# DIPLOMARBEIT

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„Richness and structure of understory bird communities in oil palm plantations in the Pacific lowlands of Costa Rica“

verfasst von

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## Abstract

Oil palm plantations are representing a major threat for tropical biodiversity as they are responsible for a great amount of forest loss. The rising demand of palm oil and its derivates since the 1960´s led to an ongoing threat for tropical ecosystems. Since research on biodiversity in oil palm plantations was mostly done in South-East-Asia, this study provides first insights of the situation of bird's biodiversity in the Neotropics. Mist-nets were used to catch understory forest birds in three different habitats (forest interior, forest margin, oil palm plantations), in order to identify and ring them afterwards. Our study supports related studies from Asia, where plantations gather less species. Forest specialists, insectivores, and range-restricted species are suffering more than species with a wide range. However, granivorous birds were found more often in plantations, as well as openland species. We found, that plantations are characterized by a distinct species composition and bird communities in forests and oil palms are very different. Since correlations between species richness and density of trees as well as density of woody plants were found, enhancing vegetation complexity within plantations might be a contribution of conservation.



**Keywords:** Central America, conservation, *Elaeis guineensis*, oil palm plantations, species richness, abundance, mist-netting, birds, understory



## Zusammenfassung

Palmölplantagen stellen eine große Bedrohung für die tropische Artenvielfalt dar, da sie für einen großen Teil an Waldverlust verantwortlich sind. Die steigende Nachfrage für Palmöl und seine Derivate seit den 1960er Jahren führte zu einer kontinuierlichen Bedrohung für tropische Ökosysteme. Da die Biodiversitäts-Forschung in Ölpalmplantagen hauptsächlich in Südostasien durchgeführt wurde, bietet diese Studie einen ersten Einblick in die Situation der biologischen Vielfalt von Vögeln in den Neotropen. Es wurden Japannetze verwendet, um Unterwuchsvögel in drei verschiedenen Habitaten (Waldinneres, Waldrand, Ölpalmplantagen) zu fangen und sie danach zu identifizieren und zu beringen. Unsere Studie unterstützt ähnliche

Studien aus Asien die zeigen, dass Ölpalmplantagen weniger Arten beherbergen. Waldspezialisten, Insektenfresser und Arten mit eingeschränkter Verbreitung leiden mehr als weit verbreitete Vögel. Körnerfressende Vögel wurden jedoch häufiger in Plantagen festgestellt, genauso Arten des Offenlandes. Wir zeigen, dass die Plantagen durch eine ausgeprägte Artenzusammensetzung gekennzeichnet sind und Vogelgemeinschaften in Wäldern und Ölpalmplantagen sehr unterschiedlich sind. Da Korrelationen zwischen dem Artenreichtum und der Baumdichte als auch der Dichte an verholzten Pflanzen gefunden wurden, könnte eine Steigerung der Komplexität der Vegetation in den Plantagen zum Artenschutz beitragen.

**Introduction**

The oil palm (*Elaeis guineensis*), a native of West Africa, is grown in the lowlands of wet tropical zones (Donald 2004). It represents the highest-yielding vegetable oil crop and one of the most rapidly increasing crops in the world (Donald 2004, Fitzherbert et al. 2008). Oil palm-derived oil is now the world's major source of vegetable oil and fat. Next to the food industry the oil is used for so called "bio-fuels" as well as oleochemical industries, where it is needed for the manufacture of soaps and detergents (e.g. Turner et al. 2008). One of the main reasons of forest loss is the construction of agricultural landscapes (Tilman et al. 2001) and in the main oil palm producing countries (e.g. Colombia, Indonesia, Malaysia) such plantations are a major cause of forest loss (e.g. Aratrakorn et al. 2006). Such loss of mostly lowland rainforest has led to the strongest decrease of biodiversity worldwide (Butchart et al. 2004). Compared to primary and secondary forests, oil palm plantations are characterized by much fewer species (Fitzherbert et al. 2008, Koh & Wilcove 2008).

Agriculture is the major risk for birds (Green et al. 2005) and intense land-use decreases bird occurrence and abundance (Newbolt et al. 2013). Studies from Southeast Asia documented that the conversion of forest to oil palm plantation results in a decline of bird species richness of ≥60%, with insectivorous and frugivorous birds, which provide important ecosystem services, suffering particularly high losses (Aratrakorn et al. 2006; Peh et al. 2006). In addition, species with limited ranges that are of high conservation interest were replaced by species with a broad range and low conservation status (Aratrakorn et al. 2006). Oil palm plantations also act as a barrier to animal movements (Edwards et al. 2010). Improvement of understory vegetation in oil palm plantations could at least reduce the adverse impact on birds (Nájera & Simonetti 2010).

Costa Rica is one of the 25 global biodiversity hotspots characterized by high concentrations of endemic plant and vertebrate species (Myers et al. 2000). In 2011, 241,000 t of palm oil were produced in Costa Rica, the harvested area was about 60,000 ha, about 40 times higher than in 1961 with 1,500 ha (FAO 2013). Costa Rica is one of the top producers worldwide in terms of harvested area per ha country. The influence of oil palm plantations on bird diversity and abundance has not yet been assessed in the Neotropics. Therefore, more detailed information on the loss of forest species in response to oil palm cultivation is urgently needed.

In our study area in the vicinity of the Tropenstation La Gamba in southwestern Costa Rica, the area of oil palm plantations increased significantly during the last decade. In 2008, already 30% of the agricultural lands around La Gamba were oil palm plantations (Höbinger et al. 2010). Because forests around La Gamba are mainly situated in rather steep and inaccessible areas, the expansion of oil palm plantations into forest areas is less likely than in other regions (Höbinger et al. 2010). However, it is largely unknown to what extent oil palm plantations can be used by forest species, which is an important precondition to evaluate to what extent they can contribute to changing the permeability of the agricultural landscape for forest species. A first study on butterflies indicated that oil palm plantations are predominantly characterized by openland species and are only of very limited value for forest species (Wiemers & Fiedler 2008).

Since birds are good indicators of general ecological models across taxa (e.g. Barlow et al. 1998), mist-netted birds were used in this study to quantify the importance of oil palm plantations connected to remaining natural forest areas for forest species. Based on results from studies on the biodiversity of oil palm plantations in other tropical regions, the following hypotheses were tested:

(1) Oil palm plantations only can be exploited by a limited number of forest birds (e.g. Aratrakorn et al. 2006, Peh et al. 2006) and are dominated by openland species.

(2) Oil palm plantations are mainly characterized by the occurrence of widespread habitat generalists while they are only of limited value for range-restricted forest specialists (e.g. Aratrakorn et al. 2006; Peh et al. 2006).

(3) Compared to other feeding guilds, oil palm plantations have a relatively low conservation value for insectivorous understory birds, which appeared to be particularly sensitive against disturbance and human habitat modification in other studies (e.g. Stouffer et al. 2009).

(4) Oil palm plantations are characterized by a distinct species composition and feeding guild structure.

**Methods**

*Study area and study sites*

The study was conducted from February to May 2012 in the vicinity of the Research Station La Gamba (http://www.lagamba.at/researchdb/pagede/index.php), located at the edge of the Piedras Blanca National Park in the Pacific lowlands of south-western Costa Rica (N 8°42'61", W 83°12'97", Altitude: 70 m). The nearby village La Gamba is embedded in a landscape matrix characterized by agricultural land with an increasing proportion of oil palm plantations. All study sites were at comparable altitudes of 70 to 200 m. The annual precipitation and the mean annual temperature of the study area are 6,000 mm and 28.5°C, respectively (Weissenhofer et al. 2008).

Study sites were pre-selected based on an available vegetation map of the area (Weissenhofer et al. 2008). The final site selection (Fig. 1) was done during a ground survey at the beginning of our field work period. A total of five replicate sites were selected in each of the three habitat types: forest interior (henceforth: FI), forest margin (FM) and oil palm plantation (OP). FI sites were closed, relative pristine primary or old-growth secondary forests at least 200 m away from the edge of the forest. We used study sites where anthropogenic influences like logging were as small as possible. FM sites were selected, where closed forests descend into a more open forest adjacent to open land, such as pastures, gardens, wide riverbeds, and oil palm plantations as well. All OP sites were adjacent to primary or old secondary forest and due to an ARCmap measurement their size was between 12 and 40 ha (Freudmann, unpublished).

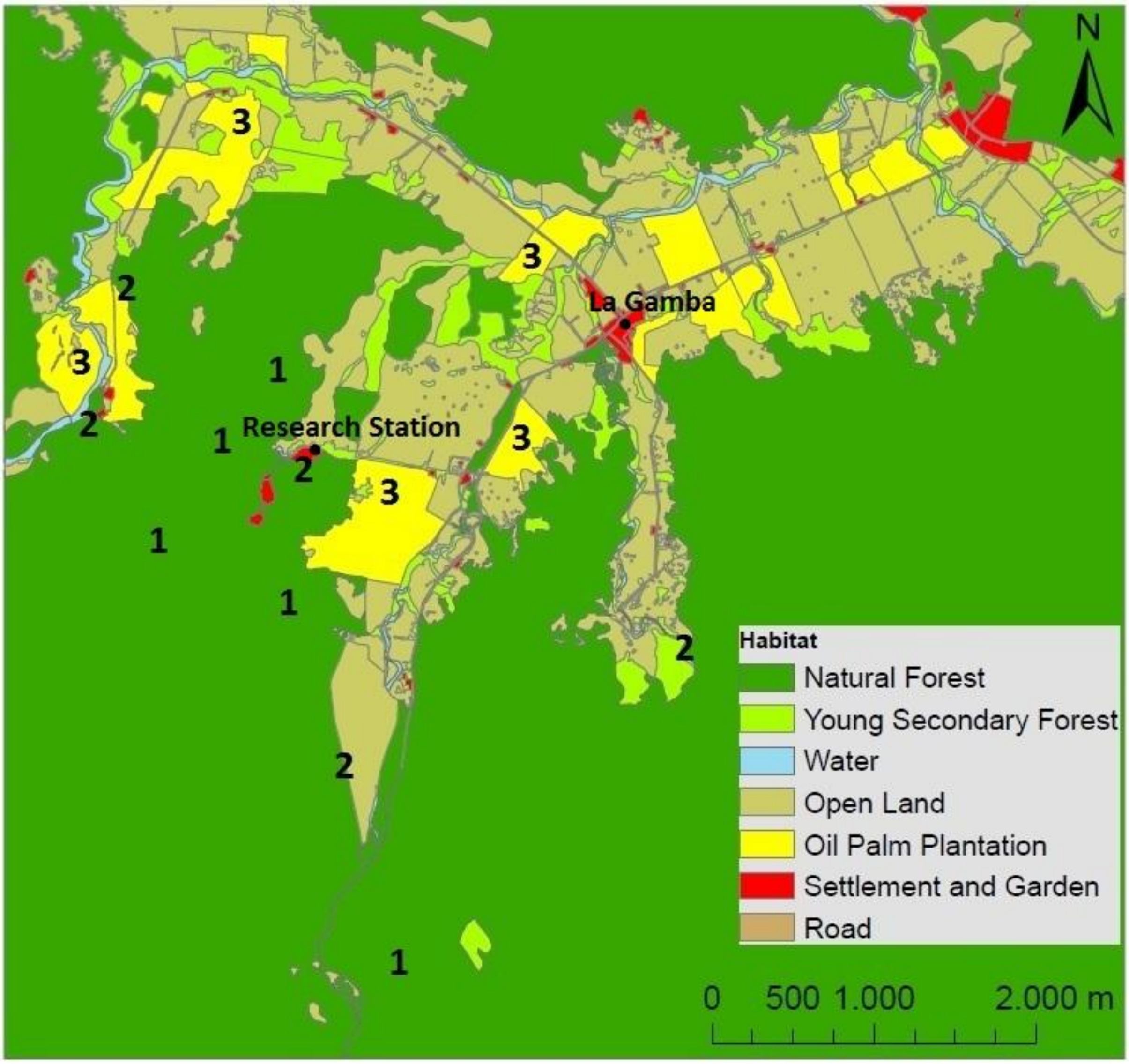


Figure 1. Schematic map of the study area in the surroundings of the Research Station La Gamba showing all mist-netting sites. Habitat types are indicated by different numbers (1 = Forest interior, 2 = Forest margin, 3 = Oil palm plantations).

*Mist-netting of birds*

Mist-netting is a very good method for assessing understory bird assemblages (e.g. Hawes et al. 2008). We used four mist nets per study site to sample the local bird assemblages, which proved to be sufficient in a former study (Seaman & Schulze 2010). Used mist-nets had a mesh size of 16 mm and a size of 12 m x 2.5 m. All four mist-nets were set up at least 15 m apart from each other. At all sites birds were mist-netted on two consecutive days (first sampling round) and on one additional day (second round) at least 39 days after the first sampling round. At each mist-netting-day nets were open from 5:00 am till 11:30 am and 3:30 pm till 6:00 pm. During rain nets were closed to avoid an increased mortality of birds (Blake & Loiselle 2001, Seaman & Schulze 2010). Nets were checked every 30 minutes for captured birds, which were then carried to a site away from the nets for ringing.

Their length of flattened wing and bill-to-skull length was measured and all birds were weighed. Any signs of moulting were noted, as well as the presence of a brood patch and, if possible, sex and age. Except of hummingbirds (Trochilidae), all trapped birds were marked by color rings to avoid pseudoreplication by multiple counts of identical birds (Seaman & Schulze 2010). Hummingbirds were marked by clipping the ends of one or two of the outer rectrices (following e.g. Paulsch & Müller-Hohenstein 2008, Seaman & Schulze 2010).

All birds were identified according to Stiles & Skutch (1989) and Garrigues & Dean (2007). Furthermore, all species were affiliated to feeding guilds (insectivores, nectarivores, granivores, omnivores, frugivores, carnivores) and classified by their habitat preferences as forest specialists (restricted to closed old-growth forest), forest generalists (occurring in different forest types including secondary forest, woodland and tree plantations) and openland species (occurring in gardens, grasslands or pastures). Birds were also classified as widespread (widespread species with a very large range), medium (birds that have a moderate range) and rare (endemic to South Nicaragua, Costa Rica and West Panama). All classifications were corresponding to the species descriptions provided by Stiles & Skutch (1989).

*Habitat variables*

To assess vegetation heterogeneity at study sites three habitat variables (canopy closure, tree density, understory density) were recorded during the study to allow for statistical testing of species-habitat relationships. Canopy closure was quantified as the proportion of visible sky hemisphere masked by vegetation when viewed from a single point (Jennings et al. 1999). Therefore, one picture of the canopy was taken from the centre of each mist net using a digital camera pointed directly towards the sky. Data of the mean percentage of canopy closure were provided by Anita Freudmann (unpublished).

Tree and understory density were measured as the number of trees with >10cm diameter at breast height (DBH) and the number of woody plants with <10cm DBH within a buffer of roughly 5 m around each net, respectively. The means of the four measures from each study site were taken for further statistical testing.

*Data analysis*

Estimated species richness was calculated with the estimator Jack1 (first-order jack-knife estimator) of *EstimateS* 8.2 (Collwell 2005). Jack-knife estimators are commonly used as species richness estimators and perform better than other estimators (Walther & Moore 2005). The use of such estimators is of particular importance because inventories of tropical species assemblages are typically very incomplete (e.g. Schulze et al. 2004). Using the resulting estimates for total species richness, the percentage of the completeness of caught species inventories was calculated.

For each site the relative species richness and the relative abundance of birds classified by their habitat preferences and their feeding guild affiliation were calculated. Analyses of variance (one-way ANOVAs) were used to test for effects of habitat on capture and recapture rates, recorded species and estimated species richness, and both relative richness and relative abundance of species grouped by their feeding guild classification. The recapture rates were calculated at each site as the number of recaptures (excluding those within the first hour after initial capture) divided by the number of initial captures (Blake & Loiselle 2002). To avoid pseudoreplication, recaptures were excluded from all other statistical analysis (Remsen & Good 1996).

Mist-netting samples were pooled by habitat to calculate species accumulation curves and their corresponding 95% confidence intervals. A non-metric multidimensional scaling (NMDS) analysis was calculated by using Bray-Curtis similarities for all possible site pairings to compare species compositions. This method allows to visualize highly complex similarity relationships between samples in a two or three dimensional ordination (Clarke 1993). Sites of higher similarity are clustered closer together than less similar sites. For easier interpretation, dashes connect all sites of the same habitat type forming a polygon. An Analysis of Similarity (one-way ANOSIM) was performed to see at which level species compositions differ between habitats.

Because the numbers of large and small trees were highly correlated, relationships between habitat variables and species richness were explored by univariate correlations. Spearman rank correlations were used, because normal distribution of habitat variables could not be achieved. Subsequently, results were corrected for False Discovery Rate (Pike 2011).

If not stated otherwise, *STATISTICA* 7.1 (Statsoft, Inc. 2005) was used for statistical analysis.

## Results

*Abundance, recapture rates and species richness*

A total of 855 birds belonging to 77 species and 22 families (including 3 waterbird species belonging to 2 families) were captured during 1,474 mist-net hours (MNH). Not considering waterbirds, 288 birds were caught at FI, 339 at FM, and 115 at OP sites, excluding 37, 69 and 12 recaptures, respectively. When standardized to the number of initial captures per 1 MNH, capture rates differed significantly between habitat types (one-way ANOVA: $F_{2,12} = 4.83$, $p = 0.029$). The lowest number of birds was recorded at OP, the highest at FM and an intermediate number at FI sites (Figure 2a).

Recapture rates (recaptures per initial capture) were significantly lower in OP than in FI and FM (one-way ANOVA: $F_{2,12} = 14.97$, $p < 0.001$; Figure 2b). Of 27 species (35% of recorded species total) only singletons or doubletons were captured. The 20 most abundant species (26% of total species) made up 73% of the total individuals.

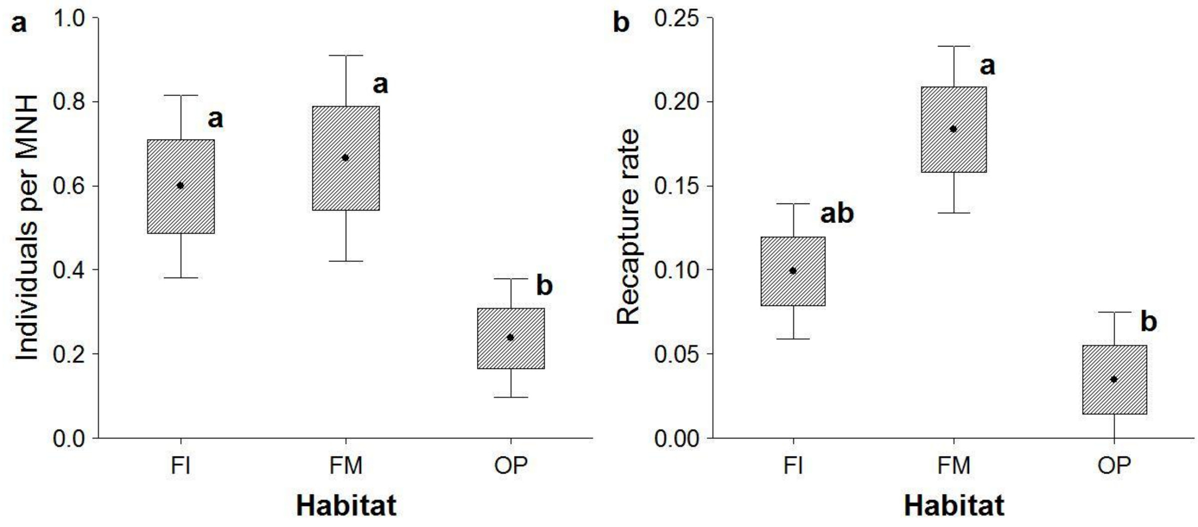


Figure 2. Captured individuals (a) and recapture rates (b) per mist net hour ± SE(box) and 95% CI (whiskers) per study site at forest interior (FI), forest margin (FM) and oil palm plantation (OP). Significant differences between habitats are indicated by different letters (Scheffé test).

Species inventories were relatively incomplete ranging between 63.40 ± 4.57% (completeness per site ± SD) at FM sites, 65.75 ± 3.78% at OP sites and 70.03 ± 4.43% at FI sites. However, completeness of species inventories did not differ between habitats (one-way ANOVA: $F_{2,12} = 3.08$, $p = 0.083$).

Recorded species richness was significantly lower in OP than in FI and FM (one-way ANOVA: $F_{2,12} = 9.74$, $p = 0.003$; Figure 3a). Also estimated species richness (Jack1) was significantly affected by habitat type (one-way ANOVA: $F_{2,12} = 9.73$, $p = 0.003$). Estimated species numbers were significantly higher at FI and FM compared to OP sites (Figure 3b).

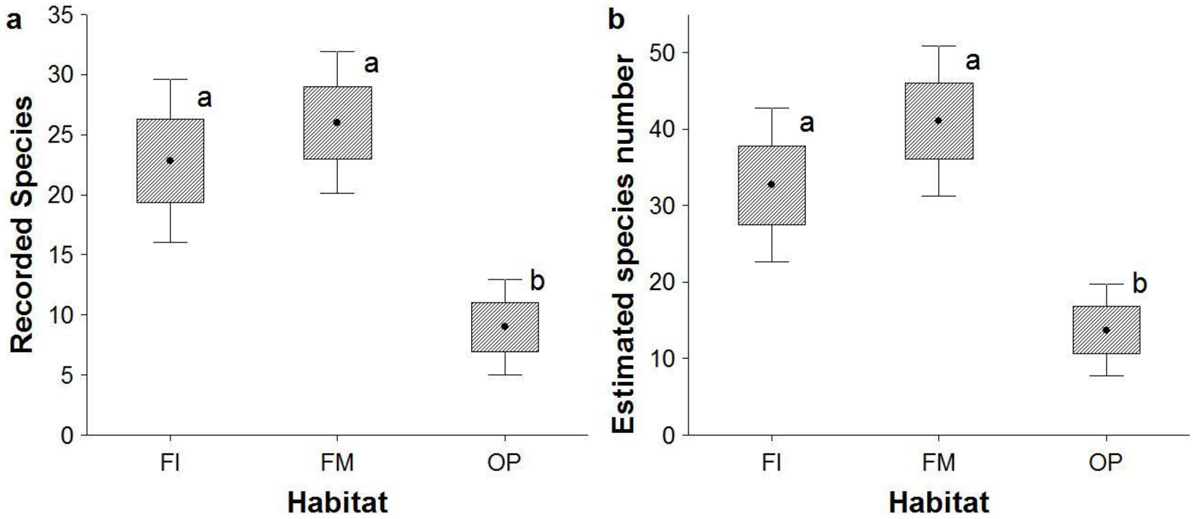


Figure 3. Mean number of (a) recorded and (b) estimated species ± SE (box) and 95% CI (whiskers) of forest interior (FI), forest margin (FM) and oil palm plantations (OP). Different letters indicate significant differences between habitats (Scheffé test).

The species accumulation curve based on pooled habitat data (Figure 4) shows different species richness of the habitat types with increasing sampling effort. The 115 individuals of OP belong to 23 species, the 288 individuals of FI to 47 species and the 339 individuals of FM to 54 species.

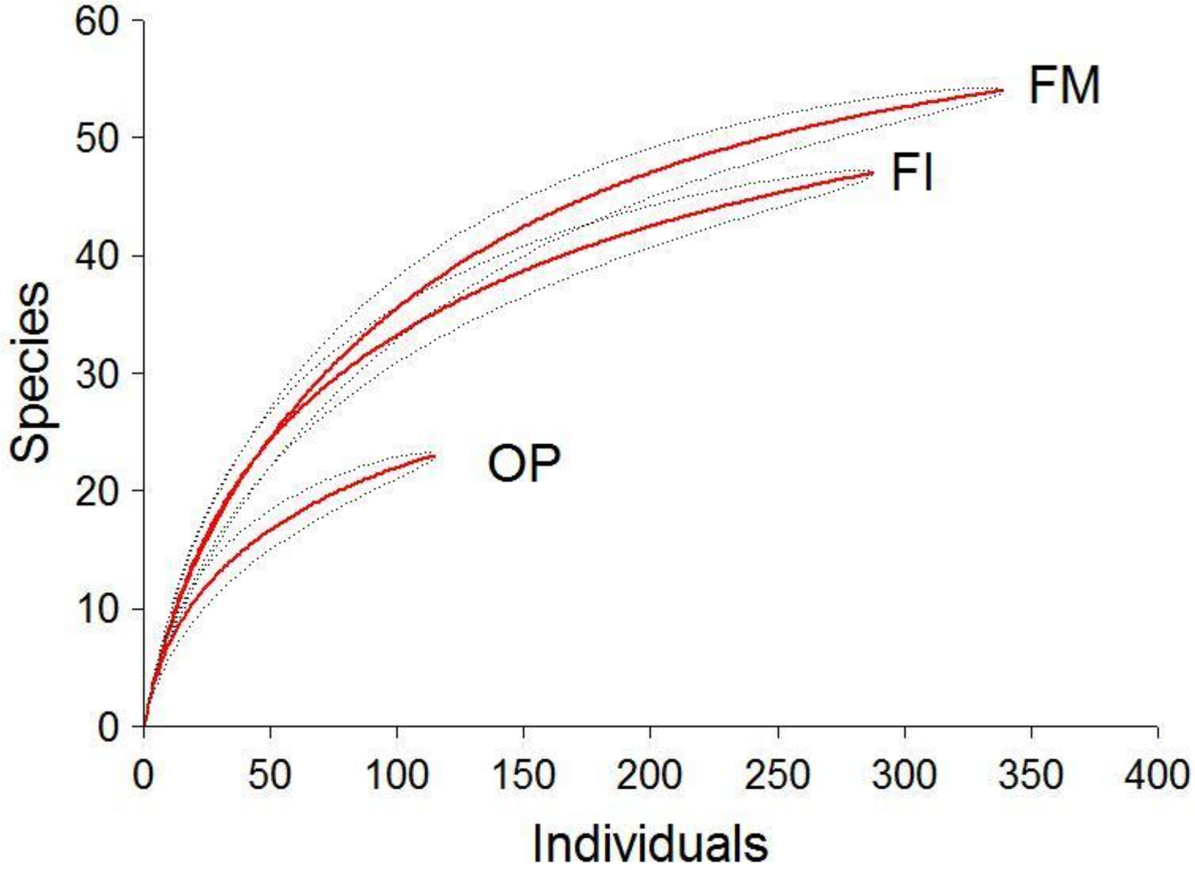


Figure 4. Rarefaction curves showing accumulation of total species ±95% confidence intervals with increasing number of captured individuals for forest margin (FM), forest interior (FI) and oil palm plantations (OP). N = 5 sites per habitat type.

*Habitat affiliation*

Forest specialists were widespread in FI (73.6% of individuals and 66% of species) and FM (58.9%, 50.9%), but rare in OP (17.3%, 13%). Openland species were hardly found in FI (1.4%, 6.3%) and FM (3.9%, 5.5%) but play an increasing role in OP (28.7%, 30.4%). Forest generalists were most common in OP (53.9%, 56.5%), followed by FM (37.3%, 46.6%) and FI (25%, 27.6%) (Figure 5).

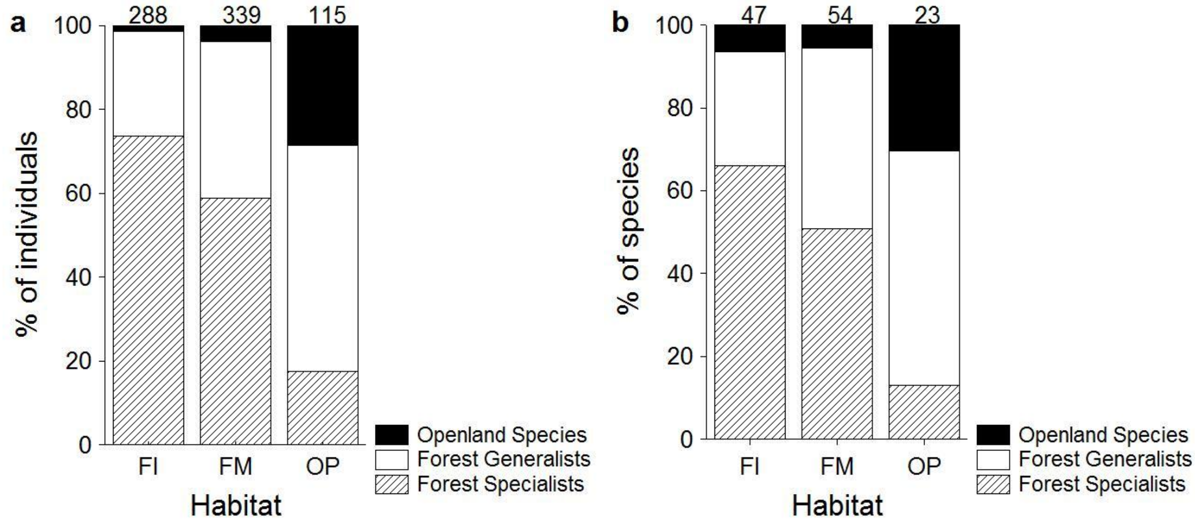


Figure 5: Total relative abundance (a) and relative species richness (b) of forest interior (FI), forest margin (FM) and oil palm plantations (OP). Numbers at the top of the bar indicate the total number of bird individuals (a) and species (b).

*Feeding guilds*

While the percentage of nectarivorous and frugivorous individuals are relatively constant over the three habitats, insectivores were less abundant in OP (28.7% compared to 45.5% in FI and 49.5% in FM) and granivores were more abundant in OP (28.7% compared to 1.4% in FI and 5% in FM, Figure 6), but this group of birds is blurred by *Leptotila verreauxi* (23 of 33 granivore individuals in OP = 69.7%).

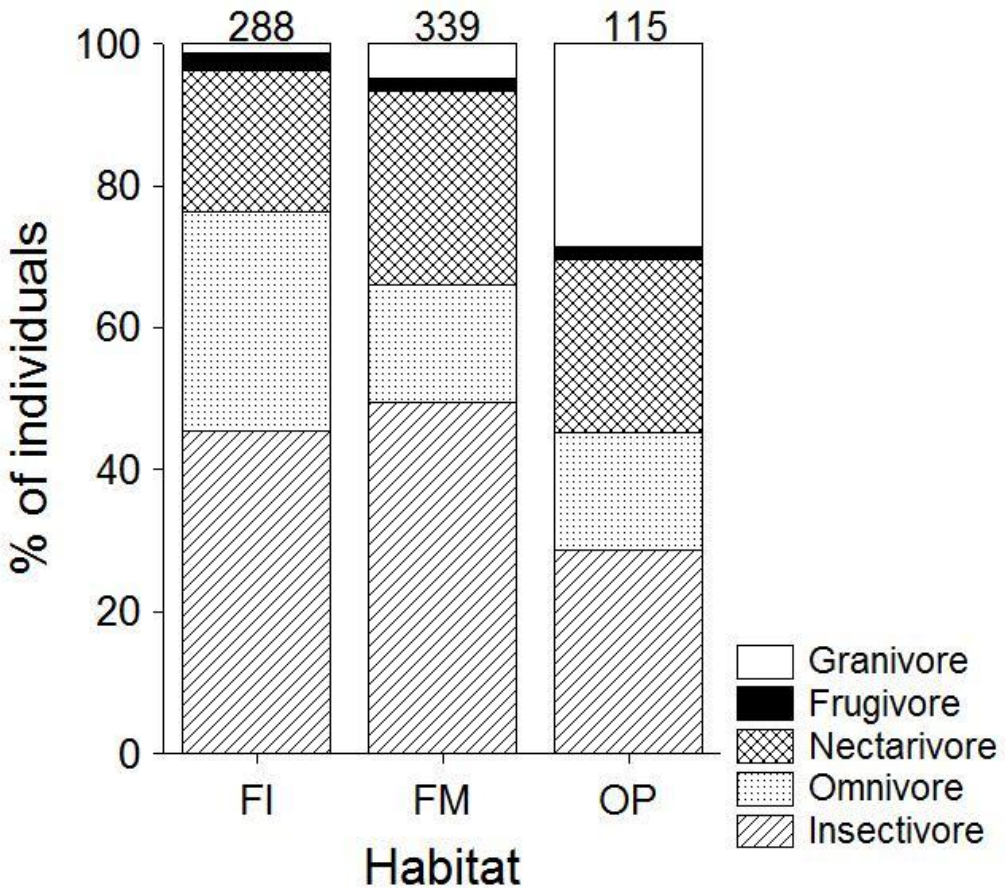


Figure 6: Total relative abundance of individuals belonging to different feeding guilds in forest interior (FI), forest margin (FM) and oil palm plantations (OP). Numbers at the top of the bars indicate the total number of bird individuals captured in the respective habitat.

While the percentage of insectivorous species was significantly higher in FI and FM (one-way ANOVA: $F_{2,12}$ = 12.27, $p$ = 0.001; Figure 7a), granivores were significantly higher in OP (one-way ANOVA: $F_{2,12}$ = 16.58, $p$ < 0.001; Figure 7b). Also omnivores were significantly higher in FI (one-way ANOVA: $F_{2,12}$ = 16.58, $p$ < 0.003; Figure 7c). No differences were found in nectarivores (one-way ANOVA: $F_{2,12}$ = 0.44, $p$ = 0.649; Figure 7d).

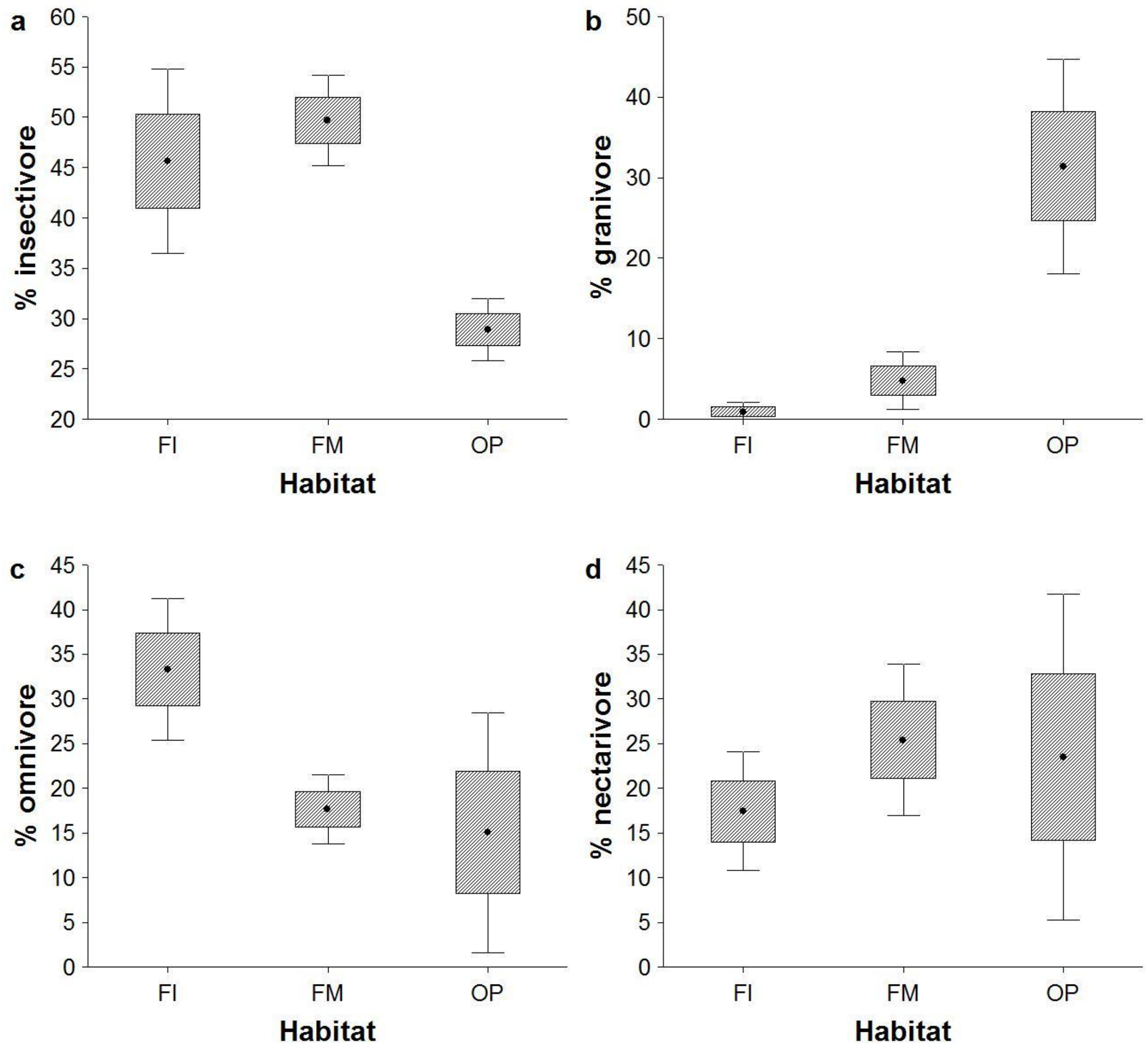


Figure 7: Mean relative percentage +SE (boxes) and 95% CI (whiskers) of individuals belonging to different feeding guilds for each habitat type: (a) insectivores, (b) granivores, (c) omnivores and (d) nectarivores.

*Species composition*

The species composition of OP differed significantly from FI (one-way ANOSIM: $R$ = 1, $p$ = 0.008) and FM (one-way ANOSIM: $R$ = 0.976, $p$ = 0.008), whereas species compositions of FI and FM differed relative slightly (one-way ANOSIM: R = 0.372, $p$ = 0.024) (Figure 8).

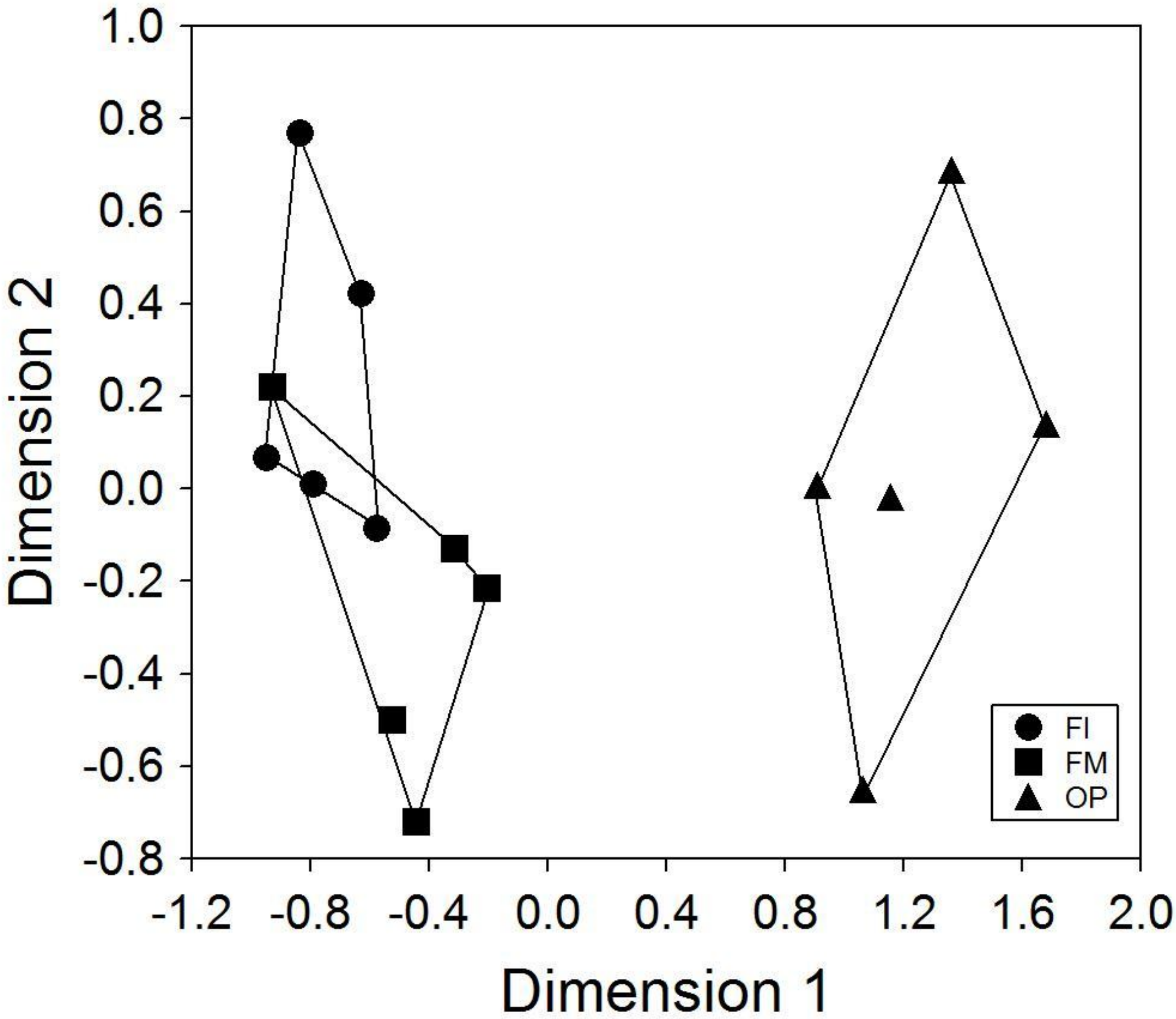


Figure 8. NMDS plot of the 15 study sites based on species richness and abundance. Different symbols indicate different habitat types. FI – forest interior, FM – forest margin, OP – oil palm plantation.

*Habitat variables*

Correlations were found between species richness and numbers of trees: The more trees, the more species were found. Both, trees with DBH <10cm (Spearman rank correlation: $r_s = 0.688$; $p < 0.005$; Figure 9a) and trees with DBH >10cm ($r_s = 0.662$; $p < 0.008$; Figure 9b) had significant influence on species richness, while canopy closure had no significant influence on species richness ($r_s = 0.313$; p = 0.255). The relationships between the density of small and large trees and bird richness remained significant after corrected for false discovery rate.

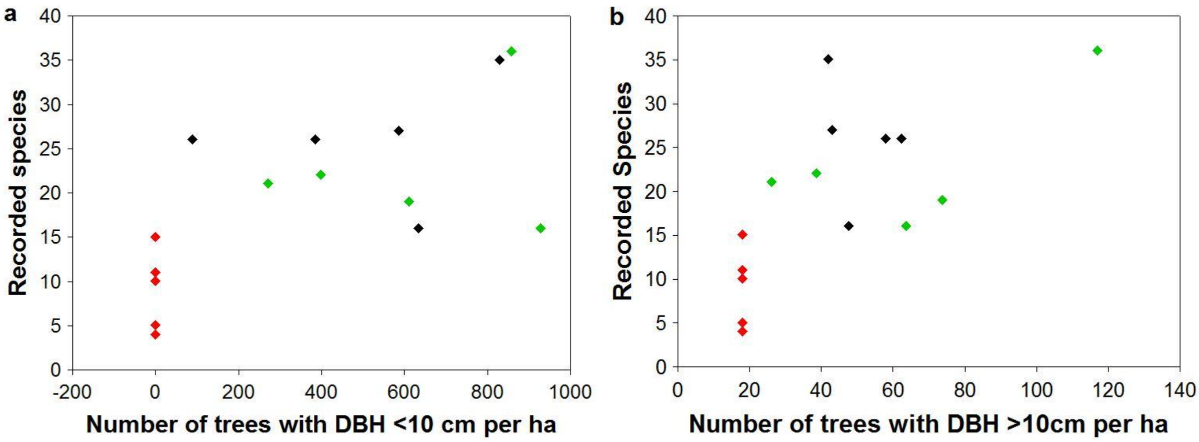


Figure 9. Relationships between species richness and (a) density of woody understory plants with DBH <10cm and (b) density of trees with DBH >10cm. FI = black; FM = green; OP = red.

## Discussion

*Abundance and species richness*

The lower abundance and species richness of birds in OP is corresponding to studies from South East Asia (Fitzherbert et al. 2008, Koh & Wilcove 2008). In our study, species richness of OP is less than one third of FI and FM. The highest abundance in FM is not surprising since ecotones are noted for providing habitats for more species (e.g. Risser 1995). Better light conditions lead to a higher productivity, which is often connected with higher species richness (Rosenzweig 1995). The fact that almost no birds were recaptured in OP indicates that birds hardly use this habitat type for establishing a territory. Hughes et al. (2002) found 43 species in an isolated oil palm plantation more than 6 km away from forest near the city of Neily, Puntarenas. However, how many of the 43 species find also adequate nesting sites in plantations, was not explored. Most likely, the limited food resources such as insects or small seeds (e.g. used by *Sporophila americana*, own observation) are only infrequently used by species from adjacent habitats.

*Habitat affiliation and range restricted species*

While openland species (e.g. *Columbina talpacoti*, *Troglotydes aedon*) and forest generalists (e.g. *Amazilia decora*, *Rhamphocelus costaricensis*) use plantations, the decline of forest specialists in OP is obvious. Of the 23 caught species in OP, only three (*Phaethornis longirostris, Threnetes ruckeri* & *Xiphorhynchus susurrans*) were classified as forest specialists, which prefer forest understory (Stiles & Skutch, 1989). OP are dominated by species of lower conservation concern and with a wide distribution (e.g. *Leptotila verreauxi*), while threatened and range restricted species are extremely rare or missing (Aratrakorn et al. 2006). Even in our plantations adjacent or even attached to old-growth forests, the loss of forest species with narrow ecological niches seems to be unstoppable.

While one endemic species was found in FI, FM and OP as well (*Amazilia decora*), the majority of endemics were either found in FI and FM (e.g. *Habia atrimaxillaris, Thryothorus semibadius, Manacus aurantiacus*) or in FI only (e.g. *Microcerculus marginatus*). A limited value of OP for range restricted forest specialists was also reported for plantations in Asia (e.g. Aratrakorn et al. 2006, Peh et al. 2006).

*Feeding Guilds*

As found in other studies before (e.g. Aratrakorn et al. 2006), insectivores had much lower abundances in OP compared to FI and FM. In Southeast Asia, epiphytes, canopy and litter contain a lower abundance and biomass of arthropods in oil palm compared to primary forest (Turner & Foster 2009). A similar situation in the Neotropics may be responsible for the decline of understory insectivores from forest sites towards OP. Several forest species are specialized in searching and gleaning ground leaf litter arthropods (e.g. Remsen & Robinson, 1990) and such ground and understory insectivores are known to be highly sensitive against disturbances like forest fragmentation (e.g. Sekercioglu et al. 2002, Stouffer et al. 2009). In our study, the disappearance of insectivores (e.g. Formicariidae) in OP is inevitable. Ant-followers (several species of Thamnophilidae, Dendrocolaptinae, etc.) are known to avoid open areas as well (Willis & Oniki 1979, Harper 1987), while inside forests, ant swarms can be followed by a high number of species and individuals (Blake & Loiselle 2001). However, epiphytes on palm trunks might be used by gleaners searching for arthropods, even if such behaviour was not observed during the field work. *Seiurus noveboracensis*, a common migrant and winter resident, was the most abundant insectivore in OP and is known to be linked to rivers, streams and ponds (Stiles & Skutch 1989).

Anthropogenic habitat disturbance is followed by an increase of granivore abundance (e.g. Gray et al. 2006). Granivore species seem to be one of the few groups, which profit in this study as well, but this group is overrepresented by *Leptotila verreauxi*. This typical ground-dove is searching the ground for seeds, grit and occasional small insects. The other three species (*Oryzoborus funereus, Sporophila americana*, *Volatinia jacarina*) mainly feed on grass seeds (Stiles & Skutch 1989).

Nectarivorous species are represented by hummingbirds only. All six species found in OP (*Amazilia decora*, *Amazilia tzacatl*, *Glaucis aeneus*, *Phaeochroa cuvierii*, *Phaethornis longirostris*, *Threnetes ruckeri*) are known to have a certain tolerance against disturbance and might easier be found in plantations (Schuchmann 1999). Hummingbirds might not find nectar resources in OP, but they seem to fly through them in order to reach more preferable habitats (Friesenbichler 2013).

*Columbina talpacoti*, the only frugivore species found in OP prefers open areas and feeds mainly on small berries and seeds on ground (Stiles & Skutch 1989).

There might be potential effects on ecosystem services due to a different feeding guild structure in OP. Birds play a major role in arthropod removal and therefore a pest removal service is decreased with lower diversity (Philpott et al. 2011). Since flower abundance in OP is extremely low (Friesenbichler 2013), pollination is decreased heavily as well.

*Species composition*

Species composition of FM is considerably more similar to FI than OP. The enormous turnover rate of species in OP implicates the impact of plantations as an effective barrier for spatial movements of forest birds. This was to be expected especially for understory forest birds, as there are several studies that show that such birds are not able to use other habitats and are extremely vulnerable to loss of required habitat (e.g. Loiselle & Blake 1992, Sekercioglu et al. 2002, Stouffer et al. 2009).

*Vegetation structure*

Understory vegetation of oil palm plantations is poor compared to natural forest. The vegetation is dominated by a herbaceous ground layer and epiphytes on the oil palm trunks (Foster et al. 2011). Several important structural components of forests, which are missing in OP, are large forest trees, lianas, epiphytic orchids and indigenous palms (Danielsen et al. 2008). Without such structural elements, microhabitats required by forest species are scarce. The importance of vertical complexity for bird richness (MacArthur & MacArthur 1961, Roth 1976) also applies in land-used systems (e.g. Greenberg et al. 1997). Intensive use of herbicides, pesticides and oil palm optimized fertilizers, as observed especially around the palm trunks, may keep that vegetation structure simple as well. Possible nesting sites inside OP are just on the top of the palms, or on the ground, where high vegetation for a hidden nesting site is missing. Hollow-breeders might also find some suitable nesting sites in the trunks.

*Implications for conservation*

Nájera and Simonetti (2010) found that more complex plantations had higher species richness than simple one and assumed that enhancing understory vegetation in oil palm plantations might reduce species declines. Oil palms are harvested regular. Therefore, heavy palm leaves are frequently cut to reach the palm fruits. Those leaves could easily destroy the sensitive understory vegetation. Furthermore, a structurally diverse understory layer is increasing the time effort for harvesting the palm fruits and consequently decreasing the economic benefit. If oil palms and semi-natural vegetation are planted more widespread, the yield-per-area rate would be reduced, which could lead to a loss of money, dependent on future demand for palm oil. Next to such low-intensity agriculture (“wildlife-friendly-farming” option by Green et al. 2005) another conservation possibility could be the intensification of production. Methods of selective breeding and hybrid crosses between different oil palm species could increase yields massively (Aratrakorn et al. 2006). In global comparison, Costa Rica has a three times higher palm oil yield than the average (Clay 2004). Increasing the yield may help conserve forested areas in Southeast Asia and other parts of the world.

The landscape around the TRS La Gamba is characterized by anthropogenic used surfaces, nestled in the foothills of adjacent rainforest and its fragments (e.g. Seaman & Schulze 2010). Such forest fragments may be useful structural elements of biological corridors and may generally be a helpful conservation tool (Beier & Noss 1998), but focus on conservation should be the protection of connected, contiguous forests outside agricultural landscapes, since forest fragments have a lower bird diversity and abundance (Edwards et al. 2010).

Related to conservation, the outlook seems to be bleak, as the demand for palm oil is going to increase. However, people have the possibility to disclaim products with palm oil or its derivates, but such direct actions as boycotts are just a drop in the bucket.

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## APPENDIX I: Numbers of mist-netted individuals excluding all recaptures

| | FI1 | FI2 | FI3 | FI4 | FI5 | FM1 | FM2 | FM3 | FM4 | FM5 | OP1 | OP2 | OP3 | OP4 | OP5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Amazilia decora* | 5 | 1 | - | 1 | - | 1 | 2 | - | - | 2 | - | 1 | 3 | 1 | - | 17 |
| *Amazilia tzacatl* | 2 | - | - | - | 1 | 3 | 1 | 9 | 1 | 5 | - | - | 3 | - | - | 25 |
| *Arremon aurantiirostris* | 7 | 2 | 5 | 4 | 5 | 7 | 6 | 6 | 7 | 10 | - | - | - | - | - | 49 |
| *Arremonops conirostris* | - | - | - | - | - | - | 1 | 1 | - | - | - | - | - | 1 | - | 3 |
| *Attila spadiceus* | 3 | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | 5 |
| *Automolus ochrolaemus* | 4 | 4 | 2 | - | 2 | 1 | - | 1 | 1 | 1 | - | - | - | - | - | 16 |
| *Campylorhamphus pusillus* | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 |
| *Capsiempis flaveola* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 |
| *Catharus ustulatus* | 11 | 1 | - | 7 | 4 | - | - | - | - | 6 | - | - | - | - | 2 | 31 |
| *Claravis pretiosa* | - | - | - | - | - | - | - | - | - | 1 | - | 1 | - | - | - | 2 |
| *Columbina talpacoti* | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | 1 | 3 |
| *Cyanocompsa cyanoides* | - | - | 3 | - | - | - | - | 2 | - | - | - | - | - | - | - | 5 |
| *Dendrocincla anabatina* | 4 | - | - | 1 | - | - | 1 | - | 3 | - | - | - | - | - | - | 9 |
| *Dendrocolaptes sanctithomae* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Dryocopus lineatus* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Empidonax flaviventris* | 1 | - | - | - | - | - | 3 | 1 | - | 1 | - | - | - | - | - | 6 |
| *Empidonax virescens* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| *Eucometis penicillata* | - | - | - | - | - | - | - | - | - | 3 | - | - | - | - | - | 3 |
| *Euphonia imitans* | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 |
| *Euphonia luteicapilla* | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | 1 |
| *Formicarius analis* | 1 | - | 2 | - | 1 | 2 | - | 1 | - | - | - | - | - | - | - | 7 |
| *Geotrygon montana* | - | - | - | - | - | 4 | - | - | 1 | 1 | - | - | - | - | - | 6 |
| *Glaucis aeneus* | 2 | - | 1 | - | - | 3 | 1 | 1 | - | 1 | - | - | - | 1 | - | 10 |
| *Glyphorhynchus spirurus* | 2 | 5 | 3 | 2 | 1 | 4 | 1 | 2 | 2 | - | - | - | - | - | - | 22 |
| *Gymnopithys leucaspis* | 2 | - | - | 2 | - | - | - | - | - | - | - | - | - | - | - | 4 |
| *Habia atrimaxillaris* | 3 | 1 | 2 | - | 4 | 1 | 4 | - | 2 | - | - | - | - | - | - | 17 |
| *Hylocharis eliciae* | 3 | - | 1 | - | 1 | - | 2 | 2 | - | 1 | - | - | - | - | - | 10 |
| *Hylocichla mustelina* | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| *Hyloctistes subulatus* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 |
| *Hylophilus ochraceiceps* | - | 1 | - | - | 3 | - | - | - | - | - | - | - | - | - | - | 4 |
| *Klais gumeti* | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 |
| *Lanio leucothorax* | - | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| *Lepidocolaptes souleyetii* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Leptotila cassinii* | 1 | - | 1 | - | - | - | 1 | 1 | 1 | - | - | - | - | - | - | 5 |
| *Leptotila verreauxi* | - | - | - | - | - | - | - | 1 | - | 1 | 4 | 3 | 4 | 8 | 4 | 25 |
| *Lipaugus unirufus* | 2 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 3 |
| *Manacus aurantiacus* | 1 | 1 | 3 | - | 4 | 12 | 6 | 13 | 3 | 5 | - | - | - | - | - | 48 |
| *Microcerculus marginatus* | - | 2 | 2 | - | - | - | - | - | - | - | - | - | - | - | - | 4 |
| *Mionectes oleagineus* | 7 | 4 | 6 | 2 | 3 | 7 | 2 | 22 | 2 | 1 | - | - | - | - | - | 56 |
| *Myiarchus tuberculifer* | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Myiobius sulphureipygius* | 4 | 3 | 3 | 3 | 1 | 1 | - | 1 | - | 2 | - | - | - | - | - | 18 |
| *Myrmeciza exsul* | 1 | 2 | 2 | - | 3 | - | - | 2 | - | 2 | - | - | - | - | - | 12 |
| *Nyctidromus albicollis* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 |

| | FI1 | FI2 | FI3 | FI4 | FI5 | FM1 | FM2 | FM3 | FM4 | FM5 | OP1 | OP2 | OP3 | OP4 | OP5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oncostoma cinereigulare* | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| *Onychorhynchus coronatus* | - | - | - | - | - | 1 | - | 1 | - | - | - | - | - | - | - | 2 |
| *Oporornis formosus* | - | - | - | - | - | - | 2 | 1 | - | - | - | - | - | - | - | 3 |
| *Oryzoborus funereus* | 2 | - | - | - | - | - | 1 | 4 | - | - | - | - | - | 5 | - | 12 |
| *Phaeochroa cuvierii* | - | - | - | - | - | 1 | - | 2 | - | - | - | - | 1 | - | - | 4 |
| *Phaeothlypis fulvicauda* | - | - | - | - | - | - | - | 2 | - | - | - | - | - | - | - | 2 |
| *Phaethornis longirostris* | 5 | 1 | 5 | 2 | 3 | 8 | 1 | 5 | 1 | 4 | - | - | 1 | - | 1 | 37 |
| *Phaethornis striigularis* | 1 | - | - | - | - | 1 | 2 | 1 | - | 3 | - | - | - | - | - | 8 |
| *Pipra coronata* | - | 2 | 1 | - | 2 | - | - | 1 | 1 | - | - | - | - | - | - | 7 |
| *Pipra mentalis* | 8 | 1 | 5 | 8 | 4 | 3 | - | 1 | 1 | 3 | - | - | - | - | - | 34 |
| *Pitangus sulphuratus* | - | - | - | - | - | - | - | - | - | - | - | - | 2 | - | - | 2 |
| *Platyrinchus coronatus* | 1 | 2 | 1 | 1 | 3 | - | - | - | 1 | - | - | - | - | - | - | 9 |
| *Quiscalus mexicanus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| *Ramphocelus costaricensis* | - | - | - | - | - | 2 | 3 | 4 | - | 3 | - | - | 1 | 6 | - | 19 |
| *Saltator maximus* | 1 | - | 1 | - | - | 1 | - | 1 | - | - | - | - | 1 | - | 1 | 6 |
| *Seiurus noveboracensis* | - | 1 | - | - | - | 1 | - | - | - | 1 | 1 | - | 1 | 3 | 6 | 14 |
| *Sporophila americana* | - | - | - | - | - | - | 2 | 1 | - | 1 | - | - | - | 4 | - | 8 |
| *Sporophila torqueola* | - | - | - | - | - | - | - | 3 | - | - | - | - | - | - | - | 3 |
| *Tachyphonus luctuosus* | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Terenotriccus erythrurus* | 1 | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| *Thalurania colombica* | 6 | 3 | 3 | 1 | - | - | - | - | 1 | - | - | - | - | - | - | 14 |
| *Threnetes ruckeri* | 5 | 2 | 2 | - | - | 4 | 2 | 3 | 1 | 17 | - | 1 | 6 | 5 | 4 | 52 |
| *Thryothorus semibadius* | 1 | - | - | - | 2 | 2 | - | 2 | - | 2 | - | - | - | - | - | 9 |
| *Tolmomyias sulphurescens* | - | - | - | - | - | - | 1 | 2 | - | - | - | - | - | - | - | 3 |
| *Troglodytes aedon* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 5 | 6 |
| *Turdus assimilis* | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| *Turdus grayi* | 1 | - | - | - | - | 5 | - | - | - | - | 3 | 1 | 2 | 6 | 4 | 22 |
| *Volatinia jacarina* | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | 1 |
| *Xenops minutus* | - | - | - | 2 | - | 1 | 1 | - | - | - | - | - | - | - | - | 4 |
| *Xiphorhynchus susurrans* | 1 | - | - | - | - | - | 1 | - | - | 2 | 1 | - | - | 1 | - | 6 |

## APPENDIX II: Persönliche Danksagung

An dieser Stelle möchte ich mich vor allem bei meiner Mutter Ingun, sowie meinen Großeltern Susanne und Peter, Elke und Ronald für die mentale, emotionale und nicht zuletzt finanzielle Unterstützung herzlich bedanken. Ihr habt mich, wenn nötig, immer ermutigt und seid hinter mir gestanden, danke dafür!

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## APPENDIX III: Curriculum vitae

| **Personal data** | |
|---|---|
| *Birth date:* | 24$^{th}$ January 1983, in St. Veit/Glan |
| *Citizenship:* | Austria |

| **Education** | |
|---|---|
| University of Vienna, Diploma study in Biology/Zoology | **since10/2002** |
| BRG Viktring, Graduation | **1993 - 2001** |

| **Further Education** | |
|---|---|
| Practical course in endocrinological laboratories at the University of Vienna | **06/2013** |
| Bird Ringing for the MRI program at the biological station in Illmitz, Austria | **2009/2010/2011** |
| Conservation and Research of sea turtles in Fethiye, Turkey | **07/2006 - 09/2006** |
| Practical course in histological laboratories at the University of Vienna | **11/2005 - 12/2005** |

**Knowledge of languages**

German (first language)
English (negotiable)
Italian (basic knowledge)

| **Travelling Experience** | |
|---|---|
| Lots of travels abroad since childhood, | |
| Costa Rica and Panama | **02/2012-05/2012** |
| Egypt | **12/2008** |
| Kenya | **12/2007 – 01/2008** |
| Thailand, Malaysia and Singapore | **07/2007 – 09/2007** |
| Turkey | **07/2006 – 08/2006** |

**Recreational activities, Interests**

Natural science, Animals, Nature photography
Sports, Arts & Culture, Travelling
Computing, Internet