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Review of the description pattern of newly recorded insect species from 1999 to 2009 in Korea

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The characteristics of insect communities in specific localities reflect climatic and environmental status and change. We investigated the description pattern of new insect species by reviewing announcements of new or newly recorded insects in Korea published in five systematic journals between 1999 and 2009: *Entomological Research* (1999–2009), *Insecta Koreana* (1999–2003), *Journal of Asia-Pacific Entomology* (1999–2009), *Korean Journal of Applied Entomology* (1999–2009), and *Korean Journal of Systematic Zoology* (1999–2009). A total of 757 new species were reported in 299 research papers. More than 85% of the newly described or reported species belonged to four orders: Coleoptera (225 species), Lepidoptera (202 species), Hymenoptera (141 species), and Diptera (82 species). The number of new species fluctuated from year to year, and a few major authors described most species. The graph of the cumulative number of species described in Korea was not asymptotic. We also examined the decadal trends in the proportion of species according to their biogeographical origin. The numbers of northern (Palearctic and Nearctic) and southern (Oriental) species recorded in Korea between 1999 and 2009 were increasing mainly due to the recent taxonomic research environment. It is also possible that recent climatic change induces new migrants to Korea from more southern parts of Oriental region, but more information is needed to confirm this hypothesis.

Keywords: description; insects; Korea; new species; Oriental; Palearctic

Introduction

Obtaining estimates of existing biological diversity is critical for addressing key issues in ecology and conservation biology (Minelli 1993). The practice of taxonomy contributes to conservation at the most elementary level by identifying species for protection. Therefore, interest in detailed estimates of biodiversity is increasing (May 1990; Minelli 1993; Valdecasas and Camacho 2003). Graham et al. (2004) suggested that museum-based collections data can be applied to biodiversity studies in two ways: to detect recent changes in geographical ranges that may be associated with climate change, and in niche modeling in conjunction with global future climate scenarios to anticipate future changes in the distributions of species and patterns of species richness.

Korea is rich in floral and faunal diversity, containing more than 33,000 species (NIBR 2008). This diversity may reflect the great north-to-south span of the Korean peninsula (33° to 43°N), the existence of more than 3000 associated islands, and the varying topography of mountain chains (Shin 2002). The total species richness of Korean insects is estimated at 12,982 species, comprising about 39.0% of the total biodiversity in Korea (NIBR 2008). Globally, insects comprise ca. 58.3% (925,000 species) of the total estimated species richness (1,587,200 species) (Grimaldi and Engel 2005). We postulate that there are still many undescribed insect species in Korea.

Climate change and its biological consequences have attracted much interest in the past decade. Changes in the physiology, phenology, and distribution of species due to recent temperature trends indicate that climate change influences biodiversity (Hannah et al. 2005). For example, Parmesan (1996), Parmesan et al. (1999), and Hickling et al. (2006) have documented northward shifts of the ranges of many invertebrate and vertebrate species in North America and Europe over the past 100 years. Similarly, the relative abundances of warm-adapted and cold-adapted species are changing; warm-adapted species are flourishing while cold-adapted species are declining in many areas (Parmesan 2005).

In the last century, Korea has become hotter. The annual mean temperature increased by about 1.5 °C during the twentieth century (Kwon 2003). Consequently diverse biological changes are occurring in Korea due to recent climate change (Kwon et al. 2002; Primack et al. 2009; Kwon et al. 2010). Even though recent changes in the abundances and distributions of insect fauna in Korea have been attributed to climate change, definitive evidence is lacking due to the absence of long-term and consistent data for Korea. This

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situation differs from that in some European countries and the United States, where long-term extensive biological data have documented climate-related changes in the distributions of plants and animals (Sparks and Yates 1997; Parmesan et al. 1999; Roy and Sparks 2000; Stefanescu et al. 2003; Hickling et al. 2006).

Because long-term biological data are unavailable in Korea, we used short-term and surrogate methods to identify possible climate-induced changes in Korean biota. We tracked new insect records over the last 10 years based on biogeography. Of newly described butterfly and geometrid species, 80% had a Palearctic origin and 20% an Oriental origin (Park and Kim 1997; Choi 2004; Choi and Chun 2009). We suspect that this ratio of species described from each biogeographic region will also apply to other insect species descriptions. Based on the assumption that Oriental species are more likely to be warm-adapted and that Palearctic species are more likely to be cold-adapted (Udvardy 1969), we hypothesize that the rates of description of Oriental species has increased over the past decade, due to shifts in species distributions related to recent climate change.

In this paper, we evaluated whether the rates of new species descriptions in major Korean systematic journals published have changed over time. We also investigated whether there were any significant changes in the proportions of southern (Oriental) and northern (Palearctic and Nearctic) species described in Korea over the past decade.

Materials and methods

We reviewed descriptions of new or newly recorded species in Korea that were published in five Korean systematic journals: *Entomological Research* (1999–2009), *Insecta Koreana* (1999–2003), *Journal of Asia-Pacific Entomology* (1999–2009), *Korean Journal of Applied Entomology* (1999–2009), and *Korean Journal of Systematic Zoology* (1999–2009). There were two categories in new insect species to fauna: new species denotes a species described for the first time in science, while newly recorded species denotes a species that is already known in other countries except Korea and described for the first time in Korea.

We constructed a database containing the following information extracted from each record: insect order, species, author and year of published paper, localities in Korea, and species biogeography. Korean provinces were abbreviated as follows: Gangwon-do (GW), Gyunggi-do (GG), Gyungsangbuk-do (GB), Gyungsangnam-do (GN), Chungchungbuk-do (CB), Chungchungnam-do (CN), Jeollabuk-do (JB), Jeollanam-do (JN), and Jeju-do (JJ).

We classified each species into one of the following biogeographic categories: Oriental, Palearctic, Holarctic, or Cosmopolitan. Species distributed in Southeast Asia (India, Thailand, Taiwan, and southern China) were described as Oriental, while species widely distributed in Eurasia (Europe, Siberia, Mongolia, Russian Far East, northern China) were described as Palearctic. Species occurring in both Palearctic and Nearctic (North America) regions were described as Holarctic, while species occurring worldwide were described as Cosmopolitan. We excluded species known only in Korea and species lacking information about geographical distribution from the analyses.

We tested the relationships between several independent variables (e.g. number of authors, localities, proportion of Oriental and Palearctic species) using correlation analysis. In addition the trend of the proportion of different biogeographic origins was analyzed by the linear regression method. All statistical analyses were carried out using SPSS-PC software (SPSS Inc. 2006).

Results

A total of 757 species new to Korea were described in 299 papers between 1999 and 2009 (Table 1). These species fell into 14 orders, and more than 85% of the records described insects in four orders: Coleoptera (225 species), Lepidoptera (202 species), Hymenoptera (141 species), and Diptera (82 species). The average number of species descriptions per insect order was 2.61. The

Table 1. Number of new insect species by insect orders from 1999 to 2009. New species indicates the species new to science and new records indicates the species new to the Korean fauna.

Order	New species	New records	Total number of species (no. of published papers)
Collembola	16	14	30 (6)
Ephemeroptera	2	0	2 (1)
Orthoptera	1	12	13 (8)
Mantodea	0	3	3 (1)
Embioptera	0	1	1 (1)
Plecoptera	1	2	3 (1)
Thysanoptera	3	8	11 (4)
Hemiptera	0	7	7 (6)
Homoptera	3	20	23 (10)
Coleoptera	42	183	225 (90)
Hymenoptera	32	109	141 (60)
Diptera	19	63	82 (34)
Trichoptera	1	13	14 (3)
Lepidoptera	12	190	202 (73)
Total	132	625	757(299)

Table 2. Statistics of new insect species by year from 1999 to 2009. New species indicates the species new to science and new records indicates the species new to the Korean fauna.

Year	New species	New records	Total number of species (no. of papers)	Ratio of description of species per paper
1999	15	92	107 (27)	3.81
2000	21	82	103 (31)	3.32
2001	28	82	110 (38)	2.89
2002	7	47	54 (31)	1.74
2003	13	32	45 (19)	2.37
2004	10	27	37 (19)	1.95
2005	9	25	34 (17)	2.00
2006	12	67	79 (20)	3.95
2007	9	51	60 (34)	1.76
2008	6	56	62 (35)	1.77
2009	2	64	66 (28)	2.36
Total	132	625	757 (299)	

total number of species described that were new to science was much lower than descriptions of species new to Korea (newly recorded species) in most orders, with the exception of Collembola and Ephemeroptera. Collembola had more new species (16 species) than newly recorded species (14 species), while only two new species of Ephemeroptera were recorded.

The rates of description of new species and newly recorded species varied during the period examined (Table 2). Species descriptions peaked in 2001 and decreased afterwards, while the number of total papers published on insect taxonomy each year did not change significantly. The average number of species described per paper was 2.55. A plot of the cumulative numbers of species described over time revealed that the asymptote has yet to be reached (Figure 1).

A handful of authors described the majority of species reported during the study period, whereas many (co)authors described one or a few species (Figure 2;

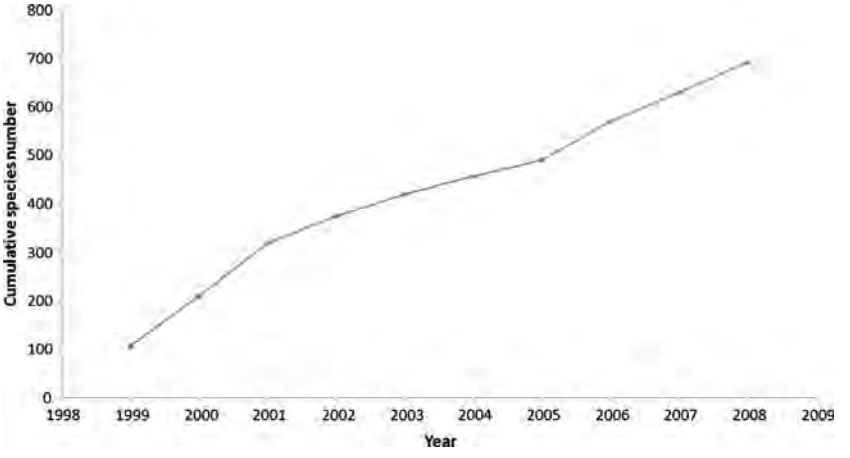

Figure 1. Cumulative number of insect species described from 1999 to 2009 in five systematic journals in Korea.

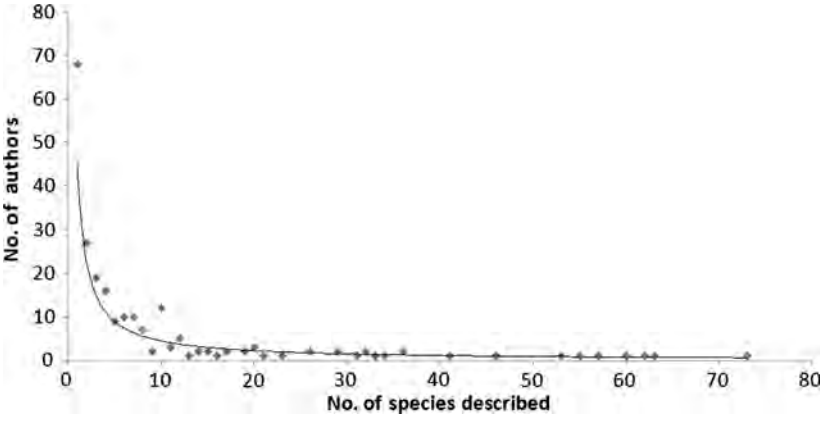

Figure 2. The relationship between the number of authors who described species and the total number of species described from 1999 to 2009 in Korea.

Table 3. List of (co)authors who described more than 30 insect species from 1999 to 2009 in five systematic journals in Korea.

(Co)Author	Insect order	Number of species described from 1999 to 2009	Number of years published between 1999 and 2009
Ahn KJ	Coleoptera	73	11
Park KT	Lepidoptera	63	7
Lee JW	Hymenoptera	62	9
Bae YS	Lepidoptera	60	7
Kim JI	Coleoptera	57	9
Hong KJ	Coleoptera	55	6
Kwon YJ	Diptera, Coleoptera	53	10
Byun BK	Lepidoptera	46	8
Woo GS	Thysanoptera	41	4
Choi JY	Hymenoptera	36	3
Suh SJ	Diptera	36	9
Sohn JC	Lepidoptera	34	6
Lee SH	Homoptera	33	7
Park SW	Coleoptera	32	5
Choi SW	Lepidoptera	32	9
Han HY	Diptera	31	7

Table 3). Most of the new species and newly recorded species were reported from GW (20%), GG (19%), and GB (12%) (Figure 3). However, the percentage of species described per provincial area was the highest for JJ (32.5%), followed by GG (14.2%) and GW (10.5%). Similarly we analyzed the location of authors who described the species in Korea and found that GG (50%) was the highest (Figure 4). We analyzed the

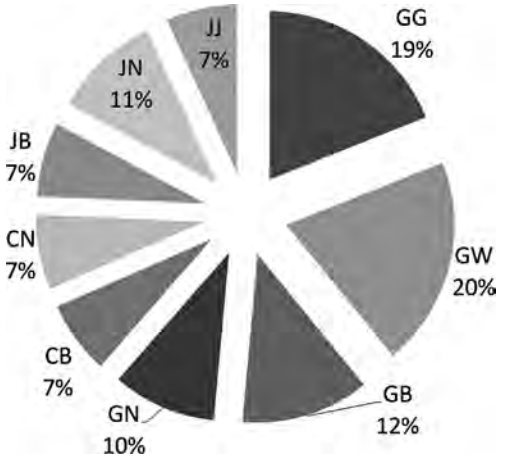

Figure 3. Proportion of provinces for the localities used for the description of new species from 1999 to 2009 in Korea. Abbreviations for provinces are Gangwon-do (GW), Gyunggi-do (GG), Gyungsangbuk-do (GB), Gyungsangnam-do (GN), Chungchungbuk-do (CB), Chungchungnam-do (CN), Jeollabuk-do (JB), Jeollanam-do (JN), and Jeju-do (JJ).

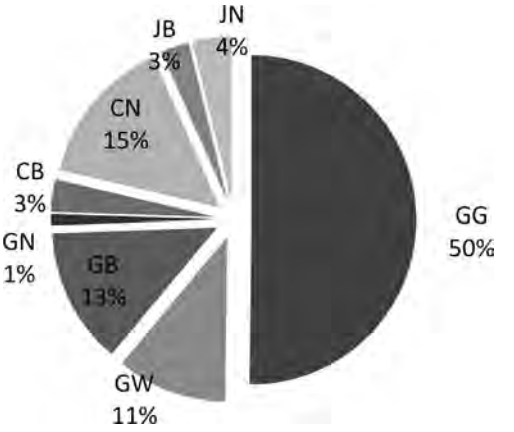

Figure 4. Proportion of provinces for the location of authors who described the insect species from 1999 to 2009 in Korea. Abbreviations for provinces are Gangwon-do (GW), Gyunggi-do (GG), Gyungsangbuk-do (GB), Gyungsangnam-do (GN), Chungchungbuk-do (CB), Chungchungnam-do (CN), Jeollabuk-do (JB), Jeollanam-do (JN), and Jeju-do (JJ).

relationship between localities and authors of the described species and found that it was significant (Spearman's $\rho = 0.67$, $P = 0.05$).

The proportion of northern (Palearctic and Nearctic) species relative to all species described during the 10-year period increased, but did not significantly increase (linear regression $F_{1,9} = 2.810$, $P = 0.128$) (Figure 5). The percentage of Oriental species also increased, but not significantly (linear regression $F_{1,9} = 3.377$, $P = 0.099$) (Figure 6). Species from between three to six insect orders were described each year. Among species of Oriental origin, Lepidoptera was the most dominant order (38 species, 41%), followed by Coleoptera (20 species, 22%) and Hymenoptera (13 species, 14%). Species belonging to six other insect orders, Homoptera (six species), Diptera (six species), Thysanoptera (four species), Orthoptera (two species), Mantodea (two species), and Collembola (one species), were also reported.

Discussion

The interpretation of temporal patterns of species descriptions is complicated by a number of factors such as the roles of individual authors, the time lag to description and synonymy, the vagaries of funding and publication, and the availability of material for previously undescribed species (Gaston et al. 1995). We showed that the total number of insect species described in Korea increased across 14 different orders over the past decade, and is approaching an asymptote. However, taxonomic studies of insects in Korea during the last decade focused mainly on four major orders;

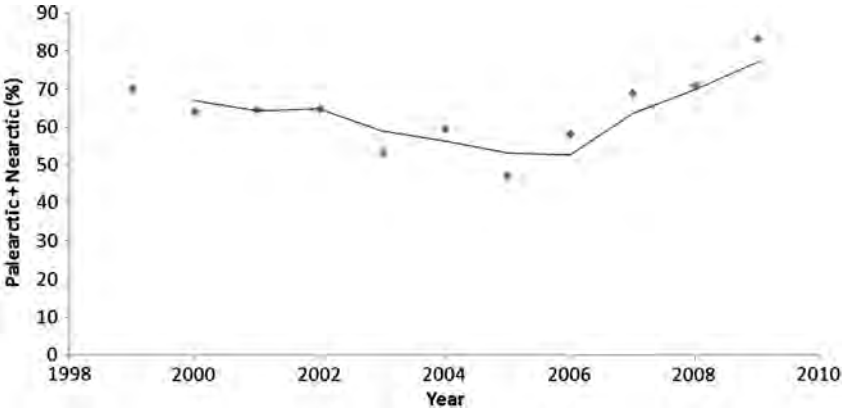

Figure 5. Proportion of the northern origin (Palearctic and Nearctic) species among the species described from 1999 to 2009 in Korea. Line indicates the moving average of two years.

descriptions of species in these four orders comprised more than 85% of all new species descriptions and records. The proportion of species described in each insect order was similar to that described for the whole world (Grimaldi and Engel 2005). This figure suggests that more taxonomic studies on the remaining insect orders are needed in Korea.

We found that a handful of authors contributed disproportionately to describing new species and newly recorded species in Korea. The rate of description of new insect species including newly recorded species varied by year. Although the relationship between authors and localities in which the new species and newly recorded species were described was strong, most species were collected in the southern (JJ) and middle regions (GW and GG) of the Korean peninsula (Figure 3). This suggests recorder bias. In terms of recorder bias, most authors described species in the vicinities of their academic institutions (Figure 4). In terms of the increase in species described in the south, the island of Jeju, which is located at the southern tip of Korea and is where the highest mountain (altitude 1950 m) in Korea is located, yielded the highest number of species descriptions of all the areas evaluated. Compared to other parts of Korea, the flora and fauna of Jeju are diverse because of this island's southern location, diverse habitats, and geological history. Consequently, recent taxonomic activity in this area remained high, with many new species reported. Based on this finding, we postulate that many bioinventory projects have revealed the diversity of insect fauna of Korea including the island of Jeju.

Recent climate change has been shown to underlie changes in the distribution ranges of several insect species (Burton 2003; Parmesan et al. 1999; Parmesan and Yohe 2003). Parmesan et al. (1999) showed that 63% of 35 non-migratory butterfly species in Europe extended their ranges north by 35 P40 km and only 3% to the south. Similarly, Burton (2003) found that 75% of 231 lepidopteran species in Europe moved northwards while only 1% moved southwards. In addition to moths and butterflies, other insect species (e.g. *Conocephalus discolor* Thunberg, *Metrioptera*

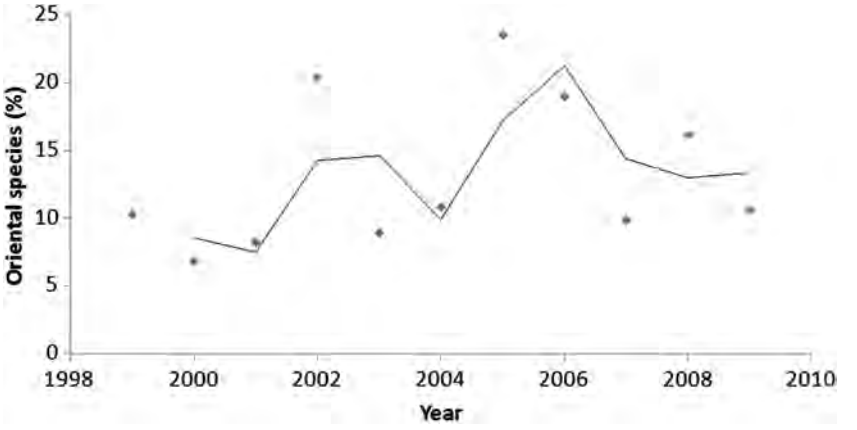

Figure 6. Proportion of the southern origin (Oriental) species among the species described from 1999 to 2009 in Korea. Line indicates the moving average of two years.

roeselii Hagenbach, *Vespa crabro* Linnaeus, *Dolichovespula media* Retzius) showed a similar northwards extension of their distribution ranges (Burton 2003 and references therein). These changes in distribution ranges may manifest as the arrival of new species from the south, and can be expressed as the increased proportion of more warm-adapted species.

In many developing countries, including Korea, changes in the ranges or inventories of warm-adapted species are rarely observed because long-term monitoring data are not available. Therefore, instead of using monitoring data, we evaluated trends in species descriptions according to biogeographic origin to monitor ecosystem changes. We found that despite year-to-year variations in the rate of description of new species and newly recorded species, the number of warm-adapted (Oriental) species described in Korea showed a consistent increase, but this rate was variable during the last 10 years. On the other hand, the proportion of northern origin was also increasing. Therefore it was difficult to relate the recent increase of proportion of southern species with new arrivals of insect species from the south, even though the possibility of new arrivals from the south is high.

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