). When we mixed guppies and shrimp from shallow pools into deep pools, they were quickly eaten by the redfins suggesting that both shrimp and guppies may remain in smaller pools to avoid predation by the redfins.

Alternatively, physical factors may determine habitat preference. The filter feeding shrimp may need fast moving shallow water to feed efficiently. Guppies, although not filter feeders, may have other physiological requirements for shallow water habitats. Many redfins are small enough to forage in shallower water, but may avoid it because it is physiologically unsuitable for them. Additionally, the three species' distributions may be influenced by substrate type (e.g., amounts and types of rocks, leaves and sand that provide shelter and could influence foraging efficiency).

We used a combination of experiments and surveys to test the effects of physical factors and predation on the distribution of guppies, shrimp, and redfins.

METHODS

On 5-8 February, 1998 we conducted field surveys and experiments in two streams, Quebrada Camerona and Quebrada Danta, at Estacion Biologica Sirena in Corcovado National Park, Costa Rica. In each stream, we sampled 20-22 sites, at 10 m intervals on a transect. We noted presence of redfins and estimated the density of shrimp and guppies as the number that swam under a 900 cm^2 frame in one minute. We recorded depth, % cover of rocks, leaves, and sand in our frame.

We examined substrate and depth preference of shrimp and guppies with Spearman rank correlations both across all sites, and only at sites where some animals occur. We compared water depth (log-transformed) and percent of each substrate type to redfin presence or absence using a Student's t-test. We examined species co-

occurrence with a chi-square analysis, using a null hypothesis of random assortment among pools.

For experiments, we chose one deep and one shallow pool at two different sites on the Q. Danta and one on the Q. Camerona. In each shallow pool, we built a rock wall creating two subpools and removed rocks and leaves from one side of each subpool. The center wall had small holes which permitted shrimp and guppies, but not redfins, to pass through. We recorded initial densities of shrimp and guppies within a 900 cm^2 frame in both substrates on each side of the enclosures, and then added a redfin to one side and observed behavior and position of all three species for 10 minutes in all four treatments. We remeasured guppy and shrimp densities 2 days after the redfin was added. Because redfins inexplicably disappeared from all pools after the first night, these data were combined with the first day's values to get average densities in different substrate types. We used an ANOVA to examine substrate preference of shrimp and guppies in these pools.

In the deep pools, we set up square mesh enclosures 0.5 m on each side, divided in half by a central pane. The enclosures were weighted to the bottom of the stream with small pebbles in their hems, and the tops were tied to trees to keep them 15 cm above water level. We added 15 shrimp and 5 guppies to each side, 1 redfin to 1 side, and monitored behavior of all species for 10 minutes. We remeasured guppy and shrimp densities 24-36 hours later. No statistical analyses were done for this experiment because all of the redfins were missing after the first night.

RESULTS

Shrimp and guppies were more abundant in shallow water while redfins were more prevalent in deep water (Sp-R = -0.62, $P < 0.0001$ and Sp-R = -0.41, $P = 0.005$ for shrimp and guppies respectively; $t_{40} = 4.87$, $P < 0.0001$ for redfins). The mean depth (± SE), in centimeters, for pools containing shrimp was 6.05 ± 1.33, 18.98 ± 2.35 for guppies and 24.83 ± 2.73 for redfins. There were no significant correlations between shrimp density and either of the three substrate types ($P > 0.05$ for rocks, sand, and leaves, both for all sites and excluding sites where shrimp did not occur). With all sites included, guppy density was positively correlated to leaf abundance (Sp-R = 0.38, $P = 0.01$), negatively correlated to sand abundance (Sp-R = -0.43, $P = 0.005$), and uncorrelated with rock abundance (Sp-R = -0.03 , $P = 0.86$), but when sites without guppies were not included, guppies were not correlated with any substrate type (all $P > 0.05$). Redfin presence was not related to any substrate type (all $P > 0.05$).

Co-occurrence of guppies with shrimp and redfins did not differ from the null model of random assortment ($\chi^2 = 0.70$ and $\chi^2 = 0.37$ respectively, both $P > 0.05$), but shrimp and redfins were found together less often than expected by chance ($\chi^2 = 4.19$, $P < 0.05$, Fig. 3). Guppies in deep sites appeared to be much larger than those in shallow areas.

When redfins were added to the shallow experimental pools, the shrimp became agitated, and backed away from the redfin, and in one enclosure the redfin struck at a shrimp. Shrimp in the side without the redfin remained stationary. Guppies in enclosures did not respond to redfins. Shrimp in shallow enclosures were more abundant on the sides cleared of leaves and rocks ($F_{1,10} = 14.32$, $P = 0.004$) while guppies showed no substrate preference ($F_{1,10} = 1.07$, $P = 0.32$).

Within 24 hrs, all shrimp had dissappeared from the enclosures in the deep pools. No bodies were found and we could not determine whether they escaped (by burrowing or climbing out of the net) or were preyed upon. After two days, most of the guppies added to the three deep pool enclosures were either dead (bodies found in the enclosure) or missing.

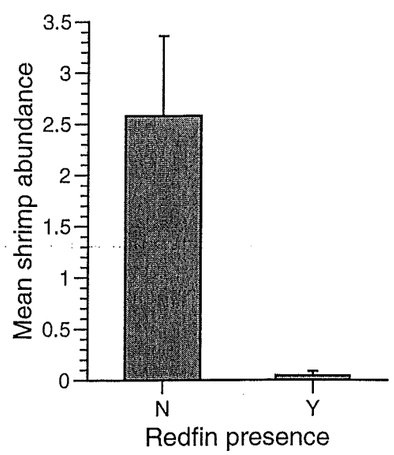

FIG. 1. Mean number of shrimp found in pools with and without redfins present, ± 1 SE.

DISCUSSION

Shrimp and redfins do not generally co-occur in the same microhabitats within a stream: shrimp and guppies primarily inhabit shallow water while redfins are found in deep water. Alhough our data could not confirm the cause of this difference in spatial distributions, we hypothesize that it results from a combination of predation and abiotic effects. The shrimp were more common in shelter-free areas in shallow pools and may prefer shallower, faster flowing water because it provides optimal filter feeding conditions. All of the shrimp disappeared from deep water enclosures, suggesting that they are not capable of surviving there. The behavioral observations in the shallow pool experiments indicate that the threat of predation may cause shrimp to inhabit shallower pools where redfins can not reach them, even if they are physiologically capable of living in deeper water.

Although there was no relationship between redfin and guppy distribution, guppy depth distribution may be predator mediated. We noticed that most guppies found in deeper pools where redfins were present were large and so may have been too big for redfins to eat. Previous work in tropical streams has found that presence of a predatory fish can cause guppies to switch their distribution to shallower water (Fraser and Gilliam 1992) and can limit their downstream distribution (Gilliam et al. 1993).

Absence of redfins from shallow pools was perplexing because many were small enough to swim in these areas and the shallow pools appeared to contain abundant food resources. We hypothesize that they avoid shallow pools because of predation risk. This is indirectly supported by the overnight dissappearance of redfins from all of our enclosures. These trapped fish may have been easy targets for predators such as tiger herons, water snakes and even large shrimp. It could also be that deep pools better meet the physiological needs of redfins for temperature or oxygen. Future studies involving improved fish enclosures could separate the effects of habitat and predator avoidance in determining shrimp, guppy and redfin distribution within tropical streams.

LITERATURE CITED

Frasier,D. F., and J. F. Gilliam. 1992. Nonlethal impacts of predator invasion: facultative suppression of growth and reproduction. Ecology 73: 959-970.

Gilliam, J. F., D. F. Fraser, and M. Alkins-Koo. 1993. Structure of a tropical stream fish community: a role for biotic interactions. Ecology 74: 1856-1870.

Goodwin, S. C., and A. N. Williams. 1997. Predator avoidance behavior in palemonid shrimp in Rio Claro Estuary. Pp. 97-99 *in* J. R. Shandro and G. S. Chen, eds. Dartmouth Studies in Tropical Ecology. Dartmouth College: Hanover, New Hampshire.