Conservation Biology

Research Note

Enhancing Avifauna in Commercial Plantations

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Abstract: *The occurrence of fauna in commercial plantations is often associated with structural complexity. Through a meta-analysis, we tested whether the structural complexity of plantations could enhance bird species assemblages and whether bird assemblages respond differently depending on taxonomic affiliation, body size, and diet. Our analyses included 167 case studies in 31 countries in which bird assemblages in forests and plantations were compared and 42 case studies in 14 countries in which bird assemblages in plantations of different structural complexity were compared. Species richness, but not abundance, was higher in forests than in plantations. Both species richness and abundance were significantly higher in complex than in structurally simple plantations. Taxonomic representation and body size did not differ between forest and plantations, except that there were fewer insectivorous birds in plantations than in forests. In the comparison of simple versus complex plantations, abundance of all taxonomic and dietary groups was higher in complex plantations. Body size did not affect bird species richness or abundance. Independent of the type of plantation, bird richness and abundance were greater in structurally complex plantations. Enhancing the structural complexity of plantations may mitigate their impact and offer habitat for some native species.*

Keywords: agroforestry, birds, meta-analysis, structural complexity, understory

Enriquecimiento de la Avifauna en Plantaciones Comerciales

Resumen: *La ocurrencia de fauna en plantaciones comerciales a menudo se asocia con la complejidad estructural. Mediante un meta-análisis, probamos si la complejidad estructural de las plantaciones podría enriquecer los ensambles de aves y si los ensambles de aves responden de manera diferente dependiendo de la filiación taxonómica, tamaño corporal y dieta. Nuestros análisis incluyeron 167 casos de estudio en 31 países en los que se compararon los ensambles de aves en bosques y en plantaciones y 42 casos de estudio en 14 países en los que se compararon los ensambles de aves en plantaciones de diferente complejidad estructural. La riqueza de especies, pero no la abundancia, fue mayor en bosques que en plantaciones. La riqueza y abundancia fueron significativamente mayores en plantaciones estructuralmente complejas. La representación taxonómica y el tamaño corporal no difirieron entre bosque y plantaciones, excepto que hubo menos aves insectívoras en las plantaciones que en los bosques. En la comparación entre plantaciones simples versus complejas, la abundancia de todos los grupos alimenticios y taxonómicos fue mayor en las plantaciones complejas. El tamaño corporal no afectó la riqueza ni la abundancia de especies de aves. Independientemente del tipo de plantación, la riqueza y abundancia fueron mayores en las plantaciones estructuralmente complejas. El incremento de la complejidad estructural de las plantaciones puede mitigar su impacto y ofrecer hábitat a algunas especies nativas.*

Palabras Clave: agroforestería, aves, complejidad estructural, meta-análisis, sotobosque

Introduction

There is an increasing need to protect biodiversity outside protected areas. Worldwide, demographic and economic trends demand more area on which to grow commodities, meaning there is less area left to allocate to reserves. Furthermore, current parks and reserves will not suffice to protect a significant fraction of biodiversity. Therefore, to use the seminatural and productive matrices for biological conservation is not only a

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Paper submitted November 11, 2008; revised manuscript accepted June 17, 2009.

Conservation Biology, Volume 24, No. 1, 319–324

DOI: 10.1111/j.1523-1739.2009.01350.x

challenge, but also a pressing need (Daily 2001; Foley et al. 2005).

Increasing evidence suggests that commercial plantations can support some native biodiversity and may even provide occasional habitat for vulnerable species (Hartley 2002; Simonetti 2006). Therefore, plantations could contribute to biodiversity conservation (Hartley 2002; Lindenmayer & Hobbs 2004; Simonetti 2006). Structurally, plantations range from simple monocultures to more heterogeneous stands with understory vegetation that may support native plant species (Hartley 2002). Plantation management practices that support and conserve biodiversity while maintaining similar levels of production and profitability are yet to be developed. Identification of the variables that enhance the occurrence and survival of wild species in plantations is then a mandatory step toward this purpose (Tews et al. 2004; Stephens & Wagner 2007; Tscharntke et al. 2008).

The occurrence of native fauna in many agroforestry systems, such as coffee and oil-palm plantations, is presumed to be associated with structural characteristics within the plantation, such as the existence of understory or multiple vegetation strata (Aratrakorn et al. 2006). In fact, understory vegetation is often regarded as the single best predictor of animal diversity within plantations because understory provides food and shelter for native species (e.g., Grez et al. 2003; Lindenmayer & Hobbs 2004; Aratrakorn et al. 2006).

If structural complexity positively affects avian community structure (Tews et al. 2004) then species richness and abundance ought to be larger in forests than in plantations. By the same token, plantations with a well-developed understory or multiple vegetation strata ought to support more species than plantations that are structurally simple. We tested these hypotheses in a meta-analysis that focused on the responses of bird assemblages to habitat complexity in forests and in structurally complex and simplified plantations.

Attributes such as body size, diet, and habitat preferences may render some species more susceptible to structural changes in plantations. Large-bodied species and habitat and diet specialists are more vulnerable to habitat modifications, and these variables may be taxon related, with some taxa containing proportionally more extinction-prone species (e.g., Owens & Bennett 2000). Within this framework, we also examined whether birds, on the basis of their taxonomic affiliation, body size, and diet habits, respond differently to structural complexity in plantations. Identifying the variables, both structural and biological, that affect biodiversity in plantations will advance management practices to fulfill both the production of commodities in high demand and the conservation of biodiversity.

Methods

We searched the ISI Web of Knowledge Database for literature that correlated bird species diversity with plantations. We searched for the terms "plantation* + bird*." We considered studies from January 2003 to May 2009 and selected only articles that compared bird richness or abundance between natural habitats and plantations with different structural complexity. We considered plantations structurally complex if they had multiple vegetation strata, dense undergrowth, abundant scrub, or multispecies canopy cover. Plantations with thinned or cleared undergrowth, scarce or no shrub cover, or single-species canopy cover were classified as structurally simple plantations (Aratrakorn et al. 2006). We compared bird richness and abundance between these two categories: simple and complex plantations.

We considered each comparison one case. Therefore, in publications in which authors report multiple comparisons, more than one case was sometimes extracted from the same article. For each case, we recorded the type of plantation, type of forest, and bird species richness and abundance. To synthesize primary research data, we used vote counting, categorizing responses in an expected versus unexpected direction regarding a specific hypothesis (Rosenberg et al. 1997). The proportion of cases with results in each direction were then evaluated. The category with the largest proportion of cases was assumed to be the statistical trend in the primary literature and was used as evidence to support or refute a given hypothesis (Rosenberg et al. 1997).

We compared bird richness and abundance between forests and plantations and between simple and complex plantations. Publications reported either total or mean species richness or abundance. Total richness and abundance refers to all species and individuals registered in the entire study. Mean species richness is the average number of species per sampling unit. Mean abundance is the average number of individuals across all species per sampling unit. All but six studies included all bird species in the study area. The other six studies considered one or two species only. (Further information is available upon request.)

First, we assessed bird responses at the assemblage level in all types of plantations regardless of the commodity cultivated. For each case, we registered how the bird assemblage responded to structural simplification from forest to plantation or to structural complexity within the plantation, in terms of increases or decreases in mean and total richness and abundance. To evaluate the consistency of the responses, we analyzed the data with a sign test both for the plantation–plantation and for the forest–plantation responses (Zar 1999). We regarded increases in bird richness or abundance in more complex habitats as a positive response.

Second, but restricted to birds in oil-palm (*Elaeis guineensis*) plantations, we assessed whether assemblages responded differently to plantations on the basis of taxonomic affiliation (at the ordinal level), body size, and diet. Body size was expressed as body length, a correlate of species vulnerability commonly used in the studies we considered here. Regarding diet, we classified species on the basis of their primary food item. For vulnerability status, we used the species' IUCN (International Union for Conservation of Nature) classification (IUCN 2007). For these analyses only, we focused on oil-palm plantations because currently oil palm is one of the fastest-growing crops. Cultivated in Southeast Asia, Africa, and Latin America, planted area reached over 13 million ha in 2006, and 250,000 ha are being added yearly (Koh & Wilcove 2008). We focused on Malaysian forests and plantations given that there is a recent database on birds in oil-palm plantations and adjacent forests (Peh et al. 2005, 2006; Koh & Wilcove 2008).

Third, within plantations with different structural complexity but of the same commodity, we determined whether birds of a particular group were more or less favored by structural complexity within plantations on the basis of taxonomic affiliation, body size, and diet. To assess whether the number of taxa and diet type or body size were consistent in the two types of plantations, we analyzed data with a Wilcoxon test (taxonomy and diet) and a sign test (body sizes; Zar 1999).

Table 1. Number of studies and cases per plantation type used in the meta-analysis of bird richness in forests and plantations.

Comparison and plantation type	*No. of publications*	*No. of cases**
Plantation vs. native forest	11	44
Coffee		
Conifer	15	37
Eucalyptus	7	18
Timber (other species)	11	20
Cacao	6	26
Rubber	3	10
Oil palm	1	2
Other	6	10
Totals	60	167
Structurally complex vs. simplified plantations		
Coffee	9	25
Forestry (pine, ash, eucalyptus [*Gmelina arborea*], sitka Spruce [*Cryptomeria japonica*])	7	11
Oil-palm	3	3
Others	3	3
Totals	22	42

**Cases: number of bird richness or abundance comparisons made between forest and plantation or between complex and simplified plantations (one publication could have more than one case).*

Results

A total of 286 papers fitting our search criteria were published from January 2003 to May 2009. From these studies, 76 publications reported quantitative information on bird richness and abundance suitable for our purposes. Sixty articles focused on forest–plantation comparisons, 22 compared different conditions of a given plantation, and seven compared both forest–plantation and plantation–plantation. Only two studies used an experimental approach to evaluate the effects of structural complexity on bird assemblages in plantations. For comparisons between natural vegetation and plantations, we examined 167 cases. Of these, 45% (75 cases) were on timber plantations, and 25% and 16% were on coffee and cacao plantations, respectively (Table 1). The data we examined were on forest and plantations in 32 countries (13 from Latin America and the Caribbean, six from Africa, six from Asia, three from Europe, three from North America, and one from Oceania). Of the 60 publications considered, 38 were conducted in tropical and subtropical broadleaved forests and 14 were carried out in temperate broadleaf and mixed forests. Three studies were conducted in mediterranean environments, and there was only one study in each of the following systems: montane grasslands and shrublands, temperate conifer, temperate grasslands and shrublands, tropical and subtropical dry forests, and tropical and subtropical conifer biome. Twenty-two publications with 42 cases in 14 countries (four from Asia, four from Latin American and the Caribbean, three from Europe, and one each from Africa and Oceania) compared plantations with different structural complexity. The most frequent plantation types were coffee (59% of cases) and forestry plantations (26% cases; Table 1; complete list available upon request).

Bird richness was significantly higher in forests than in plantations. Seventy-nine out of 109 cases (72%) exhibited higher species richness in forest than in plantations ($p < 0.01$; Table 2). Bird abundance in forests and plantations did not differ. There was no significant difference between the number of cases showing higher or lower abundance as a response to habitat simplification ($p = 0.88$; Table 2).

Bird richness and abundance were significantly higher in structurally complex plantations than in structurally simple ones. Twenty-three out of 29 (79%) and 11 out of 12 (92%) cases exhibited higher species richness and abundance, respectively, in more complex than in less complex plantations, regardless of the species planted (sign test $p = 0.002$ and 0.02, respectively; Table 2). Higher richness and abundance in complex plantations was not driven by coffee or by timber plantations alone. Complex plantations, excluding coffee, held more species than simplified ones (sign test $p < 0.001$). The same occurred in complex coffee plantations (sign test $p < 0.008$), which suggests this is a general phenomenon.

Table 2. Bird species richness and abundance (in number of cases*) as a response to structural simplification after forest conversion to plantations and to structural complexity within plantations.

	Response to structural simplification			*Response to structural complexity*		
	increases	*decreases*	p	*increases*	*decreases*	p
Richness						
total	30	79	0.0001	23	6	0.002
mean	11	59	<0.0001	13	3	0.02
Abundance						
total	24	22	0.88	11	1	0.01
mean	18	18	0.86	16	3	0.005

**Cases: each comparison of bird richness or abundance made between forest and plantation or between complex and simplified plantations (one publication could have more than one case).*

In the forest and oil-palm comparisons, although Galliformes and Trogoniformes were completely absent in the plantation, the taxonomic representation did not differ between forests and plantations. Galliformes and Trogoniformes accounted for only 6% of the avifauna in forests ($\chi^2 = 0.53$, df $= 2$; $p = 0.76$; Table 3). Differences emerged in the proportion of bird species in each dietary group (Table 3; $\chi^2 = 6.87$, df $= 2$; $p = 0.03$). In plantations insectivorous birds were 0.6 times less frequent than in forests, whereas frugivores and granivores were 1.3 and 3.3 times more common in plantations, respectively (Table 3). Regarding body size, there was no significant difference between bird species that inhabit forests compared with those that inhabit plantations (mean [SE] = 27.1 cm [2.6] vs. 22.5 cm [2.3], respectively; $U = 1804$; $p = 0.52$). Finally, oil-palm plantations hosted only one of the six vulnerable species present in native forest and 31 species of least concern (LC). The number of LC species was 1.4 times greater than would be expected if the same proportion of LC species inhabiting surrounding forests inhabited the plantation.

Table 3. Bird species by order and dietary group present in forest and oil-palm plantations (data from Peh et al. 2005, 2006).

Group	*Species in forest (%)*	*Species in oil palm (%)*
Order		
Passeriformes	65.4	61.1
Piciformes	9.4	8.3
Coraciformes	7.5	11.1
Cuculiformes	6.3	2.8
Columbiformes	3.8	8.3
Galliformes	3.1	0.0
Trogoniformes	2.5	0.0
Psittaciformes	1.9	8.3
Diet		
insectivores (I)	56.6	36.1
frugivores (F)	23.9	30.6
IF	4.4	8.3
carnivores	3.8	8.3
nectarivores (N)	3.1	5.6
granivores (G)	2.5	8.3
IG	2.5	0.0
IN	2.5	2.8
omnivores	0.6	0.0

A greater number of species in the taxonomic groups and in the dietary groups were found in structurally complex than in structurally simple plantations (Table 4; Wilcoxon $p = 0.03$ and 0.04, respectively). Contrary to this, the mean body sizes of birds in structurally complex and simple plantations were not statistically different (mean [SE] = 17.0 cm [0.78] and 16.6 cm [0.74], respectively; sign test $p = 0.6$).

Discussion

Commodity plantations are no substitute for natural forests. They support modified assemblages and fewer species compared with natural habitats (Donald 2004;

Table 4. Bird species groups that were more or less abundant in structurally complex plantations than in structurally simple plantations.

Group	*More abundant in complex (%)*	*Less abundant in complex (%)*
Order		
Passeriformes	66	29
Galliformes	89	11
Columbiformes	77	0
Coraciformes	43	43
Apodiformes	71	28
Cuculiformes	67	33
Piciformes	75	19
Strigiformes	0	67
Trogoniformes	100	0
Falconiformes	67	11
Caprimulgiformes	0	100
Psittaciformes	100	0
Tinamiformes	100	0
Diet		
insectivores	64	31
omnivores	80	16
frugivores	86	13
granivores	43	43
nectarivores	67	33
carnivores	58	25

Harvey & González-Villalobos 2007; Koh & Wilcove 2008). Nevertheless, plantations with a more complex structure hold more species than simple ones, regardless of the type of plantation. This fact could promote environmentally friendlier plantations, particularly because there are few opportunities to conserve relatively undisturbed habitat. As with other taxa, bird species richness is reduced when natural forests are replaced by plantations (Daily et al. 2003; Grez et al. 2003). Although bird abundance does not appear to be different in plantations and forest, the assemblages in plantations differ; generally, they hold more species of lower conservation concern than forests (Aratrakorn et al. 2006; Harvey & González-Villalobos 2007).

Structural complexity within plantations enhanced the avifauna assemblage and promoted increased bird species richness and abundance. Resources provided by multiple vegetation layers in plantations are yet to be assessed, but such resources can benefit birds from all dietary habits, taxonomic orders, and sizes. This suggests that, independent of the type of plantation, structural complexity generally triggers higher richness and abundance of avian assemblages in plantations.

Despite the general pattern that bird assemblages were impoverished in plantations compared with forests, occasionally plantations may hold more species than forests (Table 2). This increase could also be explained by higher habitat heterogeneity in plantations compared with native forests with simple structural complexity. Such heterogeneity could provide shelter and feeding resources for generalist species (e.g., Beukema et al. 2007; Faria et al. 2007; Harvey & González-Villalobos 2007). In these cases, although plantations might be supporting more species, these species are not necessarily significant from a conservation standpoint because they might be generalists, which are unaffected by habitat transformation (e.g., Faria et al. 2007; Harvey & González-Villalobos 2007).

When forest is converted to oil-palm plantations, vulnerable species are more affected than species of lesser conservation concern, which reinforces the fact that the communities residing in commodity-production systems are highly modified compared with original forest. Similarly, trophic structure in oil-palm plantations differs from that of original forest; insectivores are less abundant in plantations.

The reduction in insectivore abundance could be explained by managerial practices. Severe outbreaks of insect pests occur occasionally in oil-palm plantations (Zeddam et al. 2003; Koh 2008*a*) and are treated with pest-control agrochemicals. These chemicals could trigger a reduction in insect abundance in plantations and, consequently, a reduction in insectivorous birds. Most companies, however, are adopting integrated pest-management practices that promote, for example, establishment of plants and native tree species to attract insect predators (Koh 2008*a*), which adds value to plantations as habitat for bird species.

At the landscape scale, additional variables (e.g., plantation shape, distance to the native forest, and type of surrounding matrix) can affect biodiversity within a plantation (e.g., Koh 2008*b*). Nevertheless, at the local scale, our review confirms the importance of multiple vegetation strata as a driver that could help plantations host more avian biodiversity than that held in simplified plantations. Future research should experimentally test the relationship between biodiversity and understory vegetation in plantations to help determine the proximal factors behind such enhancement. Of the papers published in the time span we examined, only two were on studies in which structural variables were modified experimentally (Cruz-Angon & Greenberg 2005; Nájera 2009). The removal of understory vegetation reduces bird diversity and abundance, which supports the hypothesis that such a reduction could result in a decreased provision of food or shelter (Nájera 2009). Nevertheless, these factors must be tested because they could explain changes in species richness and abundance and in the trophic and size structure of the assemblages thriving in plantations. Similarly, experimental studies are required in a larger variety of forests and plantation types to strengthen the evidence on the patterns observed and to unravel underlying mechanisms of these patterns.

Management practices that allow or promote structural complexity and understory growth should be promoted to aid in conserving biodiversity. These practices could help shift the biodiversity-impoverished plantations to a less-hostile condition. A key question will be whether increased biodiversity is sufficient motivation for industries, organizations, and governments to change their methods.

Improving plantations for biodiversity might be highly attractive for business managers because it could provide several benefits for the community and the industry owners, besides potential pest control. Environmentally friendly plantations can expedite forest certification and thus provide access to a more environmentally conscious market, as well as some development opportunities for populations living close to plantations, among others (e.g., Rametsteiner & Simula 2003; Turner et al. 2008). Nevertheless, solid evidence that complex plantations adapted to support some biodiversity maintain their yields and profitability is also urgently needed. Despite these information shortcomings, leaving or deliberately implementing structural complexity within plantations could satisfy the current need of making commodity production a cleaner industry, aiding in the biosphere's sustainability.

Acknowledgments

A.N. was an AGCI (Agencia de Cooperación Internacional de Chile) fellow. The organization's support is appreciated.

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