Threats to biodiversity from oil palm plantations

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The following text reviews the current literature regarding the threats to biodiversity from oil palm agriculture, and has formed the basis of three publications produced by members of the Biodiversity and Oil Palm Research Network (http://groups.google.com/group/oilpalm?lnk=). Studies of biodiversity make up less than 1 % of the literature on oil palm (Turner et al. 2008), but enough is known to conclude that short-term impacts are severe and long-term impacts likely to be catastrophic to native wildlife populations. There is enormous overlap between oil palm growing areas and priority regions for biodiversity conservation. In this paper, the threats to biodiversity arising from plantation development in Central Kalimantan, Indonesian Borneo, are inferred from 23 studies across taxa. Since most studies have been undertaken in the Sundaland biogeographic region (principally in Sumatra, Borneo and peninsular Malaysia; Table 1), such inference is reliable and appropriate.

Direct impact of conversion

Conservation management in oil palm plantations requires an understanding of the levels of biodiversity plantations can support relative to prior, or alternative, land-cover. In much of Central Kalimantan oil palm plantations have directly replaced natural forest (Potter 2009); thus comparisons of biodiversity levels to undisturbed or disturbed forests are appropriate.

Species vary in their dependence of habitat features and hence their sensitivity to environmental change. Some groups may respond positively to landscape change (i.e. they thrive in plantations), and others may become locally extinct. The net response can be determined according to taxonomic group or over all species studied, and depends upon the extent to which natural habitat features are replicated. Oil palm monoculture as a potential habitat contrasts greatly with that provided by natural forest: plantations have a much less complex structure, with a uniform tree age structure, lower canopy, sparse undergrowth, less stable microclimate and greater human disturbance, and are cleared and replanted on a 25-30 year rotation (Corley and Tinker, 2003).

Table 1 reviews the findings of the 23 studies available that have compared animal diversity in oil palm plantations to that of forest. Summaries by taxonomic group are as follows:

Plants The loss of virtually all major components of forest vegetation during conversion is perhaps the most intuitively obvious impact of plantations; it lays the foundation for impacts on faunal groups, yet it has received little comment in the oil palm literature. Intensive agricultural management precludes regeneration of native vegetation, which results in forest trees, lianas, epiphytic orchids, and indigenous palms being completely absent from most plantations. In Jambi, Sumatra, more species of pteridophytes (i.e. non-flowering plants such as mosses and ferns) were found present in oil palm plantation plots than in old growth dipterocarp forest, but few forest specialists persisted in oil palm and the most dominant species were typical of regrowth on disturbed or burnt ground or along roadsides (Danielsen et al. 2009). Species composition, abundance, and use of substrate were markedly different to natural communities in forest.

Birds The impoverishment of an oil palm plantation's avifauna compared to that of forest is consistently noted, with the proportion of forest species surviving in plantations reported as between 10 and 38 % (Aratrakorn et al. 2006; Danielsen & Heegaard 1995). Moreover bird species in oil palm are significantly more widespread and are of lower conservation status than those in forest, and the losses of species are not random with respect to guild; in a study in Thailand, all forest woodpeckers, barbets and most of the babblers were absent from plantations, and there was a greater tendency for larger species such as hornbills to become locally extinct (Aratrakorn et al. 2006). For many plantations an exception to this trend would be the barn owl (*Tyto alba*), which is frequently introduced or encouraged in plantations as a natural form of pest control for rat pests (Corley and Tinker, 2003).

Mammals Studies of small mammals, bats and medium/large mammals in Jambi, Sumatra illustrate another notable decline in biodiversity levels in oil palm plantations. Only 25 % of bat species from native forests was retained in oil palm plantations, and most squirrels, tree shrews and primates were absent (Danielsen & Heegaard 1995). Other studies in Sumatra revealed that 88% of the medium to large mammals found in logged forest were absent in the surrounding oil palm plantations (Maddox et al. 2007), and small mammal species richness declined by 40 % (Scott et al. 2004).

Generalist primates such as macaques are frequently seen foraging along forest/oil palm boundaries, and high profile species such as orangutans and elephants are sometimes reported raiding plantations when they are present in neighbouring forest. Since their presence depends on proximity to neighbouring forest and access to the plantation, they are not permanent inhabitants. Wild pigs (*Sus scrofa*) have been recorded in unusually high numbers in forests bordering oil palm plantations (Ickes et al. 2001; Maddox et al. 2007). Since their food requirements are saturated by an abundance of palm fruits, they dominate the large mammal community. Generalist predators such as leopard cats (*Prionailurus bengalensis*) may also become locally abundant in oil palm landscapes. This is likely a response to high prey densities – for example rats such as *Rattus tiomanicus* can reach densities of 600 per ha in plantations (Rajaratnam et al 2007). Nonetheless, high-profile specialist predators such as clouded leopards (*Neofelis nebulosa*) have been reported as absent in plantations in Sumatra (Maddox et al. 2007).

Reptiles There are few data available from Southeast Asia, but a study of a landscape mosaic in the Dominican Republic suggested that neotropical lizards were quite resilient in oil palm plantations with 83 % of the forest fauna represented (Glor et al 2001). In Sumatra, populations of snakes such as blood pythons (*Python brongersmai*) and short-tailed pythons (*P. curtus*) have increased with anthropogenic habitat modification, especially the establishment of oil palm plantations (Shine et al 1999). Again, this is likely due to a local abundance of key prey species such as rats.

Invertebrates Invertebrates exhibit more variation in their response to conversion of forest to oil palm than vertebrates. Of 16 independent comparisons of invertebrate diversity in forest and oil palm plantations, nine revealed declines in species richness (i.e. the number of species) in plantations (Table 1). In Sabah, beetle diversity was much lower in plantations of oil palm than in those of Acacia, or logged or undisturbed forest (Chung et al. 2000). An open canopy and minimal forest vegetation and leaf litter were typical features of plantations and were linked to falls in diversity of beetle guilds. Beetles showed a shift in trophic structure across a disturbance gradient, moving from predator dominated communities within forests, to a simple community in oil palm with a much higher proportion of fungivores and sporophages. In Ghana, the scarab beetle community in oil palm was dominated by invasive savanna species, which were recorded in superabundance (Davis & Philips 2001), whereas in Sabah, ant communities were dominated by the invasive crazy ant *Anoplolepis gracilipes* (Brühl 2001). In fact, 40 % of the ant species found in oil palm plantations in Sabah were alien invasives, and the community was likened to those in heavily disturbed urban areas.

In studies of ants, bees and moths, comparisons between oil palm and forest revealed an increase in species richness of certain components of invertebrate communities (Table 1). For example, one study of bees found more species in oil palm than in forest, but might have underestimated species richness in forest because the canopy was not sampled (Liow et al. 2001). Indeed, further examination of community structure revealed that oil palm plantations typically exhibited much lower bee abundance than undisturbed forest, and honey bees (Apidae) were notably absent, with important implications for forest regeneration.

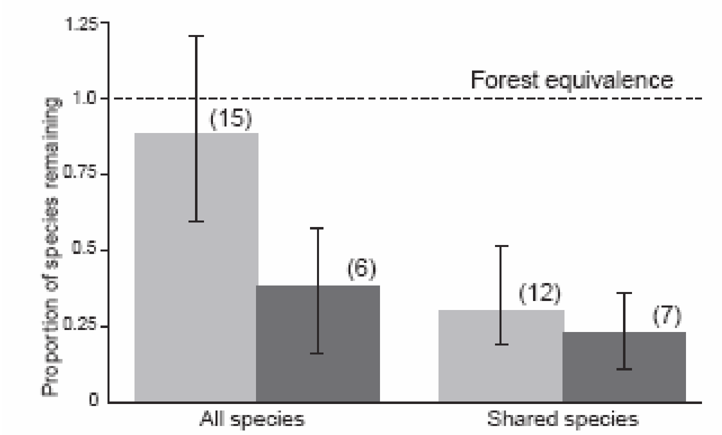
Overall trends across taxa The 23 studies reviewed in Table 1 have formed the basis of a meta-analysis to reveal trends in biodiversity following conversion of forest to oil palm (Danielsen et al. 2009; Fitzherbert et al. 2008). For each comparison, species are classified as forest-specialists or otherwise, according to independent assessments. Changes to communities are quantified for each taxonomic group and then as a mean effect size.

Across all studies (i.e. pooling vertebrates and invertebrates) a mean of only 15 % of forest species are evident in oil palm. In other words, 85 % of natural forest species are lost in conversion to oil palm. For vertebrates, the total number species in plantations is less than half (38%) that of natural forest, and only 22% of the vertebrate species found in forests are found in plantations. Species richness of birds, lizards and mammals is always lower in oil palm plantations than in forest (Table 1). Community similarity between plantations and forest is notably poor (29%), and on average, plantations are more dominated by a few species than forest (mean evenness 0.8).

The mean response of invertebrates is not as clear. On average oil palm plantations and forest sites have similar numbers of invertebrate species (i.e. mean total invertebrates species richness does not differ significantly between plantations and forests; 89 %; Figure 1). However, only 31% of invertebrate species found in forests are also found in plantations, with a similarity in community composition of just 21%. Again, on average, oil palm invertebrate communities are dominated by a few species (mean evenness 0.7).

In summary, converting forest to oil palm leads to a significantly impoverished wildlife community. Most forest species are lost and replaced by smaller numbers of largely non-forest species resulting in simpler, species-poor communities. The species lost tend to include taxa that rely on habitat features not found in plantations (such as dead wood, or large trees for cavity-dwelling species), those with the most specialised diets, those with the smallest range sizes and those of highest conservation concern (Chey et al. 2006; Peh et al. 2006; Danielsen and

Heegaard 1995). Plantation assemblages are typically dominated by a few abundant generalist non-forest species that in include alien invasives and pests. While any conversion of natural forest is inevitably damaging to biodiversity, studies that have compared several land-cover types reveal that oil palm plantations support even fewer forest species than plantations of other tree commodity products such as rubber, cocoa and *Acacia*, (Fitzherbert et al. 2008).



<u>Figure 1</u>. The impact of replacing forest with oil palms on the number of animal species (i.e. species richness). Bars represent the mean number of animal species recorded in oil palm as a proportion of those recorded in forest, and all species recorded in oil palm and only those present in both oil palm and forest ("shared species"). Data are presented as mean proportions and confidence limits for invertebrates (light grey) and for mammals, birds, and reptiles combined (dark grey). Meta-analysis sample sizes are provided in parentheses. The figure is reproduced from Danielsen et al. (2009), where the analysis is described in full.

Potential caveats A substantial proportion of the current literature suffers from several common methodological shortcomings (see Danielsen et al. 2009; Fitzherbert et al. 2008). The most obvious is that it is typically more difficult to detect species in a structurally complex forest compared to the more open structure of an oil palm plantation. Another is that sampling in oil palm near to forest borders is likely to result in inflated species richness because of transient species from the forest being recorded. It is also likely that a time lag exists between habitat loss and extinction so that species recorded in oil palm plantations cannot ultimately persist in the long-term. The net effect of these shortcomings, in addition to non-standardised analytical procedures and reporting biases, is that the biodiversity value of oil palm plantations is likely to be overestimated. The impact of converting forest to oil palm is probably even more damaging to biodiversity than is currently considered. There is clearly a need for more research. While the current literature reveals massive threats to above-ground terrestrial biodiversity from oil palm, there is virtually no reliable data available that documents threats to below-ground diversity, or freshwater and even marine communities that may be downstream of plantations.

Indirect threats through forest fragmentation

In Southeast Asia, oil palm agriculture is becoming a significant driver of forest fragmentation, a process that describes the conversion of formerly continuous habitat into smaller, more isolated patches. Given that oil palm and other tree crops are unsuitable habitats for most forest species, plantations may act as a barrier to animal movements (Struebig et al 2008; Maddox et al. 2007). Smaller forest fragments surrounded by oil palm in Malaysia support a lower diversity of butterflies (Benedick et al. 2006), ants (Brühl 2001) and bats (Struebig et al. 2008). The implication of this is that retaining remnants of natural forest in concessions may increase the biodiversity value of plantations, but most benefits will only result from retaining larger patches. Edge effects in forests are likely to exacerbate this situation. Increased vulnerability to wind, desiccation and fire, might be negligible in tall growth mature plantations, but this is yet to be examined. Increased tree sapling mortality in forests where densities of wild pigs are elevated could have more far-reaching implications for forest regeneration, resulting in forest fragments degrading over time together with the wildlife they support.

Impacts of management practices

There is the potential for a range of additional factors arising from oil palm management practices to threaten biodiversity, but these have so far not been rigorously assessed.

Initial forest clearance Replacing forest with oil palm plantations, especially on peat soils contributes substantially to greenhouse gas emissions and thus to climate change, a growing global threat to biodiversity (Danielsen et al 2009). Locally, seeds and sedentary animals are killed by fire used to clear forest or spread accidentally from plantations.

Water pollution Although the high sediment loads in streams that follow land clearance apparently return to baseline levels once a plantation is established (Corley and Tinker 2001), this requires constant monitoring that may be lacking in remote plantations. Water pollutants from plantations and on-site mills, such as POME (palm oil mill effluent), fertilisers and pesticides, are likely to severely impact aquatic wildlife. However, where POME is treated before discharge, such impacts are likely to be negligible, and pesticide use is relatively low for oil palm compared to other tree crops because of widespread use of integrated pest management (IPM) and leguminous cover crops.

Access Development of any agricultural land, including oil palm plantations, facilitates access to neighbouring forests, increasing the likelihood of human-wildlife conflict and hunting rates. This is likely to further exacerbate threats to vulnerable species, particularly mammals such as orangutans (*Pongo pygmaeus*), flying foxes (*Pteropus* spp) and pangolins (*Manis javanica*). Increased access to forests also increases vulnerability to illegal logging, compromising biodiversity through greater habitat loss.

Can biodiversity-friendly plantations exist?

It is unlikely that oil palm management practices could be improved enough to significantly increase the biodiversity value of plantations. This is because the main cause of massive biodiversity losses in oil palm areas is reduction in habitat complexity, and there are only limited opportunities to improve that whilst maintaining agricultural productivity. Retaining epiphytes or undergrowth in plantations only marginally increases the number of bird and butterfly species, and planting non-native plants such as *Euphorbia heterophylla* to attract beneficial insects does not significantly improve the biodiversity value (Koh, 2008). Of much greater biodiversity value is the protection of forest fragments and corridors within plantations, including riverside buffers and remnants on slopes. However, tens of thousands of hectares of forest are typically required to avert the extinction of many species (Falcy and Estades, 2007), meaning that avoiding oil palm development on forested land in the first place will always be the best option for biodiversity.

Table 1. The total fauna species richness for natural forests and oil palm plantations, the number of shared species, and the associated response variables from 23 studies that have studied biodiversity levels in oil palm plantations – summary adapted from a meta-analysis presented as Table 2 in Danielsen et al (2008). Independent sites contributed multiple datasets to the meta-analysis, and missing values indicate insufficient data in the source publication. Definitions:

S % loss = percent loss of species richness from converting forest to oil palm plantations (i.e. total S is standardized by the total number of species in forest)

S % shared = percent of forest species that are recorded in oil palm

Similarity = similarity of community composition between forest and oil palm plantations measured with the Bray-Curtis similarity index

Evenness = evenness of community composition measured using Pielou's Evenness index.

				Number of species (S)			*Responses*			
	Taxonomic group	*Location of study*	*Authors*	*Forest total*	*Oil palm total*	*Shared*	*S % loss*	*S % shared*	*Similarity (p/a)*	*Evenness*
Vertebrates	Birds	Sumatra	Danielsen et al. 1995	67	17	3	75	4	0.07	0.93
Vertebrates	Bats	Sumatra	Danielsen et al. 1995	11	1	1	91	9	0.22	-
Vertebrates	Lizards	Dominican Republic	Glor et al. 2001	6	5	3	17	50	0.55	1.02
Vertebrates	Small mammals	Sumatra	Scott et al. 2004[a]	5	3	2	40	40	0.29	0.43
Vertebrates	Birds	P.Thailand	Aratrakorn et al. 2006	109	21	-	62	19	0.36	-
Vertebrates	Birds	P. Malaysia	Peh et al. 2005[b], 2006	152	-	36	-	24	0.38	-
Vertebrates	Medium/large mammals	Sumatra	Maddox et al. 2007[a]	38	4	4	89	11	0.19	-
	Ground foraging ants	Papua New Guinea	Room 1975	49	29	11	41	22	0.28	0.98
	Mosquitoes	Sarawak	Chang et al. 1997	6	6	6	0	100	-	-

Subterranean beetles	Sabah	Chung et al. 2000	306	64	-	79	-	-	-
Arboreal beetles	Sabah	Chung et al. 2000	174	40	-	77	-	-	-
Ground beetles	Sabah	Chung et al. 2000	557	75	-	87	-	-	-
Ants (Site 1)	Sabah	Brühl 2001[a]	20	11	6	45	30	-	-
Ants (Site 2)	Sabah	Brühl 2001[a]	8	15	6	*	75	-	-
Ants (Site 3)	Sabah	Brühl 2001[a]	4	8	1	*	25	-	-
Bees	P. Malaysia/Singapore	Liow et al. 2001	8	17	-	*	-	-	-
Butterflies	Sabah	Benedick 2005[a]	26	12	1	54	4	0.05	0.72
Dung beetles	Ghana	Davis & Philips 2005	25	20	7	20	28	0.31	0.42
Terrestrial isopods	Sabah	Hassall et al. 2006	8	4	0	50	0	0.13	-
Moths (Site 1)	Sabah	Chey 2006	75	85	28	*	37	-	-
Moths (Site 2)	Sabah	Chey 2006	133	73	28	46	21	-	-
Moths (Site 3)	Sabah	Chey 2006	78	90	11	*	14	-	-
Butterflies	Sabah	Koh & Wilcove 2008[b]	63	-	12	-	19	0.30	-

[a] *Unpublished data sets.*
[b] *No data on the total number of species in oil palm.*
* *Greater species richness in oil palm*

References

Aratrakorn, S. *et al.* (2006) Changes in bird communities following conversion of lowland forest to oil palm and rubber plantations in southern Thailand. *Bird Conservation International* 16, 71-82

Benedick, S. *et al.* (2006) Impacts of rain forest fragmentation on butterflies in northern Borneo: species richness, turnover and the value of small fragments. *Journal of Applied Ecology* 43, 967-977

Brühl, C. A. 2001. Leaf Litter Ant Communities in Tropical Lowland Rain Forests in Sabah, Malaysia: Effects of Forest Disturbance and Fragmentation, Thesis. Univ. Würzburg, Germany.

Chang, M.S. *et al.* (1997) Changes in abundance and behaviour of vector mosquitoes induced by land use during the development of an oil palm plantation in Sarawak. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 91, 382-386

Chey, V.K. (2006) Impacts of forest conversion on biodiversity as indicated by moths. *Malay. Nat. J.* 57, 383-418

Chung, A.Y.C. *et al.* (2000) The diversity of beetle assemblages in different habitat types in Sabah, Malaysia. *Bulletin of Entomological Research* 90, 475-496

Corley, R.H.V. and Tinker, P.B. (2003) *The Oil Palm*, Blackwell Science

Danielsen, F. *et al.* (2009) Biofuel plantations on forested lands: double jeopardy for biodiversity and climate. *Conservation Biology* (In Press)

Danielsen, F. and Heegaard, M. (1995) Impact of logging and plantation development on species diversity: a case study from Sumatra. In *Management of tropical forests: towards an integrated perspective* (Sandbukt, Ø., ed), pp. 73-92, Centre for Development and the Environment, University of Oslo

Davis, A. and Philips, T. (2005) Effect of deforestation on a southwest Ghana dung beetle assemblage (Coleoptera: Scarabaeidae) at the periphery of Ankasa Conservation Area. *Environmental Entomology* 34, 1081-1088

Falcy, M.R. and Estades, C.F. (2007) Effectiveness of corridors relative to enlargement of habitat patches. *Conservation Biology* 21, 1341-1346

Fitzherbert, E. B. *et al.* 2008. How will oil palm expansion affect biodiversity? *Trends in Ecology and Evolution* 23, 538-545

Glor, R.E. *et al.* (2001) Lizard diversity and agricultural disturbance in a Caribbean forest landscape. *Biodiversity and Conservation* 10, 711-723

Hassall, M. *et al.* (2006) Biodiversity and abundance of terrestrial isopods along a gradient of disturbance in Sabah, East Malaysia. *European Journal of Soil Biology* 42, S197-S207

Ickes, K. *et al.* (2005) Impacts of nest construction by native pigs (*Sus scrofa*) on lowland Malaysian rain forest saplings. *Ecology* 86, 1540-1547

Koh, L.P. (2008) Can oil palm plantations be made more hospitable for forest butterflies and birds? *Journal of Applied Ecology* 45, 1002-1009

Liow, L.H. *et al.* (2001) Bee diversity along a disturbance gradient in tropical lowland forests of south-east Asia. *Journal of Applied Ecology* 38, 180-192

Maddox, T. *et al.* (2007) *The conservation of tigers and other wildlife in oil palm plantations*, Zoological Society of London

Peh, K.S.H. *et al.* (2006) Conservation value of degraded habitats for forest birds in southern Peninsular Malaysia. *Diversity and Distributions* 12, 572-581

Potter, L. The oil palm question in Borneo. In *Reflections on the Heart of Borneo* (Persoon, G., and Osseweijer, M., eds), Tropenbos International (in press)

Rajaratnam, R. *et al*. (2007) Diet and habitat selection of the leopard cat (*Prionailurus bengalensis borneoensis*) in an agricultural landscape in Sabah, Malaysian Borneo. *Journal of Tropical Ecology* 23, 209-217

Room, P.M. (1975) Diversity and organization of the ground foraging ant faunas of forest, grassland and tree crops in Papua New Guinea. *Australian Journal of Zoology* 23, 71

Scott, D. M., E. Gemita, and T. M. Maddox. 2004. Small cats in human modified landscapes in Sumatra. Cat News 40:23-25.

Shine, R. *et al*. (1999) Ecological attributes of two commercially-harvested python species in northern Sumatra. *Journal of Herpetology* 33, 249-257

Struebig, M.J. *et al*. (2008) Conservation value of forest fragments to palaeotropical bats. *Biological Conservation* 141. 2112-2126

Turner, E.C. *et al*. (2008) Oil palm research in context: identifying the need for biodiversity assessment. *PLoS ONE* 3, e1572