Patterns of Species Description and Species Richness of Geometrid Moths (Lepidoptera: Geometridae) on the Korean Peninsula

Author: Choi, Sei-Woong

Source: Zoological Science, 23(2) : 155-160

Published By: Zoological Society of Japan

URL: https://doi.org/10.2108/zsj.23.155

ZOOLOGICAL SCIENCE **23**: 155–160 (2006)

Patterns of Species Description and Species Richness of Geometrid Moths (Lepidoptera: Geometridae) on the Korean Peninsula

Sei-Woong Choi*

Department of Environmental Education, Mokpo National University, 61 Dorim-ri, Chungkye-myon, Muan-gun, Jeonnam 534-729, South Korea

The diversity and pattern of species description among geometrid moths in Korea from 1883 to 2004 were assessed. A total of 647 geometrid species have been described: Ennominae (275 species, 43%), Larentiinae (227 spp., 35%), Geometrinae (68 spp., 11%), Sterrhinae (67 spp., 11%), Oenochrominae (9 spp., 2%), and Archiearinae (1 sp., <1%). Fourteen authors described more than 80% of geometrid species. The cumulative curve of the number of geometrid species described showed three high-rate peaks of description, around the 1900s, 1950s, and 2000s. The cumulative curves of five subfamilies (Ennominae, Larentiinae, Geometrinae, Sterrhinae, and Oenochrominae) fluctuated equally, and none has clearly reached an asymptote. The localities where a species was first recorded in Korea are mostly in the northern and central parts of the peninsula. The utility of larentiines, which are predominant in mountainous habitats and high latitudes, as a bioindicator for global warming is briefly discussed.

Key words: biodiversity, Geometridae, cumulative curve, Larentiinae, bioindicator, global warming

INTRODUCTION

Geometrids are one of the most speciose families of Lepidoptera and are distributed in all major biogeographical regions. To date, about 21,700 geometrid species have been described (Scoble, 1999). Phylogenies at the subfamily and tribe levels are still in dispute, but it has been possible to investigate diversity patterns of geometrid moths in several tropical regions (*e.g.*, Kitching *et al*., 2000; Brehm and Fiedler, 2003; Brehm *et al.,* 2003; Axmacher *et al*., 2004), because a global database (Scoble, 1999) and extensive taxonomic revisionary works on tropical geometrids (Holloway, 1993, 1996, 1997; Pitkin, 1996, 2002; Scoble and Krüger, 2002) are available.

The Korean Peninsula is remarkably rich in terms of floral and faunal diversity, with approximately 30,000 species thriving in its small territory (Ministry of Environment of Korea, 1997). This is because of the peninsula's latitudinal spread from 33° to 43°N and two (Taeback and Nangnim) north-to-south parallel-running mountain chains, producing a unique topography and a diverse ecological environment (Park, 1996; Shin, 2002). The total number of known species of insects (*ca.* 12,500) on the Korean peninsula, however, is relatively small compared to neighboring countries (Park, 1996). This number accounts for about 1.28% of the known species in the world, while the percentages for China and Japan are 5.23% and 3.54%, respectively. The Korean entomofauna still requires a thorough investigation.

* Corresponding author. Phone: +82-61-450-2783;
Fax : +82-61-453-4843;
E-mail: choisw@mokpo.ac.kr
doi:10.2108/zsj.23.155

The purpose of the present study is to reveal the pattern of species description of geometrid moths in Korea during the last century. Since geometrid moths comprise a species-rich and well known taxon, they have been used as model organisms in many studies, *e.g.*, the global pattern of species description (*e.g.*, Gaston *et al*., 1995; Scoble *et al*., 1995; Sihvonen and Siljander, 2005) and diversity patterns in tropical rainforests (*e.g.*, Brehm and Fiedler, 2003; Axmacher *et al*., 2004). Gaston (2000) listed two reasons for the documentation of broad-scale spatial patterns of biodiversity. First is the increase in available data and analytical tools through the extensive collation of existing specimens and species-occurrence records, the establishment of distribution-mapping schemes, and the use of remote-sensing technology. Second is the concern over the present and future status of biodiversity, and its response to global environmental changes. While recent biodiversity research has focused mainly on tropical regions, or so-called hotspots, this type of research is relatively neglected in temperate regions, resulting in a high degree of variation in the knowledge of organismal diversity.

Analysis of the patterns of species description and diversity of geometrid moths in Korea and in neighboring countries will provide guidance for the direction of future research on the taxonomy and ecology of lepidopteran insects.

MATERIALS AND METHODS

Scope of study

Korea, located in the heart of East Asia and belonging to the Palearctic region, has an area of about 222,000 km^2, including about 3,400 islands mainly along its western and southern coasts. Its climate is influenced by its mid-latitudinal location and peninsular configuration, as well as by its location as an appendage to the

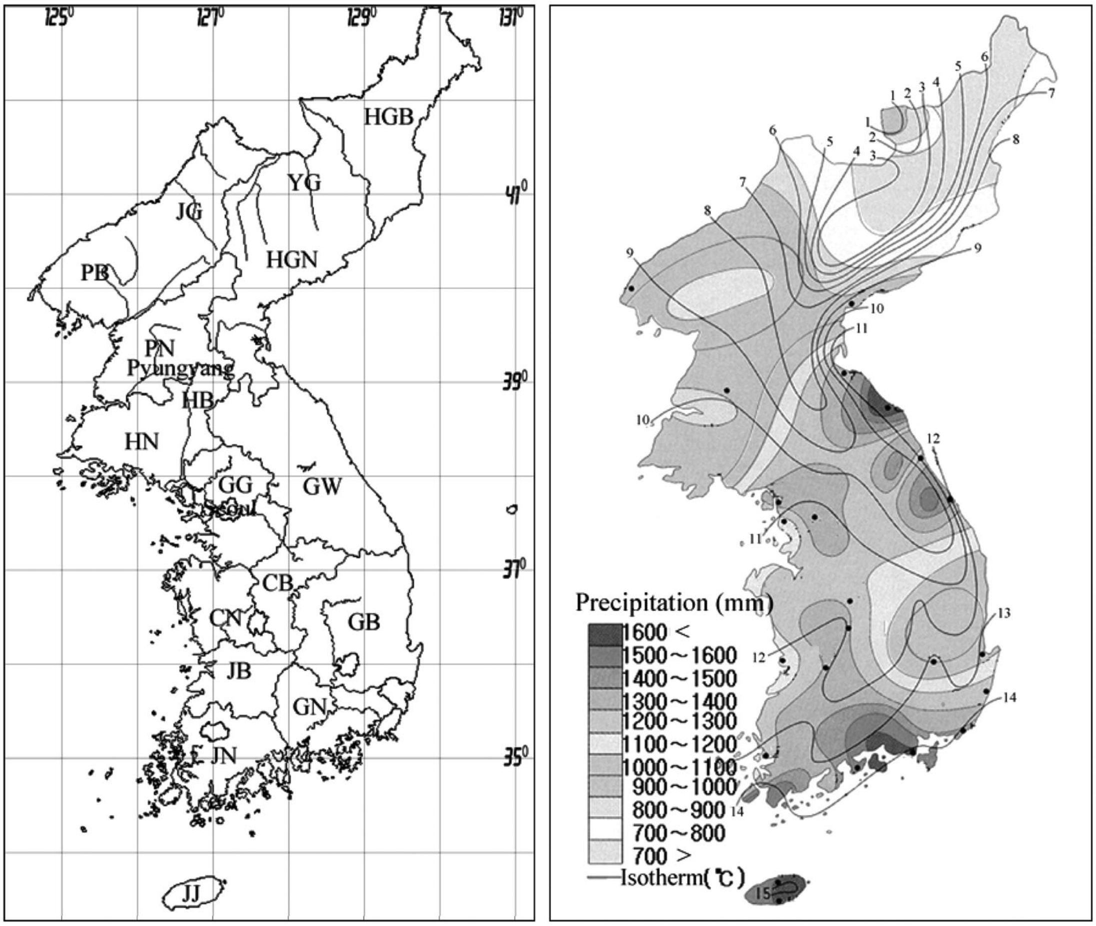

Fig. 1. Maps of the Korean Peninsula. Left, Korean provinces: HGB, Hamgyungbuk-do; HGN, Hamgyungnam-do; YG, Yanggang-do; JG, Jagang-do; PB, Pyunganbuk-do; PN, Pyungannam-do; HN, Hwanghaenam-do; HB, Hwanghaebuk-do; GW, Gangwon-do; GG, Gyunggi-do; CB, Chungchungbuk-do; CN, Chungchungnam-do; GB, Gyunsangbuk-do; GN, Gyungsangnam-do; JB, Jellabuk-do; JN, Jellanam-do; JJ, Jeju-do. Right, annual precipitation (mm) and isotherms (°C) (from Korea Meteological Agency).

Asian continent. The annual mean temperature ranges from 3–14°C, and the annual precipitation from 600–1,500 mm (Fig. 1). Its biota has been formed from a peculiar combination of northern and southern elements; the northern elements originated in the Amur-Ussuri River region, and the southern elements in central China and southern Japan (Shin, 2002).

There are several zones of Korean vegetation, owing to the peninsula's north-to-south geographic orientation and its mountainous highlands. A frigid forest zone covers the northern region and the mountainous highlands; a cool, temperate forest zone covers the land between 35° and 43° north latitude, and is divided into three subzones (the northern, central, and southern temperate forest subzones); a warm temperate zone covers the area south of 35° north latitude and the islands of the southern coastal region; and a subtropical forest zone exists at the southern tip of the peninsula (Yim, 1985; Shin, 2002).

Database

A database of Geometridae in Korea was assembled primarily from the references by Shin (1996) and Kim *et al.* (2001). Records of geometrid species published from 2001 until the summer of 2004, as well as old missing data (*e.g.*, Herz, 1905), were incorporated. For each species, information was collated by original generic name, author, year described, and source of publication, followed by the author who first described the species in Korea with the corresponding place(s) and year.

To compare the diversity of species of each subfamily of Geometridae, the following published data were used: Scoble *et al.* (1995) for global information, Karsholt and Razowski (1996) for Europe, Inoue (1982) for Japan, and Heppner and Inoue (1992) for

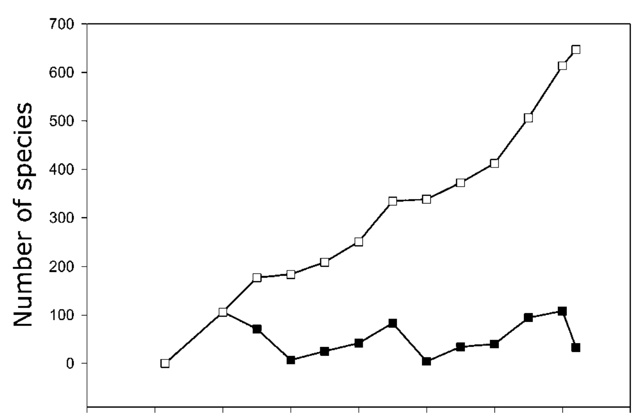

Fig. 2. Cumulative numbers (open squares) and absolute numbers (filled squares) of geometrids described by decade on the Korean Peninsula. Decades are 1883–1900, 1901–1910, 1911–1920, 1921–1930, *etc*.

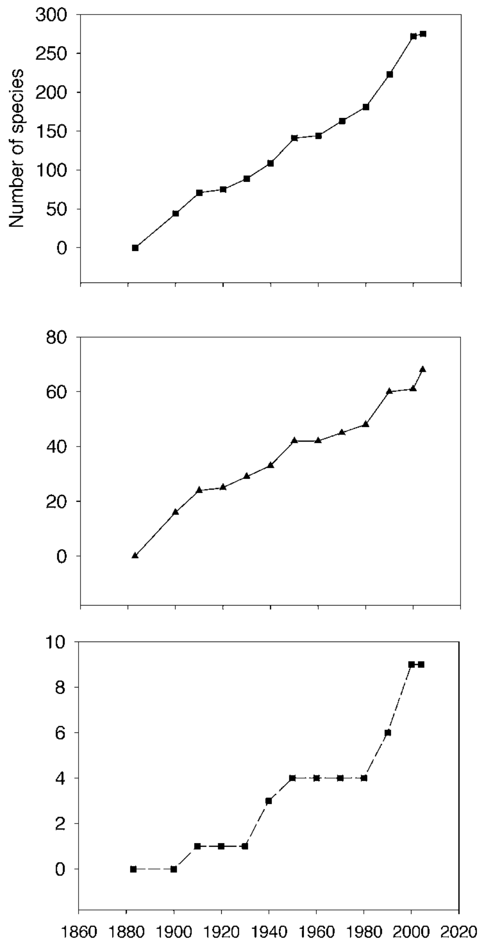

Fig. 3. Cumulative numbers, by subfamily, of species of geometrids described on the Korean Peninsula. X-axis is time from 1883 to 2004, divided by decade (1883–1900, 1901–1910, 1911–1920, 1921–1930, *etc*); Y-axis is the cumulative number of species described. Top left, Ennominae. Top right, Larentiinae. Center left, Geometrinae. Center right, Sterrhinae. Bottom left, Oenochrominae.

Taiwan. The systematic arrangement of subfamilies and genera follows Inoue (1982).

RESULTS

The first report on geometrid moths from the Korean Peninsula was made in 1883 by a British lepidopterist, Arthur G. Butler, and included three species: *Scopula hanna* (Butler), *Arichnna melanaria* (Linnaeus), and *Abraxas miranda* Butler. Since Butler's report, many local and foreign authors have reported a total of 574 geometrid species (Shin, 1996). Subsequently, Kim *et al.* (2001) added another 30 species from two subfamilies, Geometrinae and Ennominae, to the Korean fauna.

To date, 647 geometrid species comprising six subfamilies have been reported. This figure includes only the described species, but undoubtedly revisionary work on genera and an extensive faunal survey will change the total number of species. A cumulative curve of the number of geometrid species by decade shows that there were three high-rate peaks of description (around the early 1900s, the 1950s, and 2000s) (Fig. 2). The rates of description of five subfamilies – Ennominae, Larentiinae, Sterrhinae, Geometrinae and Oenochrominae –fluctuated nearly equally during the last century, with a steady increase. None of the cumulative curves for these families has clearly reached an asymptote (Fig. 3).

The subfamily Ennominae was highest (275 species, 43%) in the number of described species, followed by Larentiinae (227 spp., 35%), Geometrinae (68 spp., 11%), Sterrhinae (67 spp., 11%), Oenochrominae (9 spp., 2%), and Archiearinae (1 sp., <1%). A comparison of the proportion of species in the subfamilies of Geometridae showed other regions to have slightly different values from those of

Table 1. Comparisoin of number of species of geometrids among Korea, Japan, and Taiwan. Numbers in parenthesis indicate proportion of species in common, relative to the number of Korean species.

Subfamily	Korea and Japan	Korea and Taiwan	Korea, Japan and Taiwan
Archiearinae	1 (100)	0 (0)	0 (0)
Oenochrominae	6 (66.7)	0 (0)	0 (0)
Geometrinae	45 (66.2)	14 (20.6)	10 (14.7)
Sterrhinae	50 (74.6)	10 (14.9)	7 (10.5)
Larentiinae	146 (64.3)	23 (10.1)	16 (7.1)
Ennominae	185 (67.3)	58 (21.1)	38 (13.8)
Total	433 (66.9)	105 (16.2)	71 (11.0)

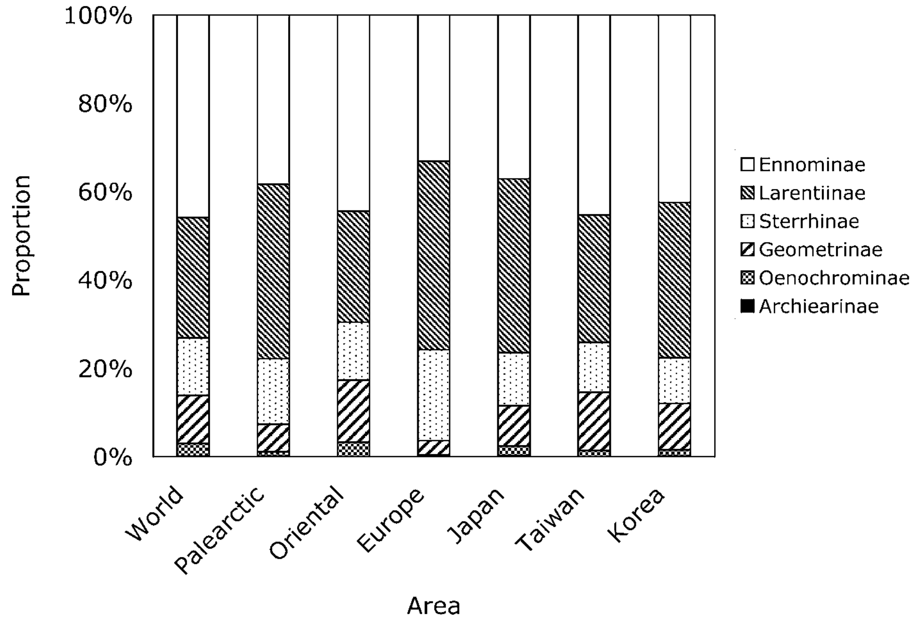

Fig. 4. Proportions of species in subfamilies of Geometridae, based on numbers of described species in different regions. Data sources: world, Palearctic, and Oriental from Scoble *et al.* (1995); Europe from Karsholt and Razowski (1996); Japan from Inoue (1982); Taiwan from Heppner and Inoue (1992). Mann-Whitney tests of the proportions of described species in subfamilies showed no statistically significant difference between Korea and Japan (P=0.485) and Taiwan (P=0.818).

Korea. For example, Europe and Japan had the largest proportion of species of Larentiinae, while Taiwan had the largest proportion of species of Ennominae (Table 1; Fig. 4). Nevertheless, Mann-Whitney tests of the proportions of the recorded species in subfamilies showed no statistically significant differences between Korea and Japan (P=0.485) and Taiwan (P=0.818) respectively.

Fourteen authors have collectively reported more than 80% of the geometrid species in Korea (Table 2). Most localities at which first records were documented were in the northern (North Korea) and central parts (Gyunggi, Seoul, and Gangwon provinces of South Korea) of the Korean peninsula (Table 3). In contrast, fewer first records were documented in southern provinces (*e.g.*, Jeonnam and Gyungnam), except for Jejudo. One hundred twelve species were not included in the analysis because they were first recorded only as collected from “Korea”, without indication of a specific locality.

Table 2. List of major authors who first reported geometrid species occurring in Korea

Author	Work period	Number of Species
Leech, JH	1890s	110
Shin, YH	1981-	97
Inoue, H	1941-	63
Herz, O	1905	57
Park, KT	1989-	54
Oh, SH	1992-	51
Kim, SS	1987-	38
Beljaev, E	1998-	31
Vojnits, A	1994	30
Bryk, F	1949	29
Choi, SW	1994-	21
Maruta, S	1920s	17
Pak, SW	1960s	15
Doi, H	1930s	14

Table 3. Distribution of locality of first record on the Korean peninsula with the total number of species recorded in each province. The total number of geometrid species in Korea is 647 and the remaining 112 species are excluded in the analysis since they were first recorded as “Korea” without stating any specific locality. Location of each province in South Korea is shown in Fig. 1.

	Province	Number of species
North Korea		266
South Korea	Total species	269
	Gyunggi (GG)	75
	Gangwon (GW)	64
	Jeju (JJ)	42
	Seoul	24
	Jeonbuk (JB)	22
	Jeonnam (JN)	15
	Gyungbuk (GB)	11
	Busan	6
	Gyungnam (GN)	5
	Chungbuk (CB)	3
	Chungnam (CN)	2

DISCUSSION

A total of 647 geometrid species have been reported from the Korean Peninsula. Gaston *et al.* (1995) and Sihvonen and Siljander (2005) showed that the cumulative numbers of geometrid species described over time tend to show a sigmoid curve, with a low rate of description early and late in documenting fauna. Since Linnaeus in 1758, the number of geometrid species described per decade peaked between around 1890 and 1910, and the rate has dramatically declined since then. The cumulative curve of described species of geometrid moths has clearly not yet reached an asymptote, and many more geometrids are likely to be discovered, although the total number is unlikely to exceed 30,000 (Gaston *et al*., 1995).

Since the cumulative curve of Geometridae in Korea is still increasing (Fig. 2), it is difficult to estimate the actual number of species of geometrid moths in Korea. On a global level, the main obstacles to determining the actual number of species are the existence of synonyms, and the many undescribed species in tropical regions (Gaston *et al*., 1995). On a regional level, such as in temperate regions, however, descriptive taxonomy and faunal investigations are believed to have revealed close to the actual species diversity (*e.g*., Gaston *et al*., 1995). The true number of species comprises the number of described species, including species needing revival from synonymy, and the number of undescribed species minus the number of species requiring synonymy (Scoble *et al*., 1995). Synonyms are an important factor in counting the total number of species at both the global and regional levels. In the present study, however, the ten species (<2%) of geometrid moths deleted from the list as synonyms did not greatly affect the total number of species. Thus estimates of the total number of geometrid species in the temperate zone are likely not be greatly influenced by the existence of synonyms. Another variable affecting the total number of species was species with no further confirmation of presence after the first record. Fifty-nine species (*ca*. 10%) were reported only once. This could have been for either artificial (misidentification) or natural (rare in nature or now extinct) reasons.

Proportions of species in subfamilies of Geometridae change along latitudinal and altitudinal gradients (*e.g*., Holloway, 1987; Brehm and Fiedler, 2003). Brehm and Fiedler (2003) analyzed the relationship between geometrid moths and latitude using European species and found that three subfamilies – Ennominae, Geometrinae, and Sterrhinae – were negatively correlated with increasing latitude, whereas Larentiinae was positively correlated with increasing latitude. Holloway (1987) and Brehm and Fiedler (2003) similarly suggested that larentiine moths predominate in high, mountainous habitats, because larentiine moths at higher altitudes feed on herbaceous plants and encounter less predation pressure from bats (Skou, 1986; Neuvonen and Niemelä, 1983; Rydell and Lancaster, 2000; Brehm and Fiedler, 2003). In East Asia, the proportions of species in subfamilies vary among countries and show a similar latitudinal pattern (Table 1; Fig. 4). In Japan, Larentiinae was the most species-rich group, followed by Ennominae, Sterrhinae, Geometrinae, and Oenochrominae; in Taiwan, Ennominae was the largest group. The species diversities of Ennominae and Geometrinae were relatively higher than that of Larentiinae in the Oriental region, and vice versa in the Palearctic region (Fig. 4; Holloway, 1997).

On the Korean Peninsula, Ennominae was the most species-rich subfamily, followed by Larentiinae, Geometrinae, Sterrhinae, Oenochrominae, and Archiearinae. Although the geometrid faunal composition of Korea was most similar to that of Japan (Table 1), the proportions of subfamilies were slightly different (Fig. 4). It is uncertain whether the proportions of subfamilies shown by the present study will change after further taxonomic studies and faunal investigations. Information on the faunal composition and species richness of the Geometridae, unlike many other animal taxa in Korea, has steadily increased and been revised (*e.g*., Shin, 1996; Kim *et al*., 2001; Choi, 2003). It should be noted, however, that additional taxonomic revisions and field studies are still urgently required.

Historically, a few localities on the peninsula were favored as areas for collecting moths and butterflies, and this led to many first records of species in Korea at these localities. Geometrid moths were no exception (Table 3). More than 70% of the records have been confined to the northern and central parts of Korea and to Jejudo Island. It should be noted that the documentation of many first records or new species from a particular locality is not an indicator of species diversity there, but is simply a reflection of collecting effort (*e.g*., Sihvonen and Siljander, 2005).

The species diversity of plants and animals on various peninsulas changes with latitude; this phenomenon is known as the “peninsular effect” (Simpson, 1964). On the Korean Peninsula, the diversity of butterfly species is significantly correlated with latitude; the number of butterfly species increases as latitude increases (Choi, 2004). Because there are no reliable estimates of local geometrid diversity along the whole peninsula, geometrids cannot yet be tested for a peninsular effect. Interestingly, Ricketts *et al*. (2002) compared the diversity patterns between moths and butterflies in Colorado, U.S.A. and found no correlation between the two groups. Butterflies were largely restricted to grassland habitats, whereas moths were not confined to a single type of habitat. A future examination of the diversity pattern of geometrids with latitude on the Korean Peninsula will be an interesting comparative study.

Due to their predominance over other subfamilies in mountainous habitats and at high latitudes (*e.g*., Holloway, 1987; Brehm and Fiedler, 2003; Axmacher *et al*., 2004), larentiine moths might be used as a model group for studying the effect of global warming on populations of high altitude or high latitude insects. In this context, Parmesan *et al.* (1999) showed that many non-migratory butterflies shifted their ranges 35–240 km to the north in the 20th century, whereas only a few species shifted toward the south. These poleward shifts to colonize new northern territories represent responses to increasing environmental temperature due to global warming, rather than responses to direct human effects, such as increasing land use. Kati *et al.* (2004) summarized three basic requirements for bioindicator taxa: they must be easily identifiable and well-known; they must be readily surveyed; and they must have the potential to be used as indicators of the distribution patterns of other, unsurveyed taxa, or of the overall biodiversity at different spatial scales. Geometrid moths are species-rich and well represented around the globe. A broad knowledge of geometrid moths, by virtue of a global database, taxonomic revisions, and ease of sampling, makes geometrids a model group for biodiversity research (*e.g*., Kitching *et al*. 2000; Brehm and Fiedler, 2003). In addition, the congruence of larentiines habitat in different regions, both in tropic (South-east Asia, Africa, South America) and temperate zones (Europe), augments their utility as bioindicators.

A few disjunctly distributed species of larentiines on the Korean Peninsula can be cited in particular as indicative of the types of population changes and extinction events that might be expected in high altitude insects following global warming. For example, the larentiine *Thera variata* (Denis and Schiffermüller) thrives in high, mountainous areas of the northern and central parts of Korea and on Mt. Hallasan on Jejudo Island. On Mt. Hallasan (Kong, 2002), a large number of alpine plants became established during the Ice Age, and these are are very intolerant of competition with temperate vegetation under mild climatic conditions. This flora has persisted in alpine areas because of harsh climatic conditions, sterile soil, and rugged topography. During the last four decades, however, the distributional ranges of many of the arctic-alpine plants on Mt. Hallasan have been retreating toward the mountaintops, probably due to recent climatic amelioration (Kong, 2002, and references therein). A parallel situation likely obtains for herbivore insects, including larentiine moths. As the risks of extinction of many larentiines in arctic and alpine habitats are increasing due to global warming, the geometrid moth assemblages in such habitats could be an important indicator of climatic changes.

ACKNOWLEDGMENTS

I thank Prof. Dr. Yoo-Hang Shin, who fully revised the database, and Dr. Pasi Sihvonen (Helsinki) and three anonymous referees for their critical reading and suggestions. I also thank Sang-Duck Na, Jeong-Seop Ahn, Marana Park, and Hyang-Hee Cheon for their help in compiling the data. This study was supported by a grant from the Korea Research Foundation (R05-2004-000-10285-0).

REFERENCES

Axmacher JC, Holtmann G, Scheuermann L, Brehm G, Müller-Hohenstein K, Fiedler K (2004) Diversity of geometrid moths (Lepidoptera: Geometridae) along an Afrotropical elevational rainforest transect. Divers Distrib 10: 293–302

Brehm G, Fiedler K (2003) Faunal composition of geometrid moths changes with altitude in an Andean montane rain forest. J Biogeogr 30: 431–440

Brehm G, Süssenbach D, Fiedler K (2003) Unique elevational diversity patterns of geometrid moths in an Andean montane rainforest. Ecography 26: 456–466

Choi SW (2003) Faunistic study on the Larentiinae (Lepidoptera, Geometridae) of North Korea. Insecta Kor 20: 313–342

Choi SW (2004) Trends in butterfly species richness in response to the peninsular effect in South Korea. J Biogeogr 31: 587–592

Gaston KJ (2000) Global patterns in biodiversity. Nature 405: 220–227

Gaston KJ, Scoble MJ, Crook A (1995) Patterns in species description: a case study using the Geometridae (Lepidoptera). Biol J Linn Soc 55: 225–237

Heppner JB, Inoue H (Eds.) (1992) Lepidoptera of Taiwan. Vol 1, Pt 2: Checklist. Association for Tropical Lepidoptera, Gainesville

Herz O (1905) Lepidoptera von Korea. Noctuidae and Geometridae. Ezheg Zool Muz Akad Nauk SSSR 9: 332–375

Holloway JD (1987) Macrolepidoptera diversity in the Indo-Australian tropics, geographic, biotopic and taxonomic variations. Biol J Linn Soc 30: 325–341

Holloway JD (1993) The Moths of Borneo: Family Geometridae, Subfamily Ennominae. Southdene Sdn. Bhd., Kuala Lumpur

Holloway JD (1996) The moths of Borneo: Family Geometridae, subfamilies Oenochrominae, Desmobathrinae and Geometrinae. Malay Nat J 49: 147–326

Holloway JD (1997) The moths of Borneo. Part 10. Geometridae: Sterrhinae, Larentiinae and addenda to other subfamilies. Malay Nat J 51: 1–242

Inoue H (1982) Geometridae. In “Moths of Japan” Ed by H Inoue, Kodansha, Tokyo

Karsholt O, Razowski J (eds.) (1996) The Lepidoptera of Europe. A Distributional Checklist. Apollo Books, Stenstrup

Kati V, Devillers P, Dufrene M, Legakis A, Vokou D, Lebrun P (2004) Testing the value of six taxonomic groups as biodiversity indicators at a local scale. Conserv Biol 18: 667–675

Kim SS, Beljaev EA, Oh SH (2001) Illustrated catalogue of Geometridae in Korea (Lepidoptera: Geometrinae, Ennominae). Insects of Korea, Ser 8. Korea Research Institute of Bioscience and Biotechnology and Center for Insect Systematics, Chuncheon

Kitching RL, Orr AG, Thalib L, Mitchell H, Hopkins MS, Graham AW (2000) Moth assemblages as indicators of environmental quality in remnants of upland Australian rain forest. J Appl Ecol 37: 284–297

Kong WS (2002) Mountain geoecology of Korea. In “Ecology of Korea” Ed by D Lee, Bumwoo Publishing, Seoul, pp 47-57

Ministry of Environment of Korea (1997) National Strategy of Biodiversity, Republic of Korea, Ministry of Environment, Seoul (in Korean)

Neuvonen S, Niemelä P (1983) Species richness and faunal similarity of arboreal insect herbivores. Oikos 40: 452–459

Park KT (1996) Status and perspective of insect biodiversity in Korea. In “Biodiversity and the dynamics of ecosystems” Ed by IM Turner, CH Diong, SSL Lim, PKL Ng, DIWPA Series Vol 1, Singapore, pp 339–351

Parmesan C, Ryrholm N, Stefanescu C, Hill JK, Thomas CD, Descimon H, Huntley B, Kaila L, Kullberg J, Tammaru T, Tennent WJ, Thomas JA, Warren M (1999) Poleward shifts in geographic ranges of butterfly species associated with regional warming. Nature 399: 579–583

Pitkin LM (1996) Neotropical emerald moths: a review of the genera (Lepidoptera: Geometridae, Geoetrinae). Zool J Linn Soc 118: 309–440

Pitkin LM (2002) Neotropical ennomine moths: a review of the genera (Lepidoptera: Geometridae). Zool J Linn Soc 135: 121–401

Ricketts TH, Dailey GC, Ehrlich PR (2002) Does butterfly diversity predict moth diversity? Testing a popular indicator taxon at local scales. Biol Conserv 103: 361–370

Rydell J, Lancaster WC (2000) Flight and thermoregulation in moths shaped by predation from bats. Oikos 88: 13–18

Scoble MJ (Ed.) (1999) Geometrid Moths of the World: a Catalogue (Lepidoptera, Geometridae) Vols 1 and 2, Apollo Books, Stenstrup

Scoble MJ, Krüger M (2002) A review of the genera of Macariini with a revised classification of the tribe (Geometridae: Ennominae). Zool J Linn Soc 134: 257–315

Scoble MJ, Gaston KJ, Crook A (1995) Using taxonomic data to estimate species richness in Geometridae. J Lepidop Soc 49: 136–147

Shin JH (2002) Ecosystem geography of Korea. In “Ecology of Korea” Ed by D Lee, Bumwoo Publishing, Seoul, pp 19–46

Shin YH (1996) Synonymic list and distribution of the Geometridae of Korea (Lepidoptera), Center for Insect Systematics, Korea

Sihvonen P, Siljander M (2005) Species diversity and geographical distribution of Scopulini moths (Lepidoptera: Geometridae, Sterrhinae) on a world-wide scale. Biodivers Conserv 14: 703–721

Simpson GG (1964) Species densities of North American recent mammals. Syst Zool 13: 57–73

Skou P (1986) The Geometrid Moths of North Europe, Entomograph Vol 6, Brill, Leiden

Yim KB (1985) Principles of Silviculture, Hyungmunsa, Seoul

(Received January 14, 2005 / Accepted November 24, 2005)