remained high, and we found no freshwater species, our study suggests that marine and peripheral species are competitively dominant to freshwater species in the dry season.

Further studies should investigate the factors which allow marine species to dominate in a freshwater environment. Possible factors include low diversity of indigenous freshwater species, high availability of food resources utilized by marine species, and close proximity to the ocean.

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THE AQUATIC INVERTEBRATE COMMUNITIES OF THREE SPECIES OF PLANTS WITH BRACT FLOWERS

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Abstract. (NDP) Inflorescences of *Heliconia wagneriana, H. latispatha,* and *Calathea lutea* contain aquatic communities within their bracts. Bracts of *H. wagneriana* are generally larger than those of *H. latispatha* which are larger than *C. lutea*. Because large bracts should have a decreased frequency of desiccation when compared to small bracts, the communities within them should persist longer and should have a greater density and diversity of invertebrates. We found, however, that bracts of *H. wagneriana, H. latispatha,* and *C. lutea* did not contain a significantly different density or diversity of invertebrates. Differences in bract volume therefore does not seem to be a major determinant of invertebrate community structure, at least during the dry season.

INTRODUCTION (NDP)

Plants of the genus *Heliconia* are characterized by large, colorful inflorescences composed of showy branch bracts emanating from a central rachis. Each bract forms a deep, boat-shaped reservoir where water and rotting detritus of the plant accumulates. These reservoirs can support small communities of aquatic invertebrates (Stiles 1983). These communities have been studied in *H. wagneriana* (Drake et al. 1993, Broughton et al. 1994) and to a lesser extent in *H. latispatha* (Stiles 1983). During our observations, we noticed a third plant, *Calathea lutea*, with bracts containing water, which we believed might also contain invertebrates because of their similar ability to hold water.

Bracts of these three plant species differ in size: *H. latispatha* bracts are long, thin and shallow, *C. lutea* bracts are small, round and shallow, and *H. wagneriana* bracts are deep and wide. Because of their greater depth and width, *H. wagneriana* bracts should contain a greater volume of water which would persist longer than the water within *H. latispatha* or *C. lutea* bracts. Based on this difference, we hypothesized that *H. wagneriana* bracts would contain a higher density and diversity of invertebrates and a longer lived community than those of either *H. latispatha* or *C. lutea* bracts. We assumed that any immigration into these pools would add to the pre-existing density and diversity there, and would be the same across the three species. This hypothesis is consistent with MacArthur and Wilson's equilibrium theory of island biogeography which predicts that large island should support more species than small islands (Begon et al. 1990). *H. wagneriana* bracts spatially and temporally represent larger islands than *H. latispatha* and *C. lutea* and thus, based on this theory, should contain more species. Likewise, *C. lutea* bracts should have the lowest density and diversity because of the smaller volume of water they appear to hold.

METHODS (NDP)

We sampled aquatic communities of *H. wagneriana, H. latispatha,* and *C. lutea* along the Naranjo Trail at Corcovado National Park, Costa Rica, on 2 February 1995. We collected water samples randomly from three inflorescences of each species. Since our hypothesis centered around the notion of persistent invertebrate communities, we sampled the water in the two oldest bracts of an inflorescence, which are located at the bottom of the inflorescence. We also recorded the width of each bract sampled, measured from the rachis to the outer tip of the bract.

We examined each water sample under a dissecting microscope and classified the invertebrates into taxonomic groups. When

an organism was unidentifiable we recorded its morphological characteristics and abundance under "Other Taxonomic Unit" (OTU).

A Shannon-Wiener diversity index (Begon et al 1990) was calculated for each inflorescence. We then obtained a single diversity index for each plant species by calculating the mean diversity index of the three inflorescences of each particular species.

We determined the maximum volume of water each bract could hold. We calculated the mean density of invertebrates for each bract by dividing the total number of individuals by this volume. We then determined the overall density of invertebrates for each species by averaging the densities of the three inflorescences of each species.

We compared the Shannon diversity indices and the mean densities among the three species.

RESULTS (AVB)

We found that *C. lutea* bracts supported invertebrate aquatic communities, as did both species of *Heliconia*. These were comprised of mostly larval insects of several orders, mites, and nematodes worms (Table 1).

The Shannon-Wiener diversity index was highest in *H. wagneriana* and lowest in *C. lutea* (Table 2). However, this difference was not significant (F=0.238, df=2,5, P>0.8). The density was comparable in *C. lutea* and *H. latispatha*, while much lower in *H. wagneriana* (Table 2). This difference was also not significant (F=0.232, df=2,5, P>0.75). Mean volume of the bracts were 5.3±0.35 ml for *C. lutea*, 12.0±2.90 ml for *H. latispatha* and 46.7±0.94 ml for *H. wagneriana*.

TABLE 1. Total number of individuals in each invertebrate taxa found in three species of bracts.

	C. lutea	*H. latispatha*	*H. wagneriana*
Chironomidae	27	32	81
Coleoptera	6	0	3
Culicidae	6	0	30
Psychodidae	0	18	12
Similudae	0	2	0
Stratiomydae	0	18	42
Syrphidae	0	0	27
Hydrocarina	15	11	45
Nematoda	10	17	27
OTU #1	3	2	0
OTU #2	1	4	3
OTU #3	0	0	3
TOTAL	68	104	273

TABLE 2. Shannon-Wiener Diversity Index and density of individuals in aquatic invertebrate communities among three species of bract-bearing plants.

Plant species	Shannon Diversity Index ± SE	Density of individuals per ml ± SE
C. lutea	1.3 ± 0.16	4.4 ± 0.1.4
H. latispatha	1.2 ± 0.30	4.3 ± 0.30
H. wagneriana	1.7 ± 0.15	2.0 ± 0.54

DISCUSSION (AVB)

We found aquatic invertebrate communities in all three plant species. Because the flowers are found in similar habitat and strata and were sampled within 500 m of each other, they probably experience the same invertebrate source population. Some of the insects probably lay their eggs in these bracts, and the communities formed depend on these visitations. All three are also visited by hummingbirds, which are either pollinators or nectar robbers. These birds may disperse invertebrates on their beaks while feeding on flowers in different bracts (Broughton et al. 1994).

Although we predicted that species with larger bracts would support both more diverse and more dense communities of aquatic invertebrates, we found no significant difference among bracts of the three species. This may be due to the possibility that larger bracts may not be able to retain water during long, dry periods. Therefore, the duration of the aquatic communities in each bract species may actually be the same during the dry season, regardless of bract size.

There was also a large variation in density and diversity among bracts within

a species. This may be due to flaws in our sampling technique. Although we sampled the oldest two bracts on each inflorescence, we could not control for differences in age of the individual inflorescences within a species or across the three species. Some of the bracts of a species might be older than the others, and therefore have a longer period of time in which to establish an invertebrate community. A larger sample size might reduce this variation.

Further studies should attempt to better quantify potential differences in diversity and abundance of organisms among the bract communities of these plants. These differences may be related to factors other than size of the bract, such as shape or depth of the bract, that affect how individuals are deposited into them. Hummingbirds and wind may also play important parts in the dispersal of these organisms about which little is known. Finally, it needs to be determined what other species of bract-bearing plants provide habitats vital to aquatic invertebrates in these mostly terrestrial forest ecosystems.

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