RESTORATION OF BUTTERFLIES IN *ACACIA MANGIUM* PLANTATIONS ESTABLISHED ON DEGRADED GRASSLANDS IN EAST KALIMANTAN

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MATSUMOTO K, NOERDJITO WA & FUKUYAMA K. 2015. Restoration of butterflies in *Acacia mangium* plantations established on degraded grasslands in East Kalimantan. The biodiversity status of insects in plantations in the tropics is little known. To evaluate the biodiversity restoration function of the plantation, we compared the species richness and species composition of butterfly assemblages in three plantations of *Acacia mangium*, two ex-forest grasslands and a native forest in East Kalimantan based on repeated 45-min sampling sessions in December 2004, May 2005 and December 2005. Higher species richness was recorded in plantation than in grassland, indicating that the plantation could support more butterfly species. Even higher species richness was found in the native forest. The species accumulation trend indicated by a rarefaction curve suggested that there were many more undiscovered species in the native forest. The butterflies found in the native forest included many range-restricted species, which were not found in the plantation and grassland. These range-restricted species were thought to be specific to the interior of the native forest and unlikely to colonise the plantations. Artificial plantations established on degraded grasslands can enrich butterfly assemblage, but this enrichment is mainly due to the increase in species with moderate or wide distribution ranges, rather than the recovery of range-restricted native forest species.

Keywords: Biodiversity, Lepidoptera, *Imperata cylindrica*, conservation, tropical rainforest

INTRODUCTION

Tropical forests have been extensively degraded due to logging, expansion of agricultural land and fire (Hurst 1990, Evans 1992, Johns 1997, Toma et al. 2000). In worst case scenario, forests have been transformed into treeless grasslands (Garrity et al. 1997, Kiyono & Hastaniah 2000, Mori 2000). Under these circumstances, the decline of biodiversity in tropical forests is of concern (Hurst 1990, Dudley 2005, Corlett 2009).

Artificial plantations of fast-growing tree species, either for tree cover recovery or industrial purposes, have been established in the past decades. Although these plantations are usually monocultures and often exotic tree species, meaning they provide poorer habitats than the original forests for native organisms, the plantation is expected to play positive roles in biodiversity restoration (Evans 1992, Lamb & Tomlinson 1994, Johns 1997, Cossalter & Pye-Smith 2005, Montagnini 2005).

It has been indicated that plantations of fast-growing tree species on degraded grasslands are likely to facilitate the recruitment of native plants (Parotta 1992, Kuusipalo et al. 1995, Haggar et al. 1997, Otsamo 2000, Bremer & Farley 2010), which may promote the enrichment of insects. Studies demonstrating this are rather limited, but Chey et al. (1997), Nakamuta et al. (2008) and Maeto et al. (2009) found higher species richness of moths, butterflies and braconid wasps respectively in plantation rather than grassland.

Species enrichment is a key aspect of biodiversity restoration, but at the same time we must carefully examine whether native species of the original forests recover in the plantations. In this context, Nakamuta et al. (2008) indicated in their study of butterflies in the island of Lombok, Indonesia that most butterflies found in the plantation were species with a relatively wide geographic distribution range. The geographic range of a species, a clear and well studied characteristic in butterflies, seems useful in monitoring biodiversity status because earlier biodiversity studies on butterflies have indicated that compared with species with a wide distribution range, those with restricted ranges are less likely to survive anthropogenic modification or disturbance of habitats such as logging and burning of tropical forests (Hill et al. 1995, Charrette et al. 2006, Cleary & Mooers 2006), agricultural landuse and urbanisation (Hiura 1976, Thomas 1991). More importantly, biodiversity restoration must involve recovery of this type of native and disturbance-intolerant species.

In the present study, we examined the butterfly species diversity in plantations of *Acacia mangium* and compared it with those in grassland and native lowland rainforest in East Kalimantan, Indonesia. We focused on (1) whether the butterfly assemblages in the plantations had higher species richness and abundance than those in degraded grasslands and (2) whether artificial plantation could restore native forest butterflies, especially the range-restricted species. *Acacia mangium* is among the commonest plantation tree species in South-East Asia due to its fast-growing nature, favourable stem form, nitrogen-fixation ability and feasibility of establishment on degraded land (Evans 1992, Awang & Taylor 1993).

MATERIALS AND METHODS

Field sampling

Field study was conducted in the Sungai Wain Protection Forest and surrounding areas near Balikpapan, East Kalimantan, Indonesia. In the lowland of East Kalimantan, a large area of original dipterocarp forests has been logged and invaded by migrant farmers practising slash-and-burn agriculture, a common process of forest degradation (Kiyono & Hastaniah 2000). Moreover, two large fires heavily damaged the forests during droughts caused by El Niño southern oscillation in 1982–1983 and 1997–1998 (Mori 2000). The burned areas were transformed to grasslands dominated by the cogon grass, *Imperata cylindrica*,or regenerating secondary forests. Artificial plantations of first growing trees, mostly *A. mangium*, otherwise *Paraserianthes falcataria* or *Gmelina arborea* and settlements of migrant farmers with newly created crop fields were also common. The Sungai Wain Protection Forest occupies 10,000 ha, of which the outer area (ca. 60% of the total) has been burned, while the unburned core area is a rather old dipterocarp forest. Although this forest once underwent selective logging, the core area is one of the last and the largest remaining near-primary native forests in the region.

Butterflies were sampled by hand-netting between 8:00 and 16:00, in the following six study sites representing *Imperata* grassland, *Acacia* plantations and old grown native forest:

(1) IGL1: A grassland dominated by *I. cylindrica* with sparsely studded wild grown *A. mangium* trees (3 m height or less) located near the management office of Sungai Wain Protection Forest. The area was planted with mahogany (*Swetenia macrophylla*) seedlings for land rehabilitation between sampling in December 2004 and May 2005, but we conveniently treated it as grassland because the mahogany remained shorter in height than the cogon grass during our sampling. Since there was no available trail or footpath in the grassland, we roughly determined a sampling route of 1000 m there. There was a small crop field near the edge of the grassland and an *A. mangium* plantation (AMP2 described below) at a distance of 400 m from the edge of the grassland.

(2) IGL2: An *Imperata* dominated grassland with a few scattered temporal crop fields. Sampling routes totalling 1000 m were chosen along a dirt road in the grassland and a footpath connecting the road and crop fields created by farmers. The grassland was close to the plantation (AMP3, 200 m at the nearest point) and a farmers' settlement (1 km).

(3) AMP1: An *A. mangium* plantation surrounding a water reservoir to protect the latter. *Acacia mangium* was first planted in 1995 (9 to 10 years old at the time of sampling) and partially replanted after a fire in 1998. The

sampling route of 1200 m was chosen along a trail in the *A. mangium* plantation. The plantation also adjoined the crop fields. The edge of the plantation was within 200 m from any position of the sampling route.

(4) AMP2: An *A. mangium* plantation located in front of the management office of Sungai Wain Protection Forest. *Acacia mangium* was planted in 1997 (7–8 years old) to boost tree coverage recovery. The sampling route of 1200 m was chosen along a trail in the *A. mangium* plantation. The edge of the plantation was within 200 m from any position of the sampling route. The plantation adjoined the office garden and crop fields.

(5) AMP3: An *A. mangium* plantation under the management of Indonesian National Forest Enterprise (Inhutani I). *Acacia mangium* was planted in 2001 (3–4 years old). The plantation was so young that the canopy layer was still open, allowing thick undergrowth of bushes. Since the plantation was so bushy to walk in, we chose a sampling route of 1200 m along a dirt road in the plantation area. The plantation adjoined a burned area of the Sungai Wain Protection Forest and a grassland (IGL2).

(6) SWPF: The unburned core area of the Sungai Wain Protection Forest. A sampling route of 1200 m, starting from the 300 m point from the entrance gate to the interior along the 'forest trail' for eco-tourism, was chosen.

As suggested by the abovementioned surrounding environments, for the grassland (IGL1 and IGL2) and plantation study sites (AMP1, AMP2 and AMP3), edge effects were probable. This was inevitable because the small size (as well as elongated shape along the edge of Sungai Wain Protection Forest as for AMP3) plantation areas were common in this region, with grasslands being increasingly colonised by immigrant farmers and crop fields developed in grasslands up to zones nearest the plantations.

We treated butterflies collected for 45 min at each site as a single sample and collected eight samples per site, including two in December 2004, two in May 2005 and four in December 2005. The voucher specimens were kept at the Museum Zoologicum, Research Center for Biology, Indonesian Institute of Science, Cibinong, Indonesia.

Geographic distribution range

The geographic distribution ranges of the butterflies were derived from the literature (Tsukada & Nishiyama 1980, Yata & Morishita 1981, Aoki et al. 1982, Tsukada 1985, 1991, Maruyama & Otsuka 1991, Seki et al. 1991) and categorised with increasing scale as follows:

(1) range-restricted species: restricted to Sundaland, including Bornean endemics,

(2) moderate range species: ranging out of Sundaland but restricted to the Asian tropics and subtropics west of Lydekker's Line, and

(3) wide range species: ranging over the Asian and Oceanian tropics or wider (up to Africa or cosmopolitans).

Data analysis

We compared species richness of butterflies among the study sites by applying one-way analysis of variance (ANOVA) to the number of species per sample and then applied the Scheffe test for post-hoc multiple comparison. Rarefaction analysis was also applied to compare the species richness between the study sites (Brzustowski 2012). These procedures were also applied to compare the richness of range-restricted species between the sites.

Number of shared species and similarity in species composition between two assemblages were examined by calculating Chao's estimator of shared species (Chao et al. 2000) and Chao's abundance-based Jaccard index (Chao et al. 2005) using EstimateS (Colwell 2009). The detrended correspondence analysis (DCA) was applied to compare the species composition of the butterfly assemblages between the study sites (McCune & Mefford 2006). The occurrence patterns of the butterfly species belonging to different range size classes over the study sites were examined by comparing the DCA axis scores of the species belonging to different range size classes using the Kruskal–Wallis test followed by the Scheffe test for post-hoc multiple comparison.

RESULTS

Species richness and abundance

The specimens included 421 individuals belonging to 71 different species (Table 1). Significant difference was detected in the number of species (species richness; ANOVA, df = 5, F = 6.36, p = 0.0002) observed per sample between the study sites (Figure 1a). The species richness per sample in AMP1, AMP2 and AMP3 exceeded those in IGL1 and IGL2, but was lower than that in SWPF, with significant differences detected by the post-hoc Scheffe test between SWPF and IGL1 (p = 0.001), SWPF and IGL2 (p = 0.045). and AMP2 and IGL1 (p = 0.045).

The rarefaction curve for SWPF indicated much higher species richness than the other study sites (Figure 2a). There was no overlap of 95% confidence limits with other study sites when sample size was 40 or beyond. The curve for AMP2 indicated that AMP2 was the next species rich study site, without overlap of 95% confidence limits with AMP1, AMP3, IGL1 and IGL2, whereas the curves for the latter four sites did not show clear difference in species richness between sites (Figure 2a).

Species composition with regard to geographic range

Clear dominance was found in plantation sites. The most abundant species (Table 1) was *Eurema hecabe* in AMP1 (39.2% of the total number of individuals), and *Ypthima pandocus* in AMP2 (33.3%) and AMP3 (73.3%). However, *Y. pandocus* in AMP1 (29.6%) and *E. hecabe* in AMP2 (12.8%) were also abundant (Table 1). We observed many *E. hecabe* females laying eggs on the seedlings (wildings) of *A. mangium* in AMP1 and AMP2. Although the butterflies found in IGL1 and IGL2 were fewer, *Y. pandocus* was also most abundant in these grassland sites. In SWPF, however, neither *Y. pandocus* nor *E. hecabe* was found and *Jamides pura* was the most abundant, but it occupied only 15.9% of the total. Most species collected in SWPF were represented by only one or two individuals.

The assemblages in the grasslands and plantations mainly consisted of moderate range and wide range species (IGL1, IGL2, AMP1 and AMP2) or mainly moderate range species (AMP3). Most of the species found in SWPF were either range-restricted or moderate range species. Only one individual of wide range species (*Ionolyce helicon*) was found in SWPF (Figure 3). Only *Y. pandocus* was the abundant range-restricted species in AMP1, AMP2 and AMP3. This species also occurred in IGL1 and IGL2. However, it was not found in SWPF. No other range-restricted species was found in IGL1, IGL2 and AMP1. Only one individual each of range-restricted species other than *Y. pandocus* was found in AMP2 (*Arhopala norda*) and AMP3 (*Mycalesis anapita*) (Table 1).

Highly significant differences between study sites were detected in terms of the number of range-restricted species per sample (ANOVA, df = 5, F = 26.41, p < 0.0001), with significant differences by the post-hoc Scheffe test between SWPF and the rest of the sites (p < 0.0001) (Figure 1b). The rarefaction curves drawn for range-restricted species also indicated far higher species richness in SWPF than in the rest of the study sites without overlapping of the 95% confidence limits (Figure 2b).

Plantations and grasslands shared some species with rather high Chao's abundance based-Jaccard indices. However, the plantations and SWPF shared only a small number of species with very low similarity, and SWPF and grasslands shared no species (Table 2). DCA ordination (Figure 4) indicated that SWPF differed considerably in terms of composition of butterfly assemblage from the other study sites, characterised by the very high score (637) of the first axis (axis 1; eigenvalue = 0.873). Although the differences were much smaller, the first axis scores for AMP1 (83), AMP2 (57) and AMP3 (78) exceeded those for IGL1 (21) and IGL2 (0). The plantation sites were plotted somewhat distantly and linearly along the second axis (axis 2; eigenvalue = 0.340) and the increasing scores (0, 65 and 192 for AMP1, AMP2 and AMP3 respectively) coincided with the order of the plantation age.

Axis 1 scores (Figure 5a) for the species differed significantly between the different geographic distribution range categories (Kruskal–Wallis test, df = 2, χ^2 = 20.73, p = 0.00003). Multiple comparison by Scheffe test indicated significant differences between range-

Table 1 List of species with number of collected individuals at each sampling site

Family	Species	Distribution range	SWPF	AMP1	AMP2	AMP3	IGL1	IGL2
Hesperiidae	*Halpe ormenes*	M				1		
	Koruthaialos rubecula	M	4					
	Ancistroides nigrita	M			1			
	Taractrocera ardonia	M		7	1			
	Potanthus omaha	M			1			
	Potanthus hetaerus	M		1				
	Polytrermis lubricans	M		1				1
Papilionidae	*Graphium evemon*	M				2		
	Papilio demoleus	W						1
	Papilio polytes	M			6			
Pieridae	*Eurema hecabe*	W		49	10	1	2	1
	Eurema sari	M	1	1				
	Leptosia nina	M		1				
	Appias olferna	M		6			2	
Lycaenidae	*Allotinus leogoron*	R	2					
	Arhopala atosia	R	1					
	Arhopala avatha	M	1					
	Arhopala democritus	M	1					
	Arhopala denta	R	1					
	Arhopala elopura	M	1					
	Arhopala epimuta	R	4					
	Arhopala norda	R			1			
	Arhopala puseudomuta	R	3					
	Drupadia niasica	M	2					
	Drupadia theda	M	4					
	Hypolycaena erylus	W			1			
	Spindasis lohita	M				1		
	Acytolepis puspa	M				1		
	Jamides caeruleus	M	1					
	Jamides celeno	W		2				
	Jamides pura	M	11	4	3	3		
	Nacaduba beroe	M			1			
	Prosotas nora	W				1		
	Ionolyce helicon	W	1					
	Lampides boeticus	W			3			2
	Zizina otis	M			1		1	12
	Curetis santana	M				1		
Nymphalidae	*Anosia melanippus*	M		2	4			
	Idea stolli	R	1					
	Ideopsis vulgaris	M		4		1		
	Parantica aspasia	M	2	2				
	Parantica agleoides	M		1	2			
	Euploea mulcibar	M			1	1		

(continued)

Table 1 (continued)

Family	Species	Distribution range	SWPF	AMP1	AMP2	AMP3	IGL1	IGL2
Nymphalidae	*Erites elegans*	R	1					
	Coelites epiminthia	M	1					
	Coelites euptychioides	R	3					
	Mycalesis anapita	R	2			1		
	Mycalesis horsfieldi	M		2	1			
	Mycalesis mineus	M		1	3	1	2	9
	Mycalesis perseus	W		3			1	2
	Orsotriaena medus	W		1	2			2
	Ypthima pandocus	R		37	26	55	6	15
	Melanitis leda	W			1			
	Faunis stomphax	R	3					
	Thaumantes odona	R	1					
	Thaumantis noureddin	R	3					
	Neptis hylas	M			2	1	2	5
	Pantoporia paraka	M						1
	Athyma asura	M				1		
	Athyma kawana	M				1		
	Maduza procris	M				2		
	Tanaecia aruna	R	1					
	Tanaecia pelea	R	1					
	Cynitia cocytina	R	1					
	Cynitia godarti	R	1					
	Cirrochroa emalea	M			1			
	Cupha erymanthis	M	6					
	Eulaceura osteria	M	3					
	Prothoe franck	M	1					
	Hypolimnas bolina	W			4		2	
	Junonia orithya	W			2		3	2
	Total number of individuals		69	125	78	75	21	53
	Total number of species		31	18	23	16	9	12

R = range-restricted species, M = moderate range species, W = wide range species; SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

restricted species and moderate range species ($p = 0.005$) and between range-restricted species and wide range species ($p = 0.0001$) but not between moderate range species and wide range species ($p = 0.087$). The axis 2 scores (Figure 5b) did not differ significantly between the species belonging to different range categories (Kruskal–Wallis test, df = 2, $\chi^2 = 0.86$, $p = 0.6518$).

DISCUSSION

The butterfly assemblage in degraded grassland

The biodiversity of butterfly assemblages in degraded grasslands has never been examined except for the study by Nakamuta et al. (2008).

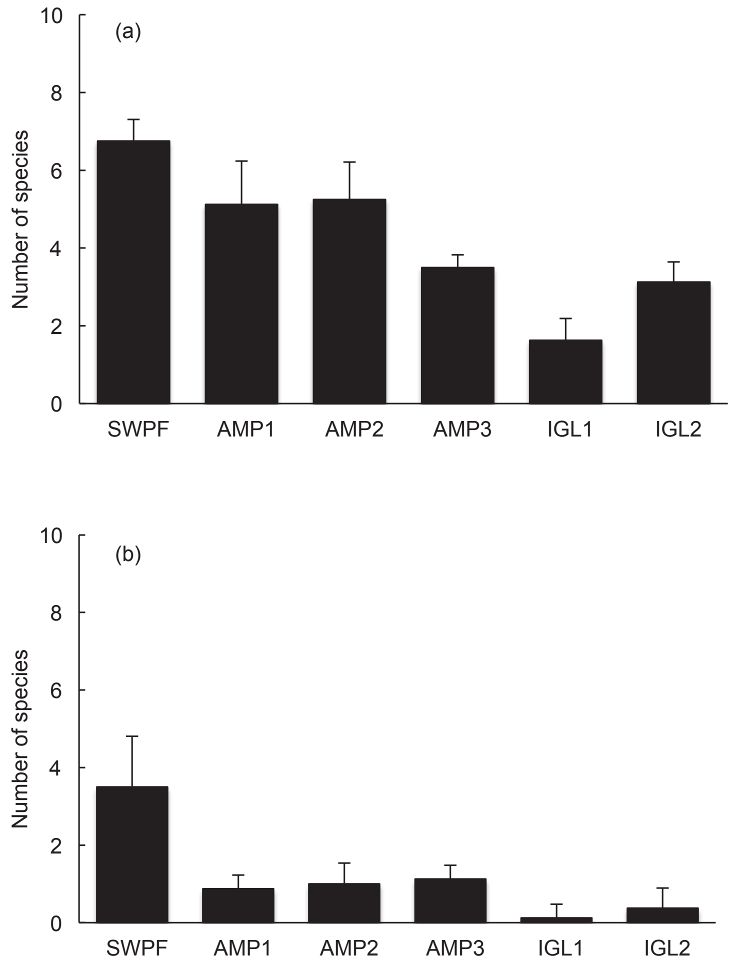

Figure 1 Average number of all species inclusive per sample (a) and average number of range-restricted species per sample (b) at each study site; vertical bars show standard errors; SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

In the present study, the species found in the grasslands were either moderate range or wide range species, except for *Y. pandocus.* There was no shared species between the grasslands and the native forest, whereas the grasslands shared a large portion of species with the plantations. Moreover, 10 of the 14 species recorded in the grasslands in the present study were also recorded in degraded grasslands or young plantations or both in the study by Nakamuta et al. (2008) in Lombok. This indicates commonality of the species that prevail in the degraded grasslands over a wide range in the Asian tropics.

Actually these 10 species (*Papilio demoleus, Appias olferna, E. hecabe, Hypolimnas bolina, Zizina otis, Junonia orithya, Mycalesis mineus, M. perseus, Lampides boeticus* and *Neptis hylas*), as well as *Orthotriaena medus* found in the grasslands, are commonly found in various human-dominated habitats in South-East Asia. *Papilio demoleus* and *A. olferna* were recent invaders from the monsoon regions of the Asian continent (Matsumoto 2002, Yata & Morishita 1981). Matsumoto (2002) suggested that the recent range expansion of *P. demoleus* could be due to forest degradation. The same reasoning may also apply to the range expansion of *A. olferna.* The occurrence of the grass-feeding species, *O. medus, M. mineus, M. perseus, Y. pandocus* and *Polytremis lubricans,* could also be related to high availability of larval food resources in the grasslands. *Eurema hecabe,* which was abundant in older plantations, and

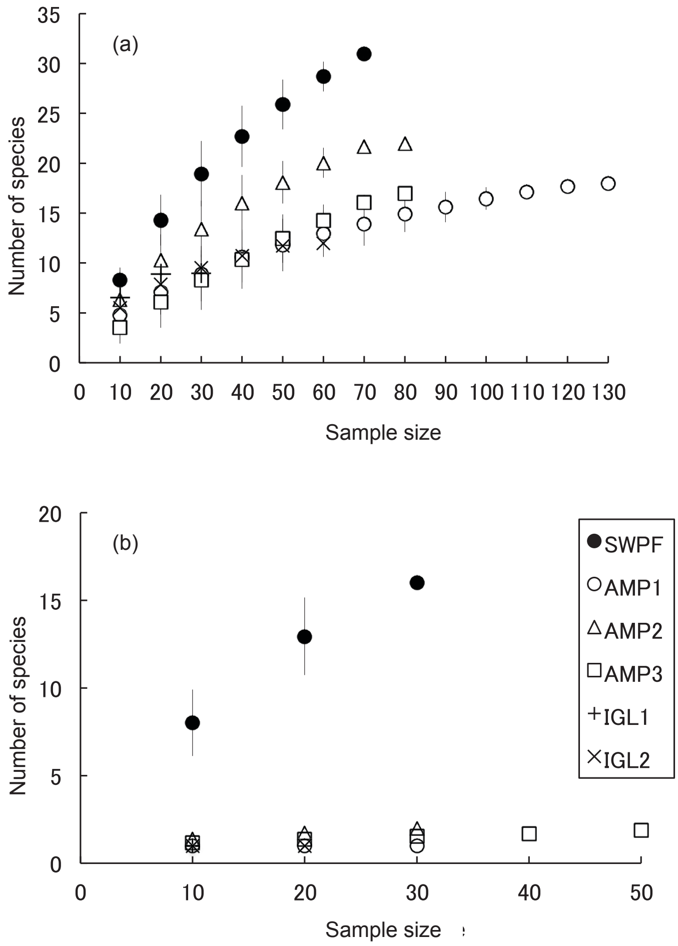

Figure 2 Rarefaction curves for all species inclusive (a) and range-restricted species (b) at each study site; vertical bars show 95% confidence limits; SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

the forest edge-preferring *N. hylas* and *Pantoporia paraka* recorded in the grasslands could be vagrants from the nearest plantations.

Restoration function of the plantation

The butterfly assemblages in the plantations had higher species richness and abundance than the grasslands, indicating a positive restoration function of the plantation. The species richness in the plantations may be affected by some open habitat species (e.g. *P. demoleus*, *A. olferna*) flying into the plantations from the nearest open habitats (e.g. grasslands and crop fields). However, as indicated by the higher species richness, the species occurring in the plantations included those which did not occur in the grasslands. The development of undergrowth vegetation would boost restoration of herbivorous insects such as Lepidoptera in the plantation (Chey et al. 1997, Nakamuta et al. 2008). Maeto et al. (2009) also suggested that the recovery of the species richness of parasitic braconid wasps in the plantation was dependent on the species richness of plants and the associated richness of herbivorous insects through biotic interactions, and that the braconid assemblage found in the plantation was at a rudimentary stage compared with that in the mature native forest.

The butterfly assemblages in the plantation sites were also characterised by high dominance of *Y. pandocus* or *E. hecabe* or both. The high

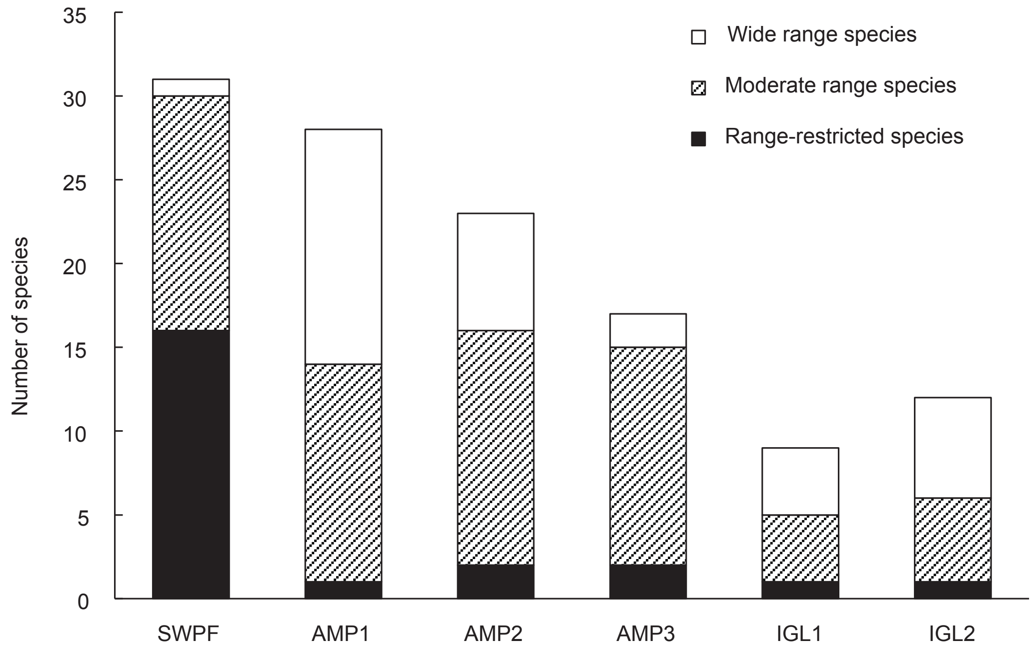

Figure 3 Number of species in the pooled samples at each study site; SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

Table 2 Number of shared species observed, that estimated by Chao's method and Chao's abundance-based Jaccard index of similarity of butterfly assemblages between sampling sites

Assemblages compared	Shared species observed	Shared species estimated	Chao-Jaccard similarity index
SWPF–AMP1	1	3.5	0.048
SWPF–AMP2	1	0.0	0.033
SWPF–AMP3	2	2.0	0.044
SWPF–IGL1	0	0.0	0.000
SWPF–IGL2	0	0.0	0.000
AMP1–AMP2	9	19.4	0.693
AMP1–AMP3	5	7.3	0.819
AMP1–IGL1	5	7.2	0.556
AMP1–IGL2	6	25.4	0.847
AMP2–AMP3	6	10.8	0.833
AMP2–IGL1	7	7.2	0.596
AMP2–IGL2	8	8.0	0.662
AMP3–IGL1	4	7.0	0.769
AMP3–IGL2	4	7.8	0.770
IGL1–IGL2	7	8.1	0.799

SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

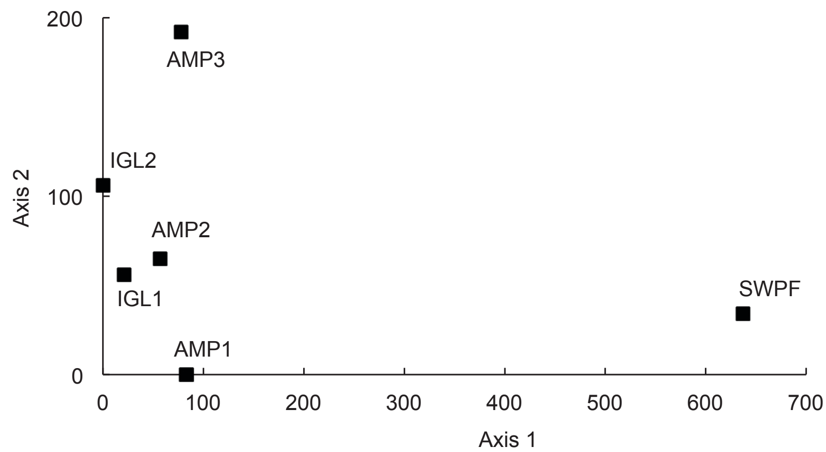

Figure 4 Detrended correspondence analysis ordination of the butterfly assemblages at six study sites; SWPF = Sungai Wain Protection Forest, AMP = *Acacia mangium* plantation, IGL = *Imperata* grassland

abundance of *Y. pandocus* in the plantation could be supported by the remaining *I. cylindrica* as an undergrowth and as a host plant of the butterfly. The gradual decrease in abundance of *Y. pandocus* with plantation age could be related to the decrease of *I. cylindrica* in the undergrowth succession together with increasing shade.

Unlike the other range-restricted species, *Y. pandocus* was not found in SWPF. This species was not so abundant in the grasslands. These indicate that the interior of the native forest is not a suitable habitat for this species. At the same time, treeless grassland may not be the best habitat, despite the vast abundance of larval food resource. It seems that a slightly shaded but not very dark habitat such as the young plantation may be optimal for *Y. pandocus*. Probably, typical natural habitats of *Y. pandocus* can be semi-open areas in and near the forests such as forest gaps and river areas, before human activities modify the landscape.

Eurema hecabe was also abundant in AMP1 and AMP2 but rather rare in AMP3. This is because *E. hecabe* depends on compound leaves of the seedlings of *A. mangium* as larval food in AMP1 and AMP2. It is known that *E. hecabe* larvae will accept a compound leaf of the seedling of *A. mangium* but not the phyllode (transformed petiole functioning as a leaf) of an established tree of *A. mangium* (Matsumoto 2000), hence older *Acacia* plantations producing many seeds provide suitable habitat for *E. hecabe* but young plantations such as AMP3 do not.

The plant species composition of the plantation is rather simple, having only *A. mangium* in the tree layer and rich in *I. cylindrica* when the plantation is young, featuring a few species of butterflies due to plentiful food resources, resulting in the high dominance. The assemblages of the butterflies found in the plantations were almost a mixture of moderate range and wide range species, whereas those found in the native forest a mixture of range-restricted and moderate range species. The plantations share very few species with the native forest, which means very limited species sharing also applies between moderate range species occurring in the plantations and native forest. The majority of the species found in the native forest, including moderate range species, could be those depending on larval host plants growing in the interior of the forest or those preferring a shadowy environment or both. The species found in the plantations could be those having larval host plants available in the plantations or those preferring open woodland or both.

The first axis of DCA ordination may indicate these environmental gradients. Other potential related factors could include species richness

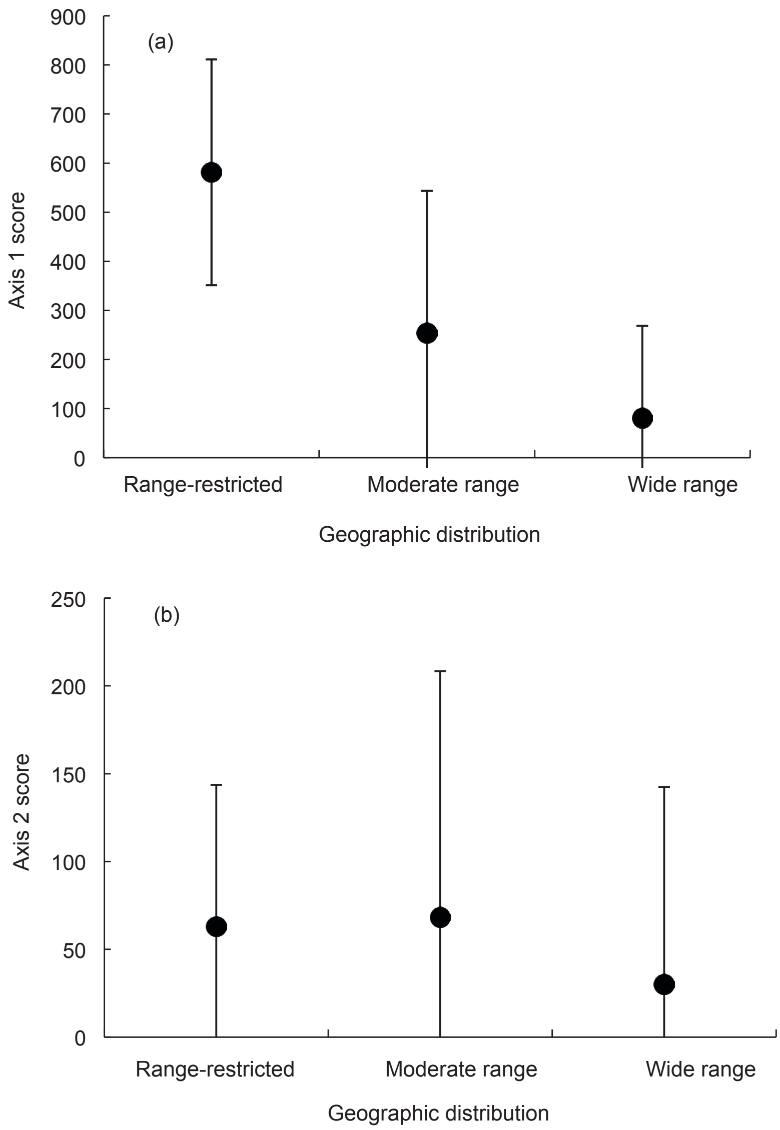

Figure 5 Averages of (a) the first axis scores and (b) second axis scores of detrended correspondence analysis for range-restricted species, moderate range species and wide range species; bars indicate standard deviation

of plants, structural complexity of vegetation, shading and stability. The higher the first axis score, the more likely the range-restricted species occur. The gradient indicated by the second axis is unclear, but it may be related to the abundance of *Y. pandocus* and *E. hecabe*. The second axis score is high where the former species is abundant and low where the latter is abundant. The high abundance of *Y. pandocus* in the plantation means a continued high abundance of *I. cylindrica*, as is typical of young plantations and a high abundance of *E. hecabe*, maturation of *A. mangium*. The second axis score is, thus, high for a young plantation and low for an older plantation. Conversely, the score may be related to plant species richness, which is expected to be high in older plantations (lower scores). IGL2 may have somewhat higher plant species richness than IGL1 because of the presence of some crop fields.

CONCLUSIONS

The planting of *A. mangium* on degraded *Imperata* grasslands contributes to biodiversity by increasing the number of butterfly species with moderate and wide distribution ranges. Hence, it is better than leaving the grasslands unchanged.

The plantations may generally have this function as a by-product even though the purposes are not for biodiversity restoration (e.g. for timber production or water conservation) and so they are not green deserts. However, the majority of the species found within the native forest, which were largely endemic to Sundaland, would not recover or were very slow to do so in the plantations. Therefore, if the purpose of plantation is for biodiversity restoration, planting of a commercial tree species such as *A. mangium* has limitation.

The plantations are generally young, mostly less than 20 years. Hence, the understorey vegetation has accumulated relatively few plant species, lacking host plants for many butterfly species. Many butterfly species depending on tall trees may hardly recover in the plantation because the tree layer consists of planted trees only. In fact, no *Arhopala* species feeding on leaves of wild trees (*Lithocarpus*, *Macaranga*) were found in the plantation except for one individual of *A. norda* found in AMP2. Although some plant species of natural forest may recover in the plantation, those species having low ability of seed dispersal or tolerance to desiccation or both, as may be the case for majority of the natural forest plants, are unlikely to recover, and the butterflies depending on these plants cannot recover in the plantation. Likewise, the butterfly species dwelling in the interior of old grown native forests preferred shade or stable environment and would not colonise the plantation, across open environments such as grasslands, crop fields and other human-dominated environments.

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