Journal of Asia-Pacific Biodiversity xxx (2018) 1–10

Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

journal homepage: http://www.elsevier.com/locate/japb

Original Article

# Changes in butterfly assemblages and increase of open-land inhabiting species after forest fires

Sung-Soo Kim [1], Tae-Sung Kwon [2,*]

[1] Research Institute for East Asian Environment and Biology, Amsa-3 dong, Gangdong-gu, Seoul 05236, Republic of Korea
[2] Forest Insect Pests and Diseases Division, National Institute of Forest Science, 57 Hoegi-ro, Dongdaemun-gu, Seoul 02455, Republic of Korea

ARTICLE INFO

*Article history:*
Received 7 June 2017
Received in revised form
28 October 2017
Accepted 14 November 2017
Available online xxx

*Keywords:*
abundance
butterflies
conservation
fire
occurrence
rarity
richness

ABSTRACT

The objective of this study was to determine influence of fire on butterfly assemblages and postfire butterfly faunal change in South Korea. Butterflies were surveyed for several years (5 or 9 years) from 2005 to 2015 at four sites (2 burned sites and 2 unburned sites) in the eastern coastal region (3 sites in Samcheok and Uljin) and the western region (1 site in Pocheon). Butterflies were surveyed monthly from April to October at each site (route length 1.5∼2 km) with line transect method. Open habitat species were increased in richness and abundance. However, richness of total species was not increased because of decreased forest species. Rare open habitat species such as *Argynnis nerippe*, *Boloria oscarus*, and *Hesperia florinda* were found only at burned sites. These burned areas are likely to become habitats for venerable open habitat insects. Butterfly assemblages were significantly influenced by fire and region. Our results confirmed a positive correlation between regional occurrence and local abundance, a general ecological phenomenon (common species is abundant). In addition, our results showed a positive correlation of local occurrence with regional occurrence and between local abundance.





## Introduction

The risk of large wild fires has been increasing in South Korea because logs and litters that can be used as fuel have been accumulating in forests as forests grow nationwide (Lim et al 2006). Since the mid-1990s, large forest fires have occurred in the eastern coastal region where pines (*Pinus densiflora*) are dominant. Pines are more vulnerable to fires than oaks or other kinds of trees are because of the highly combustible pine resin. The dry and windy climate in spring in this region is another main cause of large forest fires. In 1996, a large fire burned 3,672 ha of pine forests in Goseong, Gwangwon-do. In 2000, the largest fire in Korea burned about 24,000 ha of forests in Goseong, Gangnung, Samcheok, and Uljin. From 2005 to 2007, three large fires burned about 3,000 ha (about 1,000 ha each) in Gangleung, Yangyang, and Uljin (Kwon and Kim 2016).

Fires abruptly change plants and other organisms in burned forests. In forests, insects are the most diverse and abundant ones among minute animals. After fires burn forests, insect assemblages are changed greatly in response to environmental changes (Swengel 2001). Butterflies largely feed on plants. They are strong fliers with large wings. Therefore, butterflies might be able to respond rapidly to vegetation changes after fire. Many studies have been conducted on response of butterfly assemblages to environmental changes caused by fire (e.g. Cleary and Moores 2006, Vogel et al 2007). In South Korea, Kwon et al (2013a,b) have surveyed butterflies burned area of Uljin for 5 years from 2007 to 2011 and reported change in butterfly assemblages after fire to examine the influence of fire. However, they did not find any evidence that fire influenced the richness, abundance, or species composition of butterflies.

This study is an extension of study of Kwon et al. In this study, butterflies at the same two sites in Uljin burned area were surveyed for three years (2012∼2014) after 2011 when the butterfly survey for the study of Kwon et al (2013a,b) ended. In the study of Kwon et al (2013a,b), no repetition (one burned site, one unburned site) weakened the statistical power of their data. Therefore, they could not determine whether the influence of fire on butterfly assemblages was significant despite a clear difference in assemblages between two sites. Therefore, another burned site and unburned site where butterflies had been surveyed for 5 years were selected.

* Corresponding author. Tel.: +82 2 961 2653; fax: +82 2 961 2679.
*E-mail address:* insectcom@korea.kr (T.-S. Kwon).
Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

https://doi.org/10.1016/j.japb.2017.11.004
pISSN2287-884X eISSN2287-9544/

These additional two sites would increase the statistical power of data to examine the influence of fire on butterfly assemblages. Most butterfly surveys were short-term survey of 1 or 2 years due to the limitation of fund (Kwon et al 2010). Therefore, our long-term data might be valuable for future ecological analysis.

Using our survey data, several hypotheses related to the influence of fire or other ecological topics were examined. First, forest fires kill trees, changing forests into open habitats with grasses and shrubs. Therefore, open habitat inhabiting species (hereafter, open species) will increase in abundance (number of individuals) and richness (number of species), whereas forest inhabiting species (hereafter, forest species) will decrease. Second, butterfly species feeding on herbs and shrubs are richer than butterfly species feeding on trees (Kwon et al 2013a,b). Hence, richness of butterflies after fire would increase. Third, as results of the first and second expectation, species composition of butterfly assemblages would be changed after fire. Fourth, more common species with high mobility and wide niche would be more abundant in the burned area than in the unburned area. Lastly, a positive relationship between local abundance and regional occurrence has been widely reported, and such relationship is regarded as one of the few general rules of ecology (Hartley 1998). Therefore, a positive relationship between local occurrence and regional occurrence or between local occurrence and local abundance is expected to occur under the assumption of similar distribution pattern of butterfly species (e.g. distribution pattern is not different between common species and rare species). These relationships were examined using data of this study and published data (Kwon et al 2012a,b).

## Material and Methods

### *Study sites*

Butterflies were surveyed at four sites: two burned sites (Uljin burned, UB; Samcheok burned, SC), and two unburned sites (Uljin unburned, UU; Gwangneung unburned, GN). In Uljin-gun, one burned site (UB; 36.851 N and 129.39 E) and one unburned site (UU; 36.859 N, 129.397 E) were selected. Distance between the two sites was 2.7 km. Fire occurred twice (in 2000 and 2007) around UB. UB was a trail of grassland at length of about 1.5 km. UU was a forest road of about 1.5 km in length with pine forest of about 30 years old. *P. densiflora* was the dominant species. Map of sites and information for other Uljin sites have been described previously (Kwon et al. 2013a).

In Samcheok city, one burned site (SC; 37.201 N, 129.323 E) was located in the burned area where the largest fire occurred in 2000 (Figure S1). This site was located in heterogeneous landscape containing remained (unburned) forest fragments, burned open habitats (bushes/grasslands), stream, and stream sides. SC was a trail of about 2 km in length. These three sites (UB, UU, SC) were located in the eastern coastal region (eastern region) of South Korea. SC was about 30 km away from Uljin sites.

Another unburned site (GN) in Pocheon city was located in Gwangneung forest, an old (>100 years) deciduous forest well-conserved in South Korea (Byun et al 2006). GN (37.763 N, 127.158 E) was located in the western region in South Korea. It was about 210 km away from other sites. GN is neighbored with Seoul with a distance of about 20 km. Map of GN has been described in detailed previously (Kwon et al 2009). GN was a forest road of about 2 km in length. The deciduous forest surrounding GN was dominated by *Capinus laxiflora* and *Quercus serrata* tree species (Kwon et al 2009). GN was selected as a reference site to represent undisturbed old forest with high insect diversity (Byun et al 2006).

When these four sites were ranked by the duration after disturbance, GN was the least disturbed forest (>100 years after disturbance), UU was a moderately disturbed secondary forest which was forested from grassland about 30 years ago (about 30 years after disturbance). Survey at SC had been carried out in 5, 6, 9, 10, and 11 years after fire. Therefore, the duration after disturbance was 8.2 years in average. Survey at UB had been carried out within 0 to 8 years after fire. Therefore, the duration after disturbance was 4 years in average. Thus, disturbance of sites from the least to the most was in the order of GN < UU < SC < UB.

### *Survey of butterflies*

Butterflies were surveyed with the line transect method (Pollard and Yates 1993). Butterflies were observed within 10 m width of route (trail and road). The number of butterflies along the routes of each site was counted by walking slowly along the route. When species identification was impossible by observation, butterflies were collected with net. After species identification, butterflies were released at the points of collection. Butterfly surveys were conducted monthly in nonrainy days (10:00 ∼ 14: 00) from April to October. Uljin sites (UB, UU) were surveyed for 9 years (from 2007 to 2015). Other sites (SC, GN) were surveyed in 2005, 2006, 2009, 2010, and 2011. Survey at SC was conducted in 2005 and 2006 by Dr. TU Kim (National Institute of Biological Resources). Other surveys were conducted by author (S-S Kim). Surveys were conducted in 53 days at UB and UU sites and in 35 days at SC and GN sites.

### *Data analysis*

Habitats of butterfly species were classified into two types: forest and open habitat. Kim et al (2012) have classified habitats of butterflies into three types: forest, forest edge, and grassland. To simplify analysis, forest edge and grassland were combined as open habitat in this study. Regional (national) occurrence of butterfly species was calculated using national data of standardized occurrence published by Kwon et al (2012a,b). To standardize occurrence in four butterfly atlases with different sampling efforts from 1938 to 2011, Kwon et al (2012a,b) have transformed recorded points (recorded sites) into grids (grid scale, 0.5$^{o}$ latitude$\times$ 0.5$^{o}$ longitude). In this study, regional occurrence was represented by the number of recorded grids of each species in recent period (1996–2011). The regional occurrence is likely to be a robust index for the rarity or commonness of each species. Local occurrence was represented as number (1–4) of recorded sites in this study. Local abundance of each species was indicated by the number of total individuals observed at each site.

Butterfly survey was annually repeated (pseudo-replicated). However, years seemed to be fixed-effect factor because time was a main factor for faunal change after fire. Therefore, year was considered as a fixed-effect factor and a random factor, so mixed-effects model was used to control pseudo-replication by years to determine the influence of three factors (fire, region, and years) on richness and abundance. Mixed-effects model was used for three types of data: total species, open species, and forest species. The mixed-effects model is robust for parametric assumption such as normality and equal variance of data (Crawl 2007). Due to difference in sampling efforts (i.e. 9 years at UB and UU but 5 years at SC, GN), observed pooled richness could not be directly used to compare richness. Two richness estimation tools (Preston's log-normal richness estimation and Chao index available in "vegan" package in R) were used to estimate richness at each site. In the latter case, mean and standard deviation (SD) of richness were calculated with regard to number of samples. In this study, annual data were used. Therefore, values (mean and SD) at minimum replicates (5 years) were used to calculate t-values for two samples t test (Zar 1999). Count data were analyzed by $\chi^2$ test in the

Please cite this article in press as: Kim S-S, Kwon T-S, Changes in butterfly assemblages and increase of open-land inhabiting species after forest fires, Journal of Asia-Pacific Biodiversity (2018), https://doi.org/10.1016/j.japb.2017.11.004