

Supplementary Online Material

Rehabilitation of Logged Rainforests: Avifaunal Composition, Habitat Structure, and Implications for Biodiversity-friendly REDD+

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METHODS

REHABILITATION PROTOCOL WITHIN INFAPRO.—Rehabilitation management utilised a combination of liberation cutting and enrichment planting. Before management, the INFAPRO area was divided into compartments each ≈ 25 ha in size.

Liberation cutting: Liberation cutting was conducted throughout each compartment and entailed all non-*Ficus* vines and bamboos being cut six months prior to and three years after enrichment planting. In addition, immediately before and three months after enrichment planting, non-commercial understorey trees, shrubs and gingers were cut along 1 m wide planting lines spaced at ten metre intervals (Mosigil & Yap 2001, Yap & Ganing 2001). Pioneers and other canopy trees were not cut.

Enrichment planting: Every 5 m along each planting line, a $2 \text{ m}^2 \times 2 \text{ m}^2$ plot was surveyed for existing tree regeneration. If a plot contained 0 - 1 trees it was marked for planting, but if a plot contained ≥ 2 Dipterocarp or wild fruit trees, or was too rocky then it was not to be planted. Compartments in which $\geq 80\%$ plots were not to be planted did not receive enrichment planting. All other compartments were enrichment planted with a single seedling in each marked plot (max. planting density ≈ 200 seedlings ha^{-1}). The species mix of seedlings planted was matched as best as possible with natural regeneration in the compartment, and consisted of 95% Dipterocarp plus 5% wild fruit tree species. These seedlings were drawn from a pool of 40 Dipterocarp and twelve fruit tree species (see Table S1). If seedling mortality was $> 5\%$ after 3 months or $> 25\%$ after 3 years, then additional seedlings were planted (Yap & Ganing 2001).

LITERATURE CITED

- MOSIGIL, G., AND S. W. YAP. 2001. Experience of liberation thinning in a large-scale rainforest rehabilitation project in Sabah, in: Lim, M. T., Yap, S. W., Tay, J., editors. Proceedings of the INFAPRO workshop year 2000: Rainforest rehabilitation for CO_2 sequestration in Sabah, Malaysia. Innoprise Corporation Sdn Bhd, Kota Kinabalu, Malaysia, pp. 28-39.
- YAP, S. W., AND A. L. GANING. 2001. A fine example of enrichment planting with indigenous species in Sabah, Malaysia, in: M. T. Lim, S. W. Yap, and J. Tay, editors. Proceedings of the INFAPRO workshop year 2000: Rainforest rehabilitation for CO_2 sequestration in Sabah, Malaysia. Innoprise Corporation Sdn Bhd, Kota Kinabalu, Malaysia, pp. 20-27

TABLE S1. *The Dipterocarp and fruit tree species planted within INFAPRO between 1992 and 2009. The number of seedlings planted of each species is shown.*

Dipterocarpaceae species	N planted	Wild fruit tree species	N planted
<i>Dipterocarpus acutangulus</i>	1,405	<i>Baccaurea macrocarpa</i> (Euphorbiaceae)	350
<i>Dipterocarpus applanatus</i>	5,554	<i>Lansium domesticum</i> (Meliaceae)	6,917
<i>Dipterocarpus caudiferus</i>	1,629	<i>Walsuran pinnata</i> (Meliaceae)	378
<i>Dipterocarpus conformis</i>	12,871	<i>Diospyros spp.</i> (Ebenaceae)	14,624
<i>Dipterocarpus spp.</i>	68,925	<i>Alangium javanicum</i> (Alangiaceae)	15,064
<i>Dryobalanops beccarii</i>	24	<i>Baccaurea angulata</i> (Euphorbiaceae)	17,500
<i>Dryobalanops lanceolata</i>	263,204	<i>Dimocarpus longari</i> (Sapindaceae)	4,691
<i>Hopea nervosa</i>	72,327	<i>Durio spp.</i> (Bombalaceae)	7,702
<i>Hopea nutans</i>	721	<i>Nephelium lappaceum</i> (Sapindaceae)	8,715
<i>Hopea sangal</i>	37,852	Aras-aras (local name)	250
<i>Hopea spp.</i>	6,924	<i>Canarium spp.</i> (Burseraceae)	1,845
<i>Parashorea malaanonan</i>	39,588	<i>Artocarpus odoratissima</i> (Moraceae)	4,173
<i>Parashorea tomentella</i>	158,060		
<i>Shorea acuminatissima</i>	136		
<i>Shorea agamii</i>	858		
<i>Shorea argentifolia</i>	9,434		
<i>Shorea beccariana</i>	701		
<i>Shorea faguetiana</i>	100,622		
<i>Shorea falciferoides</i>	9,196		
<i>Shorea fallax</i>	31,853		
<i>Shorea gibbosa</i>	3,587		
<i>Shorea guiso</i>	2,037		
<i>Shorea johorensis</i>	86,660		
<i>Shorea leprosula</i>	167,650		
<i>Shorea leptoderma</i>	6,167		
<i>Shorea macrophylla</i>	4,299		
<i>Shorea macroptera</i>	5,249		
<i>Shorea mecistopteryx</i>	215		
<i>Shorea ovalis</i>	2,000		
<i>Shorea parvifolia</i>	23,609		
<i>Shorea parvistipulata</i>	5,235		
<i>Shorea pauciflora</i>	1,408		
<i>Shorea pinanga</i>	1,235		
<i>Shorea seminis</i>	9,467		
<i>Shorea smithiana</i>	834		
<i>Shorea superba</i>	1,331		
<i>Shorea symingtonii</i>	1,588		
<i>Shorea xanthophylla</i>	254		
<i>Vatica dulitensis</i>	7,063		
<i>Agathis spp.</i> (Araucariaceae)	3,698		
Total	1,151,772		82,209

TABLE S2. *The number of birds sampled of different species in unlogged forest (UL), naturally-regenerating logged forest (NR) and rehabilitated logged forest (R). Guild codes: F = frugivore; I = insectivore; G-FI = generalist frugivore-insectivore (i.e., species that include both fruit and insects in their diet); S = sallying forager. Red List codes: LC = Least Concern; NT = Near Threatened; VU = Vulnerable. * Species that declined significantly after logging (see **Methods** for details).*

Species	Guild	Red List	UL	NR	R	Total
<i>Spilornis cheela</i>		LC	0	0	1	1
<i>Accipiter trivirgatus</i>		LC	0	2	1	3
<i>Accipiter virgatus</i>		LC	1	0	0	1
<i>Chalcophaps indica</i>	F	LC	35	38	1	74
<i>Cuculus vagans</i>	I	NT	1	1	0	2
<i>Surniculus lugubris</i>	I	LC	0	1	0	1
<i>Phaenicophaeus chlorophaeus</i>	I	LC	1	0	0	1
<i>Harpactes diardii</i>	I,S	NT	1	1	2	4
<i>Harpactes orrhophaeus</i>	I,S	NT	2	0	0	2
<i>Harpactes duvaucelii</i>	I,S	NT	1	0	0	1
<i>Actenoides concretus</i> *	I	NT	6	1	1	8
<i>Lacedo pulchella</i>	I	LC	1	0	0	1
<i>Ceyx erithacus</i>	I	LC	22	25	21	68
<i>Alcedo meninting</i>		LC	0	2	0	2
<i>Alcedo euryzona</i>		VU	0	7	3	10
<i>Megalaima mystacophanos</i>	F	NT	0	1	0	1
<i>Calorhamphus fuliginosus</i> *	I	LC	4	0	0	4
<i>Indicator archipelagicus</i>	I	NT	1	0	1	2
<i>Sasia abnormis</i>	I	LC	35	64	35	134
<i>Picus puniceus</i>	I	LC	0	0	1	1
<i>Blythipicus rubiginosus</i>	I	LC	2	2	0	4
<i>Meiglyptes tukki</i>	I	NT	2	1	8	11
<i>Calyptomena viridis</i>	F	NT	9	8	1	18
<i>Eurylaimus javanicus</i>	I,S	LC	0	0	2	2
<i>Eurylaimus ochromalus</i>	I,S	LC	0	0	1	1
<i>Pitta granatina</i>	I	LC	1	4	1	6
<i>Pitta baudii</i>	I	VU	8	3	4	15
<i>Pitta guajana</i>	I	LC	1	0	2	3
<i>Pitta sordida</i>	I	LC	1	0	0	1
<i>Chloropsis cyanopogon</i>	G-FI	NT	0	1	0	1
<i>Chloropsis sonnerati</i>	G-FI	LC	1	0	0	1
<i>Dicrurus paradiseus</i>	I,S	LC	0	0	1	1
<i>Oriolus xanthonotus</i>	G-FI	NT	0	1	0	1
<i>Rhipidura javanica</i>	I,S	LC	2	3	1	6
<i>Rhipidura perlata</i> *	I,S	LC	6	0	1	7
<i>Hypothymis azurea</i> *	I,S	LC	10	3	3	16
<i>Terpsiphone paradisi</i>	I,S	LC	7	9	7	23
<i>Platysmurus leucopterus</i>	G-FI	NT	0	2	0	2
<i>Pycnonotus melanoleucos</i> *	G-FI	NT	28	15	0	43
<i>Pycnonotus atriceps</i>	G-FI	LC	1	1	0	2
<i>Pycnonotus eutilotus</i>	G-FI	NT	4	5	3	12
<i>Pycnonotus simplex</i>	G-FI	LC	0	1	1	2
<i>Pycnonotus brunneus</i>	G-FI	LC	2	1	2	5
<i>Pycnonotus erythrophthalmos</i>	G-FI	LC	8	20	9	37
<i>Tricholestes criniger</i>	G-FI	LC	33	51	23	107
<i>Iole olivacea</i>	G-FI	LC	0	0	1	1
<i>Alophoixus bres</i>	G-FI	LC	26	16	19	61
<i>Alophoixus phaeocephalus</i>	G-FI	LC	48	51	30	129

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Species	Guild	Red List	UL	NR	R	Total
<i>Orthotomus atrogularis</i>	I	LC	1	5	2	8
<i>Orthotomus sericeus</i>	I	LC	3	1	3	7
<i>Orthotomus ruficeps</i>	I	LC	1	1	1	3
<i>Pellorneum capistratum</i>	I	LC	17	23	11	51
<i>Trichastoma rostratum</i>	I	NT	1	3	4	8
<i>Trichastoma bicolor</i>	I	LC	49	49	22	120
<i>Malacocincla sepiaria</i>	I	LC	31	22	21	74
<i>Malacocincla malaccensis</i>	I	NT	66	58	44	168
<i>Malacopteron magnirostre</i>	I	LC	28	19	12	59
<i>Malacopteron affine</i>	I	NT	5	2	2	9
<i>Malacopteron cinereum</i>	I	LC	31	34	38	103
<i>Malacopteron magnum</i>	I	NT	24	25	17	66
<i>Malacopteron albogulare</i>	I	NT	0	0	1	1
<i>Pomatorhinus montanus</i> *	I	LC	3	0	2	5
<i>Ptilocichla leucogrammica</i> *	I	VU	10	3	0	13
<i>Kenopia striata</i> *	I	NT	22	7	17	46
<i>Napothera atrigularis</i>	I	NT	7	2	1	10
<i>Stachyris poliocephala</i>	I	LC	20	32	27	79
<i>Stachyris leucotis</i>	I	NT	4	3	2	9
<i>Stachyris maculata</i>	I	NT	15	13	11	39
<i>Stachyris erythroptera</i>	I	LC	43	34	30	107
<i>Macronous ptilosus</i>	I	NT	19	25	7	51
<i>Alcippe brunneicauda</i> *	G-FI	NT	27	11	9	47
<i>Yuhina zantholeuca</i>	I	LC	1	0	0	1
<i>Zoothera interpres</i>	G-FI	NT	14	8	3	25
<i>Philentoma pyrhoptera</i>	I,S	LC	23	21	35	79
<i>Philentoma velata</i>	I,S	NT	1	0	1	2
<i>Copsychus malabaricus</i>	I	LC	10	15	12	37
<i>Trichixos pyrropygus</i>	I	NT	17	8	6	31
<i>Enicurus ruficapillus</i>	I	NT	6	13	6	25
<i>Enicurus leschenaulti</i>	I	LC	11	10	5	26
<i>Rhinomyias umbratilis</i> *	I,S	NT	24	8	15	47
<i>Ficedula dumetoria</i> *	I,S	NT	9	2	1	12
<i>Eumyias thalassinus</i>	I,S	LC	2	0	0	2
<i>Elminia albicauda</i>	I,S	LC	0	1	6	7
<i>Cyornis superbus</i>	I,S	LC	7	2	5	14
<i>Cyornis caeruleus</i>	I,S	VU	22	13	6	41
<i>Culicicapa ceylonensis</i>	I,S	LC	2	0	0	2
<i>Prionochilus maculatus</i>	G-FI	LC	45	35	20	100
<i>Prionochilus xanthopygius</i>	G-FI	LC	3	8	6	17
<i>Dicaeum trigonostigma</i>	G-FI	LC	2	1	1	4
<i>Anthreptes simplex</i>	G-FI	LC	7	8	5	20
<i>Anthreptes singalensis</i>	G-FI	LC	0	4	0	4
<i>Hypogramma hypogrammicum</i>	G-FI	LC	47	47	30	124
<i>Aethopyga siparaja</i>	G-FI	LC	1	0	0	1
<i>Aethopyga temminckii</i> *	G-FI	LC	3	0	0	3
<i>Arachnothera longirostra</i>		LC	154	226	185	565
<i>Arachnothera crassirostris</i>		LC	0	1	1	2
<i>Arachnothera flavigaster</i>		LC	1	0	0	1
<i>Arachnothera affinis</i>		LC	5	8	12	25
Total			1155	1152	832	3139

Table S3: *Contributions of different variables to the two principal components of variation in understorey vegetation structure. Variables making main contributions are in bold. See **Methods** for further details.*

Vegetation variable	FAC1	FAC2
Seedling density	0.30	0.76
Large lianas	0.74	0.16
Small lianas	0.81	-0.08
Climbing bamboos	0.44	-0.64