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ABSTRACT

Costa Rica has high moth (Lepidoptera) diversity, with relatively little known about its distribution (Hanson 2000). Insects tend to decrease in richness and abundance along an altitudinal gradient (Brehm and Fiedler 2003). Lepidopterans are important indicators of environmental health, important herbivores, vital prey species, and a large draw for the country's main source of income, ecotourists. The purpose of this study was to compare moth diversity and abundance at varying altitudes. Moths were trapped using an ultra violet light and a sheet at three different altitudes (1530 m, 1639 m, and 1759 m) over six nights between July 26th and August 2nd, 2004, in the forest behind the Estación Biológica, Monteverde, Costa Rica. One hundred and seventy one moths were caught, representing 76 morphospecies. The lowest elevation had the greatest species diversity as well as the greatest total number of moths (H'=1.553, 69 moths), followed by the highest elevation (H'=1.528, 67 moths). Both the lowest diversity (H'=1.318) and the lowest number of moth individuals (35 moths) were collected at the middle elevation. The diversity was significantly different between the lowest and the middle elevation ($t=3.91$, $p=< 0.002$) and between the middle and the highest elevation ($t=3.33$, $p= < 0.002$) and was not significantly different between the lowest and highest elevation. The largest amount of species overlap was found between the lowest and the middle elevations ($J= 0.60$). The study did not support the hypothesis that there would be less diversity and abundance of moths as elevation increased. It does, however, seem to indicate that there is a difference in the species found at each elevation. Additionally, the study seems to indicate that there were factors at the middle elevation that reduced the moth abundance and diversity relative to the highest and lowest elevations. Further studies are necessary to determine whether or not the distribution trends observed are specific to the sites, time of year, or sampling nights during this study.

RESUMEN

Costa Rica tiene una alta diversidad de mariposas nocturnas (Lepidoptera), con relativamente poco conocido acerca de su distribución. Los insectos tienden a disminuir en riqueza y abundancia a lo largo de un gradiente altitudinal son. Los lepidópteros son indicadores importantes de la salud del ambiente, herbívoros importantes, especies presa vitals, y un gran atractivo para la principal fuente de divisas del país, ecoturistas. El propósito de este estudio fue comparar la diversidad y abundancia de mariposas nocturnas en varias altitudes. Las mariposas se atraparon usando una luz ultravioleta y una sábana en tres diferentes elevaciones (1530 m, 1639 m, y 1759 m) durante seis noches entre el 26 de Julio y el 2 de agosto del 2004, en el bosque detrás de la Estación biológica de Monteverde, Costa Rica. Se capturó ciento setenta y un mariposas nocturnas, representando 76 morfoespecies, 64% de las cuales fueron únicas a la elevación en que fueron colectadas. La elevación más baja tuvo la mayor diversidad de especies así como el mayor número de mariposas nocturnas (H'=1.553, 69 mariposas nocturnas), seguida de la elevación más alta (H'=1.528, 67 mariposas nocturnas). Tanto la diversidad más baja como el número más bajo de mariposas nocturnas individuales (H'=1.318, 35 mariposas) fueron colectados en la elevación mediana. La diversidad fue significativamente diferente entre las elevaciones más baja y mediana ($t=3.91$, $p=< 0.002$) y entre las elevaciones mediana y más alta ($t=3.33$, $p= < 0.002$). El mayor traslape de especies se encontró entre las elevaciones más baja y la mediana ($J= 0.60$). El estudio no apoya la hipótesis de que habría menos diversidad y abundancia de mariposas nocturnas en tanto la elevación aumentaba. Más bien, el estudio parece indicar que hubo factores en la elevación mediana que redujeron la abundancia y diversidad de mariposas nocturnas en relación con las elevacions más alta y la más baja. Se necesita estudios futuros para determinar si las tendencies de distribución observadas son específicas para los lugares, época del ano, o para las noches de colecta durante este estudio.

INTRODUCTION

Costa Rica has tremendous diversity of moths and butterflies (O: Lepidoptera). The order Lepidoptera is estimated to contain around 13,500 species, most of which are moths in at least eighty families (Hanson 2000). It is well known that many nocturnal species of moths are attracted to light, especially in the ultra violet (UV) spectrum. One theory states that this is because the moths use distant points of light, such as stars or the moon, as reference points for navigating by keeping the light points at particular angles. Lights closer to the earth's surface disorient them and draw them in (Janzen 1983). It is suggested that the best way to catch nocturnal moths that are attracted to light is to set up a UV light in front of a sheet, which both reflects the light and is usable for collecting the specimens (Covell 1984). The distance from which moths are attracted to light is unknown, but it is speculated to be between 500 m and several kilometers (Janzen 1983).

It has been said that Lepidoptera are good indicators of general environmental health (Hanson 2000). Therefore, having a greater understanding of their typical distribution pattern is valuable for monitoring the health of both the Lepidoptera population and of its surrounding habitat. Lepidopteran species are also vital because they are a major draw for ecotourists in Costa Rica and are therefore economically important. Furthermore, in their larval stage they are one of the most important groups of plant-feeding animals as well as a critical food source for birds.

Relatively little is known about moth distribution patterns in Costa Rica (Hanson 2000), and there is a relative paucity of studies conducted on insect distributions across altitudinal gradients, especially in the tropics (Brehm and Fiedler 2003). This study used UV lights placed in the understory to compare moth diversity and abundance between 1530 m and 1760 m at Monteverde. It was hypothesized that both the number of individuals and the number of species would decrease with increased elevation.

MATERIALS AND METHODS

This study was conducted on the pacific slope of the Tilarán mountain range in Monteverde, Costa Rica, within the lower montane rainforest life zone (Haber 2000). This life zone is characterized by a mean annual temperature of 18.8º C, with a minimum and maximum annual temperature of 9 º C and 27 º C respectively, and with 1.7-3.2m/year of annual precipitation. The forest receives much of its moisture from cloud cover, resulting in an additional 25% of water/year in mist (Clark et al. 2000). Data were collected in the forest along the principal trails behind the Estación Biológica, at 1530 m, 1630m, and 1759 m. The individual sampling sites were chosen for similar forest canopy and tree density conditions and were placed at approximately 10 m from the trail. Data were collected over six nights between July 26th and August 2nd, 2004. Each elevation was sampled five times.

Data collection began every night after sundown, starting at 6:30pm, at the highest site to be sampled. Upon arrival at the site, a white sheet (1.4 m x 2.4 m) was positioned next to a UV light with a long cylindrical bulb of about 14 cm. The sheet was hung over a taught rope about 2 m from the ground and its corners were tied down. After recording the elevation and time, the UV light was turned on and then clipped with a carabiner onto another rope that hung it such that it was touching the sheet. Twenty minutes later the next sampling site was started in the same manner at the next elevation, followed by the third. After 80 min. had passed, the moths present at the 1st site were collected and placed into a net. Moths were collected off the sheet until no moths were left on the sheet or until six minutes had elapsed. The samples were taken back to the station where specimens were pinned and separated into morphospecies.

Species diversities were compared using the Shannon-Weiner diversity index and subsequent modified t-tests. The Jaccard similarity index was also used to compare overlap in morphospecies between the three elevations.

RESULTS

A total of 171 moths were collected from the three elevations, representing 76 morphospecies. Of the 69 species collected at the lowest sampling elevation (1530 m), 20 species were unique to the lowest elevation, 20 species of the 67 species collected at the highest elevation (1759m) were unique to the highest elevation, and 9 species out of 35 species collected at the middle elevation (1630m) were unique to the middle elevation (Table 1). In total, 49 species out of 76 (64%) of the species collected were unique to their respective elevations. The most common morphospecies was species T, with 14 individuals.

The lowest elevation had the highest species diversity (H'=1.553), followed by the highest elevation (H'=1.528) Table 2. The middle elevation had the lowest diversity (H'=1.318). The subsequent T-tests comparing the richness of each of the elevations showed that there was a significant difference between the species richness of the lowest and middle elevations (t=3.91, $p < 0.002$), and between the middle and highest elevations (t=3.33, $p < 0.002$) Table 2. The t-tests showed that no significant difference was found in species diversity between the lower and higher elevations.

The Jaccard similarity tests were run to determine the diversity overlap between each of the elevations sampled. The greatest species diversity overlap was found between the lowest and middle elevations (= 0.60), and the least overlap occurred between the highest and middle sites (= 0.55) Table 2. The lowest and highest elevations had intermediate overlap (=0.57).

DISCUSSION

The data collected did not support the hypothesis that there would be a decrease in diversity and abundance of moths as elevation increased. Instead, the data exhibited a bimodal pattern, with the highest and lowest sites exhibiting the highest species diversity, abundance, and richness. Because of the small number of samples taken, it is likely that this pattern resulted from environmental factors other than elevation, which is ponderous considering the study was performed within one Holdridge life zone, where environmental factors should be relatively similar.

There was, however, according to the Jaccard similarity tests, more variation in the species present at each of the sites than one might expect considering the relatively small altitudinal spread and distance between the elevations sampled. At least 40% of the species found were only present at one elevation. This pattern may indicate that, despite the fact that all sample sites were located within one life zone, specialization is occurring along relatively small altitudinal gradients, or is perhaps a result of some other environmental factor. These differences are important because they may indicate that Holdridge life zones are not sufficiently precise in their habitat delineation for comprehensive conservation planning. The amount of species overlap also indicates that the distances that moths travel to light are shorter than is currently hypothesized (500 m to several km) because the sample sites in this study were less than 500m apart. It would be expected that a change in elevation that aligns with a change in Holdridge life zones would result in even less species overlap.

Further studies should collect data over more nights and over more sample sites in order to determine what factors may have caused the distribution patterns of moths found in this study. A helpful future study would be one that examined distances from which moths can be attracted to light in order to dictate a better altitude and distance for placing sample sitess. Also, it would be interesting to find out if the direction the sheet faced had an effect on the moths collected, assuming that the moths are indeed using the lights for navigational purposes.

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Table 1: Numbers of moth morphospecies and individuals collected at each site. Those species names that are in bold were unique to the highest elevation, those starred were unique to the middle elevation, and those that are underlined were unique to the lowest elevation.

Species	SITE 3 (1759 m)	SITE 2 (1630 m)	SITE 1 (1530 m)	**Species**	SITE 3 (1759 m)	SITE 2 (1630 m)	SITE 1 (1530 m)
WDWPN	2	1	1	LL	1	1	2
SPG	2	2	0	MM	0	0	3
A	2	0	0	**NN**	1	0	0
B	1	0	1	OO	3	0	1
C	8	0	1	PP	0	1	1
D	1	0	0	QQ*	0	3	0
E	2	0	2	RR*	0	1	0
F	3	1	0	SS	0	1	1
G	4	0	1	TT*	0	1	0
H	2	0	0	UU*	0	1	0
I	1	0	0	VV	0	0	0
J	4	0	0	WW*	0	1	0
K	1	0	1	XX	0	0	2
L	1	0	0	YY	0	1	3
M	1	0	0	ZZ	0	1	2
N	1	0	0	AAA	0	0	1
O	1	0	0	BBB	0	0	1
P	1	0	0	CCC	0	0	1
Q	1	0	0	DDD	0	0	1
R	1	0	1	EEE	0	0	4
S	1	0	0	FFF	0	0	1
T	3	6	5	GGG*	0	2	0
U	1	0	0	HHH*	0	1	0
V	1	0	0	III	0	1	1
W	1	1	3	JJJ*	0	1	0
X	1	0	0	KKK	0	0	2
Y	2	1	5	LLL	0	0	4
Z	1	0	1	MMM	1	0	1
AA	1	0	0	NNN	0	0	1
BB	1	0	0	OOO	0	0	1
CC	1	0	1	PPP	0	0	1
DD	1	0	0	QQQ	0	0	1
EE	1	2	1	RRR	0	0	1
FF*	0	1	0	SSS	0	0	1
GG	1	0	2	TTT	0	0	1
HH	1	1	0	UUU	0	0	1
II	1	1	0	VVV	0	0	1
JJ	1	0	0	WWW	0	0	1
KK	1	1	0	XXX	0	0	1
				Total	**67**	**35**	**69**

Table 2. Moth Shannon-Weiner diversity indices and the subsequent results of the T-test diversity composition and Jaccard diversity overlap comparisons between each elevation. Information is offset after T-Values in order to indicate that it is a comparison between the elevations in the row above and below.

Site/Comparison	H'	t	V	P (P value)	Jaccard Overlap
Lowest (1530m)	1.55				
Lowest vs. Middle		3.91	66.27	< 0.002	0.60 (most)
Middle (1630m)	1.32				
Middle vs. Highest		3.33	74.75	< 0.002	0.55 (least)
Highest (1759m)	1.53				
Highest vs. Lowest		0.49	132.79	Not Significant	0.57 (middle)