Rarity and shifts in occurrence of endangered butterflies in South Korea

Cheol Min LEE[1] and Tae-Sung KWON[2]*

Division of Forest Ecology[1], Forest Insect Pests and Diseases Division[2], Korea Forest Research Institute, Seoul 130-712, Republic of Korea
*Correspondence : insectcom@chol.com

Summary : Endangered species are often the focus of public attention, partly because of their vulnerability to environmental changes, such as climate and land use change, and subsequently being at high risk of extinctions. Hence, red lists of endangered species play anessential in nature conservation. Although several endangered butterfly species have been previously listed as endangered species by government and/or individuals in South Korea, these red listsrarely include reliable quantitative population data. This has led to endless and unproductive debates on the selection of endangered species. Following Korean butterfly atlases, we assessed the population status of Korean endangered butterfly species whose distributions have been previously published. We hypothesized that these endangered species are rare and are decreasing in occurrence. We found that the decrease in occurrence is more important in determining endanger status than rarity. Using values of rarity and shifts in species occurrence, we selected endangered species from the previously published endangered species. Only eight species of 20 previous endangered species were defined as endangered by this semi-quantitative classification. This finding suggests that the subjective determination based on expert's perception would define more species as endangered compared to the quantitative determination based on population data.

Key word : Butterflies, endanger species, occurrence, rarity, conservation, SouthKorea

Introduction

Many butterfly species are now endangered because of environment changes such as habitat transformation, climate and land use change[2,3,9,10,13)]. Endangered butterfly species may be more vulnerable to such environmental changes than the non-endangered counterparts. Recently, Choi and Kim[1)] documented the population status on a range of selected endangered butterfly species from Korea. They classified the population status of 20 endangered butterflies into three risk levels such as "vulnerable" (3 species), "endangered" (14 species), and "critically endangered" (3 species). However, this classification was primarily based on subjective personal perceptions and literature reviews rather than on objective estimations of the population status foreach species.

Received December 9, 2013.
Accepted February 4, 2014.

In South Korea, only limited data are available on the population status for most species, thereby making it important to evaluate the method of determining endangered species. We hypothesized that the endangered species status determined by subjective decision is based on rarity, and/or tends to include species whose occurrence is decreasing. We selected the 20 species defined as endangered by Choi and Kim[1)] and two additional endangered species determined by the Environmental Ministry[8)]. We estimated rarity and shift in occurrence of these endangered species from data of atlases[5,6,12)], and selected semi-quantitatively endangered species from them.

Materials and Methods

Four series of butterfly atlases and one review atlas have been published in South Korea from 1973 to 2012. In the first atlas, Seok[12)] reported the distribution maps for Korean butterfly species based on field data, museum specimens, and literatures published from 1938 to 1950. Kim[4], in the second atlas, defined the distribution maps of butterflies on the basis of published data and university and museum specimen dating from 1955 to 1975. In the third atlas, Park and Kim[11] published their butterfly distribution maps based on their own survey data, combined with published literature and specimens from 1977 to 1996. More recently, Kim *et al*.[5] published the fourth butterfly atlas, including data from 1996 to 2011.In an attempt to standardize the data recorded in the four different atlases, Kwon *et al*.[6] transformed the point records in each atlas into the grid cell records (0.5° by 0.5° latitudinal and longitudinal grid). In the present study, site occurrence was defined as the number of recorded localities in the four series of atlases[4,6,11,12] and the grid occurrence was defined as number of standardized grid cells in the review atlas[6]. For simplicity we used the site occurrence of butterfly species only from the first (1938–1950) and last (1996–2011) atlases.

All resident species in each period were arranged from most frequent to most rare for each of the two periods to visualize rarity of the 22 endangered species (as defined in above, Fig. 1). To standardize the values, the site occurrence (SO) of component species (i) in each period was calculated as percentiles by following equation : $SO_i = 100 \times$ (number of recorded localities of species i/ number of recorded localities of most frequent species). In addition, all butterfly species were ranked according to their site occurrences for each of the two periods (occurrence rank, hereafter). Their ranks were assessed as inverse percentiles (i.e., a 100% would correspond with the most frequent species, with lowest values indicating rarest species). Differential values (i.e., valuesfor 1996–2011–valuesfor 1938–1950) of the three indices (i.e., site occurrence, occurrence rank, and grid occurrence) were used to evaluate shift in occurrence for each species. Difference in grid occurrences between two periods was tested using Fisher's exact test[14]. In this test, the numbers of recorded and unrecorded grid cells were compared by a 2×2 contingency table between two periods.

In the present study, endangered species were defined by two criteria ; rarity and decrease in occurrence. Rarity was estimated from grid occurrence ; if the species was recorded in ≤ 3 grid cells (accounting to < 5 % frequency, 71 grid cells in total), it was defined as rare. A species occurrence was considered to decrease if a negative score was recorded for the three occurrence indices or when a negative shift in the grid occurrence was significantly different between two periods. Thus, a rare species whose occurrence had decreased between two periods was defined as an endangered species.

Resultsand Discussion

Site occurrences of 22 Korean endangered species are shown in Fig. 1. During 1938–1950, occurrence ranksfor endangered species ranged from 83% (for the frequently recorded butterfly *Argynnis nerippe*) to 0.6% (for the rarest species ; Table 1). For most species, their ranks decreased during 1996–2011, when they ranged from 47.6% (moderately frequent, *A. nerippe*) to zero (local extinct). Thus, the decrease in the occurrence rank values for endangered species was steeper than that for other species. The three occurrence indices were significantly correlated between the two periods ($r = 0.716 - 0.823$, $p < 0.001$). It is likely that the definition of a species as endangered was more dependent on rarity during 1996–2011 than that during 1938–1950. However, there are more rare species than endangered species recorded for the period 1996–2011 (Fig. 1), suggesting that rarity was not the unique factor influencing the subjective definition of endanger status.

Regarding the shift in species occurrence, majorityof endangered species (15 species) decreased in occurrence (i.e., negative scores for the three occurrence shift indices shown in Table 1), of which the numbers of 5 species (*Burata striata, Melitaea britomartis, Argynnis nerippe, Coenonympha amaryllis*, and *C. oedippus*) significantly decreased (Table 1). Hence, the decrease in occurrence may influence the expert's decision to define a speciesas an endangered

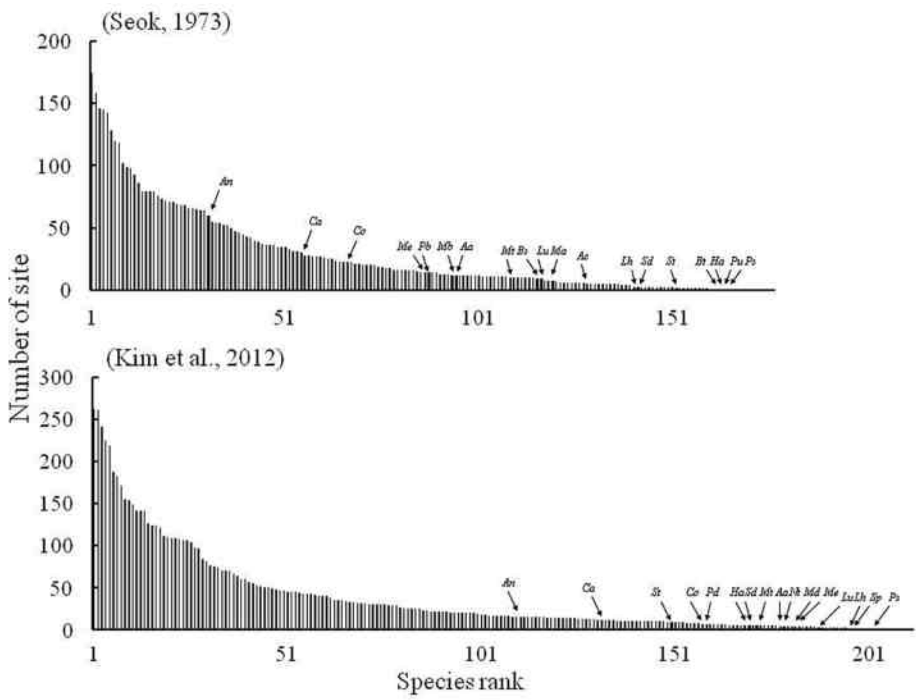

Fig. 1 Species rank of butterflies along site occurrence gradient (number of recorded sites) for 1938–1950 (Seok 1973) and for 1996–2011 (Kim et al. 2012). Acronyms represent 21 endangered butterfly species in South Korea.

Ac, Aporia crataegi ; Aa, Argynnis aglaja ; An, Argynnis nerippe ; Bs, Burara striata ; Bt, Boloria thore ; Ca, Coenonympha amaryllis ; Co, Coenonympha oedippus ; Ha, Hipparchia autonoe ; Lu, Leptalina unicolor ; Lh, Limenitis homeyeri ; Ma, Maculinea arionides ; Mt, Maculinea teleius ; Mb, Melitaea britomartis ; Me, Melitaea ambigua ; Nt, Neptis tshetvericovi ; Pb, Parnassius bremeri ; Ps, Protantigius superans ; Pu, Plebejus subsolanus ; Sp, Seokia pratti ; Sd, Shijimiaeoides divines ; St, Spindasis takanonis.

species more rather than rarity. Following our criteria for determination of endangered species, only eight species of the 20 endangered species (including both endangered and critically endangeredspecies from the previous determinations) are defined as endangered. *Maculinea kurentzovi*, which has not been recorded in four atlases, is defined as endangered owing to its extreme rarity. The other selected endangered species fulfill both of our two decision criteria. The scarcity of the data available prevented us from achieving the fine level of classification pursued by the IUCN[7] methods (Maes and van Swaay, 1997), although we followed its main rules, which are also based on two criteria of rarity and population decline criteria. Our grid cells (0.5° latitudinal and longitudinal) are much larger than those usually applied in Europe (e.g., 25 km^2 grid cells in Belgium and Netherlands, Maes and van Swaay, 1997). The criteria to define a species as rare (<5% of grid cells) is same as that of the IUCN. Instead of the fine quantitative classification on population decline defined within the IUCN method, we only used a simple method based on an obvious signal for population decline. Although these criteria are less restrictive than those of the IUCN's, only less than half of the 20 allegedly endangered species were defined as endangered. This strongly suggests that subjectively defining levels of threat are likely to result in a large number of species defined as endangered than a critical quantitative determination.

Argynnis nerippe was defined as a second class endangered species (equivalent to endangered following Choi and Kim's criteria) by the Ministry of Environment in South Korea. However, Korean butterfly experts disagree with this definition[1]. This species has been relatively common during

Table 1. Occurrence of the previously published endangered butterfly species in South Korea.

Species	ME	Choi and Kim (2012)	Occurrence rank percentage		Change	Site occurrence		Change	Grid occurrence		Change	Population status
			1938–1950	1996–2011		1938–1950	1996–2011		1938–1950	1996–2011		
Hesperiidae												
Burara striata	II	CR	34.5	0.0	–34.5	5.2	0.0	–5.2	7	0	–6*	EN
Leptalina unicolor		EN	34.5	8.5	–26.0	5.2	1.1	–4.0	9	3	–6	EN
Lycaenidae												
Plebejus subsloanus		EN	0.6	0.0	–0.6	0.6	0.0	–0.6	2	0	–2	EN
Maculinea kurentzovi		CR	–	–	–	–	–	–	–	–	–	EN
Maculinea teleius		EN	35.6	17.0	–18.6	5.7	1.9	–3.8	7	3	–4	EN
Maculinea arionides		VN	32.8	17.0	–15.8	4.6	1.9	–2.7	7	5	–2	
Shijimiaeoides divina	II	VN	15.3	0.0	–15.3	1.7	0.0	–1.7	4	3	–1	EN
Spindasis takanonis	II	EN	10.2	28.3	18.1	1.1	3.4	2.3	1	6	5	
Protantigius superans	II		0.6	0.5	–0.1	0.6	0.4	–0.2	1	1	0	
Nymphalidae												
Boloria thore		EN	0.6	0.0	–0.6	0.6	0.0	–0.6	1	0	–1	EN
Melitaea ambigua		EN	49.7	12.3	–37.5	8.0	1.5	–6.5	11	4	–7	
Melitaea britomartis		EN	43.5	12.3	–31.2	6.9	1.5	–5.4	11	3	–8*	EN
Seokia pratti		EN	0.0	3.3	3.3	0.0	0.8	0.8	0	2	2	
Limenitis homeyeri		EN	15.3	3.3	–12.0	1.7	0.8	–1.0	2	2	0	
Hipparchia autonoe	I	VN	0.6	17.0	16.4	0.6	1.9	1.3	1	2	1	
Argynnis aglaja		EN	43.5	12.3	–31.2	6.9	1.5	–5.4	9	4	–5	
Argynnis nerippe	II		83.1	47.6	–35.4	34.5	6.1	–28.4	38	14	–24***	
Neptis tshetvericovi		EN	–	12.3	–	–	1.5	–	–	4	–	
Coenonympha amaryllis		EN	69.5	36.8	–32.7	17.2	4.6	–12.7	22	7	–15**	
Coenonympha oedippus		EN	62.1	23.1	–39.0	13.2	2.7	–10.5	16	5	–11*	
Pieridae												
Parnassius bremeri	II	EN	49.7	23.1	–26.6	8.0	2.7	–5.4	11	6	–5	
Aporia crataegi	I	CR	28.2	0.0	–28.2	3.4	0.0	–3.4	5	0	–5	EN

These species were defined by Choi and Kim (2012) and by the Ministry of Environment (ME). Roman numerals (I, II) indicate the risk level for endangered species. The first level (I) is equivalent to critically endangered (CR) in Choi and Kim (2012) and second level (II) is equivalent to endangered (EN). The additional level (VN) defined by Choi and Kim (2012) means vulnerable. Details for the three occurrence indices are given in text. Fisher's exact test was applied to test for significant differences in gird occurrence between 1938–1950 and 1996–2011 (Kwon 2012) on a 2×2 way contingency table, using the number of recorded and unrecorded grid cells. * : $P<0.05$, ** : $P<0.01$, *** : $P<0.001$.

the two periods despitea recent steep decline (Fig. 1, Table 1)[5,6], and subsequently this species cannot be defined as endangered for its abundance. This suggests that the previous definition was based neither on reliable data of population status nor on the expert's perception because field-oriented butterfly specialists would never define a common species as a rare species. In that case why are other rare species not defined as endangered (i.e., 93 of the non-endangered species were in fact rarer than *A. nerippe* during 1996-2011 ; Fig. 1)? We assume that these rare but non-endangered species may have not decreased in occurrence as dramatically as endangered species. The answer for this question may contain the key information regarding past determinations of endangered species.

Our findings suggest that the nature of a fine-scale classification of endangered species without the support of reliable data may not go beyond the subjective personal guess. Despite this fundamental flaw, expert's perception would likely remain to be an important factor in future determinations of endangered species, because of the paucity of population status information for most countries. Efforts directed towards a data-based definition of endanger status and the development of logical and qualitative determination methods are essential to secure a solid and widely accepted decision-making process. It is possible that a mistaken conservation measure directed to luckily-selected species can become an added disturbance to biosphere, which has been increasingly influenced by the growing anthropogenic stresses such as decrease in biodiversity, climate change, habitat alterations, and changes in biogeochemical cycles.

Acknowledgments

This study was conducted as part of a research project of the Korea Forest Research Institute (Project FE 0100-2009-01, Effect of climate change on forest ecosystem and adaptation of forest ecosystem).

References

1) Choi, S-W. and S-S. Kim (2012) The past and current status of endangered butterflies in Korea. *Entomol. Sci.* 15 : 1-12.
2) Forister, M.L., A.C. McCall, N.J. Sanders, J.A. Fordyce, J.H. Thorne, J. O'Brien, D.P. Waetjen and A.M. Shaprio (2010) Compounded effects of climate change and habitat alteration shift patterns of butterfly diversity. *PNAS* 107 : 2088-2092.
3) Franco, A.M., J.K. Hill, C. Kitschke, Y.C. Collingham, D.B. Roy, R. Fox, B. Huntley and C. Thomas (2006) Impacts of climate warming and habitat loss on extinctions at species' low-latitude range boundaries. *Global Change Biol*. 12 : 1545-1553.
4) Kim, C.W. (1976) Distribution Atlas of Insects of Korea. Series 1. Rhopalocera Lepidoptera. Korea University Press, Seoul.
5) Kim, S-S., C.M. Lee and T-S. Kwon *et al*. (2012) Korean butterfly atlas 1996-2011. Research Note 461, Korea Forest Research Institute.
6) Kwon, T-S., C.M. Lee, S-S. Kim and J.H. Sung (2012) Distribution change of Korean Butterflies 1938-2011. Research Note 472, Korea Forest Research Institute.
7) Maes, D. and C.A.M. van Swaay (1997) A new methodology for compiling national red lists applied to butterflies (Lepidoptera, Rhopalocera) in Flanders (N-Belgium) and the Netherlands. *J. Insect Conserv*. 1 : 113-124.
8) Ministry of Environment (2005) Endangered plants and animals in Korea. Ministry of Environment of Korea, Seoul.
9) Nakamura, Y. (2011) Conservation of butterflies in Japan : status, actions and strategy. *J. Insect Conserv*. 15 : 5-22.
10) Ogawa-Onishi, Y. and P.M. Berry (2013) Ecological impacts of climate change in Japan : The importance of integrating local and international publications. *Biol. Conserv*. 157 : 361-371.
11) Park, K.T. and S-S. Kim (1997) Atlas of Butterflies (Lepidoptera). Insects of Korea Series 1. Korea Research Institute of Bioscience and Biotechnology, Center for Insect Systematics, Jeonghaengsa, Seoul.
12) Seok, D.M. (1973) The Distribution Maps of Butterflies in Korea. Pochinjai, Seoul.

13) Warren, M.S., J.K. Hill and J.A. Thomas *et al*. (2001) Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature* 414 : 65-69.
14) Zar, J.H. (1999) Biostatistical analysis (fourth edition). Prentice Hall International, Inc. USA.

韓国における絶滅危惧チョウ類の希少性と発生数の変化

Cheol Min LEE and Tae-Sung KWON
韓国国立森林科学院森林保全部森林生態課

要　約

温暖化や土地開発などの環境変化にさらされ，高い絶滅の危機にある絶滅危惧種が非常に注目を浴びている。それゆえ絶滅危惧種のレッドリストが自然を保全する上で重要な役割を果たしている。数種の絶滅危惧チョウ類は，すでに政府や個人によって韓国南部の地域ではリストアップされているが，これらのレッドリストは信頼性のある個体数データを元に作られたものではない。それゆえ“どの種をどんな理由で”レッドリストに入れるのかという多くの議論が出てくる。我々は ‘Korean butterfly atlases’ を使って，以前に報告された韓国の絶滅危惧チョウ類の生息状況を評価した。我々は，絶滅危惧種は非常に少なく且つ個体数が減少している種という仮説をたてた。絶滅種を決定する上で個体数の減少は，希少性と比較してより重要であることがわかった。希少性と個体数変化の定量的値を用いて，我々は過去に報告された種から絶滅危惧種を選定した。その結果，以前の絶滅危惧20種のうち８種のみが，この定量的分類手法で絶滅危惧種として定義された。このことは専門家の感覚だけに基づいた主観的な決定は，個体数データに基づいた定量的決定に比べて，より多くの種を絶滅種に指定していることを示唆している。

キーワード：チョウ類，絶滅危惧，発生数，希少性，保全，韓国南部