

Monitoring Insects to Maintain Biodiversity in Ogawa Forest Reserve

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Abstract—The results of a biodiversity monitoring program conducted in the Ogawa Forest Reserve and its vicinity, situated in a temperate region of Japan, identified three different patterns for species richness. Forests of the region are characterized by a mosaic of secondary deciduous stands of various ages scattered among plantations of conifers. The three different types of change in species richness observed in response to the stand age are as follows:

1. Type I (butterflies, tube-renting bees and wasps, hoverflies, fruit flies, and longicorn beetles), the species diversity was highest in open areas, just after clear cutting, decreasing with the stand age;
2. Type II (mites associated with mushrooms), older stands showed greater diversity than younger stands; and,
3. Type III (moths, oribatid mites, collembolas, carabid beetles, and ants), the number of species did not change greatly with the stand age, though ordination analysis revealed that there was variation in species compositions. These results indicate that combinations of stands of different ages, or heterogeneously arranged stands, can contribute to the maintenance of insect biodiversity at the landscape level.

Introduction

In Japan, many natural broad-leaved forests were converted into conifer plantations of Japanese cedar (*Cryptomeria japonica*) or hinoki cypress (*Chamaecyparis obtusa*) throughout the country in order to fulfill urgent needs for timber as construction materials after World War II. Many of the remaining broad-leaved forests have been managed as small scale woodlots to obtain logs for mushroom culture, for example. These practices have contributed to the formation of a landscape, typical of many Japanese villages, which is characterized by a mosaic of small, secondary broad-leaved stands of different ages scattered among conifer plantations.

In order to better understand the present status of biodiversity in this man-made landscape, we have been conducting a biodiversity monitoring program in broad-leaved and conifer stands in cool temperate Japan. In both, the monitoring was carried out in a

chronosequential series of stands, in order to see how biodiversity changes over time in secondary broad-leaved forests and in conifer plantations. Results of the monitoring program will contribute to the development of a management policy for the village landscape that considers the maintenance of biodiversity as an objective. In this report, we describe the monitoring design and outline the tentative results for insects and soil arthropods in the broad-leaved forests.

Monitoring Methods

Study Sites

The monitoring sites were located in the Ogawa Forest Reserve (OFR) (36°56' N, 140°35' E) and its vicinity, situated near the northern border of Ibaraki Prefecture, Japan. Although OFR is an old growth natural forest, the surrounding area is predominantly occupied by

plantations of Japanese cedar and hinoki cypress with scattered secondary deciduous forests of various ages. From the total study area (about 3200 ha about 600 to 800 m a.s.l.) including OFR, we selected nine monitoring plots (4 to 98 ha), ranging from grasslands just after clear-cutting to old growth forests over 170 years old. Konara oak (*Quercus serrata*), Mongolian Oak (*Q. Crispula*), Japanese Beech (*Fagus japonica*), Sweet chestnut tree (*Castanea crenata*), are some of the predominant tree species (Inoue 2003). In addition to the plots, a few grasslands near OFR were also monitored for butterflies. Monitoring was primarily carried out in 2002 with the exception of the butterfly transects which were done in 1997 to 2001 (Inoue 2003).

Plants in the OFR have been studied intensively by a host of ecologists (Nakashizuka and Matsumoto 2002) and inventory studies have been conducted in OFR and its vicinity for some insect taxa (Maetô and Makihara 1999, Totok and others 2002, Sueyoshi and others 2003, Inoue 2003).

Biodiversity Monitoring

Plants

Because all animals depend on plants directly or indirectly, information on the vegetation is indispensable as a background to any analysis of insect diversity. Trees and vines taller than 2m and larger than 5 cm d.b.h. were tagged in forty 5m x 5m quadrats. Forest floor vegetation (vegetation height smaller than 2 m) was inventoried following the Braun-Branquet method for 40 subquadrats (1 x 1 m) along a 100 m line in each plot. Standing dead stems larger than 5cm d.b.h. were also tagged and measured.

Insects and other arthropods

Target organisms were selected from a variety of taxa representing different ecological roles. The particular insect traps mentioned below were placed well inside the study plots to avoid possible edge effects.

Butterflies

Butterflies are typical herbivores: during the larval stage they almost exclusively feed on plants, while adults generally depend on nectar or other carbohydrates. Line transects were conducted to monitor butterflies. One-hour transect counts were made twice a month from April to October between 9:00 and 15:00 (Inoue 2003). Species and the number of butterflies sighted (or collected in a small number of cases where species were not identified at sight) were recorded at each census.

Nocturnal moths

Larvae of moths are also herbivores, though they use woody trees more frequently than butterflies. We used portable light traps (Okochi 2002) to collect nocturnal moths. Once or twice in June or July, a single trap was left overnight at each of the monitoring sites, and moths trapped inside were collected the following morning.

Carabid beetles on the forest floor

Carabids are usually predators of small animals. They have been widely studied as promising indicators of forest conditions using pitfall traps (Niemelä 2001). The pitfall trap we used was a transparent plastic bottle (77 mm diameter, 158 mm height) with three small holes (about 5 mm in diameter) in the middle for drainage of rainwater. A 20 x 20 cm white plastic plate was fixed above the opening with stainless wire in order to prevent various materials falling into the trap. In each plot, ten pitfall traps were aligned in three parallel lines (three, four, and three traps per line, respectively) with a distance of 10 m between each trap and between adjacent lines. Trapped insects were collected every two weeks from April to November.

Tube-renting bees and wasps

Solitary bees and wasps respectively play roles as pollinators and predators of various insects or spiders. Some groups preferentially or obligatorily nest in pre-existing holes. It is thus possible to monitor their abundance and diversity using nesting traps with various tube sizes (Fye 1965, Tscharrntke and others 1998). The nesting trap we used was made of 16 bamboo stalks (approximately 8 to 16 mm in diameter) and four reeds (6 mm), which were tied together side by side with strings. Nine traps were tied to tree trunks or wooden posts (where no substrate trees are available) at 1.5 m above the ground in April, and removed in November. Any immature wasps or bees were reared until eclosion for identification.

Longicorn beetles

Longicorn beetles (Cerambycidae) are usually xylophagous at the larval stage. Many feed on recently felled or killed trees, contributing to the decomposition of dead woody materials. Adult longicorn beetles, particularly of the subfamily Leputurinae, frequently visit flowers to feed on pollen and nectar. Longicorn beetles were collected with standard Malaise traps (Golden Owl Publishers, 180 cm long, 120 cm wide, 200 cm high); five traps were set in April at each plot at intervals of 10 m. Collection of trapped insects was made every two weeks as in pitfall traps.

Hoverflies and fruit flies

Adult hoverflies (Syrphidae) visit flowers to feed on nectar, and probably on pollen. Feeding habits of larval hoverflies are divided into aphidophagous, phytophagous, xylophagous, and fungivorous. Fruit flies (Tephritidae) are phytophagous, feeding on various parts of plant tissues at the larval stage. These flies were also collected with Malaise traps (Sueyoshi and others 2003).

Ants on forest floor

Ants were collected between July and August with litter sampling and pitfall traps along a 100 m (or 200 m in a few sites) transect line in each plot. Litter was sampled at intervals of 20 m, and ants were hand-sorted. Pitfall traps (disposable plastic cups) were set along the same line at 10 m intervals for a maximum duration of three days.

Oribatid mites and Collembola in forest floor litter

Both of these arthropods play important roles as decomposers. A cylindrical core (25 cm² x 5 cm high) of soil was removed from eight divisions (4 x 2 m) of a quadrat (8 x 8 m) in April, August, and November. Soil arthropods were later extracted with Tullgren funnels (Hasegawa and others 2004).

Mites associated with mushrooms

Mushroom fruiting bodies were collected in each plot once a month from April to November. Mites were hand-sorted and identified under a microscope.

Results and Discussion

Species richness of the various indicator organisms groups, in response to stand age after clear cutting, is schematically depicted in figure 1. Trofymow and others (2003) did a similar analysis for arthropod species richness in Douglas-fir forests in Canada as a test of the conceptual ideas presented by Spies and Franklin (1988).

Forest floor vegetation in young stands, was composed of a large number of species. While there was a slight decrease in middle-aged stands, the number of species increased thereafter. Plants in the tree layer with d.b.h. larger than 5 cm showed increased diversity after clear-cutting, saturating at 50 to 60-years. Responses of arthropods to stand age were classified into the following three types.

Type I: Species richness (the number of species) is high in grasslands or in early stages of succession,

while much lower in older forests. This pattern of change was observed with butterflies, hoverflies, fruit flies, tube-renting bees and wasps, and cerambycid beetles.

Type II: Species richness is low in early stages of succession, but becomes greater as forests mature. This pattern of change was observed with mites associated with mushrooms.

Type III: Species richness does not significantly change with forest age. This pattern was observed with moths, oribatid mites, collembolas, and carabid beetles, and ants. Although the species richness of oribatid mites and collembolas was a little lower in a plot one year after clear-cutting, it soon recovered thereafter (Hasegawa and others 2004). Moths also showed a relatively small change across the chronosequence of stands. Their change pattern was moderately bell-shaped, attaining the peak at 50 to 60 years following clear-cutting.

Taxa showing the Type I change pattern response are herbivores during the larval stage, and/or largely depend on flowers for carbohydrates as adults. Many butterfly species live in grasslands and utilize herbaceous plants as hosts. Even species whose host are tree species visit herbaceous plants for nectar (Inoue 2003). Tube renting bees and wasps probably collect nectar and pollen, or

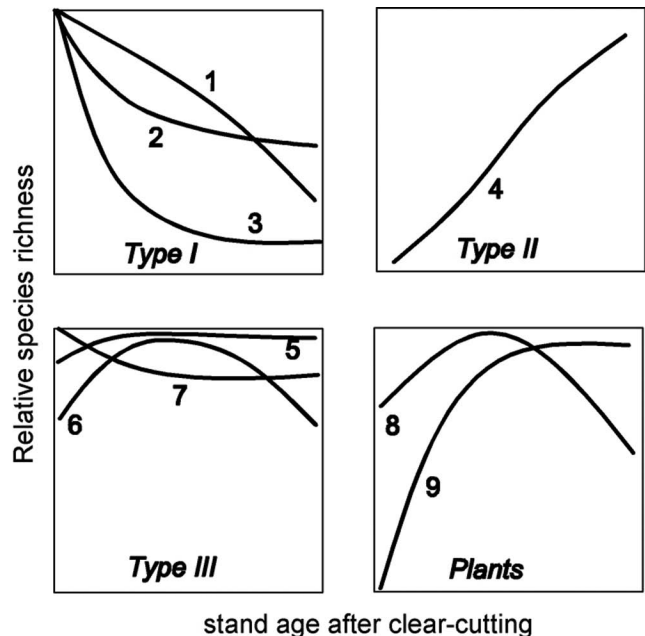


Figure 1. Schematic representations of species richness response to the age of deciduous broad-leaved stands after clear-cutting. Numbers near the response curves represent the following arthropod taxa: 1, butterflies; 2, tube-renting bees and wasps, and longicorn beetles; 3, hoverflies and fruit flies; 4, mites associated with mushrooms; 5, oribatid mites and collembola; 6, moths; 7, carabid beetles and ants; 8, forest floor plants; 9, tree layer plants (d.b.h. >5cm).

hunt prey (for example, lepidopterous larvae, spiders, and grasshoppers) respectively, in grasslands or in very young and open stands. Although most longicorn beetles feed on dead trees during the larval period, adult insects frequently visit flowers. These ecological observations indicate that, for Type I species, abundance of flowers is one of the important factors contributing to the high species richness in plots of early stages of succession. This hypothesis can be tested by monitoring density and abundance of flowering plants in the study sites throughout the seasons.

For mites associated with mushrooms, the species richness response clearly reflects the number of mushroom species, which in turn increased with the forest age. This response seems to be partly due to the frequency of fallen trees, important substrates for mushrooms, which was much greater in older stands.

The arthropod taxa showing the Type III change pattern (moths, oribatid mites, collembola, carabid beetles, and ants) did not show change in species richness in response to forest age. It is noteworthy that moths and butterflies, both lepidopterans feeding mainly on plant leaves, showed different responses to forest age, in spite of the systematic and ecological affinity of the two groups. This may be partly due that a greater percentage of butterfly hosts are herbaceous plants as compared with moth hosts, according to host records from Miyata (1983) for moths, and Matsuka (1994) for butterflies. In addition, adult moths do not depend on flowers for food as butterflies do. Although the underlying mechanisms are unknown, these feeding behaviors may partly explain the observed differences between moths and butterflies.

The Type III pattern with little observed change in species diversity with forest age, does not mean that different aged stands were inhabited by the same assemblage of arthropods. For example, with the exception of the first year following clear-cutting plot, the number of species of oribatid mites did not differ greatly between plots in different age stands. A multivariate ordination analysis, however, showed that a four-year-old plot had an oribatid community distinct from those in other, older plots (Hasegawa and others 2004).

The different responses in terms of species richness shown by different taxa indicate that combinations of stands of different ages, or heterogeneously arranged stands, contribute to the maintenance of insect diversity at the landscape level. Future studies, will monitor other animals, in addition to other insect taxa, to test hypotheses formulated using the results of this study. More detailed analyses of communities or species assemblage of both plants and animals will be undertaken in order to understand how diversity changes over time following clear-cutting.

In this short paper, we have only reported on species richness as a measure of biodiversity. Future studies will also analyze information additional ecological variables beyond species inventories including abundance of coarse woody debris (snags, fallen trees or twigs) as a biotic factor, and light intensity or soil properties as abiotic factors.

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