Observational Analysis of Insect Diversity, Richness, and Abundance on the fungus, *Auricularia delicata* (Basiodiomycata)

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ABSTRACT

Fungi are important to ecosystems because of their ability to release nutrients back into the environment and their relationships with insects. This study determined the diversity and richness of insects attracted to *Auricularia delicata* and related it to external conditions. Eleven colonies of *Auricularia delicata* were located near the Estación Biológica de Monteverde and observed to determine the morphospecies and abundance of insects present. The results illustrated that insect abundance significantly increased with species diversity ($R_S = 0.778$, $P = 0.0001$.) Insect abundance significantly increased with colony surface area ($R_S = 0.659$, $P = 0.0371$) and number of fruiting bodies present in a colony ($R_S = 0.487$, $P = 0.0171$). Morphospecies richness significantly increased with surface area ($R_S = 0.693$, $P=0.0284$), and with insect density ($R_S = 0.802$, $P < 0.0001$). Diversity was compared to surface area and total number of fruiting bodies but was not found to be significant affected by either. This study indicates that important interactions take place between insects and *Auricularia delicata*.

RESUMEN

Los hongos son importantes para los ecosistemas debido a su habilidad para liberar nutrimentos de vuelta en el ambiente y a sus relaciones con los insectos. Este estudio determinó que la diversidad y riqueza de insectos atraídos a *Auricularia delicata* y relacionó esto a condiciones externas. Once colonias de *Auricularia delicata* se localizaron cerca de la Estación biológica de Monteverde y fueron observadas para determinar las morfoespecies y abundancia de insectos presentes. Los resultados ilustran que la abundancia de insectos aumentó significativamente con la diversidad de especies ($R_S = 0.778$, $P = 0.0001$). También se encontró que la abundancia de insectos incrementó significativamente con el área de la superficie de la colonia ($R_S = 0.693$, $P = 0.0371$) y con el número de cuerpos fructíferos presentes en la colonia ($R_S = 0.487$, $P = 0.017$). La riqueza de morfoespecies incrementó significativamente con el área de la superficie ($R_S = 0.693$, $P = 0.0284$) con respecto a la diversidad de especies ($R_S = 0.802$, $P < 0.0001$). La diversidad estuvo relacionada con el área de la superficie y con el total de cuerpos fructíferos y se encontró que no es significativa. Este estudio indica que hay interacciones importantes que se dan entre insectos y *Auricularia delicata*.

INTRODUCTION

Approximately 72,000 species of fungi have been described, out of a possible 1.5 to 9.9 million species total (Gilbert and Sousa 2002.) With so many undescribed fungi, and limited knowledge about many of the species, studies are needed to further our understanding of this important group of organisms.

The cycling of nutrients is very important in the tropics because nutrients follow strict pathways in order to be quickly reintroduced into the ecosystem (Mata 1999). Some fungi provide plants with nitrogen directly but most fungi are decomposers, essential in making nutrients available to other organisms. They ensure that leaf litter, fallen limbs, and even man-made objects such as leather, cloth, plastic, and rubber do not build up

(Mata1999.) Besides these processes, fungi interact with other organisms, namely insects. It is known that several families of insects feed on fungi (Daly et al. 1998.) Insects are also extremely important medically, economically, and ecologically (Zumbado 1999.) Without fungi to supply nutrients and their interactions with insects, our world could not exist. However, with not much known about fungi, they could be ignored when political, economic or ecological decisions are made, which would not only upset nutrient cycles, but also food webs and even biomes.

Fungi are categorized into four different groups, based on reproductive structures. Basiodiomycata are characterized by microscopic structures called basidia that produce the spores, mostly in groups of fours, outside the basidia structure. Within Basidiomycata, there is the order Auriculariales. This order has 6 families with 30 genera (Alexopoulos et al 1996) including the family Auriculariaceae and the species *Auricularia delicata.*

A. delicata are glutinous mushrooms generally 2.0-6.5 cm wide and 0.5-4.5 cm long, exhibiting a light brown upper side and a net-like underside that is an identifying characteristic of this species (Mata 1999.) This species is edible, and there is evidence that larva of *Decameria* (Hymenoptera) feed on it (Hanson & Gauld 2000.) It is not known if other insect species are attracted to *A. delicata*, or the nature of these interactions.

Preliminary observations indicated that a wide range of insects would be attracted to *A. delicata*. The objective of this study was to observe *A. delicata* and determine the morphospecies richness and diversity of insects that visit it. Relationships between insect abundance, morphospecies richness, colony surface area, number of fruiting bodies present in a colony, time of day and weather conditions were determined.

MATERIALS AND METHODS

The study site was conducted in the forest near the Estación Biológica de Monteverde, Monteverde, Costa Rica. The study was conducted between June 18, 2004 and August 8, 2004. Eleven colonies of *A. delicata* were located within the altitude range of 1510 to 1555 meters. A colony of *A. delicata* was defined as any number of fruiting bodies located on a single substrate. Most colonies were located close to the Quebrada Maquina, and found on a variety of wooden substrates including fallen branches, rotting stumps, fallen trees, and cut logs. Colonies were observed to record the number of morphospecies and abundance of insects located on the fungi. Insects were identified to morphospecies by physical characteristics. Colony observations were taken in two intervals of fifteen minutes. Observations were taken on different days to vary environmental conditions and time of day.

Weather was categorized into three divisions: sunny with some cloud cover, overcast and raining conditions. No more than one observation at a particular colony was taken per day. Times of day were categorized into morning (5:25 am-12 pm), afternoon (12 pm-3:45 pm) and evening (3:45 pm-5:30 pm). Twenty-five total observations were taken, amounting to 12.5 hours, each colony had 2-3 observations, with the range of individual fruiting bodies (2-20) observed per observation.

Shannon-Weiner diversity indices (H') were used to compare insect diversity between colonies. Effects of weather and times of day were determined using Kruskal-

Wallis tests. Spearman rank correlations determined significance between morphospecies, insect abundance, surface area, total number of fruiting bodies, and density of insects per fruiting body. Simple bivariate regressions illustrated the variables tested with Spearman rank correlations. Histograms were used to show the distribution of insects, species, and H'. Box plots were used to illustrate the difference between times of day.

RESULTS

A total of 80 morphospecies were identified. The abundance of each morphospecies ranged from 1-62 individuals (average of six, standard deviation of 12.15). Each colony contained a range of 2-23 morphospecies (average 11, standard deviation of 7.14) and a range of 2-162 individuals. For each half hour observation period, 0-17 insect morphospecies were observed (average of 5, standard deviation of 4), while 0-84 individuals were observed per observation.

The number of morphospecies was significantly positively correlated with number of insects R_S=0.778, P=0.0001 (Figure 1). The number of insects was also significantly positively correlated with the number fruiting bodies R_S= 0.487, P=0.0171 (Figure 2). Number of individuals increased with increasing surface area R_S==0.659, P=0.0371(Figure 3). A similar trend occurred with surface area and species richness, R_S=0.693, P=0.0284 (Figure 4).

The number of insect species increased significantly in relation to the density of insects per fruiting bodies R_S =0.802, P<0.0001(Figure 5). Density of insects per fruiting bodies was not statistically significant related to colony surface area.

Shannon Weiner diversity indices ranged from H'= 0.301 (colony 1) to H' = 1.048 (colony 4) with an average of H' = 0.754 (Table 1). Site 11 had a significantly higher diversity (H' = 0.774) than site 12 (H' = 0.699)(t-value = 2.369, P = 0.02) (Table 2). Site two had a significantly higher diversity (H' = 1.042) than site three (H' = 0.852) (t-value = 2.134, P = 0.05). Site four had a significantly higher diversity (H' = 1.048) than site seven (H' = 0.735) (t-value = 6.248, P <0.0001). Site one had a significantly higher diversity (H' = 0.301) than site 11 (H' = 0.774) (t-value = -14.954, P < 0.0001). Site four had a significantly higher diversity (H' = 1.048) than site seven (H' = 0.735) (t-value = 4.362, P < 0.0001).

Weather and time of day were not found to be statistically significant in regards to insect abundance, species diversity or insect density. Species abundance was very similar for morning and afternoon.

DISCUSSION

This study found that as insect abundance on *A. delicata* increased, the higher the morphospecies diversity became. There was a very strong trend for morphospecies richness to increase with density of insects per fruiting body. It was also found that total number of fruiting bodies directly affects morphospecies richness and insect abundance.

The ranges show that there was wide variance between the abundance of morphospecies and the numbers recorded per colony. The positive trends of abundance when compared to surface area and total number of fruiting bodies and diversity to surface area were interesting. If the insects have a negative affect on the fungi, it would be in *A. delicata's* best interest to not grow in large colonies or on large substrate. Therefore, insects could be positive for the fungi, perhaps being a spore disperser. However, colonies were noted to contain larvae within the colony, with the larvae believed to be eating through the fungi. It was also noted that flies extended a white body part in the vicinity of their mouth and poked at the fungi at top and underside. This indicates the insects could have a negative affect on the fungi, but perhaps the benefits of the insects were greater than the cost. There was a strong trend to have diversity of species increase with density of insects per fruiting body. Certain flies displayed by flapping their wings and moving towards other flies, believed to be a territorial behavior. However, this could lower abundance of certain morphospecies that limit diversity, allowing more morphospecies to be present.

It was found that some colonies, especially after rains, would lose some individuals. Before some fungi fell off the site, for an unknown reason, they became gelatinous and changed to a darker color or became more translucent which could be a sign of natural aging. A study could be done to determine the lifespan of colonies and what it is dependent on. In contrast, certain sites contained a high proportion of dried up individuals, which may be related to the sites' ability to hold water. Studies could be done to quantify the health of colonies and relate it to insect diversity and abundance. Colony health could be related to humidity and insects may be observed to prefer "healthy" over "unhealthy" individuals.

A study using insect traps to determine if insects visit *A. delicata* at night would be interesting. It has been proven that different morphospecies are active during the night (Rosenthal, 2004). Although the diversity and richness of insects has been found, there are no studies that investigate how they are interacting with the fungi. The mechanism of spore dispersal must be investigated, as from the observations taken insects seem to prefer the bottom of the fruiting body, where the spores are located, over the top.

This study indicates that there are strong interactions between insects and *A. delicata* and external factors affect insect presence. Insect presence affect other organisms nearby and affect the overall food web if that region.

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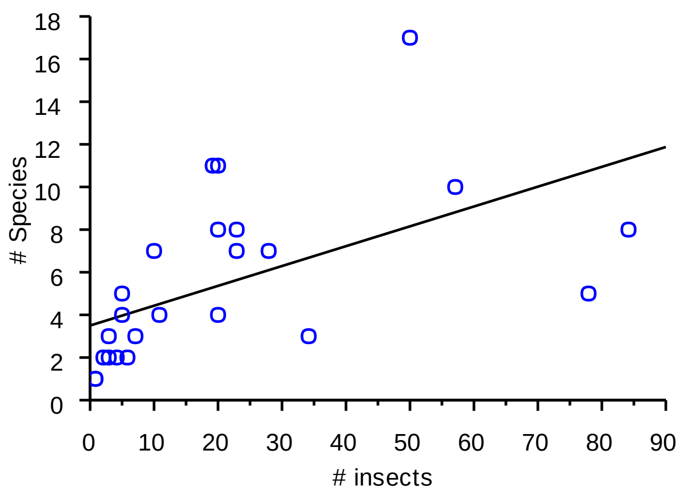

Figure 1: Positive relationship between the number of morphospecies of insects on 11 colonies of *A. delicata* and the number of individuals during 25 observations ($R_S = 0.778$, P = O.000) (Monteverde, Costa Rica)

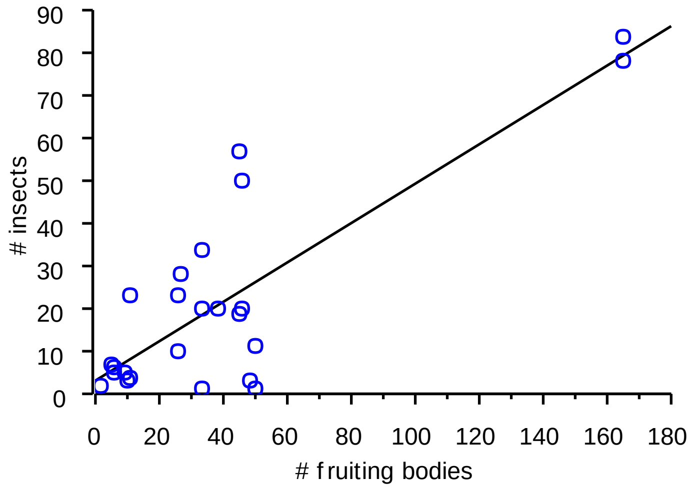

Figure 2: Positive relationship between number of fruiting bodies and number of insects on 11 colonies of *A. delicata* in Monteverde, Costa Rica (R_S =0.487, P= 0.0171)

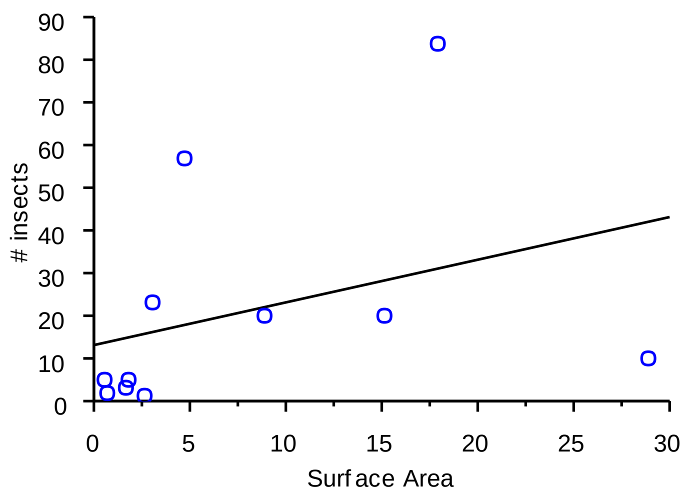

Figure 3: Positive correlation between surface area and number of insects on 11 colonies of *A. delicata* in Monteverde, Costa Rica (R_S = 0.659, P= 0.0371)

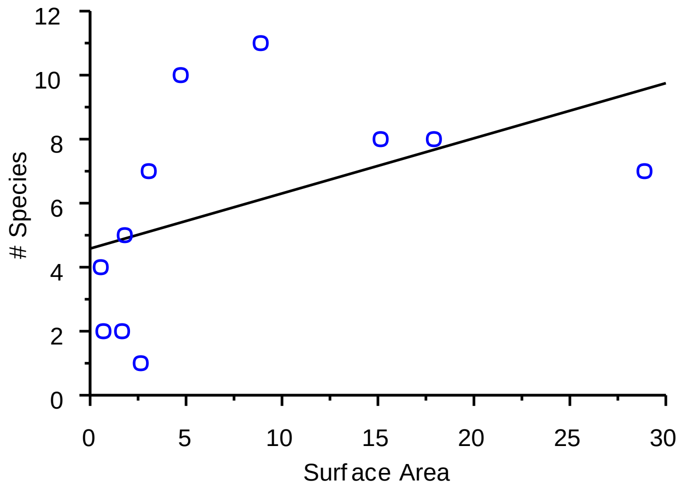

Figure 4: Positive correlation between surface area and number of species on 11 colonies of *A. delicata* in Monteverde, Costa Rica (R_S = 0.693, P= 0.0284)

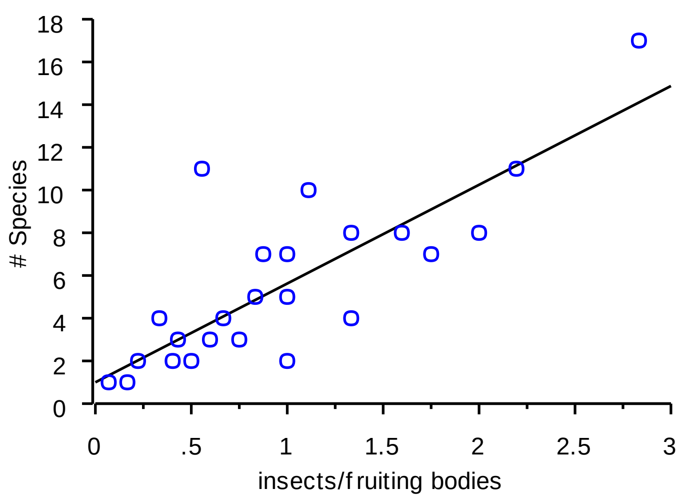

Figure 5:Positive correlation between density (insects per fruiting bodies) and number of species taken from 25 observations and 11 colonies of *A. delicata* in Monteverde, Costa Rica (R_S = 0.802, P <0.0001)

Table 1:Shannon-Weiner indices of diversity calculated for 11 colonies of *A. delicata* in Monteverde, Costa Rica. Average of H' were calculated

Colony	H'
site 1	0.301
site 2	1.042
site 3	0.852
site 4	1.048
site 5	1.003
site 7	0.735
site 8	0.628
site 9	0.719
site 10	0.493
site 11	0.774
site 12	0.699
Avg	0.754

Table 2: Unpaired t-test used to compare the 11 different colonies H' (Table 1) to find significant difference between diversity of the colonies of *A. delicata* in Monteverde, Costa Rica

comparisons	t-value	variance	significance
site 11 & 12	2.369	162	0.02
site 9& 10	1.723	52.863	X
site 7& 8	1.116	29.271	X
site 4& 5	0.516	102.967	X
site 2 &3	2.134	133.079	0.05
site 7& 11	-0.512	26.11	X
site 1& 11	-14.954	162	<.001
site 4 & 7	4.362	11.812	<.001