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ABSTRACT

Protists are microscopic organisms which play an important role in nutrient degradation in tank bromeliads (Carrias *et al* 2001). Their diverse communities provide good subjects of study on community assembly and their existence in bromeliads make them a unique, yet accessible case study. Resource based models suggest that an increase in resources leads to an increase in biodiversity. Since no two species can occupy the same niche, increased resources can lead to niche differentiation, promoting community diversity (Osborne 2000). This study hypothesized that as the amount of light, area, water, and food sources increase in a bromeliad community, the diversity of protists will also increase. Data were collected among 48 bromeliads at the Ecolodge San Luis (1100 m), Monteverde, Costa Rica, at the end of dry season, between April 20 and May 5, 2005. Shannon Weiner indices (H', N, S, and E) were calculated and analyzed against the four resources (light, area, water, and food source) using a multiple regression. The results of the multiple regression showed that an increase in these resources had no significant effect on protist diversity in bromeliads (p values > 0.05). This study indicates that there may have been other factors influencing protist diversity in bromeliads. An increase in resource diversity may have effects on protist diversity, but further study is needed.

RESUMEN

Los protistas son organismos microscópicos que tienen un papel importante en la degradación de nutrientes en los tanques de bromelias (Carrias et al 2,001). Sus comunidades diversas proporcionan especímenes adecuados para el estudio de la composición de comunidades y su existencia en las bromelias las convierte en sujetos de estudio únicos y accesibles. Los modelos basados y rucursos sugieren que un incremento en recursos conlleva un aumento en la biodiversidad. Ya que dos especies no pueden ocupar el mismo nicho, un aumento en los recursos puede producir diferenciación.de nichos, promoviendo la diversidad de comunidades (Osborne 2,000). Este estudio propuso la hipótesis que conforme la luz, el agua, el área y la fuentes de alimento aumentan en la comunidad de la bromelia, la diversidad de los protistas también aumenta. Se recolectaron datos de 48 bromelias en el Ecolodge de San Luis (1,100 m), Monteverde, Costa Rica., hacia el final de la estación seca entre el 20 de abril y el 5 de mayo del 2,005. Los índices de Shannon Weiner (H', N, S, y E) fueron calculados y analizados comparando los cuatro recursos (luz, área, agua, y fuentes de alimento) usando regresiones múltiples. Los resultados de las regresiones múltiples mostraron que el incremento en estos recursos no tenía un efecto significativo en la comunidad de protistas en las bromelias (p > 0.05). Este estudio indicó que pueden haber habido otros factores que influencian la diversidad de protistas en las bromelias. Un aumento en diversidad de recursos puede tener effectos en la diversidad de protistas, pero se necesitan más estudios al respecto.

INTRODUCTION

Most tank bromeliads are epiphytic plants compensating for water and nutrient deficiency with the adaptation of a central, watertight-well that can hold up to five liters of water (Heywood 1993). The plant gains its nutrients from organisms and detritus that are collected in the well water. This well is home to a community of macro-invertebrates and protists, the main sources of nutrients to the plant. These organisms are essential to bromeliads because they reduce the detritus through consumption and excretion, allowing for nutrient uptake by trichomes, found on the bromeliad leaves (Carrias 2001).

Although both protists and macro-invertebrates play a role in the nutrient uptake of tank bromeliads, protists may have a more significant contribution, acting as pathways for dissolved organic matter, and important consumers of bacteria (Caron 1991). Protists are unicellular, microscopic organisms that thrive in water. They are an essential part of the communities that exist in bromeliad tanks because of the role they play in releasing nutrients to the plant (Carrias *et al.* 2001). Given that bromeliads are habitats for such a diverse community of organisms, it is important to investigate the quantity of resources that bromeliads offer individuals of these communities.

Community diversity is the result of many different variables. According to the Theory of Island Biogeography proposed by Robert MacArthur (1967), species diversity and abundance increases with area, immigration, and distance from the mainland. The rules of community assembly state that an abundance of a resource base is followed by an abundance of species. Niche differentiation occurs, leading to increased diversity, and those species that depended on the same resources before can now partition, allowing for coexistence (Wilson 1992). The Niche Hierarchy Model, following the rules of community assembly, confirms that diversity is a direct result of partitioning for resources. Sugihara *et al.* (2003) described this model using a community of birds, which forage at different heights off the ground. The bird species thus occupy different niches, further differentiating with species that forage at the same tree height as them by utilizing different resources. As the diversity of resources increase, there are more resources for different types of species, thus increasing community diversity. It can therefore be concluded that "diversity begets diversity" and an abundance and diversity of resources will result in a diverse community of organisms (Jeffries 1997).

The resources available in bromeliads may include light, temperature, water, area, energy, food source, and productivity. A study done by Bernal (2002), confirmed that protist diversity and abundance increased with turbidity, which is the decreased reflection of light from the tank water. This indicates that protists require organic matter for resources, suggesting that an increase in other resources should also increase diversity.

This niche assembly perspective affirms the theory that community assembly is limited to species that can coexist at equilibrium as a result of niche partitioning of limiting resources (Osborne 2000). This contradicts the Unified Neutral Theory of Biodiversity and Biogeography, proposed by Hubbell in 2001. This theory includes a dispersal-assembly perspective that states that "ecological communities are open, continuously changing, nonequilibrium assemblages of species whose presence, absence, and relative abundance are governed by random speciation and dispersal, ecological drift and extinction" (Hubbell 2001). Assaf (2005) examined Hubbell's theory using protist community assemblages in bromeliad tanks, and found that the model did not apply; however, it was found that two of three meta-communities studied demonstrated that an increase in the number of individuals resulted in an increase in diversity of the meta-community. This finding suggests that community diversity may be a result of species interactions and not a result of chance, as proposed by Hubbell's theory. This study aims to assess if these findings are due to a separate niche assembly model acting on the community, opposing the importance of chance in Hubbell's community theory.

Additionally, protists require many resources for survival, and an increase in these resources could cause a higher diversity in the protist community. This study hypothesizes that as the amount of light, area, water, and food sources increase in a bromeliad community, the diversity of protists will also increase.

MATERIALS AND METHODS

Data were collected from 48 bromeliads at the Ecolodge San Luis (1100 m) at the end of dry season, between April 20 and May 5, 2005 in the San Luis Valley, Costa Rica. Tank diameter, canopy density, water volume, protist abundance and diversity, and detritus mass were measured for each bromeliad. It was noted whether or not each bromeliad had an inflorescence present. Canopy density was determined using a canopy densitometer. Water was extracted from the center well of each bromeliad tank using a pipette, and placed in a labeled vial to be examined for protists the same day. Slides of the protists were prepared by first mixing the vial to insure that an accurate representation of the protist population was being examined. A drop was put on the slide, followed by a drop of diluted aloe solution, which was used to slow the protists to facilitate identification. The two drops were gently mixed together on the slide using the tip of the pipette. The slide was examined under the microscope first at 10x magnification to find locations on the slide where protists were abundant, and then at 40x magnification for identification. Five different portions of each slide were viewed and examined for protists, to insure an accurate representation of the species in the population. Protists were identified to morphospecies and diversity and abundance were calculated.

To determine the amount (grams) of detritus present, the remaining water from the vial was poured into a funnel lined with a piece of filter paper, and the filtrate volume was measured after it drained into a graduated cylinder. The remaining particles from the water were left on the filter paper, which was placed under a light and dried out for weighing.

Shannon-Weiner diversity indices (H', E, N, and S) were calculated for protist communities in each bromeliad and plotted on a multiple regression against the four measured resources. A t-test was then run to determine if the presence of an inflorescence was responsible for a difference in protist community diversity.

RESULTS

For the 48 bromeliads, there were 27 species of protists observed. The average species richness for the community was 7.06 (S.E. = 0.27) (Figure 3). The average Shannon-Weiner index for diversity (H') per bromeliad was 1.36 (S.E. = 0.06), with an average evenness (E) of 0.7 (S.E, = 0.03), and an average number of individuals (N) of 119.2 (S.E. = 13.25) (Figures 4, 2, and 1, respectively). The graphs in Figures Two - Four suggest that the bromeliad community was relatively homogenous, and most of the bromeliads contained similar ranges of species (S) (3 -10), diversity (H') (0.31 – 2.15), and evenness (E) (0 – 0.93). The number of individuals (N), however, showed a large range of between 17 – 424 individuals among the bromeliad samples (Figure 1).

Multiple regressions of H', N, S, and E against tank diameter, canopy density, detritus mass, and water volume showed that there were no significant effects of resources on protist diversity. The multiple regression of H' versus the four independent variables showed that these resources had no significant effect on diversity ($p = 0.76$). The same trend can be seen for the multiple regression of E versus the four independent variables ($p = 0.76$). A multiple regression of N versus the four variables also showed no significance, indicating that the number of individuals in the population were not influenced by the amount of these four resources ($p = 0.22$). Finally, the multiple regression of S versus the four independent variables was not significant, indicating that the amount of protist species found in the bromeliad tank was not influenced by the amount of the available resources studied ($p = 0.94$) (Table 1).

A one tailed t-test performed on inflorescence presence indicated that protist diversity (H'), number of individuals (N), species richness (S), or evenness (E) found in bromeliads were not effected by the presence of an inflorescence (p values > 0.05) (Table 2).

DISCUSSION

These results do not support the original hypothesis that an increase of light, area, water, and food sources would lead to an increase in protist diversity (p values > 0.05) (Table 1). Table two also illustrates that the presence of an inflorescence had no effect on diversity with a one tailed t-test (p values > 0.05). These results may be contrasted with the amount of homogeneity observed in Figures Two - Four, which suggest that diversity, species richness, and evenness, were similar across all bromeliads. These similarities may be due in part to habitat homogeneity because all bromeliads sampled were found on the same tree species, at the same elevation, and on the same one hectare plot. Habitat homogeneity results in a lower diversity of resources, and therefore a lower diversity of species, in that community (Jeffries 1997). Similar to what MacArthur (1967) demonstrated when comparing the effects of different habitats on bird diversity, when habitat homogeneity is present, niche partitioning will be low, decreasing diversity (Rosenzweig 1995). This draws the conclusion that a lower diversity of resources results in a lower diversity of species, however this was not accounted for in this study. Although there may have been an abundance of the measured resources, they may not have increased protist diversity if the diversity of resources was low.

Although this study indicates that an increase in resources does not result in an increase in diversity, a previous study conducted during wet season in 2002 in Monteverde, Costa Rica, demonstrated that protist diversity was related to turbidity of water in bromeliad tanks ($r^2 = 0.288$, $p = 0.0022$) (Bernal 2002). Given that turbidity refers to the cloudiness of the tank water which is a direct result of detritus abundance, it can be assumed that the amount of detritus has an affect on protist diversity. While the data collected for this study contradict these findings, the observed difference could have been due to sampling error. Resources may not have had an effect on protist diversity in this case, due in part to seasonal variability that took place during the dry season. Dry season climate is more dynamic in that there are long periods of sun with a few rainy days in between, leaving an insufficient amount of time for protists to adapt to changes and reestablish their communities after a day of rain. Although protists are known for having quick responses to changes in environmental conditions, samples were sometimes collected the day after a heavy rain, an insufficient amount of time for the protist community to re-stabilize (Bernal 2002). This resulted in a dilute community with less turbidity; therefore, individuals were more spread out, and samples taken were a less accurate representation of the protist community.

Another reason that protist diversity may not have increased with abundance of resources could be because some protists rely on different resources, therefore responding differently to changes in the availability of overall resources, making it important to differentiate between them. Some protists rely on light as a resource and are photosynthetic, while others rely strictly on detritus and are detritivores. Had these protists been differentiated, results may have indicated a correlation between diversity of photosynthetic protists in relation to light, and diversity of detritivore protists in relation to detritus.

It would be helpful if this same study were conducted during wet season, to lessen seasonal variability and obtain accurate data points. It would also be helpful to choose a study site that was more heterogeneous, with bromeliads that may have access to a larger diversity of resources. Another factor that could be accounted for in future studies would be to differentiate between protists that are photosynthetic and those that are detritivores, and compare them to the abundances of their food source.

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TABLE 1. Results from a multiple regression analysis of indices, S, E, H’, and N, all considered separately, versus canopy density, detritus mass, water volume, and tank diameter. P-values indicate that the four independents (canopy density, detritus mass, water volume, and tank diameter), were not significantly correlated to S, E, H’, and N.

	DF	F-value	R^2	P-value
S	4	0.208	0.02	0.9326
E	4	0.343	0.04	0.8475
H'	4	0.349	0.04	0.8436
N	4	1.311	0.122	0.2811

TABLE 2. T-test results showing the comparison of bromeliads that contained inflorescences, and bromeliads that did not contain inflorescences and their influence on diversity (H’), species richness (S), number of individuals (N), and evenness (E). The results indicate that inflorescences had no significant effect on these four indices (P>0.05).

	Mean H'	Std. Error	Mean S	Std. Error	Mean N	Std. Error	Mean E	Std. Error
With Inflorescence	1.43	0.08	7.2	0.44	112.1	18.4	0.73	0.03
Without Inflorescence	1.33	0.08	7	0.35	123.2	18.1	0.69	0.04
T value (P)	-0.8 (0.42)		-0.46 (0.65)		0.40 (0.70)		-0.92 (0.36)	

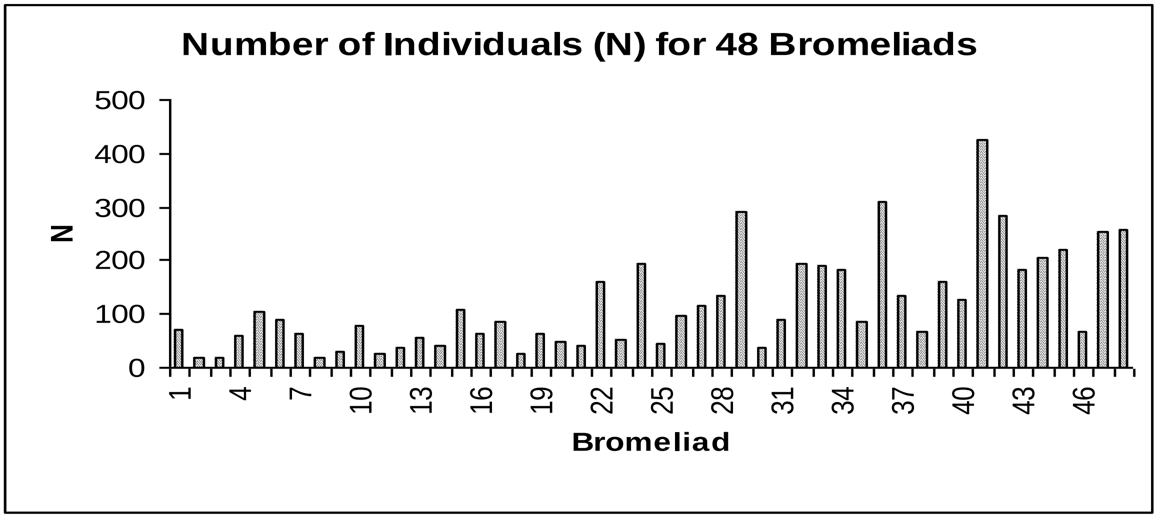

FIGURE 1. Number of individuals (N) of protists for the 48 bromeliads sampled. These numbers range from 17 – 424.

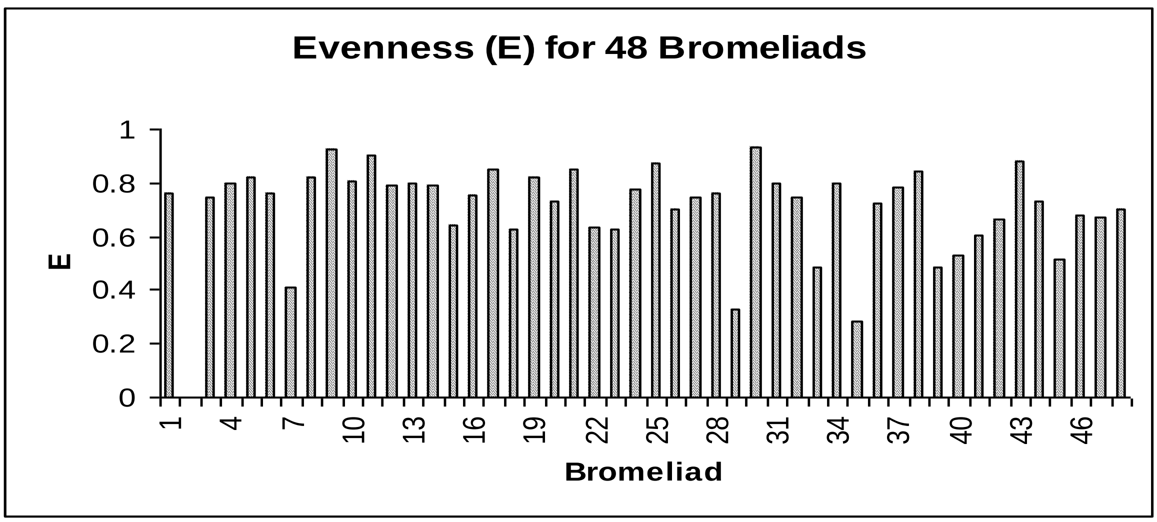

FIGURE 2. Evenness (E) of protist diversity found for the 48 bromeliads sampled. The range is between 0 – 0.93.

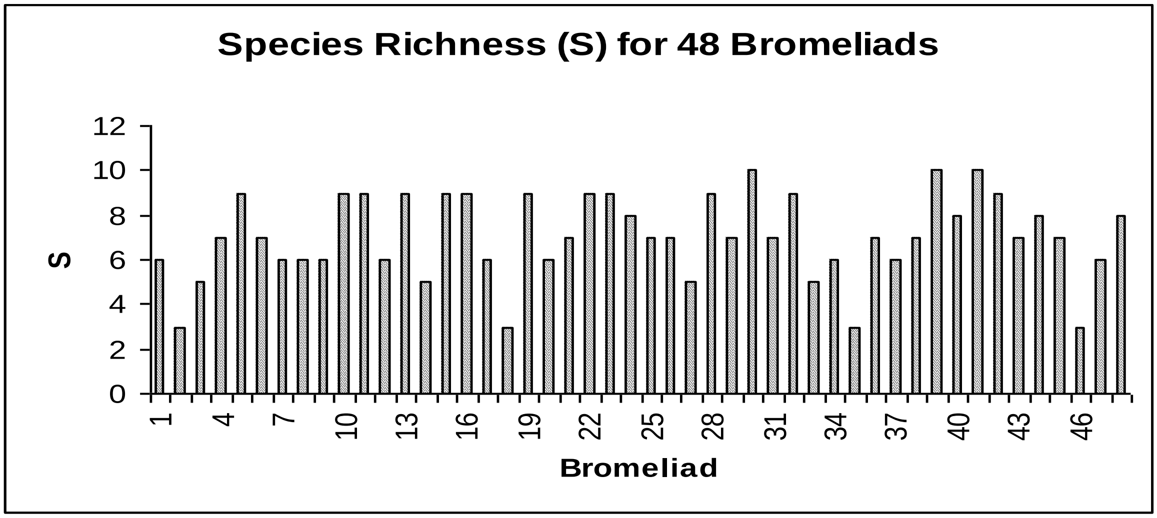

FIGURE 3. Species richness (S) found for the 48 bromeliads sampled. The range is from 3 – 10.

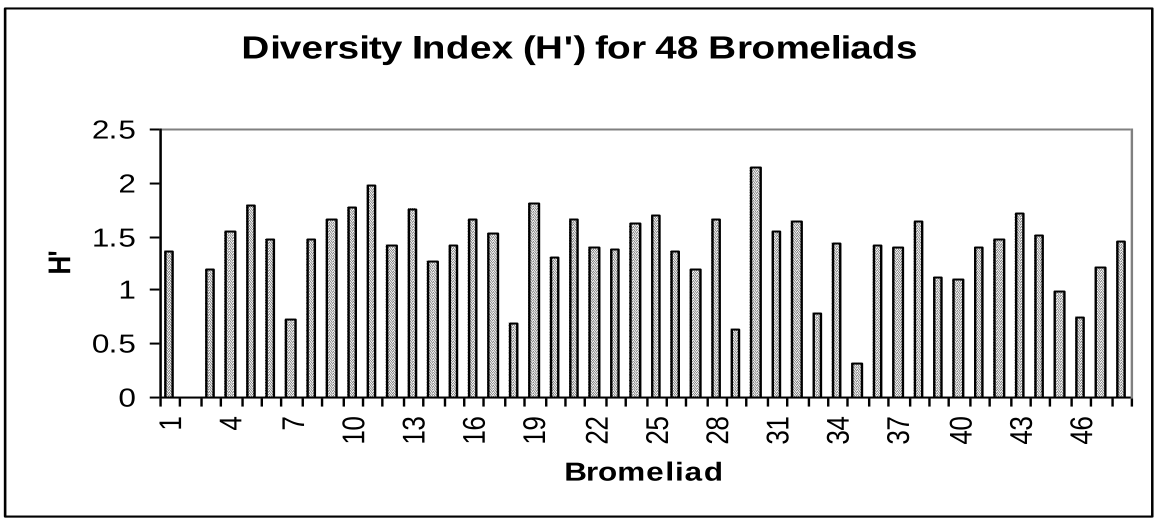

FIGURE 4. Diversity (H’) for each of the 48 bromeliads sampled. The range is between 0.31 – 2.15.