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Population Changes of Moths (Insecta: Lepidoptera) from Mt. Wolchul National Park, Jeollanam-do, Korea

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ABSTRACT: We investigated the moth fauna and monthly changes in moth populations at three sites - Dogapsa, Gyungpodae and Muwisa - in Mt. Wolchul National Park, Jeollanam-do, South Korea. From February to October, 2006, we collected a total of 1677 individuals comprising 348 species in 14 families. Monthly changes in the abundance of species and individuals showed an M-shaped pattern, with the highest peak in June and a second high peak in August. The diversity of the three dominant families (Noctuidae, Geometridae and Pyralidae) at the three sites varied, possibly due to differences in vegetation and other environmental factors. Diversity at Dogapsa was relatively higher than Gyungpodae and Muwisa, but, the fauna at Dogapsa more closely resembled Muwisa than Gyungpodae. 28 species occurred at the same time in all three sites, included the families Geometridae (14 species), Noctuidae (9 species), Pyralidae (2 species), Arctiidae (1 species), Nolidae (1 species), and Limacodidae (1 species). The present study provided baseline information about biodiversity and phenological patterns of moth abundance and permitted evaluation of moth biodiversity as a monitoring tool for vegetation structure and environmental change.

Key words: Biodiversity, Korea, Moth, Population change

INTRODUCTION

Insects have a significant role in forest communities, affecting both primary production by their grazing activities and nutrient turnover by their roles as decomposers (Price 1997). Lepidopteran insects, or moths and butterflies, contribute to essential ecosystem processes such as pollination, herbivory and predator/prey interactions (Lowman 1982, Lomov et al. 2006). The better-known groups of Lepidoptera such as butterflies and day-flying moths have been advocated as preferred indicators of environmental change and impact. Butterflies are, however, not easily trapped and are often only poorly represented in forest environments (Kitching et al. 2000). Most families of moths are readily attracted to light traps that can provide a standard measure of the fauna flying in a particular period and place. Therefore, moths can be used as forest type indicators (Kitching et al. 2000, Summerville and Crist 2003, Fiedler and Schulze 2004). It was noted that the close relationship between moth fauna and forest types (e.g. primary, logged or advanced secondary forest) has implication in conservation biodiversity (Hilt and Fiedler 2006).

This study aims to provide baseline information about moth biodiversity in Mt. Wolchul National Park, Korea. Shin et al. (1989) reported 227 moth and butterfly species in 23 families, and Oh (1998) reported 78 species in 18 families in preliminary surveys at Mt. Wolchul. However, both previous studies were undertaken over short periods of time and with limited resources. We investigated the moth fauna of Mt. Wolchul more comprehensively through a year-long trapping program in three different localities. An additional aim of the study was to examine fluctuations in moth abundance in space and time. At a local level, abundance and richness of moths can vary depending on environmental factors such as vegetation and microclimate, as well as weather changes (Harrington et al. 2001). We investigated spatial and temporal changes in populations of moth species to assess the utility of moth groups as indicators of environmental changes.

MATERIALS AND METHODS

Study Site

The study area included three survey sites within Mt. Wolchul National Park. Mt. Wolchul, which spans two counties, Yeongam-gun and Gangjin-gun, Jeollanamdo, was designated as Korea's 20th national park in 1998. The three surveyed sites were spatially distinct from each other (maximum distance 4.4 km between Dogapsa and Gyungpodae; minimum distance 2.2 km between Muwisa and Dogapsa) (Fig. 1). The Dogapsa site (N 34° 44' E 126° 39', altitude 112 m a.s.l.) was covered with vines (e.g. *Pueraria thunbergiana*)

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Fig. 1. Map showing the study site, Mt. Wolchul. Dark triangles indicate the surveyed sites.

and low oak trees; whereas the Muwisa site (N 34° 44' E 126° 41', altitude 177 m) was mainly covered with trees such as *Camellia japonica* and *Quercus acuta*; and the Gyungpodae site (N 34° 44' E 126° 42' altitude 200m) was covered with mixed conifers and broad-leaves trees such as *Pinus densiflora*, *P. rigida*, *Quercus mongolica*, *Q. serrata*, and *Chamaecyparis obtusa*.

Sampling and Statistical Analysis

Moths were sampled from February to October, 2006 using a portable light trap (22 W circular black light operated by a 12 Volt battery, BioQuip, USA). Sampling was carried out once per month when weather and sampling conditions permitted (sampling was not conducted under conditions of heavy rain, strong wind and around the full moon). All collected specimens were identified to the species level and are now preserved at Mokpo National University.

Monthly fluctuations in the numbers of species and individuals were summed and Simpson's indices of heterogeneity and evenness were calculated using the software SDR-Ⅳ (Seaby and Henderson 2006). Magurran (2004) noted that Simpson's index of heterogeneity is one of the most meaningful and robust measures available, although this index is heavily weighted towards the most abundant species in the sample.

We used ANOVA to test for differences in the species composition of the dominant families from the three survey sites. In addition, species abundance and richness in the three largest families (Noctuidae, Geometridae and Pyralidae) were compared among sites using the Wilcoxon Signed Ranks test. All statistical analyses were conducted using the SPSS-PC program (SPSS 2003).

We also conducted cluster analysis for similarity of moth assemblages of the three survey sites in Mt. Wolchul, as well as three sites from neighboring areas, Mt. Seungdal, Muan and Mt. Duryun, Haenam, which are located approximately 53 km and 45 km away, respectively. We calculated average linkage using the Bray-Curtis method and PC-ORD software (McCune and Mefford 1999).

RESULTS

We collected a total of 1,677 individuals from 348 species in 14 families. A full check list can be obtained from the corresponding author. The family Noctuidae was the most species-rich group (134 species) on Mt. Wolchul, followed by Geometridae (85 species), and Pyralidae (62 species). For the number of individuals collected, Geometridae (591 individuals) was the most abundant family, followed by Noctuidae (589 individuals) and Pyralidae (299 individuals; Table 1).

Alpha diversity for each locality of Mt. Wolchul is shown in Table 2. We recorded the highest number of species at Gyungpodae, followed by Dogapsa and Muwisa. However heterogeneity was relatively higher at Dogapsa than Gyungpodae.

Monthly changes in the numbers of species and individuals showed an 'M'-shaped pattern, increasing from February to June, then sharply decreasing in July and increasing again after August (Fig. 2). Monthly changes in Simpson's heterogeneity indices also showed a clearly 'M'-shaped graph (Fig. 3), while monthly changes in Simpson's evenness index showed a flat line with the highest peak in August (Fig. 3). The rank abundance for three sites of Mt. Wolchul showed a strong right skew (Fig. 4).

Moth family diversity did not statistically differ among the three survey sites ($F_{2,39}$=0.396, P=0.676). However, the species abundance and richness for the three dominant families, Geometridae, Noctuidae and Pyralidae, showed a consistent pattern (Figs. 5 and 6): more species and individuals were recorded in Gyungpodae and Dogapsa than Muwisa, while the number of individuals from Dogapsa was statistically no different from that of Muwisa.

In the present study, 28 species (8.05% of the total recorded) occurred synchronously in all three sites, of which species in the family Geometridae were most numerous (14 species), followed by Noctuidae (9 species), Pyralidae (2 species), and Arctiidae, Nolidae, and Limacodidae (1 species each) (Table 3).

Table 1. Summary of the number of species and individuals of moths collected from Mt. Wolchul. Nomenclature follows Inoue et al. (1982).

Family	No. of species	No. of individuals
Arctiidae	9	26
Drepanidae	12	46
Epiplemidae	1	6
Geometridae	85	591
Ennominae	45	362
Larentiinae	14	47
Sterrhinae	13	140
Geometrinae	13	42
Lasiocampidae	2	2
Limacodidae	11	23
Lymantriidae	11	27
Noctuidae	134	589
Acontiinae	17	64
Acroniotinae	3	7
Amphipyrinae	24	78
Catocalinae	10	12
Chloephorinae	4	8
Cuculliinae	9	44
Hadeninae	10	88
Herminiinae	19	122
Hypeninae	4	10
Noctuinae	8	18
Ophiderinae	24	134
Plusiinae	1	2
Sarrothripinae	1	2
Nolidae	4	40
Notodontidae	10	16
Pyralidae	62	299
Sphingidae	4	4
Thyrididae	2	2
Zygaenidae	1	6
Total	348	1,677

Cluster analysis showed a strong similarity between the moth faunas at Dogapsa and Muwisa (Fig. 7). The Gyungpodae site had about 60% similarity with the other two sites. Overall, site location was the main factor used to combine the sites.

Table 2. Indices of heterogeneity and evenness from three sites from Mt. Wolchul

	Muwisa	Dogapsa	Gyungpodae	Total
Number of species	116	200	201	347
Simpson's D	47.16	71.54	70.58	91.82
Berger-Parker dominance	0.06	0.05	0.07	0.04
Fisher's alpha	61.07	103.3	92.79	132.9
Simpson's E	0.41	0.36	0.35	0.26

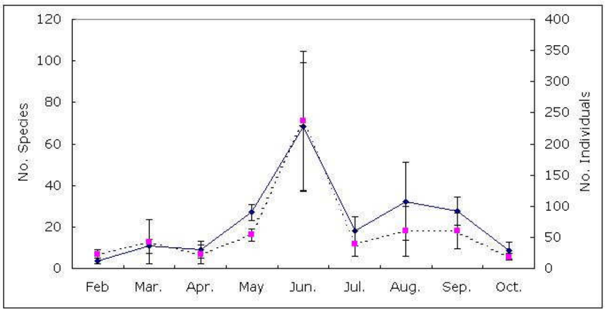

Fig. 2. Mean number of species (± SD, solid line) and individuals (± SD, broken line) in Mt. Wolchul by month.

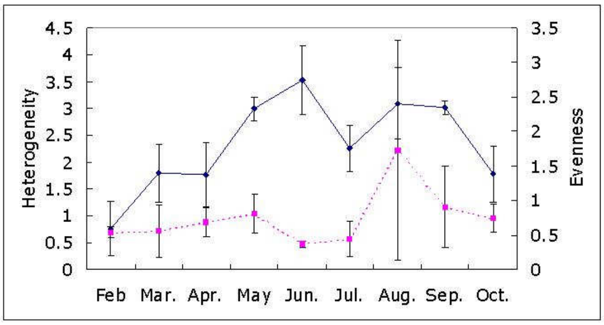

Fig. 3. Mean Simpson's heterogeneity index (± SD, solid line) and evenness index (± SD, broken line) in Mt. Wolchul by month.

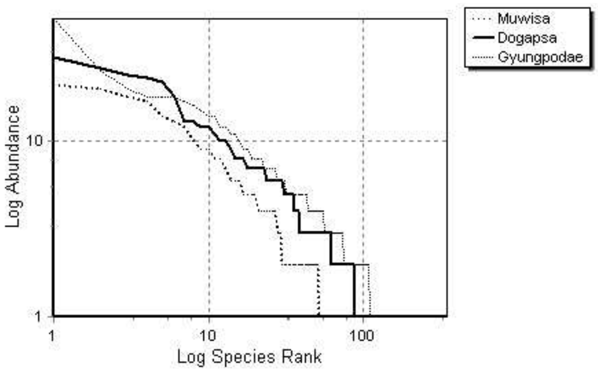

Fig. 4. Rank-abundance graph of moths captured from Mt. Wolchul.

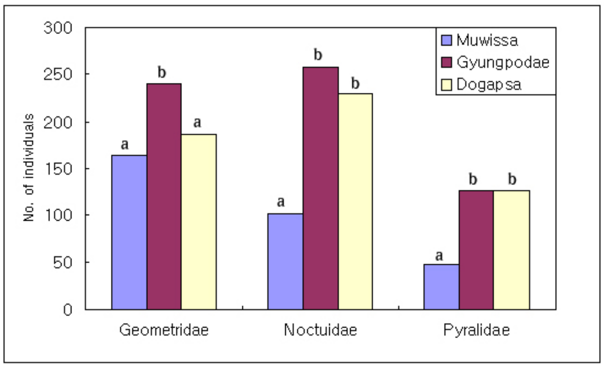

Fig. 5. Wilcoxon signed rank test of number of individuals for three sites on Mt. Wolchul. Bars with the same letters did not differ significantly (P>0.05).

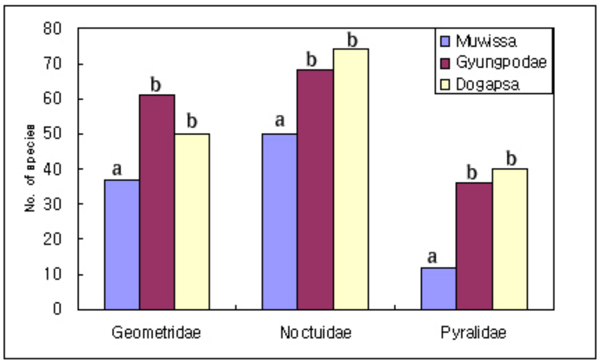

Fig. 6. Wilcoxon signed rank test of number of species for three sites on Mt. Wolchul. Bars with the same letters did not differ significantly (P>0.05).

Table 3. Synchronized species at three survey sites of Mt. Wolchul

Family	Species	Flight period	No. Individuals			
			WC1[1]	WC2[2]	WC3[3]	Total
Arctiidae	*Miltochrista aberrans*	Jun	1	1	2	4
Geometridae	*Agriopis dira*	Feb, Mar	26	11	20	57
	Alcis angulifera	May	4	14	3	21
	Descoreba simplex	Mar	1	2	6	9
	Nothomiza aureolaria	Apr	1	7	13	21
	Pareclipsis gracilis	Apr, May	6	8	4	18
	Protoboarmia simpliciaria	May	3	1	5	9
	Synegia hadassa	Jun, Jul	22	12	18	52
	Synegia limitatoides	Jun	24	1	17	42
	Comibaena amoenaria	Jun	1	6	5	12
	Ecliptopera umbrosaria	Sep	1	4	1	6
	Idiotephria evanescens	Apr	8	5	4	17
	Idaea biselata	Jun	13	10	5	28
	Scopula floslactata	Jun	7	25	8	40
	Scopula pudicaria	May	1	3	9	13
Limacodidae	*Latoia sinica*	Jun	5	3	1	9
Noctuidae	*Hoplodrina euryptera*	Sep	1	1	2	4
	Oligonyx vulnerata	Aug	1	3	2	6
	Conistra albipuncta	Feb	1	3	6	10
	Daseochaeta viridis	Oct	8	5	7	20
	Orthosia paromoea	Mar	12	50	1	63
	Hydrillodes morosa	May, Jul	18	6	12	36
	Gonepatica opalina	Jun	2	16	1	19
	Pangrapta flavomacula	Jun	7	14	2	23
	Pangrapta lunulata	May, Jun	6	11	9	26
Nolidae	*Meganola fumosa*	Jun	5	15	1	21
Pyralidae	*Bradina atopalis*	Jul	23	8	14	45
Pyralidae	*Endotricha portialis*	Jun	7	18	21	46

[1]Dogapsa, [2]Gyungpodae, [3]Muwisa.

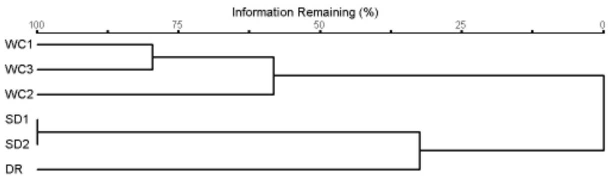

Fig. 7. Dendrogram showing percent similarity of moth assemblages. WC1: Dogapsa, WC2: Gyungpodae, WC3: Muwisa, SD1: Mt. Seungdal, South SD2: Mt. Seungdal, North, Duryun: Mt. Duryun, Haenam.

DISCUSSION

A total of 449 species of lepidopteran insects are distributed in the Mt. Wolchul region based on two previous studies (Shin et al. 1989, Oh 1998) and the present analysis, which together provide a more or less comprehensive faunal list for moths. Monthly changes in the numbers of species and individuals in Mt. Wolchul showed an 'M'-shaped pattern that was similar to those displayed in neighboring areas such as Mt. Seungdal, Muan (Park et al. 2007), and Mt. Duryun, Haenam (Choi and Na 2005). There seems to be a close relationship between climatic factors and individual abundance. Seasonal effects are a manifestation of historical selection pressures on life histories, which affect adult emergence schedules, generation times, and voltinism, while regional and local effects are caused by ecological constraints (Shapiro 1975, Summerville and Crist 2003). There was sudden decrease in number of individuals in July, the month with the highest precipitation (333.2 mm) and mean relative humidity (85.6%) at Mokpo (Korea Meteorological Agency 2006). It is reported that moths decrease in abundance during the wet season in tropical forest of Costa Rica (Boinski and Scott 1988). However, the dry season also negatively affects arthropod abundances through stress caused by food shortage or unsuitable conditions for development (Pinheiro et al. 2002 and references therein). This pattern of decrease in moth abundance could be viewed as an evolutionary adaptation to rainy spells in the Korean summer monsoon (Park et al. 2007).

Moth diversity differed among localities on Mt. Wolchul (Table 2). The total numbers of species collected at Dogapsa and Gyungpodae were almost identical, but the indices of heterogeneity were different. Differences in moth community composition are often caused by factors like local dispersal patterns, local climate or variation in host tree quality (Kitching et al. 2000, Zhang and Alfaro 2003). Moreover, many environmental factors change along successional gradients. In the absence of a forest canopy, microclimatic conditions are significantly altered, resulting in higher insolation, lower humidity, more rapid temperature decreases after sunset and generally, a higher variance in microclimatic parameters (Hilt and Fiedler 2006). In the present analysis, the three survey sites differed in plant species richness, vegetation structure and forest cover. Oh (1998) reported that plant species richness is highest at Gyungpodae (240 species), followed by Muwisa (206 species) and Dogapsa (199 species). Unfortunately the relationship between diversity of plant species and moths could not be examined in this study since the timing and sampling sites differed between the previous and the current analyses. However, we expect that the diversity of plant species and the extent of forest cover played major roles in determining the abundance and richness of moths in the study area.

Spatial synchrony means that multiple species occur in a set of distant areas (local or regional) at the same time. It seems that synchrony is common for many species, especially among vagile insects, but it remains unclear why synchronization does not occur among other species (Liebdold and Kamata 2000, Zhang and Alfaro 2003). Isolation of local communities caused by fragmentation and disturbance may force communities to depend on surrounding resources (Liebhold and Kamata 2000, Zhang and Alfaro 2003). Hypotheses for the causes of synchronization include the effects of common stochastic factors such as weather and the responses of shared predator populations (Raimondo et al. 2004 and references therein). Accordingly, Raimondo et al. (2004) reported that species sharing similar larval feeding strategies and morphologies against predators showed greater synchrony.

Moths have significant impacts as pest insects, feeding on foliage in forests and orchards (Zhang and Alfaro 2003). It seems that outbreak cycle of moth community is present at local-level based on empirical study (Zhang and Alfaro 2003). The link between spatial synchrony and regional environmental factors such as large-scale climatic fluctuations is called the 'Moran' effect, and pest outbreaks may be synchronized by a combination of a spatially autocorrelated Moran effect and a high dispersal rate (Liebhold and Kamata 2000, Zhang and Alfaro 2003). Researching synchronous phenomena at local as well as regional levels in the long-term may help in the development of strategies to prevent or minimize pest insect damage (Zhang and Alfaro 2003). In the present analysis, we found spatial synchrony in 28 moth species at three sites of Mt. Wolchul (Table 3). Species-rich families had more synchronous species: we collected 14 synchronous species in the family Geometridae and 9 synchronous species in the family Noctuidae. Future population data from these synchronous species, coupled with host plant and environmental data, should clarify the status and mechanism of synchrony in southwestern Korea.

Cluster analysis grouped geographically close localities together. Two sites on Mt. Seungdal shared almost identical moth communities, and two sites of Mt. Wolchul, Muwisa and Dogapsa displayed about 80 % similarity. Nonetheless, comparisons including species from the three dominant moth families demonstrated differences among sites (Fig. 7). Although Gyungpodae had larger numbers of the three dominant families than Dogapsa and Muwisa, the species composition of the three sites was different. Other factors such as the composition of plant species and habitat types may play a role in grouping sites.

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