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〈Short Communication〉

# Small-Scale Dynamics of Moths in Spring from a Coniferous Forest of Southwestern Korea

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**ABSTRACT**: The small-scale dynamic of moth populations in spring was examined in a coniferous forest of southwestern Korea. Moths were collected with one 22-watt light trap for 29 days in April 2007. A total of 450 individuals of 38 species in 5 families were collected. The most abundant species was an epiplemid moth, *Epiplema plagifera*. The relationship between these dominant moths and their host plants is briefly discussed. We also examined influence of weather factors on the number of species and individuals collected. Multiple regression analyses showed that the two-day temperature difference explained 18% of the variance in the number of species collected, while air and ground temperatures explained 51% of the variance in the log-transformed number of individuals collected. This suggests that temperature affects local population sizes in spring, but variables other than weather may also affect the diversity of local moth populations.

***Key words***: Moth, Population, Temperature, Weather

## INTRODUCTION

Moths are one of most diverse herbivorous insect radiations and are a useful group for ecological studies since their taxonomy and ecology are more accessible than those of other insects (Hill et al. 1995, Kitching et al. 2000). Light trapping is a useful sampling method for the study of diverse aspects of moth ecology such as diversity, abundance, migration times, population trends, development, phenology, and life history (Bailey and Horn 2007). The responses of herbivorous insects to global environmental changes are important to ecosystem functioning since they play an important role as a link between producers and consumers (Harrington et al. 2001). Warmer conditions may speed up many insect physiological processes because they are poikilothermic, leading to more rapid development, more generations per year, and poleward spread of insects (Parmesan et al. 1999, Harrington et al. 2001, van Asch and Visser 2007).

The purpose of the present study was to survey the richness and abundance of moth populations in spring on a local level using a light trap and to examine the relationship between moth collections and weather variables at the time of collection. Long-term sampling of moth populations would allow researchers to monitor the general trends in richness and abundance with environment change (e.g. Choi and Na 2005). However human resources, time and financial support are not always sufficient for long-term monitoring or large-scale bioinventory projects, so alternative measures are often favored (Basset et al. 2004, Goldstein 2004). In the present study, we sampled moths for almost the full month of April, to monitor the response of the first moth population of the year to the weather in the previous winter and spring.

## MATERIALS AND METHODS

The study was conducted in a coniferous forest in Mokpo National University campus (N 34° 54' 45", E 126° 26' 19"), Muan, Korea. We sampled moths daily using one 22-Watt ultraviolet light trap (BioQuip Co. USA) daily for 5 hours after sunset from April 2 to April 30, 2007, for a total of 145 collecting hours. The samples collected were identified to the species level and kept as voucher specimens at Mokpo National University, Korea.

Daily weather variables were monitored by a weather station about 30 m from the survey site with a HOBO data logger. Data recorded include: precipitation (mm), air temperature (℃), dew point (℃), relative humidity (%), wind speed (m/sec), ground temperature (℃) and solar radiation (w/m$^2$). Two-day temperature differences were calculated by subtracting the temperature of a given day from the temperature the next day. Day of the lunar cycle and cloud cover were also recorded to explore the influence of moon phase on moths. Cloud cover and duration of sunshine were obtained from the Korea Meteorological Administration (http://www.kma.go.kr).

Stepwise regression analysis was used to investigate the effects of weather variables on species richness and abundance of moth populations. All correlation and regression analyses were conducted

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using the SPSS-PC program (SPSS 2006).

## RESULTS AND DISCUSSION

### Weather and Moth Abundance

In April 2007, total precipitation was 8.01 mm and the highest daily rainfall was 4.20 mm on 16 April. Daily mean, maximum and minimum air temperatures ± SD were 11.22 ± 2.76℃, 16.92 ± 3.95℃ and 5.49 ± 3.14℃, respectively. Daily mean ± SD ground temperatures were 13.17 ± 1.87℃. Daily mean dew point was 4.66 ± 4.30℃. Daily mean ± SD relative humidity was 68.49 ± 11.63 %, mean wind speed was 1.10 ± 0.55 m/sec and mean solar radiation was 190.49 ± 72.22 $w/m^2$. The average two-day temperature difference was 0.14 ± 2.80℃.

A total of 450 individuals in 5 families and 38 species were collected and identified (Table 1). The families from which the most species were captured were Geometridae and Noctuidae, with 19 and 16 species, respectively, whereas only one species from each of the other three families (Epiplemidae, Notodontidae, and Pyralidae) was captured. The two dominant families, Geometridae and Noctuidae, had been also dominant in the area in sampling conducted throughout the year (e.g., Choi and Na 2005, Park et al. 2007). The most abundant species in our collection was an epiplemid moth, *Epiplema plagifera,* with 352 individuals captured. This moth is known to feed on *Vibrunum dilatatum* (Caprifiliaceae) (Sohn and Yen 2005) which is widespread around the survey area (Kim Hui personal communication). The second most commonly captured species was a geometrid moth, *Nothomiza aureolaria,* that primarily feeds on *Quercus* spp. (Fagaceae) (Teramoto 1993). The survey area was mainly dominated by *Pinus* species, but many moths were non-conifer feeding generalists (e.g., Geometridae: *Cleora insolita, Ectropis excellens, Idiotephria Amelia, Chloroclystis v-ata,* and Noctuidae: *Clavipalpula aurariae, Orthosia paromoea*) (Sugi 1987), that probably were able to live in the area due to the mixed vegetation of *Pinus* spp. and understory herbaceous plants. Among the geometrid species in the present study, only *Heterothera postalbida* is known to feed on conifers, although information about host plants was limited. The relationship between area of vegetation cover and moth appearance in spring was not strong in the present study. This finding was consistent with that of Usher and Keiller (1998), who found no difference in the moth communities of conifer, deciduous, and mixed-canopy forests, and suggested that herb-feeding moths are not affected by woodland canopy type. However, it is difficult to draw firm conclusions from the present study because of the short sampling period and single study site.

The numbers of individuals and species collected each day are shown in Fig. 1. The numbers of species were normally distributed (Kolmogorov-Smirnov test, Z = 0.12, $p > 0.05$), while the numbers of individuals were not (Z = 0.17, $p > 0.05$) and were therefore log-transformed prior to further statistical analyses. There was a strong correlation between the numbers of species and individuals collected in a day (Pearson correlation, $r = 0.74$, $p > 0.005$). There is often a close relationship between number of species collected, body mass and number of individuals (Siemann et al. 1999). Siemann et al. (1999 and references therein) summarized the causal factors affecting species richness and abundance in arthropods: (1) ecological processes such as local immigration and extinction, (2) high extinction rates of rarer species, and the dependence of the number of species in a group of interacting species (i.e., animals of similar size) on the number of individuals in the group and their abundance distribution. The detailed mechanism behind the close relationship between moth species richness and abundance is not known, and investigation of the underlying mechanism was beyond the scope of the present study.

### Relationships between Moth Species Richness and Abundance and Weather Variables

Stepwise regression analysis of the relationship between the number of species and weather variables detected a significant effect of only one weather variable (Table 2): the two-day temperature difference ($R_{adj}^2 = 0.18$, $F_{1,26} = 6.94$, $p > 0.05$). The regression analysis of the relationship between log-transformed number of individuals and weather variables detected significant effects of three weather variables: daily maximum temperature, daily average ground temperature and daily minimum temperature ($R_{adj}^2 = 0.51$, $F_{3,23} = 9.99$, $p > 0.001$). The moth trap catch appeared to be strongly influenced by daily temperature, which thus may serve as a predictor of moth appearance. Roy and Sparks (2000) noted the strong relationship between the first appearance of butterfly adults and temperature: warmer weather tended to produce earlier first and peak appearance. Choi (2003) showed the close relationship between temperature and butterfly diversity in southern Korea.

Moth catches in light traps are affected by various abiotic factors such as photoperiod, moonlight, temperature, wind speed, wind direction, and the illumination and functioning of the light trap (Manley 1993, Young 1997, Bailey and Horn 2007, Choi 2008). The appearance of moths, butterflies, and caterpillars in tropical regions is signaled by the combination of different weather variables. Stamp and Casey (1983) found that in a long, dry, hot period, a cool air pulse attracted enormous numbers of moths to light traps. In the present study, the temperature difference explained only 18% of the variance in the species richness. Battisti et al. (2005) and Buffo et al. (2007) found that temperature during winter (December to February) was the main factor affecting mortality of colonies of a pine

Table 1. A list of species collected in April, 2007 in a coniferous forest in Mokpo National University, Muan, Korea

| Family | Species | Korean name | Individuals |
|---|---|---|---|
| Epiplemidae | *Epiplema plagifera* | 검은띠쌍꼬리나방 | 352 |
| Geometridae | *Cleora insolita* | 그늘가지나방 | 1 |
| | *Descoreba simplex* | 큰빗줄가지나방 | 1 |
| | *Ectropis excellens* | 줄고운가지나방 | 1 |
| | *Eilicrinia paryula* | 노랑귀무늬가지나방 | 1 |
| | *Heterolocha aristonaria* | 뒷분홍가지나방 | 1 |
| | *Ninodes splendens* | 보라애기가지나방 | 1 |
| | *Nothomiza aureolaria* | 앞노랑가지나방 | 20 |
| | *Pareclipsis gracilis* | 끝짤룩가지나방 | 1 |
| | *Plagodis pulveraria* | 띠넓은가지나방 | 9 |
| | *Plesiomorpha punctilinearia* | 민무늬뾰족가지나방 | 3 |
| | *Xanthorhoe biriviata* | 흰줄물결자나방 | 1 |
| | *Xerodes albonotaria* | 점짤룩가지나방 | 7 |
| | *Jodis lactearia* | 두줄애기푸른자나방 | 1 |
| | *Chloroclystis v-ata* | 먹줄초록물결자나방 | 1 |
| | *Eupithecia clavifera* | 이른봄애기물결자나방 | 2 |
| | *Evecliptopera decurrens* | 흰그물물결자나방 | 1 |
| | *Heterothera postalbida* | 밑무늬물결자나방 | 2 |
| | *Idiotephria amelia* | 노랑무늬물결자나방 | 1 |
| | *Pylargosceles steganioides* | 끝무늬애기자나방 | 3 |
| Noctuidae | *Acronicta pulverosa* | 흰배저녁나방 | 4 |
| | *Athetis cinerascens* | 흑점밤나방 | 2 |
| | *Oligonyx vulnerata* | 끝갈색밤나방 | 1 |
| | *Gelastocera hallasana* | 한라애기밤나방 | 3 |
| | *Pseudoips sylpha* | 큰쌍줄푸른밤나방 | 1 |
| | *Clavipalpula aurariae* | 얼룩무늬밤나방 | 1 |
| | *Orthosia paromoea* | 곧은띠밤나방 | 1 |
| | *Panolis japonica* | 소나무붉은밤나방 | 1 |
| | *Perigrapha hoenei* | 선녀밤나방 | 1 |
| | *Hydrillodes morosa* | 넓은띠담흑수염나방 | 3 |
| | *Herita belinda* | 가운데흰수염나방 | 1 |
| | *Rhynchina cramboides* | 줄꼬마수염나방 | 1 |
| | *Schrankia separatalis* | 띠꼬마짤름나방 | 9 |
| | *Cerastis pallescens* | 엘자무늬밤나방 | 7 |
| | *Lygephila recta* | 목검은밤나방 | 1 |
| | Unidentified sp1 | | 1 |
| Notodontidae | *Neodrymonia marginalis* | 뾰족날개재주나방 | 1 |
| Pyralidae | *Pionea minnehaha* | 앞붉은들명나방 | 1 |

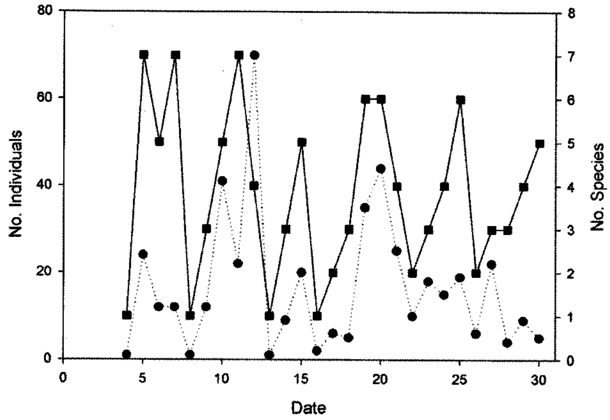

Fig. 1. Daily changes in the number of moth species (broken lines with circles) and individuals (solid lines with squares) in April 2007 in a coniferous forest in southwestern Korea.

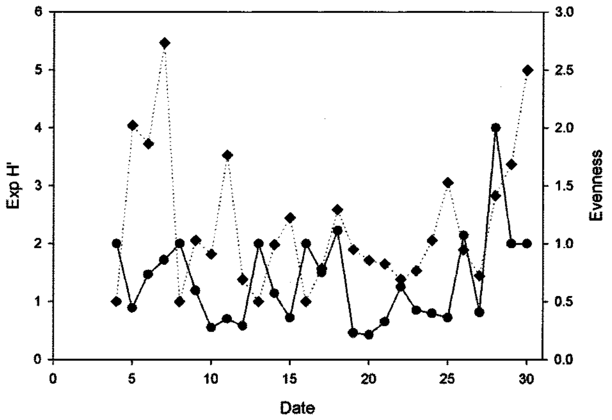

Fig. 2. Daily changes in indices of heterogeneity (broken lines with diamonds) and evenness (solid lines with circles) for collected moths in April 2007 in a coniferous forest in southwestern Korea. Heterogeneity was obtained using the Shannon-Wiener formula and changed to an exponential function (Exp H') and evenness was obtained using the Simpson formula (Magurran 2003).

defoliator, *Thaumetopoea pityocampa*, in Europe. Bailey and Horn (2007) found that two large saturniid species were affected differently by the same weather factor: *Dryocampa rubicunda* populations were strongly influenced by temperature, but those of *Actias luna* were not. Holyoak et al. (1997) concluded that moth populations in light traps were influenced by abiotic factors such as temperature and rainfall. Choi (2008) found that members of different moth families were affected by different sets of weather factors such as rainfall, relative humidity, and duration of sunshine due to different life-history strategies.

Moth activity is greatly influenced by the brightness of moonlight and some researchers advise avoiding light trapping during the full moon (Yela and Holyoak 1997). However Bailey and Horn (2007) found that catches of two saturniid moths in Ohio were not influenced by cloud cover or moonlight luminescence. In the present study, cloud cover and lunar day were not closely related with moth species richness (Pearson correlation, cloud cover: $r = -0.151$, $P = 0.44$; lunar day: $r = -0.12$, $P = 0.54$) or log-transformed abundance (Pearson correlation, cloud cover: $r = -0.06$, $P = 0.76$; lunar day: $r = -0.14$, $P = 0.49$). This may have been because the full moon occurred at the start and end of the survey period, which might have reduced the ability to detect the effect of the full moon on moth catches.

Woiwod (1997) summarized three main and readily observable consequences of climate change on individual species, although these changes may also interact: changes in abundance, changes in distribution and changes in phenology. The present study focused on one month in spring only, and showed that temperature affects both species richness and abundance. Continuous long-term monitoring of moth populations at the study site in April would provide information about moth population trends on the southwestern coast of Korea.

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Table 2. Stepwise regression parameters for regression of moth species richness and abundance against temperature

| Dependent | $R_{adj}^2$ | $F$-value | Independent variables | | |
|---|---|---|---|---|---|
| | | | Predictor | $\beta$ | $t$-value |
| Number of species | 0.18 | 6.94* | Temperature difference | 0.46 | 2.68* |
| Log (Individuals) | 0.51 | 10.0** | Maximum air temperature | 1.22 | 5.36** |
| | | | Average ground temperature | −1.06 | −3.92** |
| | | | Minimum air temperature | 0.38 | 2.08* |

* $p < 0.05$, ** $p < 0.005$.

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