Journal of Asia-Pacific Biodiversity 7 (2014) 319–346

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Contents lists available at ScienceDirect

Journal of Asia-Pacific Biodiversity

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

Original article

# Diversity of beetles in Gariwangsan Mountain, South Korea: Influence of forest management and sampling efficiency of collecting method

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ARTICLE INFO

*Article history:*
Received 26 May 2014
Received in revised form
24 June 2014
Accepted 30 June 2014
Available online 4 August 2014

*Keywords:*
Beetles
Diversity
Forest management
Gariwangsan Mountain
Korea

ABSTRACT

This study was conducted to examine the community structure and diversity of beetles (Coleoptera) inhabiting diverse forest management areas in the Gariwangsan Mountain. The survey was carried out monthly at five study sites of the national forest including a clear-cut area, a heavily thinned forest, a selectively thinned forest, a larch plantation, and a deciduous forest from May 2011 to September in 2011. Beetles were sampled using pitfall trap, Malaise trap, black light, and sweeping. A total of 4883 beetles belonging to 310 species in 43 families were collected. The diversity in the selectively thinned site was lower compared with that in other sites. Of the sampling methods, Malaise traps showed the highest efficiency for collecting diverse beetles. The composition of the functional guild for beetles directly sampled using the sweeping method was different from the composition of those sampled by other methods (e.g. pitfall trap, Malaise trap, and black light), which depended on the activity of the insects.


## Introduction

Biological diversity can constantly provide an essential ecological service through enhancing the resilience of the ecosystem (Elmqvist et al., 2003). Human influences on the natural environment consistently deteriorate the ecological functions and biological diversity (Baral et al., 2014). The major factors that threaten biological diversity are fragmentation, loss and decline of habitats, invasion of exotic species, lack of natural resources, inadequate policy against forest fires, and climate changes (Reid, 1994; Werner and Raffa, 2000; Steffen et al., 2009). The importance of biological diversity has been widely recognized because it affects not only the global economy and human welfare, but also human survival. Therefore, it is significant to understand how biological diversity affects ecological functions such as productivity and ecological stability (Bengtsson et al., 2000). The mountain areas, in particular, have different vegetation and habitat conditions depending on the altitudes and inclination, compared to the lowland areas. The mountain areas also show the characteristics of fauna adapted to specific environments. Moreover, mountain areas are high in biological diversity because there are few human activities in these areas, compared to the lowland areas (Lomolino, 2001). The information on biological diversity in the mountain areas is ultimately essential for the efficient management and use of biological resources, the changes in distribution and density of useful biological resources, and the conservation of species (Jung et al., 2011b).

In order to evaluate the changes in biodiversity, biological indicator species have been widely used. The influence of forest management on the forest ecosystem or structure can be investigated by using biological indicator species (Pearce and Venier, 2006). Insects have been commonly used to evaluate biological diversity. Of the insects, about 350,000 species of beetles have been reported around the world as they have the largest diversity (Gullan and Cranston, 2010). Beetles not only play critical roles as predator, herbivore, detritivore, and fungivore of ecosystems in the web food structure and the flow of energy, but are also used as source of food for birds, mammals, amphibians, and reptiles

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Peer review under responsibility of National Science Museum of Korea (NSMK) and Korea National Arboretum (KNA).

http://dx.doi.org/10.1016/j.japb.2014.06.005

(Holland, 2002; Triplehorn and Johnson, 2005). Moreover, beetles are used as biological indicator species to evaluate forest management, the segmentation of mountain forest, deforestation, and forest fire (Werner and Raffa, 2000; Maeto et al., 2002; Rainio and Niemelä, 2003; Pearce and Venier, 2006). Therefore, the functional characteristics of the forest ecosystem in the Gariwangsan Mountain can be explored by investigating the beetles' diversity in the Gariwangsan Mountain.

Even though Gariwangsan Mountain is considered to have a high biological diversity because of the well-balanced preservation and management programs put in place, little research has been undertaken to investigate the insects in that area. The national survey of natural ecosystems conducted by the Ministry of Environment reported the list of species in the Gariwangsan Mountain (Ryu and Jeon, 1998). The list of moths surveyed in highlands (altitude of 1180 m) using black light was reported by Kim and Kwon (2013). The study of beetles in the Gariwangsan Mountain was partially reported by Lee et al. (2009). The inhabitation status of Carabidae was reported by Jung et al. (2011a). With regard to Hemiptera, Jung et al. (2013) reported the effects of forest roads on the diversity of Hemiptera in Gariwangsan Mountain and provided a list of species. Hence, the primary purpose of this study is to understand and summarize the current status (i.e. species list and species abundance) of beetles inhabiting the Gariwangsan Mountain. In addition, this study also aims to evaluate the influence of diverse forest management practices on species diversity, species structure, and community structure for beetles.

The biotic community simply refers to the group of species, but it is closely related to the ecological functions in the ecosystem (Choi et al., 2010). Choi et al. (2010) reported that the functional guild composition of beetles was optimized according to the seasonal variations of the environmental condition. As the structure or environmental condition of the forest has been changed depending on the type of forest management, the functional guild of beetles can also be expected to change. Based on this assumption, this study examines the spatial and seasonal changes of functional guild structure of the beetle communities. Furthermore, we compared the efficiency of the sampling methods including pitfall trap, Malaise trap, black light, and sweeping, all of which have been widely used to study beetle diversity.

## Materials and methods

### *Study site*

This study was conducted in the Gariwangsan Mountain (1561 m, 37°27′N, 128°33′E) and the Jungangsan Mountain (1561 m, 37°46′N, 128°56′E) in Gangwon-do, Korea (Figure 1). Gariwangsan Mountain is the inland alpine area in Gangwon-do. It has diverse flora because of its relatively wide distribution of natural deciduous forest areas and its favorable soil conditions (Kim and Um, 1997). Jungwangsan Mountain is located in the west side of Gariwangsan Mountain. In terms of the vegetation in Gariwangsan Mountain, *Quercus mongolica* is dominant, and coniferous forests including *Pinus densiflora*, *Abies nephrolepis*, *Abies holophylla*, and *Taxus cuspidata* are partially dominant (Paik et al., 1998). Gariwangsan Mountain has abundant natural deciduous forest areas relatively heavily planted with *Larix kaempferi*. From 2006 to 2008, the Korea Forest Service (KFS) designated certain parts of the Gariwangsan Mountain as protected areas for forest genetic resources. A total of 2462 ha has been placed under the protection of the KFS as part of this move. Moreover, the KFS has been conducting diverse forest management practices (e.g. forest road development, afforestation, thinning, shelterwood forest, selectively thinned forest, and inducement of larch plantation into natural deciduous

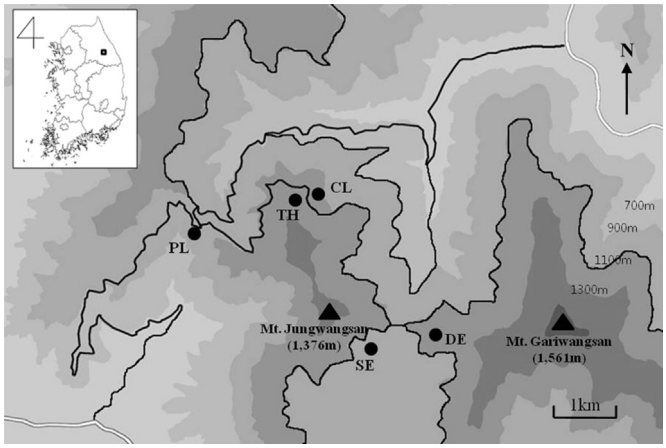


**Figure 1.** Study sites in Gariwangsan Mountain. Dark circles and lines indicate research sites and forest roads, respectively. CL = clear-cut area; DE = deciduous forest; PL = plantation of larch; SE = most big trees selectively thinned deciduous forest; TH = thinned deciduous forest.

forest) in this area to develop a sustainable forest management technology. The Korea Forest Research Institute has carried out comprehensive research regarding the influence of such forest management practices on the ecosystem (Korea Forest Research Institute, 2013). The various forest management projects conducted might affect the biota and the biodiversity in the Gariwangsan Mountain.

The annual mean temperature of this area is 9.7°C, and the annual precipitation is 1761.4 mm (Byeon et al., 2012). The study sites in this research are national forests where the natural deciduous forest areas are partially deforested, and various plantations including *Larix kaempferi* and *Pinus koraiensis* have been developed. Additionally, the KFS and the Seoul National University developed shelterwood forest, selectively thinned forest, and two storied forest in 1997 to develop Korean forest management methods for natural deciduous forest areas (Lee et al., 2009).

In forest management, clear-cutting is a forestry practice used to renew the forest after cutting down most trees from a stand in one cutting. Among the methods of partial deforestation, thinning results in the increase of the total production of timber by facilitating the growth of the remaining crop of trees after removing inferior trees. By contrast, selective thinning is used to maintain multicohort by involving the selective removal of superior trees and then accelerating the growth of young trees in shrubbery layers (Lee, 2012). This study was carried out in five places: three forest managed sites where clear-cutting, thinning, and selective thinning were performed; one larch plantation aged $>$ 30 years; and one deciduous forest site maintaining its natural condition.

Five study sites were selected according to the type of forest management (Figure 1). For the clear-cut areas, this consisted of the place where the shelters for visitors were built after clear-cutting the mountain forest in 1989 and the green lands involving shrub trees and grassland existing nearby [clear-cutting area (CL); altitude1180 m; coordinates 37°28′N, 128°31′E]. The thinned forest site comprised deciduous forest areas near the CL sites, involving places where the density of trees was very low because of heavy thinning [heavily thinned forest (TH); altitude1210 m; coordinates 37°28′N, 128°31′E]. The density of trees was about one-half of the density of the forest in general. The selectively thinned forest site was the place developed in 1997, about 200 m away from Mahangchi [selectively thinned forest (SE); altitude 1100 m; coordinates 37°27′N, 128°32′E]. The plantation site was a larch plantation (PL) aged about 30 years (altitude1100 m; coordinates