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Change of arthropod abundance in burned forests: Different patterns according to functional guilds

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ABSTRACT

Forest fires are one of the most frequent and important causes of forest disturbances, the occurrence of which is globally increasing due to the effects of climate change. This study aimed to determine the impacts of fire and human activity on arthropod communities in affected forests. Twelve study sites in three burned areas were selected for this study. Intensities of disturbance in the study sites were characterized as follows: Disturbance Degree (DD) 0 (no fire), DD 1 (surface fire), DD 2 (crown fire), and DD 3 (crown fire followed by reforestation). Arthropods were collected using pitfall traps. Fourteen arthropod taxa (families, orders or classes), which are relatively homogeneous in their feeding habits and abundant, were analyzed. Depth of litter layer was selected as an environmental indicator for disturbance intensity, as it decreases linearly as the degree of disturbance increased. Changes of arthropod abundance in response to disturbance differed among functional guilds. As disturbance intensity increased, the abundance of detritivores decreased, but the abundance of herbivores increased. However, the abundance of predators varied between taxa. Formicidae and Araneae increased in disturbed sites, whereas Carabidae and Staphylinidae did not change. The abundance of Thysanura and Diptera was highly correlated with disturbance intensity, and may be suitable as a bioindicator for forest disturbance. Arthropod communities were more heterogeneous in forests of intermediate disturbance.

Introduction

Due to successful reforestation in South Korea, combustible materials, such as leaf litter, dead branches and wood have accumulated in forests, resulting in an increased risk of large-scale forest fires (>1000 ha). In late April 1996, a large fire burned 3672 ha of forests in Goseong in Gwangwon province (Korea Forest Research Institute, 1997). In April 2000, the largest fire ever recorded in Korea burned 23,794 ha of forests across Goseong, Gangneung, Samcheok in Gwangwon province and Uljin in Gyoungbuk province, causing serious disturbance to the forest ecosystems as well as economic damage to the local communities (Ro et al., 2000).

Various disturbances play important roles in the formation of the structure and function of ecosystems. Moderate disturbances promote heterogeneity of habitat and increase biodiversity through the migration of organisms (Kwon and Park, 2005; Noske et al., 2008). Gaps in forests created by fire or wind produce different microhabitats and vegetation structures, and support higher overall species diversity (Lain et al., 2008). In addition, dead wood created by disturbance provides habitats and food for various organisms (Gibb et al., 2006; Lachat et al., 2006). After the large-scale fire in 2000, homogeneous landscapes composed of pine forests (*Pinus densiflora*) were replaced with diverse landscape mosaics (Choung et al., 2004). To increase biodiversity within forests, moderate disturbances, such as prescribed fire, clear cutting, and thinning, are artificially applied (Gondard et al., 2003; Glasgow and Matlack, 2007; Kwon et al., 2010a; Maleque et al., 2010).

In Korea, the artificial reforestation of burned forests has been usually applied for the recovery of burned forests. After the large-scale fire in 2000, however, the natural reforestation was recommended for the burned areas (Choung et al., 2004). After some debate, both reforestations were used for the recovery of burned forests. Prior to the artificial reforestation, dead trees and branches, small trees and shrubs were removed, leading to increased disturbance to the burned forests. However, to our knowledge, no study has been conducted to investigate the impact of fire intensity and reforestation on arthropod communities. Arthropods are important components of the forest ecosystems.

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They perform a variety of functions within the forest ecosystem, including nutrient cycling, pollination, litter decomposition, and pest control (Kremen et al., 1993; Niemelä et al., 1996; Triplehorn and Johnson, 2005). They respond rapidly to ecosystem changes because of their short generation time, high mobility, and dependence on temperature (Kremen et al., 1993; Samways, 1994; Schowalter et al., 2003; Maleque et al., 2009). Hence, arthropods are useful bioindicators to estimate the impact of various disturbances, such as windfall, forest thinning, insecticide usage, and fire (Schowalter et al., 2003; Kim and Jung, 2008; Kwon, 2008; Yi and Moldenke, 2008; Jung et al., 2010; Kwon et al., 2010b).

Surface fires mainly burn understory vegetation, whereas crown fires burn all vegetation (Jung et al., 2010). Thus, the effect of fires on forest ecosystems depends greatly on their intensity (Whelan, 1995). As noted above, it is expected that arthropods may be further affected by reforestation of burned forests. This study aims to evaluate the impact of disturbance intensity due to fire and reforestation on arthropod communities in burned forests. The impacts of thinning on arthropods were higher in detritivores than in predators and herbivores in the Korean pine plantation (Kwon et al., 2010a). These differential impacts due to forest disturbance are expected to occur for arthropod communities after forest fire. To test this hypothesis, the abundance of three functional guilds was compared among four disturbance intensities (no fire, surface fire, crown fire, and crown fire followed by reforestation) among three burned areas.

Materials and methods

Study sites and disturbance degree

This study was carried out in three burned areas (those of Goseong, Gangneung, and Samcheok) in the north-eastern coast region of South Korea. Forests in the north-eastern coast region are composed mainly of pine forests and have most frequently experienced forest fires in South Korea due to the occurrence of a strong and dry northeasterly wind in early spring. Forests of 3672 ha in Goseong were burned on 23 to 25 April in 1996 (Korea Forest Research Institute, 1997). This fire started accidentally during army training and the economic loss was about $1,800,000. In April 2000, a very large fire burned forests of 23,794 ha in four counties, including Goseong, Gangneung, Samcheok, and Uljin. It was the largest recorded fire in Korea and it burned 0.37% of the total forest in South Korea (Ro et al., 2000). This fire is thought to have been intentionally started (Ro et al., 2000). In April 2004, a medium fire burned a pine forest of 430 ha in Gangneung.

A total of 12 study sites (4 study sites in each of 3 burned areas) were selected for this study. Disturbance intensity was characterized as one of four disturbance degrees (hereafter DD). DD of unburned pine forest was 0, and DD after a surface fire was 1. DD after a crown fire was 2, and DD after a crown fire followed by reforestation was 3.

The average annual temperatures in Goseong, Gangneung, and Samcheok in 2005 were 11.9 °C, 12.9 °C, and 12.1 °C, respectively (Korea Meteorological Administration, 2005). Annual rainfall in 2005 was 1349 mm in Goseong, 1650 mm in Gangneung, and 1433 mm in Samcheok. Study sites were located 1 to 12 km from the coast, and at elevations of 20 to 192 m. Site aspects are north (8 sites), south (2 sites: Samcheok, DD 2 and DD 3), east (Donghae, DD 2), and west (Goseong, DD 1). In Goseong, DD 2 and 3 were located at N38°18′, E128°29′, DD 1 at N38°19′, E128°27′, and DD 0 at N38°20′, E128°30′. In Gangneung, DD 1 to DD 3 were located at N37°36′, E129°01′, DD 0 at N37°35′, E129°01′. In Samcheok, DD 1 to 3 were located at N37°14′, E129°16–18′, and DD 0 at N37°20′, E129°14′. Site slopes were mostly 3 to 30°, though 2 sites (DD 2 and 3) in Samcheok were steeper (ca. 50°). Soils at the study sites originated from granite, and soil textures were silt loam, loam, or sandy loam. Red pines (*Pinus densiflora*) of about 30–40 years old were the main trees in the 3 study areas. Shrubs and herbs were growing moderately under pine trees. No or a few pine trees were found in DD 2 and DD 3, while shrubs and herbs were growing well in the understory vegetation.

Vegetation, litter and soil property

Vegetation at the study sites was investigated by a botanist (Dr. Ryu) who recorded the plants growing in a plot of 450 m^2 (width 10 m, length 45 m) where pitfall traps were set up. To estimate vegetation structure, the coverage (%) of the tree, sub-tree, shrub, and herb layers was estimated. Depth of the litter layer was measured in 10 replicates per plot (450 m^2), and the average of the values was used for analysis. Five soil samples (ca. 100 ml) per plot were randomly sampled from the surface to a depth of 5 cm, using a small shovel after removing the litter layer, and samples were pooled for each plot. Soil samples were analyzed in the soil analysis laboratory of the Korea Forest Research Institute for determining pH, soil texture (i.e., composition of sand, fine sand, and silt), organic matter, total nitrogen, and cation exchange capacity (CEC, $cmol_c/kg$).

Arthropod sampling

Arthropods were collected in pitfall traps consisting of a plastic cup (depth 6.3 cm, mouth diameter 8 cm, and bottom diameter 6 cm). Twenty pitfall traps were buried at each study site for 10 days in late May 2005. The survey period is considered to be the best for sampling of arthropods since arthropods are active and abundant at higher temperatures during the low rainfall season (from late May to early June in Korea) (Kwon et al., 2005, 2010a). For 10 days, 20 traps were placed 5 m apart from adjacent traps along two parallel lines which were about 10 m apart. The 10 day sampling duration is optimal for the collection of arthropods in Korea, because an abundance of arthropods may be collected, but bodies of arthropods will not have decomposed beyond identification (Kwon, personal observation). Disturbance of samples (e.g., loss of traps, and attraction of arthropods by rotted bodies) increases in longer (>10 days) sampling periods (Kwon, unpublished data). Each trap was filled about one-third with ethylene glycol as a preservative. This arthropod survey has been annually conducted in the same season since 2005 to monitor the long-term arthropod change in the burned pine forests. As a preliminary step, the present study aims to find impacts of forest fire intensity and recovery methods using the first year data of the annual survey. Annual change of arthropod communities will be published in following papers. The number of arthropods collected is dependent on their activity, so it represents a relative abundance rather than an actual density. Despite this limitation, pitfall traps are widely used for monitoring arthropods due to the high efficiency for collection of diverse arthropods, as well as their simplicity. All arthropod specimens were isolated from debris in the laboratory, stored in 80% ethyl alcohol, and identified to order or family level using taxonomic keys (Choi, 1996; Triplehorn and Johnson, 2005). All specimens were deposited at the Forest Ecology Laboratory of the Korea Forest Research Institute.

Functional guilds of arthropods

Microarthropods, such as springtails and mites, were excluded from analysis because of the inaccuracies in counting these very small individuals during counting (Kwon et al., 2010a). Arthropods that have relatively homogeneous feeding functions at the coarse taxon level (i.e. family, order, or even class) were used for analysis. Crustacea, Thysanura, and Diplopoda are representative detritivores. Diplopoda were not used in the analysis due to their low abundance (Table 1). Although Diptera have several feeding functions, they