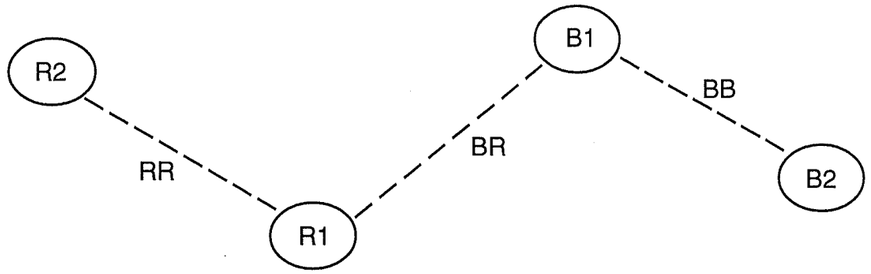

Fig. 1. Configuration of sample trees in relation to each replicate "focal" tree with a P. flavicornis colony. BB represents the distance between the focal tree and nearest P. flavicornis tree. BR represents the distance between the focal tree and nearest P. spinicola tree. RR represents the nearest neighbor distance between two P. spinicola trees.

ant species found on the focal's nearest neighbor is associated with a significant interaction of height and light of the focal tree (logistic regression, whole-model $P < 0.001$, effects test: height $P = 0.047$, light $P = 0.049$).

Discussion

As expected from the higher density of *P. spinicola* colonies, the distance between neighboring red ant trees was less than that for *P. flavicornis* trees. However, we found no evidence that the black ant is an early successional species. Black ants and red ants occupy the same range of light environments. Furthermore, the trees that we initially located as focal trees with black ant colonies were taller than the nearest neighboring *A. collinsii* hosting red ant colonies. These trends were the reverse of our predictions. However, it is possible that the height comparison was biased, as we may have found tall trees more easily than short ones in our initial search for black ant colonies.

We cannot explain the mechanisms underlying the significant interaction between focal tree, height, and light environment in our logistic model predicting nearest neighbor species. This may be an interesting pattern to investigate in future studies.

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Effects of vegetation and prey size on the predation efficiency of belostomatids and naucorids (Hemiptera)

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Abstract: Naucorids and belostomatids are important invertebrate predators in vegetation in freshwater systems. Having observed that naucorids tend to swim more than belostomatids, we hypothesized that naucorids would prey more effectively on damselfly nymphs in open water treatments than in vegetated treatments, and that the opposite would be true for the more sedentary belostomatids. Belostomatids tended to spend less time swimming than naucorids, but we found no correlation between prey consumed and predator type or presence of vegetation, and no interaction between predator type and vegetation treatment. Despite their different predation methods, both predators are equally effective when preying on damselfly nymphs.

Key Words: Belostomatidae, damselfly nymphs, Naucoridae, predation strategies

Introduction

Naucorids and belostomatids are hemipteran aquatic predators found primarily among vegetation in ponds, streams, small lakes, and marshes (Border 1964). Belostomatids are sit-and-wait predators known to feed on all kinds of aquatic organisms including tadpoles, small frogs, and fishes (Pennak 1978). While naucorids are known to prey on small animals, not much is known about their ecology (S. Hampton, pers. comm.). Our initial observations of belostomatids and naucorids collected in Palo Verde National Park, Costa Rica, suggested that naucorids may swim more readily than belostomatids and that both groups prey upon Odonata (damselfly, dragonfly) nymphs. We also noted that the marsh habitat available to these predators consists of areas ranging from no vegetation to dense vegetation. We hypothesized that naucorids, as seemingly more active swimmers, would prey more efficiently in areas of no vegetation, while belostomatids, as very sedentary predators, would be more successful in vegetated areas.

Methods

We collected all study organisms using aquatic sweep nets in the Palo Verde marsh (near the OTS Biological Station in Palo Verde National Park, Costa Rica) on the morning and afternoon of January 12, 2001.

For our first experiment, we filled each of 20 1-gallon bags with 2 liters of tap water. We introduced 6 damselfly nymphs into each bag. In 10 of the bags, we put a handful of reeds pulled from the Palo Verde marsh for "vegetation" treatments. The other 10 bags were left vegetation-free for "open" treatments. We added one belostomatid or naucorid to each replicate, with 5 vegetation and 5 open treatments for each predator type. We also set up five controls in which 6 damselflies were kept in plastic cups with tap water for the length of the experiment. The experiment ran for 13 hours (5 hours of light, 6.5 hours of dark, and another 1.5 hours of light). We then counted the number of damselflies left alive in each replicate. The results from this experiment were analyzed using a 2-way ANOVA (predator type x vegetation).

For the second experiment, we filled 20 plastic cups with half tap water and half pond water. We placed one belostomatid in each of 7 cups and one naucorid in each of 10 cups, and left 3 cups as predator-free controls. Two small and one large damselfly nymphs were added as prey. The predators were left in the cups for 90 minutes and each predator's behavior (classified as swimming, feeding, or sitting) was observed for a 10-minute period.

After 90 minutes, the numbers of small and large damselfly nymphs consumed per cup were recorded. We compared proportions of time spent engaged in each behavioral classification and number of each prey size consumed by each type of predator using t-tests.

Results

Our first experiment (Fig. 1) showed no significant difference in feeding success between belostomatids and naucorids (2-way ANOVA, F = 0.42, df = 1, P = 0.53), no difference between success in open and vegetated treatments (2-way ANOVA, F = 0.0025, df = 1, P = 0.96), and no interaction between predator type and vegetation treatment (2-way ANOVA, F = 0.20, df = 1, P = 0.66). All damselfly nymphs used in the control treatments survived.

Belostomatids tended to spend less time swimming (Fig. 2) than naucorids during the 10-minute observation period of the second experiment, although not quite significantly (Welch's ANOVA F = 4.55, df = 1, P = 0.06). There was no difference in the proportion of time the two predator types spent sitting (t-test = -0.13, df = 15, P = 0.90) or feeding (t-test = 0.57, df = 15, P = 0.58).

The number of large damselflies eaten during the 90-minute run of the experiment was the same for both belostomatids and naucorids ($\chi^2 = 0.30$, P = 0.59), as was the number of small damselflies ($\chi^2 = 1.89$, P = 0.39). All damselfly nymphs used in control treatments also survived.

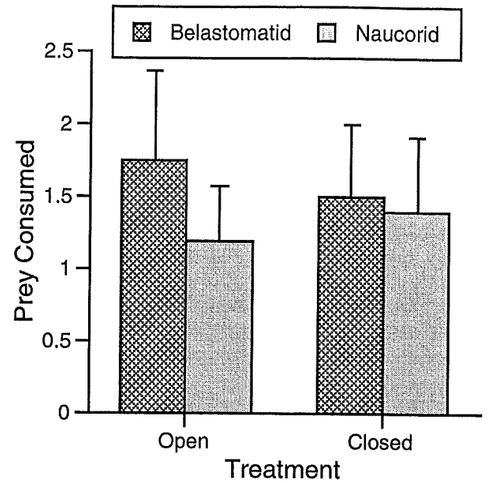

Fig. 1. Mean number of damselfly nymphs consumed (± 1 SE) by belostomatids (n = 8) and naucorids (n = 10) in vegetated and open experimental 1-gallon bags.

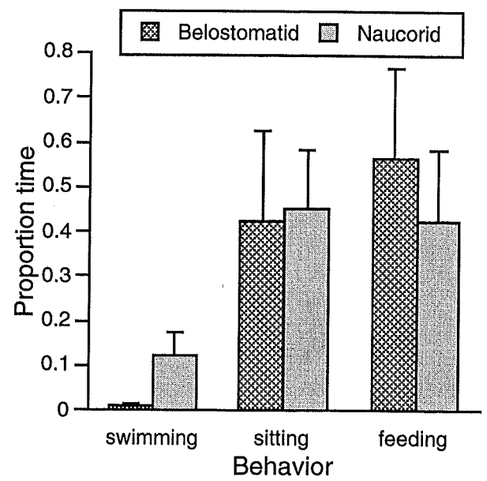

Fig. 2. Mean proportion of time spent (± 1 SE) by belostomatids (n = 7) and naucorids (n = 10) in different behaviors over a 10-minute period in treatment with three damselfly nymphsin 16 oz. cups.

Discussion

We have incidentally observed, as have others (Borror 1964, Pennak 1978), that both naucorids and belostomatids live primarily among vegetation. Contrary to our expectations, in the first experiment, naucorids and belostomatids preyed equally well on damselfly nymphs in both the presence and absence of vegetation. We were unable to demonstrate that low use of open water by the predators in nature is attributable to differences in predation success dependent upon vegetation. There are several possible explanations: (1) naucorids and belostomatids live among vegetation for reasons unrelated to predatory style, such as refuge from predators or higher prey density in vegetation, (2) the different predatory styles of belostomatids and naucorids might result in differential success with prey other than damselflies, or (3) larger or smaller predators may depend on more or fewer perches for foraging.

The second experiment confirmed that the predators were equally successful with damselfly prey but revealed that naucorids swam more than belostomatids (Fig. 2). With prey other than damselflies, this difference could result in different predatory success. In addition, the higher swimming rate suggests that naucorids expended more energy than belostomatids to capture the same number of prey. Further study could compare the energy budgets of the two predators, and how differing success with prey other than damselfly nymphs could limit direct competition between them.

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