

Underuse of Coppice Woodlands Decreases the Abundance of Parasitoid Wasps, Potential Natural Enemies of Agricultural and Forest Insects, in Central Japan

Kaoru Maeto, Shun Kitabatake

Graduate School of Agricultural Science, Kobe University

Introduction

Coppice woodlands, which have been rotationally harvested for the production of wood, charcoal, fertilizer, and mushrooms, are a typical vegetation cover in satoyama landscapes in Japan (e.g., Takeuchi et al. 2003). Satoyama landscapes include not only woodlands, but also farmlands (rice paddies, orchards, vegetable fields, and other agricultural areas), settlements, and water reservoirs. These landscape elements are mutually connected in terms of ecological processes. Rural woodlands and other semi-natural ecosystems neighboring agricultural fields can be used as temporal habitats of natural enemies that invade croplands and control insect pests (e.g., Altieri and Nicholls 2004; Hajek 2004). Biological control is one of the most sought-after services of insect biodiversity (Samways 2005).

However, the area of regeneration cutting for rotational harvesting has gradually decreased over the last several decades, mainly from considerable changes in energy consumption and fertilizer use in Japan (Takeuchi et al. 2003). This may decrease the abundance and function of indigenous natural enemies in rural agricultural and forest landscapes. Such rural landscape changes and underuse of coppice woodlands have affected a variety of arthropods, including endangered or rare species (Maeto and Makihara 1999; Takeuchi et al. 2003; Inoue 2003; Makino et al. 2006; Maleque et al. 2006), but little is known about changes in the assemblages of parasitoid wasps, which are among the major groups of natural enemies of pest and non-pest insects (e.g., Gauld and Bolton 1988; Hajek 2004). The decline in understory vegetation, which is often observed in old coppice woodlands, may reduce the abundance and diversity of parasitoids, although no evidence is currently available to support this prediction.

The aim of this study was to clarify the effects of underuse, i.e., aging of deciduous coppice woodlands, on the abundance of parasitoid wasps in the understory layers. We focused on the family Braconidae (Hymenoptera), the second largest group of parasitoid wasps. Members of this group have highly diversified host ranges and are very important in bio-control programs of pest insects (Gauld and Bolton 1988; Hanson and Gauld 1995).

Materials & Methods

Study area

This study was conducted in an area of coppice woodlands in Ogawa (580-800m a.s.l.), located at the southern edge of the Abukuma Mountains in Kitaibaraki, Ibaraki Prefecture, central Japan (Makino et al. 2007). In this area, woodlands have been subjected to human activities such as burning, cattle grazing and clear-cutting for fuel wood (Suzuki 2002), and small scale clear-cutting of broad-leaved stands has been ongoing through the present. We selected nine plots in deciduous broad-leaved stands, dominated by

Quercus serrata, *Q. mongolica*, and *Fagus crenata*, representing a chronosequence from 4 to > 100 years after clear-cutting (Table 1).

Table 1 Study plots and collection summary of braconid parasitoids in Ogawa in 2002

Plot code	Age (years)	Area (ha)	Number of braconid subfamilies	Number of braconid individuals
O4	4	5	15	1110
O12	12	4	13	670
O24	24	24	15	797
O51	51	10	14	405
O54	54	14	15	311
O71	71	19	15	408
O128	128	98	13	343
O174	174	11	15	340
O178	178	10	13	368

Sample collection

Parasitoid wasps were collected with Townes-style Malaise traps (Golden Owl Publishers; 180 cm long, 120 cm wide, 200cm high; coarse mesh) in 2002. The traps were placed in study stand to avoid edge effects. Trapped insects were collected every 2 weeks from late April to early November. A mixture of ethanol and propylene glycol was used as preservative in the insect containers of the traps.

Parasitoid wasps

Braconid wasps (Hymenoptera, Braconidae) collected in two traps, 10 m distant from each other, were used for each plot in the following analyses. All specimens were dried, mounted, and identified to subfamily or tribe, and all voucher specimens were deposited at Kobe University (Graduate School of Agricultural Sciences), the Museum of Nature and Human Activities, Hyogo, and the Forestry and Forest Products Research Institute (FFPRI).

Analyses

Data on braconid wasps were pooled for each plot through the seasons. Principal component analysis (PCA) was performed on the abundance of subfamilies (tribes) in each plot to make an ordination of plots and braconid subfamilies. Simple regression of the abundance of parasitoids was analyzed in relation to stand age after clear-cutting. For these analyses, the number of individuals per trap was log-transformed as $\log_{10}(X + 0.5)$. Statistical analyses were carried out with SPSS for Windows, ver. 11.5.1 J (SPSS Inc.).

Results

In total, we collected 4,752 individuals of braconid parasitoids (Table 2). The number of captures increased abruptly in May, remained high during summer, and dropped from mid-August to September (Fig. 1). The specimens belonged to 17 subfamilies, and the major guilds of their host insects are summarized in Table 2. Fourteen subfamilies (including the tribe Dacnusiini of the Alysiinae) were presumed to be parasitoids of

plant feeders (herbivores), and four subfamilies (including the tribe Alysini of the Alysiinae) were presumed to be parasitoids of detritus feeders (including wood borers and mushroom feeders). The former group accounted for 74.7 % and the latter for 25.3 % of total captures.

Table 2 Subfamilies of braconid parasitoids collected, and presumed feeding guilds of their host insects

Subfamily (tribe)	Major feeding guild of hosts	Recorded range of host insects*	Number of individuals
	P – plant feeders D – detritus feeders	C – Coleoptera, L – Lepidoptera, D – Diptera He – Hemiptera, Hy – Hymenoptera	
Agathidinae	P	Plant-feeding larvae of L	54
Alysiinae (Alysiini)	D (P)	Detritus-, mushroom-, or rarely plant-feeding larvae of D	509
Alysiinae (Dacnusiini)	P	Plant-feeding larvae of D	229
Aphidiinae	P	Plant feeders of aphids	8
Braconinae	P (D)	Plant-feeding or occasionally wood-boring larvae of C, L and D	257
Cheloninae	P	Plant-feeding larvae of L	692
Doryctinae	D (P)	Wood-boring larvae of C, or rarely plant-boring larvae of L	326
Euphorinae	P (D)	Plant feeders or rarely detritus feeders of C, He, etc.	50
Helconinae	D (P)	Wood-boring, mushroom-feeding, or seed-boring larvae of C	249
Homolobinae	P	Plant-feeding larvae of L	24
Ichneutinae	P	Plant-feeding larvae of L and Hy	42
Macrocentrinae	P	Plant-feeding larvae of L	72
Meteorinae	D (P)	Wood-boring or mushroom-feeding larvae of C larvae, or plant-feeding larva	118
Microgastrinae	P	Plant-feeding larvae of L	1,392
Miracinae	P	Plant-feeding larvae of L	13
Opiinae	P	Plant-feeding larvae of D	305
Orgilinae	P	Plant-feeding larvae of L	2
Rogadinae	P	Plant-feeding larvae of L	410
Total			4,752

*According to Shaw and Huddleston (1991), Wharton et al. (1997), and literature cited by them

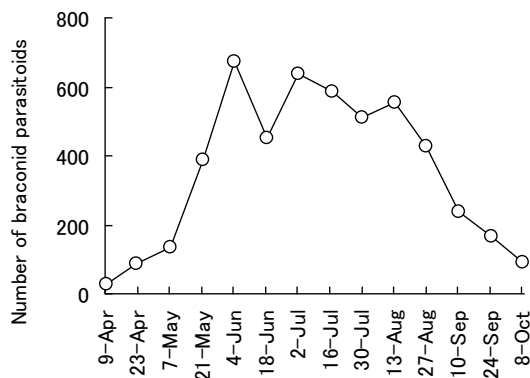


Fig. 1 Seasonal prevalence of braconid parasitoids collected by Malaise traps in Ogawa in 2002

Figure 2 shows the PCA ordination of plots and subfamilies (tribes) with more than 20 individuals. Along the first axis (proportion of variance = 0.462), nine plots were arranged by the age of stands (Fig. 2a; $\tau = -0.889$, $P < 0.001$, between the first axis score and stand age), and the parasitoids of plant feeders were mostly clustered among younger plots (Fig. 2b). In contrast, the parasitoids of detritus feeders were near the origin of the first PCA axis, indicating no obvious relation to stand age.

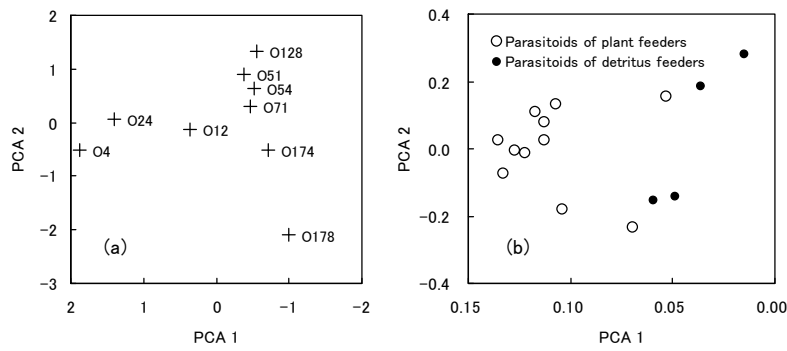


Fig. 2 Ordination of plots (a) and braconid subfamilies (b) by principal component analysis (PCA)

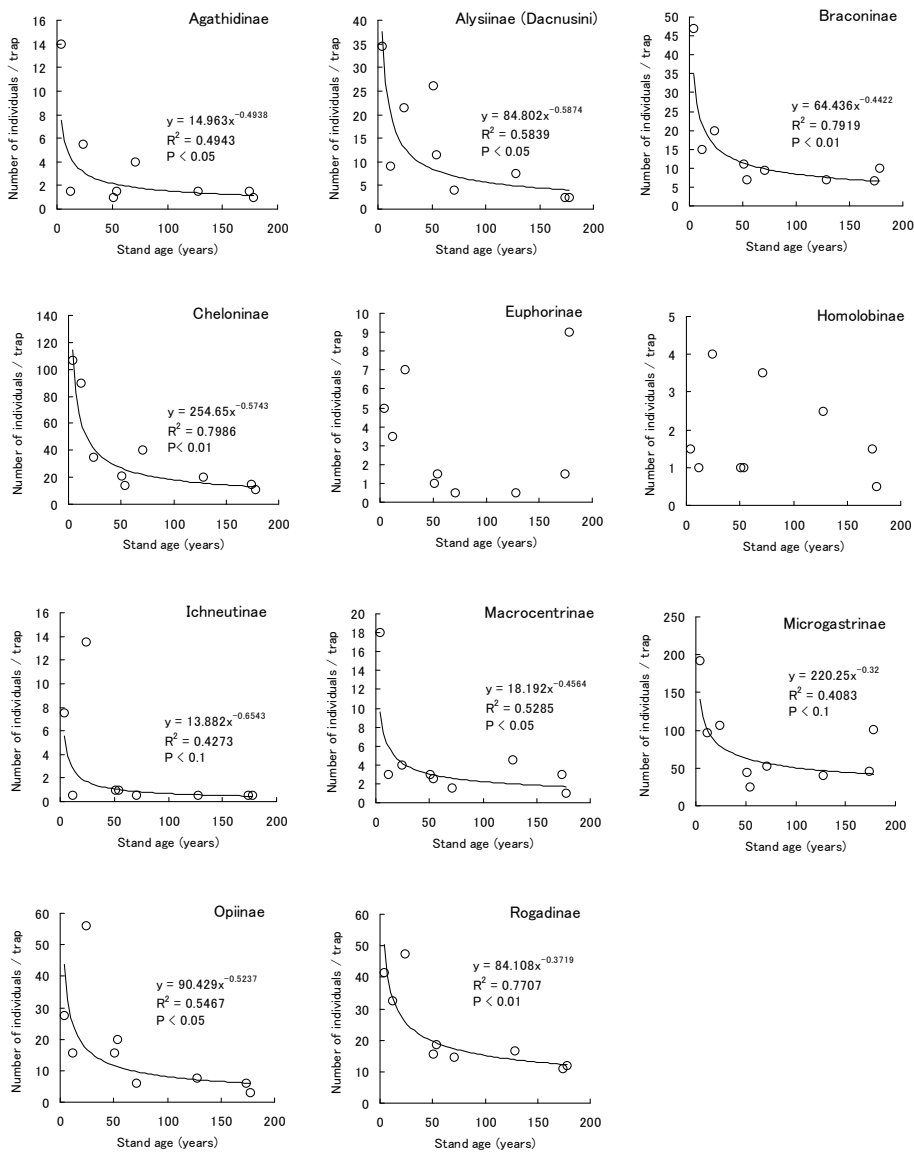


Fig. 3 Relationship between stand age after clear-cutting and the abundance of braconid parasitoids of plant feeders for each subfamily

Figure 3 shows the abundance of the parasitoids of plant feeders in relation to stand age after clear-cutting. The number of captures per trap in most groups except for two small subfamilies, the Euphorinae and Homolobinae, declined markedly with the increase in stand age. In the parasitoids of detritus feeders, however, changes in abundance along with stand age were not consistent (Fig. 4), whereas a temporal increase and decrease in the middle-aged stands were evident for the Alysini (Alysiinae) and the Doryctinae, respectively.

Data of the parasitoids of plant feeders were pooled. Their collective abundance along with stand age is shown in Fig. 5. Overall abundance of the parasitoids of plant feeders declined steeply for about 50 years after clear-cutting, indicating a power function of stand age.

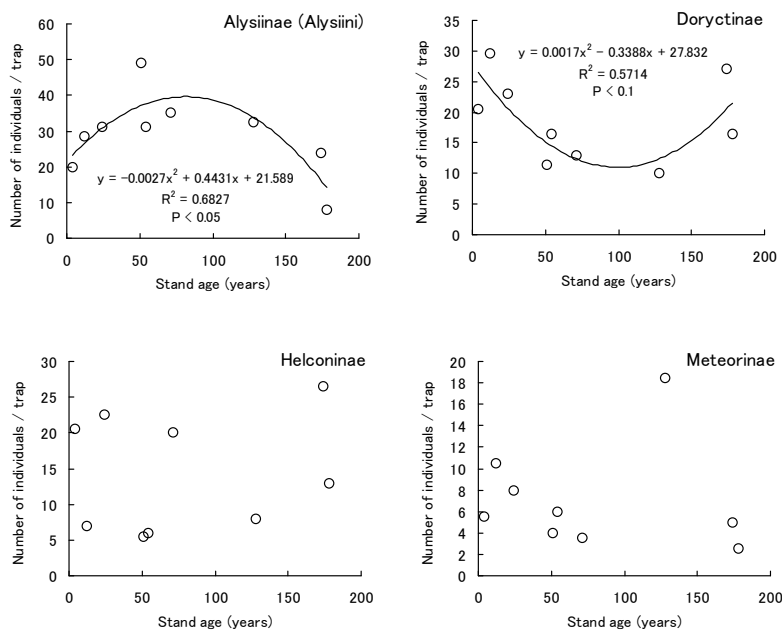


Fig. 4 Relationship between stand age after clear-cutting and the abundance of braconid parasitoids of detritus feeders for each subfamily

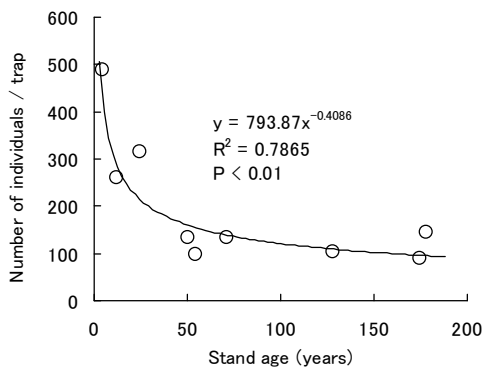


Fig. 5 Relationship between stand age after clear-cutting and the overall abundance of braconid parasitoids of plant feeders

Discussion

In rural landscapes of Japan, old-growth secondary forests provide invaluable habitats for saproxylic insects, such as stag beetles or *Pidonia* longicorn beetles, as well as for some herbivores feeding on flowers and seeds in the canopy (Maeto and Makihara 1999; Maeto et al. 2002; Inoue 2003). Thus, old woodlands free from agricultural or forestry use should be preserved when possible for the conservation of regional biodiversity.

On the other hand, large elements of biodiversity in satoyama landscapes have deteriorated with the abandonment of conventional land use in temperate Japan (Takeuchi et al. 2003; Inoue 2003, 2007; Sueyoshi et al. 2003; Ishii and The Nature Conservation Society of Japan 2005; Makino et al. 2006, 2007). Besides aquatic plants and animals, herbs, grasses, shrubs and herbivorous insects feeding on them are declining in semi-natural grasslands and in the understory layers of coppice woodlands. This not only leads to the extinction of endangered insect species (butterflies), but also weakens ecological functions of rural landscape elements.

In traditional rural ecosystems, semi-natural elements, such as meadows and coppice woodlands, are potential sources of natural enemies for neighboring paddy fields, orchards, vegetable fields, and tree plantations. In the conservation of biological control agents (e.g., Altieri and Nicholls 2004), we expect indigenous natural enemies in semi-natural vegetation to regulate agricultural and forest insect pests. However, our study shows that abandonment or underuse of young coppice woodlands impoverishes the assemblages of indigenous parasitoids of plant-feeding insects and depletes their populations. At least some of them must be potential natural enemies of insect pests in agricultural and forestry fields.

The geographical transition in the abundance of braconid parasitoids of plant feeders in Ogawa and its neighboring area was reconstructed from our data shown in Fig. 5 on a regional forest GIS developed by the FFPRI (courtesy of Dr. A. Miyamoto). It shows that the high-density habitats of parasitoids (over ca. 250 individuals per trap) have been reduced in the last few decades (Fig. 6).

Well-preserved assemblages of indigenous natural enemies in semi-natural elements within rural landscapes make up the base of Integrated Pest Management (IPM), which has been proposed in order to reduce the use of chemical pesticides in pest management (e.g., Pedigo 2002). Modest conventional use of woodlands should be more encouraged in satoyama landscapes for the purpose of environment-oriented agriculture and forestry.

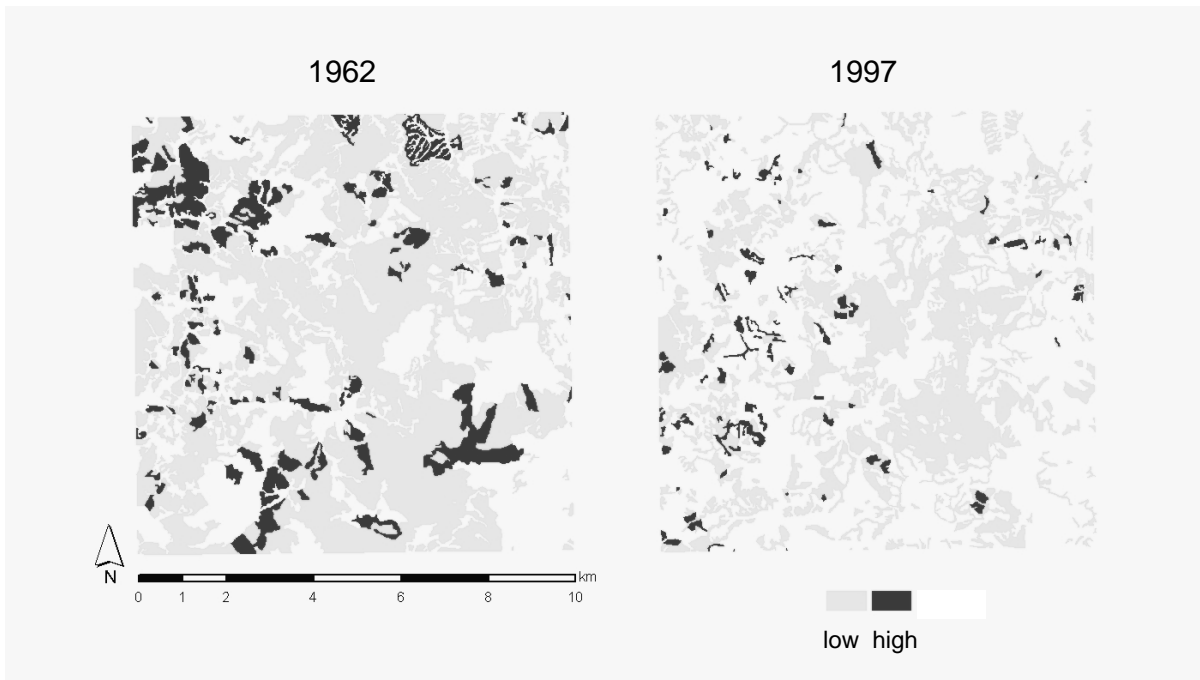


Fig. 6 Reconstructed map of the transition in the abundance of braconid parasitoids of plant feeders in Ogawa and its neighboring area from 1962 to 1997 on a regional forest GIS developed by the FFPRI (courtesy of Dr. A. Miyamoto). Dark and light areas indicate coppice woodlands with more and less than ca. 250 parasitoid individuals per trap, respectively

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