BIRD SEED DISPERSAL AND RESTORATION OF THE SUNDALAND BIODIVERSITY HOTSPOT IN SUMATRA

PRELIMINARY ANALYSIS

Project period:	September-August 2012
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Funded by

The Rufford Small Grants Foundation
www.ruffordsmallgrants.org

Suggested citations:

Marthy, W. 2012. Bird seed dispersal and restoration of the Sundaland Biodiversity Hotspot in Sumatra, Indonesia.

Front cover: Spectacled Bulbul *Pycnonotus erythropthalmos*

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The data presented here are preliminary findings, further compilation and analysis is underway and therefore assertion made here are tentative.

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1. INTRODUCTIONS

Forest restoration is defined as “re-establishment of the original forest ecosystem that was present before deforestation occurred” (Forest Restoration Research Unit 2005). This activity involves planting native tree species and extending forest boundaries by artificial and natural regeneration (Bawa *et al.* 1990). This type of activity is becoming more important as many natural forests are being degraded and fragmented due to anthropogenic disturbances. In addition, there is also a growing recognition of the value of secondary forest for biodiversity conservation. The secondary forest, defined as “forests regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/or canopy species composition with respect to nearby primary forests on similar sites” (Chokkalingam & de Jong 2001), still possess some similarity in species richness with the primary forest (Lambert & Collar, 2002; Barlow *et al.*, 2007), thus they have the capacity to recover given appropriate treatments.

In Southeast Asia, the tropical rainforest and its associated biodiversity is disappearing fast, and this is threatened the continuous existence not only the forest but also other biodiversity that live within the tropical forest (Sodhi *et al*., 2004). Asian tropical forest is unique as, for instance, it has many groups of birds that are more diverse in this region than elsewhere (Corlett, 2007). Together with other tropical forest in the world, tropical forest covers only 10% of the Earth land surface but it has 50-60% of world’s species (Dirzo & Raven 2003).

Indonesia, with about 138 million ha or 10% of the world’s remaining tropical forests, holds one of the largest areas of tropical forest of any country. Approximately 60 million ha of Indonesia’s forests are classified as production forest, and many of these forest have been degraded and/or fragmented. Besides that, there is a tendency that secondary forest and heavily logged forest will most likely to be converted to oil-palm monoculture (Fitzherbert *et al.,* 2008). It was estimated that, under a business-as-usual scenario, 14 million ha of production forest could be lost or seriously degraded by 2030 (IFCA Consolidation Report, 2008). In 2004, the Indonesia Ministry of Forestry issued legislation for a new type of forestry license in production forests – namely a license for ecosystem restoration. This license is granted for up to 95 years and requires the holder to protect and restore the forest ecosystem. As logging is forbidden, the holder is required to find income from alternative sources. This is a good opportunity for these forests to “recover” and be managed sustainably in the future (e.g. extension of the cutting cycle and reducing the logging effect on residual stands (Sianturi & Kanninen, 2006).

However, large scale degraded forest restoration (i.e. secondary forest) is not an easy task. The main goal of restoration is to create a self-supporting ecosystem that is resilient to perturbation without further assistance (SER 2004). To achieve this goal there are many things that need to be considered, the main question being how to achieve restoration goal in efficient and effective ways. Or it is simply stated that how much interventions are needed beyond simply protecting the site from further disturbances (Lamb & Gilmour, 2003). There are at least six type of intervention that focus on biodiversity restoration, ranging from no planting is implemented (site protection) to intensive mixed-species planting (Lamb & Gilmour, 2003). To come to the decision on what type of intervention, one should first understand the current condition of the site, such as the occurrence of seed dispersal species, current vegetation structure, closeness to natural forest, etc (Forest Restoration Research Unit, 2008). In other words, one needs to understand the current condition and trying to capitalize as much as possible the natural system that are still operating.

Animal seed dispersers play an important role in delivering propagules to other part of the forest and or disturbed areas (Muscarella & Flemming 2007), and is defined as the removal and deposition of viable seeds away from parent plants (Nathan & Muller-Landau, 2000). Poor seed dispersal has been considered as a major limiting factor for forest recovery (Wunderle Jr., 1997; Ruiz-Jaen & Aide, 2005; Babweteera & Brown, 2008), hence understanding the current seed dispersal system that is still operating in the intended restoration area will greatly help in deciding what type of intervention (e.g. intensity of planting, type of species to be planted) that is needed to be implemented in a particular site. Plant species have evolved several different mechanisms of seed dispersal to achieve dispersal from the mother plant including anemochory (wind-dispersed), hydrochory (water-dispersed), barochory (gravity-dispersed), autochory (self-dispersal by explosion), and zoochory (animal-dispersed, Wilson & Traveset, 2000). Within this variation of mechanism, promoting animal seed dispersal has the potential to speed up restoration process (Corlett & Hau 2000, Forest Restoration Research Unit, 2008). Among vertebrates, birds and mammals are probably the most important seed dispersers in terms of the number of dispersed seeds (Stiles, 2000). This dispersal mechanism can play a crucial role in the maintenance of species diversity in a plant community (Levey *et al.* 2002).

Many studies have shown that anthropogenic disturbances, such as logging and/or forest fragmentation, can impact the frugivorous bird abundance and composition; hence influence the pattern of seed dispersal and plant regeneration (Moran *et al.* 2010, Lehouck *et al.* 2010, Meijaard *et al.*, 2005). A recent study by Garcia *et* al. (2010) in three different temperate ecosystems (secondary forest, shrub lands and mature forest) revealed that frugivorous bird abundance is a good indicator on the degree of seed dispersal. They also found that even in the degraded habitat the bird visitation was still intense, thus these habitats still received disperse seeds. A similar pattern was also found in the tropical rainforest system where seeds were seeds are still being dispersed into disturbed/degraded area but with lower intensity due to decrease in visitation rate of particularly frugivorous (Babweetera & Brown, 2008). However, even within the same frugivorous guild there will also difference in their contribution as seed dispersers to the future reproduction of a given plant (Schupp, 1993). In this sense, the seed delivered can also be an indication of the plant resources available within that area; hence one may want to introduce native tree species that are not present in the delivered seeds. In short, as suggested by Hobbs (2007) that it is important to identify when ecological system can recover unaided and when they require active restoration efforts.

Harapan Rainforest is the first ecosystem restoration project in Indonesia, and covers approximately 100,000 ha of ex-logging lowland forest. This type of forest is part of the Sundaland biodiversity hotspot in the world (biodiversity hotspots are the richest but yet the most threatened reservoirs of plant and animals on earth; Myers *et al*., 2000). Based on canopy cover and tree density the area can be classified into three secondary forest types: old, intermediate, and young secondary forest. As in many restoration projects around the world, the main question is what level of intervention (as mentioned earlier) that is needed to be implemented. For example, if the seed dispersed are mainly pioneer species seeds or small seeded tree species then one can assume that enrichment planting using climax tree species or tree species with large seeds (as a mean of anthropogenic intervention) is needed to assist the recovery of that particular degraded forest. Moreover, it will be also interesting to assess the frugivorous bird species composition in various degree of degradation types as a reflection of not only seed dispersal potential but also to understand what physical factors (canopy openness, stand structure etc.) that influence the presence of particular frugivorous bird composition/structure hence driving the seed rain diversity. Site traits (perches, structural complexity, fruiting trees) were important, not only as an attractant in increasing seed rain (Wunderle Jr., 1997), but also influence the persistent of species in particular disturb forest (Dent, 2010).

To sum up, understanding the bird seed dispersal will greatly assist in achieving forest restoration objective. As each restoration area is unique, more specific studies are needed to reflect local conditions, particularly in an attempt to understand the potential for animal dispersers in enhancing plant diversity on degraded sites (Wunderle Jr., 1997). This understanding is very crucial in designing forest restoration programs.

2. RESEARCH OBJECTIVES, SURVEY METHODS AND STUDY SITE

2.1 RESEARCH OBJECTIVES

Capitalizing current natural process that is still occurred within a degraded forest is crucial in the successful implementation forest restoration program. This research aims to assess bird seed dispersal service in assisting regeneration of the secondary dry lowland forest in Harapan Rainforest, Jambi-Province, Sumatra-Indonesia

1. To assess the influence of habitat structure on frugivorous bird species
2. To quantify seed rain in various types of secondary forest (What seeds are dispersed and where);
3. To assess the germination success of dispersed seeds in various types of secondary forest.

2.2 SURVEY METHODS

Eleven transects (each 2 km long) were used in this study and they covered various secondary habitat gradients in the study area. Each transect was 2 km long and placed at least 1.5 km apart to avoid spatial-autocorrelation. All survey data collections were conducted on these transects. The study was conducted in two time periods: October-December 2011 and April-June 2012.

Table 1. Survey timeline

Objectives	Note	Repetition	Data collection period	
			Oct-Dec 2011	Apr-June 2012
Bird & Vegetation Point transect	11 (2km) transect (total survey points 121)	3 repetitions per transect per period	YES	YES
Seed trap survey	Seed traps set in four transect. Ten seed traps per survey point. Four survey points per transect.		YES	YES
Experimental planting	Seeds captured on seed traps were planted on 1 m quadrate near the respective traps.		YES	

2.2.1 Assessing the influence of habitat structure on frugivorous bird species diversity

The bird data collections were conducted in the two survey periods (Table 1). The point transect method will be used to gather bird and habitat data. The bird survey will cover all bird species presence in each site (currently 293 bird species had been recorded in the Harapan Rainforest). Eleven transects (each transect was 2 km long) were selected to represent various vegetation covers/conditions in the study site. In each transect, bird and habitat data were collected at 200 meters interval (11 data collection point per transect).

Point-transect surveys conducted from 06.30 to 10.00. Count duration was 10 min and started upon arrival at the point. The horizontal distance to each bird was estimated directly using Digital-Rangefinder. To reduce the chance of double counting, only birds detected within 50 m of the observer were used in the analyses. Also excluded from analyses were birds detected flying over but not utilizing the unit (point). A-10 minutes sound recording per survey point was also conducted to aid bird species identification.

Habitat structure data were collected within 25 m radius at each survey point for all 121 survey points, and covering geographical variables (e.g. distance from forest edge & water source), vegetation structural characteristics (e.g. 10 nearest tree with diameter > 20 cm will be measured for total height, canopy height and tree diameter), tree species composition (presence/absence of Fig trees, fruiting trees, flowering trees), and evidence of human activities (e.g. cut stamps, hunting traps).

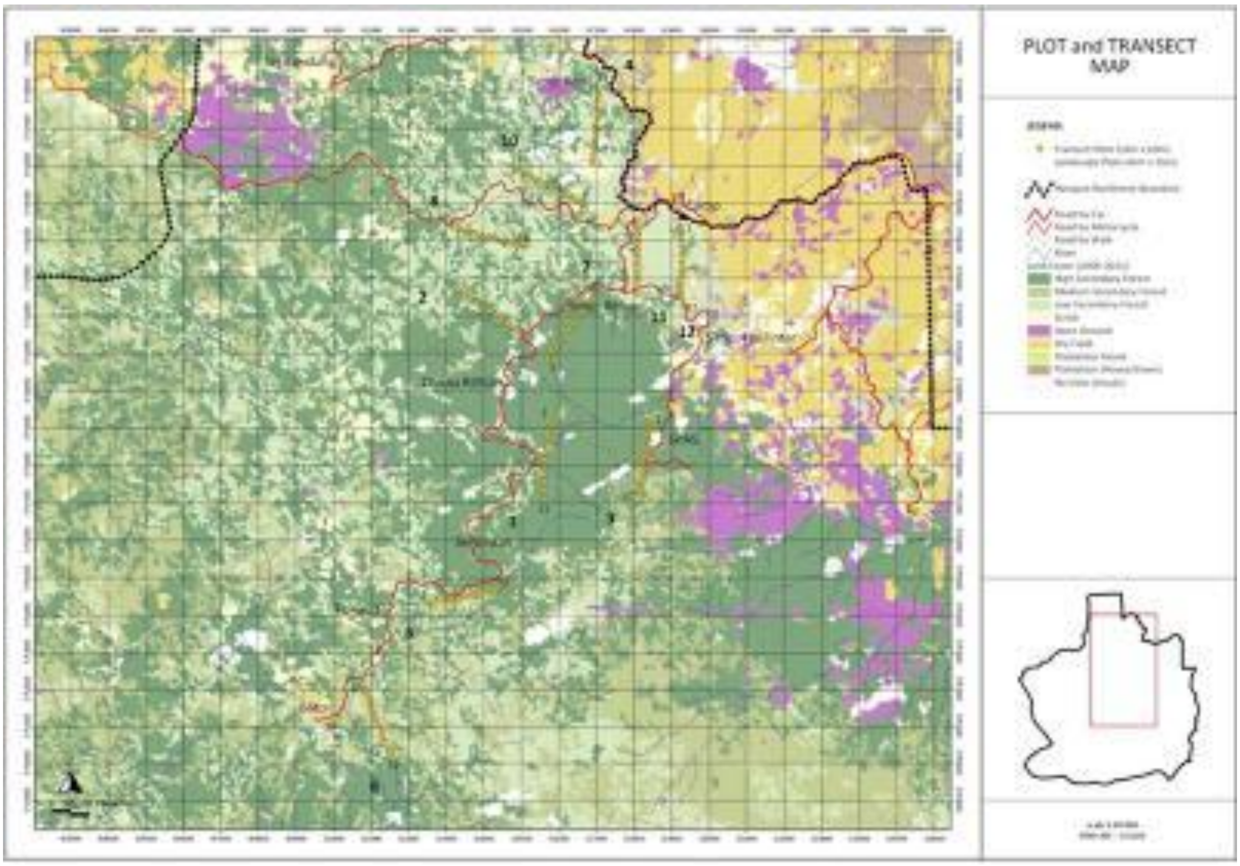

Figure 1. Bird and habitat survey transects

2.2.2 Quantifying the seed rain in various types of secondary forest

Seed traps survey will be implemented to capture magnitude and variations of seed rain at each secondary forest type. The seed trap (0.5 m^2) were placed at four points (each point was 200 m apart) in four different transects. These four transects represented secondary forest gradients (selected out of the 11 bird point transects). In each point, 10 seed traps were randomly placed, in total 160 seed traps used. Seed trap was made from green nylon fishing net to shape a square basket, with mesh size of < 0.1 mm. Each corner of the trap was then connected to a plastic rope where these ropes were then secured to a nearest poles/branch hence hold the trap approximately 1 meter above the ground (Figure 2). The information collected per seed trap will be: presence/absence of seed, type of seed (animal/wind dispersed), seed dimension and coloration, and photographs of the seed.

Figure 2. Hanging the seed trap

2.2.3 Germination success of dispersed seeds in various types of secondary forest

Field experimental planting will be conducted for all seeds "capture" by the traps (after recording the identity of the seeds (i.e. temporary ID, photographs in scale paper) to measure the germination success of dispersed seeds. All seeds will be sowed in a 1 m^2 planting quadrate that is placed on the side of each seed traps.

2.3 STUDY SITE

The Harapan Rainforest (http://www.harapanrainforest.org) covers an area of 98,554 ha, located in the Jambi and South Sumatra Provinces. It is the first ecosystem restoration in production forest in Indonesia. The whole area has been logged, hence the current habitat consist of mosaics of approximately 40% old secondary forest, 25% intermediate secondary forest, 25% young secondary forest (Figure 3). The remaining 10% comprises of scrub and open ground.

The Harapan Rainforest gained the concession right for the southern concession block (South Sumatra Province) in 28 August 2007, and the northern forest block (Jambi Province) in 25 May 2010. The Harapan Rainforest was an ex-logging concession, consisted of two ex-logging concessions: PT. INHUTANI V in the southern part of the Harapan Rainforest (South Sumatra Province) and PT. Asialog in the northern part of the Harapan Rainforest (Jambi Province). The main target logged species during the logging concession time was tree species mainly from Dipterocapaceae species (most of the species within this family have wind dispersed seed). From the rapid vegetation survey conducted in Harapan Rainforest (Partomihardjo *et al.*, 2004) it was found that perhaps most of the forest area is dominate by pioneer species (such as *Macaranga* spp. - Euphorbiaceae Family), except for some part of the area that has been secured in the past (during logging period) as source of genetic diversity. The similar result was found by Muslich (2010) and where each secondary forest typology had different tree community. He also found that, based on the vegetation composition, that the young and intermediate secondary forest had lower commercial tree species composition (i.e. tree species from Dipterocarpaceae family).

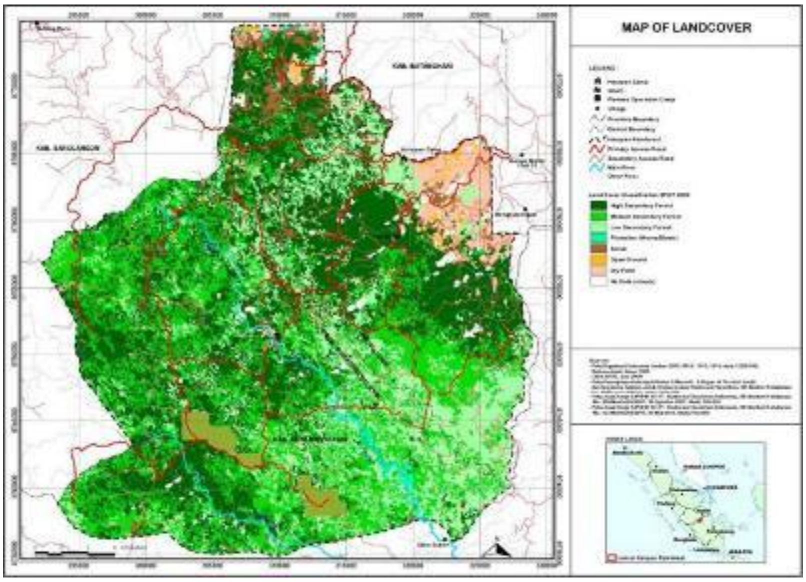

Figure 3. Distribution of different vegetation types within Harapan Rainforest

Figure 4 shows change in the domination of basal area of Dipterocarpaceae and Euphorbiaceae between “undisturbed” lowland forest (data from forest inventory in Pasir Mayang, Jambi Province; Sianturi & Kanninen, 2006) and in disturbed forest (Harapan Rainforest; Partomihardjo *et al.*, 2004). However, this figure is only for illustrating the changes and is not representing a direct comparison due to differences in sample size and survey efforts).

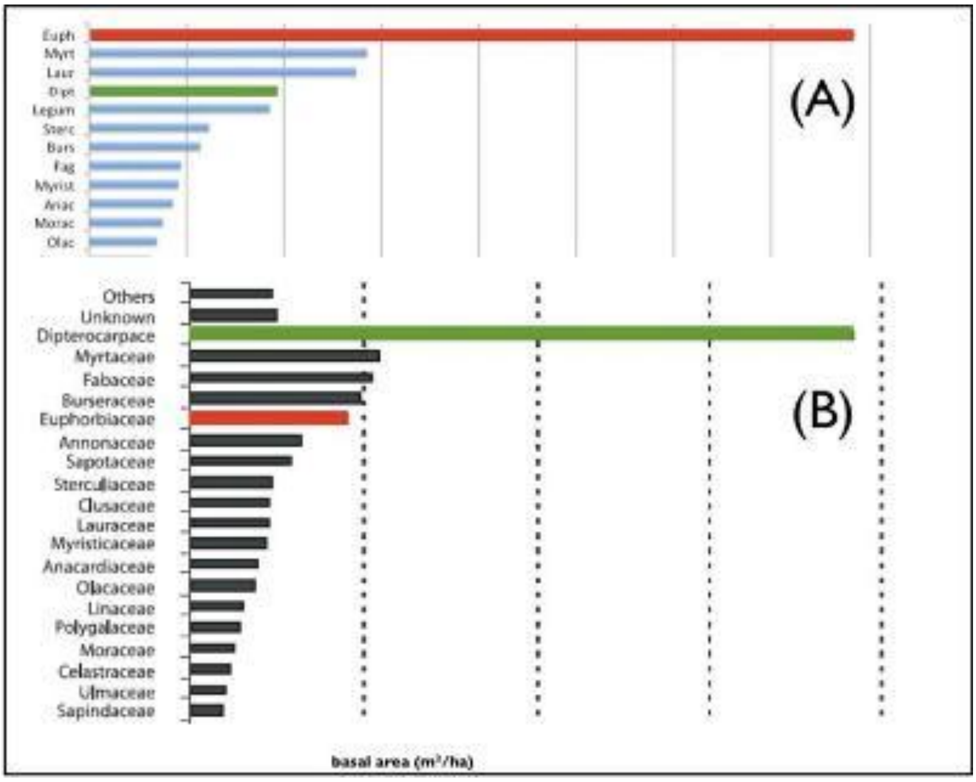

Figure 4. Changes in the basal area between disturbed (A) and undisturbed (B) lowland rainforest

3. PRELIMINARY DATA ANALYSIS

I separated frugivorous bird species according to three criteria (Table 2): body mass (Dunning, 2008), feeding guild (Lambert, 1992; Lambert & Collar, 2002) and frugivory importance (Corlett, 1998), which I use as a proxy for ecological function (Tscharntke et al., 2008). Species abundance is calculated as the proportion of site (point count) where that particular bird species was recorded in that transects.

Non-metric multidimensional scaling (NMDS) was used to visualize differences in frugivorous bird species composition between sites; and vectors describing continuous environmental variables were superimposed. The significance of the fitted vectors was assessed using 1000 permutations of environmental variables. The goodness of fit statistic is the squared correlation coefficient $r2$. For this preliminary analysis, the data from survey period 1 and 2 were combined together.

All analyses were conducted in *R* (R Development Core Team, 2007), with additional functions provided by the *R* package *vegan* (Oksanen et al., 2007) for NMDS.

4. PRELIMINARY RESULTS

4.1 ASSESSING THE INFLUENCE OF HABITAT STRUCTURE ON FRUGIVOROUS BIRS SPECIES DIVERSITY

The bird survey were planned to be conducted in 11 transects. However, in the second survey period, one transect had to be abandoned due to illegal encroachment activities which changes the habitat structure in Transect 12. Nevertheless, 10 transects were successfully surveyed in both periods.

In total 53 frugivorous bird species recorded in both survey periods (Table 1), 51 species in the first survey period (October-December 2011) and 44 species in the second survey period (April-June 2012). The difference in the number of species probably because the bird call identification for survey period 2 is still in progress. Nine species were only recorded in the first survey period: Scarlet-breasted Flowerpecker *Dicaeum cruentatum*, Scarlet-breasted Flowerpecker *Prionochilus thoracicus,* Rubby-cheeked Sunbird *Anthreptes singalensis,* Red-throated Sunbird *Anthreptes rhodolaemus*, Grey-breasted Spiderhunter *Arachnothera affinis,* Purple-throated Sunbird *Nectarinia sperata*, Great Argus *Argusianus argus*, Blue-rumped Parrot *Psittinus cyanurus,* and Crested Fireback *Lophura ignita*. On the other hand, two species were recorded only in the second survey period: White-crowned Hornbill *Aceros comatus* and Jambu-Fruit-Dove *Ptilinopus jambu*.

In general, most frugivorous bird species recorded, for both periods, were from Pycnonotidae family (12 species in the survey period 1 and 13 species in survey period 2). *Pycnonotus erythropthalmos* was the most common species observed in both survey periods (recorded in 88 points out of 110 points in survey period 1 and 83 points in survey period 2). The full list of frugivorous bird species recorded is presented in Table 1.

The feeding guild of most of the frugivorous bird species recorded were arboreal foliage gleaning insectivores/s (19 species), and followed by nectarivores / insectivores / frugivorous (14 species) and arboreal frugivorous (11 species). In term of body mass class, most of the frugivorous bird species recorded were in the weight class 3 (15 species) and 1 (10 species).

Seed dispersal importance is defined as the predicted impact of local extinction of the taxon on plant communities through loss of seed dispersal services (Corlett, 1998). Nearly 50% of the frugivores bird recorded were important seed dispersal (class 4) and most of them were in the weight class 3 (21-40 g) and part of the arboreal foliage gleaning insectivores/frugivorous feeding guild. These important species are mainly those in the Pycnonotidae bird family such as Red-eyed Bulbul *Pycnonotus brunneus*, Spectacled Bulbul *Pycnonotus erythropthalmos*, and Cream-vented Bulbul *Pycnonotus simplex*.

There are differences in frugivorous bird species richness across all transects for both survey periods. The highest number of frugivorous bird species were recorded in Transect B3, 34 species (for survey period 1) and Transect 6, 34 species (for survey period 2, Fig. 5). The lowest number of frugivorous bird species recorded was in Transect 11 (19 bird species).

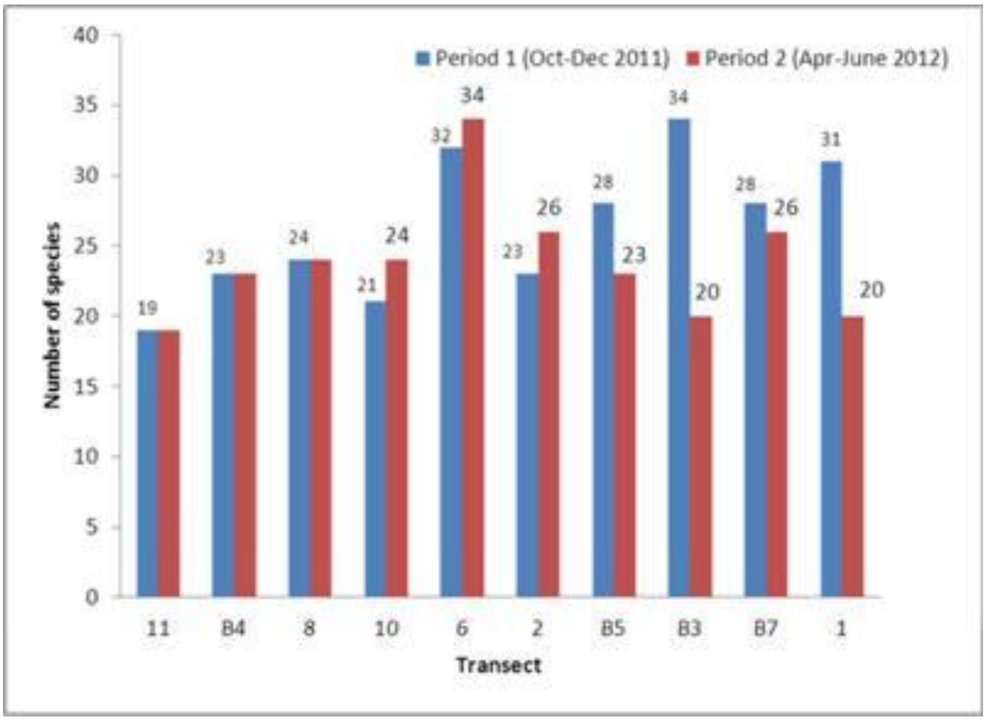

Figure 5. Number of frugivorous bird species per transect per survey period.

Table 2. List of 53 bird species detected in the secondary tropical rainforest in Jambi Province-Indonesia, species codes used in NMDS ordination and ecological characteristics (Feeding guild: af= arboreal frugivorous, afp=arboreal frugivorous/predators, afgif=arboreal-foliage gleaning insectivores/frugivorous, nif=nectarivores/insectivores/frugivorous, tom=terrestrial omnivores; Seed dispersal (SD) importance: 0= not important, 1 to 4 = minor to major; Weight: 1=0-10 g, 2=11-20 g, 3=21-40 g, 4=41-80 g, 5=81-160 g, 6=161-320 g, 7=321-640 g, 8=641-1280, 9=> 1280 g).

NMDS	Family	Species	Period 1 (Oct-Dec 2011)	Period 2 (Apr-Jun 2012)	Feeding guild	SD importance	Weight
1	Bucerotidae	*Aceros comatus*		1	afp	4	9
2	Bucerotidae	*Aceros corrugatus*	1	2	afp	4	9
3	Bucerotidae	*Aceros undulatus*		3	afp	4	9
4	Bucerotidae	*Anorrhinus galeritus*	3	3	afp	4	8
5	Bucerotidae	*Anthracoceros malayanus*	4	7	afp	4	8
6	Bucerotidae	*Buceros rhinoceros*	5	2	afp	4	9
7	Chloropseidae	*Chloropsis cochincinensis*	53	49	nif	2	3
8	Chloropseidae	*Chloropsis cyanopogon*	7	6	nif	2	3
9	Chloropseidae	*Chloropsis sonnerati*	8	7	nif	2	4
10	Columbidae	*Ducula aenea*	3	1	af	4	7
11	Columbidae	*Ptilinopus jambu*		1	af	4	7
12	Columbidae	*Treron olax*	1	6	af	3	5
13	Corvidae	*Platsmurus leucopterus*	10	9	afgif	2	6
14	Dicaeidae	*Dicaeum concolor*	35	3	nif	2	1
15	Dicaeidae	*Dicaeum cruentatum*	2		nif	2	1
16	Dicaeidae	*Dicaeum trigonostigma*	64	13	nif	2	1
17	Dicaeidae	*Prionochilus maculatus*	19	9	afgif	2	1
18	Dicaeidae	*Prionochilus percussus*	4	3	afgif	2	1
19	Dicaeidae	*Prionochilus thoracicus*	1		afgif	2	1
20	Eurylaimidae	*Calyptomena viridis*	9	4	af	4	4
21	Nectariniidae	*Anthreptes malaccensis*	3	5	nif	1	2
22	Nectariniidae	*Anthreptes rhodolaemus*	1		nif	1	2
23	Nectariniidae	*Anthreptes simplex*	19	1	nif	1	1
24	Nectariniidae	*Anthreptes singalensis*	14		nif	1	1
25	Nectariniidae	*Arachnothera affinis*	4		nif	0	3
26	Nectariniidae	*Hypogramma hypogrammicum*	31	36	nif	1	2
27	Nectariniidae	*Nectarinia jugularis*	7	1	nif	1	1
28	Nectariniidae	*Nectarinis sperata*	2		nif	1	1
29	Oriolidae	*Irena puella*	17	21	af	2	4
30	Oriolidae	*Oriolus xanthonotus*	22	15	afgif	2	4
31	Phasianidae	*Argusianus argus*	1		tom	2	9
32	Phasianidae	*Lophura ignita*	1		tom	0	9
33	Psittacidae	*Loriculus galgulus*	2	3	af	0	3
34	Psittacidae	*Psittinus cyanurus*	4		af	0	3
35	Pycnonotidae	*Alophoixus bres*	6	3	afgif	4	4
36	Pycnonotidae	*Alophoixus phaeocephalus*	36	44	afgif	4	3
37	Pycnonotidae	*Iole olivacea*	24	48	afgif	4	3
38	Pycnonotidae	*Ixos malaccensis*	16	22	afgif	4	3
39	Pycnonotidae	*Pycnonotus atriceps*	30	50	afgif	4	3
40	Pycnonotidae	*Pycnonotus brunneus*	42	13	afgif	4	3
41	Pycnonotidae	*Pycnonotus erythropthalmos*	88	83	afgif	4	2
42	Pycnonotidae	*Pycnonotus eutilotus*	2	2	afgif	4	3
43	Pycnonotidae	*Pycnonotus melanicterus*	2	1	afgif	4	3
44	Pycnonotidae	*Pycnonotus plumosus*	4	12	afgif	4	3
45	Pycnonotidae	*Pycnonotus simplex*	46	82	afgif	4	3
46	Pycnonotidae	*Tricholestes criniger*	45	57	afgif	4	2
47	Rhampastidae	*Calorhamphus fuliginosus*	13	23	afgif	4	4
48	Rhampastidae	*Megalaima australis*	13	37	af	4	3
49	Rhampastidae	*Megalaima chrysopogon*	4	12	afp	4	5
50	Rhampastidae	*Megalaima henricii*	4	8	af	4	4
51	Rhampastidae	*Megalaima rafflesii*	10	1	af	4	5
52	Sturnidae	*Gracula religiosa*	9	4	af	3	6
53	Timaliidae	*Alcippe brunneicauda*	18	16	afgif	0	2

Examining the distribution of species by their feeding guild, body weight class, and seed dispersal importance also reveal differences of species per-transect (Fig. 6). In the survey period 1, Transect 6 and B5 had the highest number of bird species from body weight class 3 (21-40 g). Transect 6 still had the highest number of bird species from body weight class 3 in the survey period 2 but not for Transect B5. Transect B3 had more arboreal foliage gleaning insectivore/frugivorous guild compared with other transect in the survey period 1. However, this was changed in the survey period 2 where Transect 6 had more species of arboreal foliage-gleaning insectivore/frugivorous guild than any other transects. Moreover, Transect 2 and B3 had the highest number of bird species classified as high important as seed dispersal (group 4).

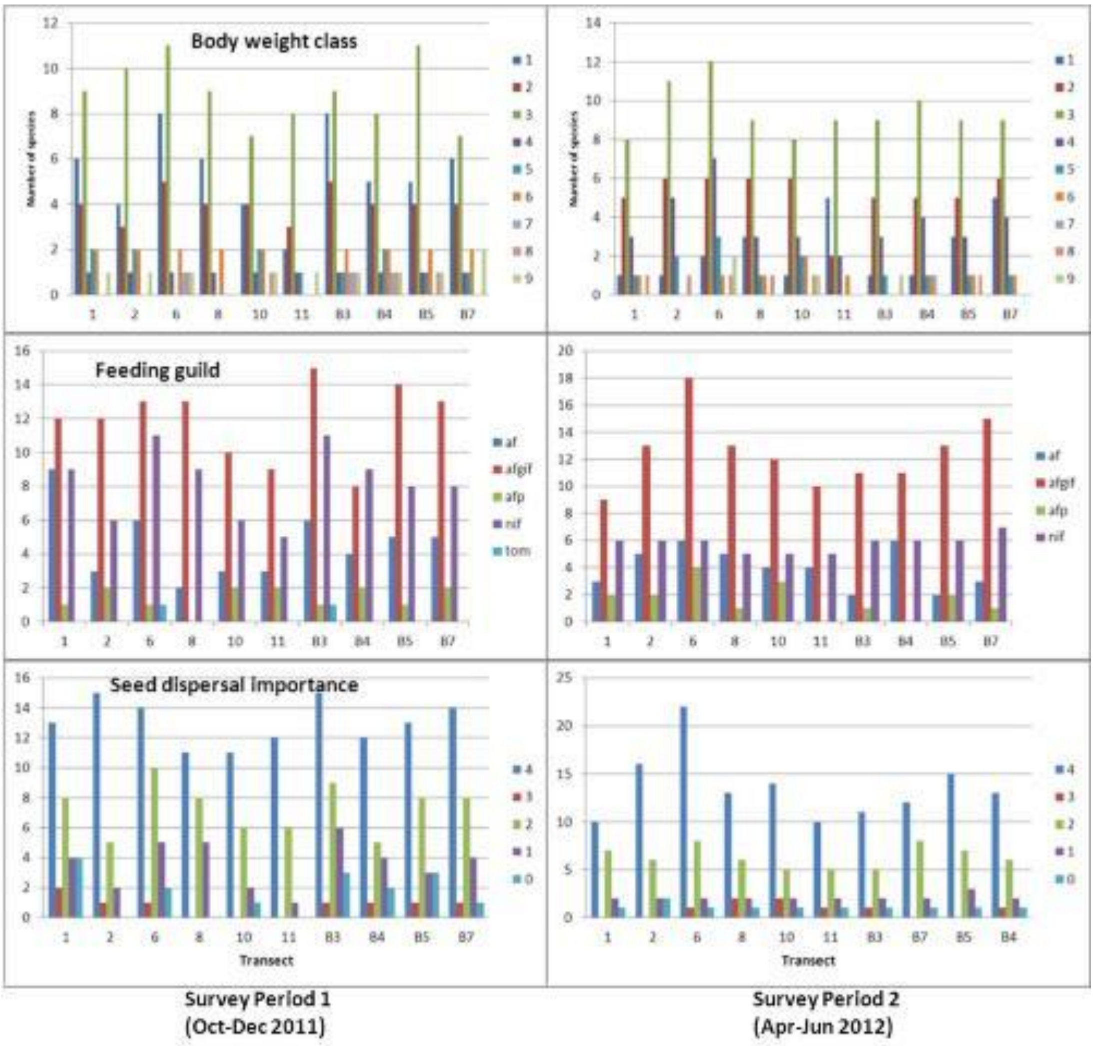

Figure 6. Number of species per-transect grouped by their body weight class, feeding guild, and seed dispersal importance (*see* Table xx for group definitions).

Bird data from both survey periods were pooled together for analyzing using NMDS. The non-metric multidimensional scaling can be used to plot sites and species in a two dimensional space (no convergent solution found, best solution after 20 tries, stress=0.29, Fig. 7). Fitting environmental variables as vectors into this space revealed that clumping of trees (disctr), tree height (treeht.m), number of dead tree (d_tree), number of saplings (sap), amount of open land (bare) and canopy openness (can) were useful in explaining gradients (goodness of fit: clumping of trees, r_2=0.16, p<0.001; tree height, r_2=0.14, p<0.001; number of dead tree, r_2=0.12, p<0.001; number of saplings, r_2=0.15, p<0.001; amount of open land, r_2=0.15, p<0.001; and canopy openness, r_2=0.01, p=0.001). Species situated towards the left-lower left of the multidimensional scaling plot tend to occur in site with high sapling density and less clumping of big trees. Examples are Jambu Fruitdove *Ptilinopus Jambu* and Scarlet-breasted Flowerpecker *Prionochilus thoracicus*. On the upper left-upper left part of the plot, species such as Grey-breasted Spiderhunter *Arachnothera affinis,* can be found, which occur in site with sparser tall trees. On the lower right side of the scaling plot are species that occur in sites with sparser tree clumping, more open area, and more dead tree, such as Green Imperial Pigeon *Ducula aenea*.

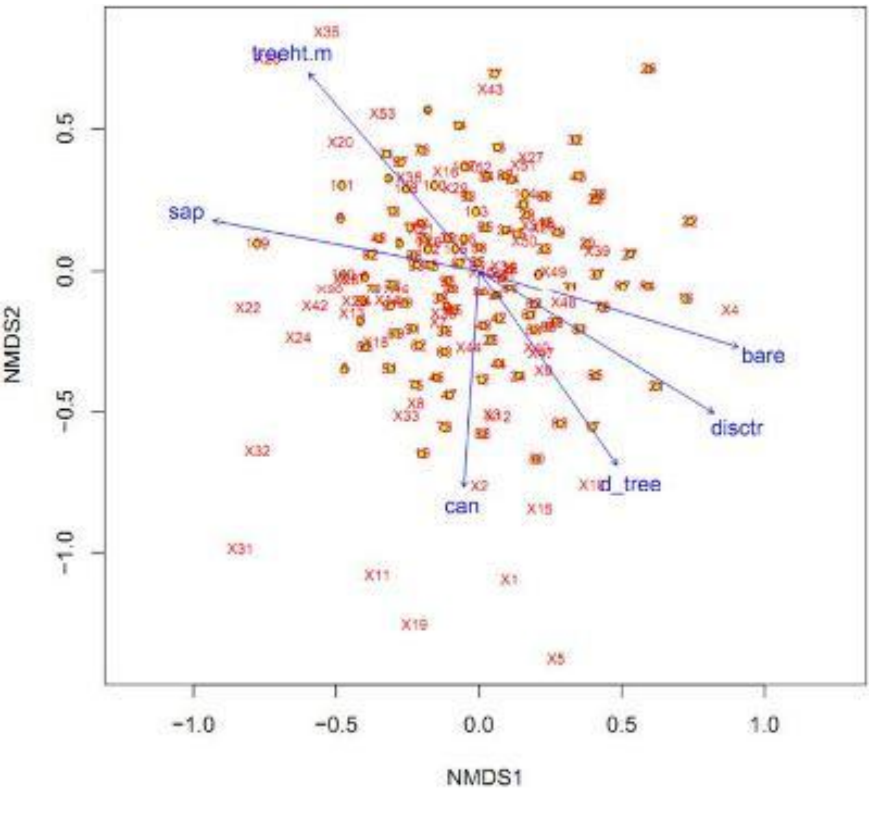

Figure 7. NMDS ordination biplots of site scores (points) and species (numbers) with the environmental variables clumping of trees (disctr), tree height (treeht.m), number of dead tree (d_tree), number of saplings (sap), amount of open land (bare) and canopy openness (can) superimposed. Species codes are listed in Table 2.

4.2 SEED RAIN AND GERMINATION SUCCESS

Seed traps were managed to be placed in four transects. The previous method where the seed traps were supported by four PVC tube did not successful in collecting seeds due to disturbances by wild pigs. Hanging the seed traps using plastic ropes proof to be more effective where no seed traps were destroyed by wild pigs (Figure 8).

Figure 8. Hanging the seed traps to avoid disturbance by wild pigs (right)

In total there were 160 seed traps distributed in four locations per transect (there were four transect). As in the bird survey, Transect 12 had to be abandoned due to illegal encroachment activities.

In total there were 13 seed morpho-species recorded: nine seed morpho-species recorded in the survey period 1, and six morpho-species in the survey period 2. Transect 2 had the highest richness of seeds dispersed by birds than other transects in the survey period 1, but this changed in the survey period 2 where transect 4 and 7 had more diverse seed morpho-species captured in the seed traps (Figure 9).

From the 13 seed morpho-species, five can be identified until species levels: *Leae indica, Callicarpa petandra, Bellucia pentamera, Clidemia hirta*, and *Mallotus panniculatus*. These five species are considered as pioneer species and produced very small seeds (except for *Laea indica* with seeds size approximately 0.4 cm). Five other species can only be identified to genus level: Girroniera sp., Litsea sp., Ficus sp., Memecylon sp., and Knema sp.

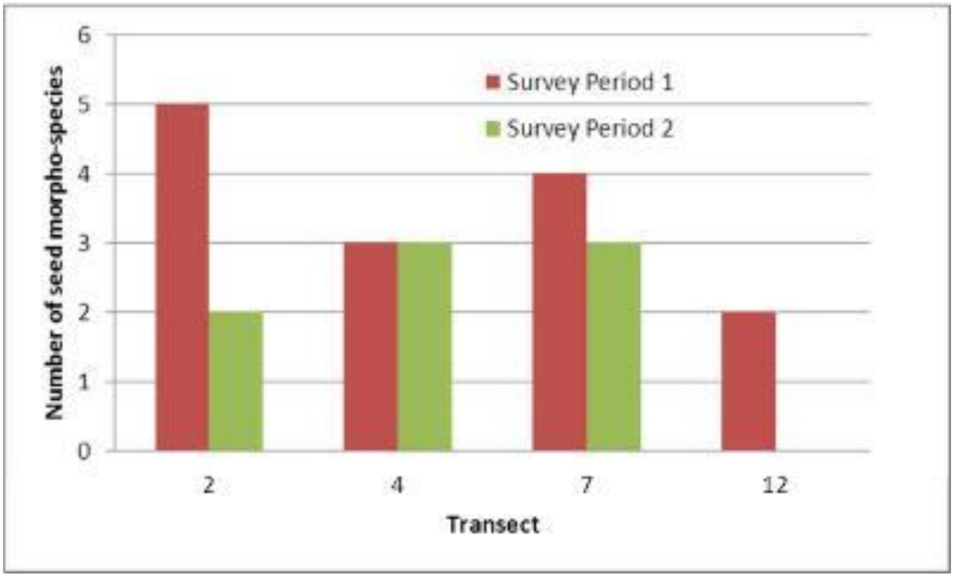

Figure 9. Number of seed morpho-species per transect

Seed germination experiment cannot be completed due to the low number of seeds per morpho-species captured in the seed traps. Besides that, I collect the seed from the seed traps at least every 2 weeks, and unfortunately this caused many seeds already in bad condition (rotten and damage by insects).

Nevertheless, I managed to collect 25 seeds from *Polyalthia* sp.. These seeds were collected from under the tree after regurgitated by Bushy-crested Hornbill *Annorhinus galeritus*. Germinating these seeds in the nursery had shown that there was no difference in the germination rate between seeds collected after regurgitated by hornbills and seeds that were hand cleaned.

5. PRELIMINARY DISCUSSION

Forest restoration is aimed to re-establish of the original forest ecosystem that was present before the deforestation occurred (Forest Restoration Research Unit, 2005), and the first important step before implementing forest restoration is to identify whether natural regeneration process is still taking place or not and hence to determine how much human interventions are required.

There are at least six types of intervention in forest restoration (Table 3) which are based not only on the habitat condition but also on what environmental services that are still operating in that particular area (Society for Ecological Restoration, 2004). The current preliminary analysis revealed that frugivorous bird species were still present even in the most degraded secondary habitat within the study site. The mosaic habitat conditions perhaps contribute to the relative evenness distribution of frugivorous across the study area.

Table 3. Possible restoration approaches based on field conditions (FORRU, 2008)

Restoration approach	Determining factors					
	Vegetation	Soil	Source of regeneration	Forest	Seed dispersers	Fire risks
Protection	Trees dominate	remains mostly fertile	e.g. dense seedling bank	large remnants remains as seed source	common (large and small)	low
Assisted Natural Regeneration	Mixed trees and herbaceous weeds	remains mostly fertile	e.g. seed and seedling bank depleted	remnants remains as seed source	large species rare, small species common	medium
Framework Species Method	Herbaceous weeds dominate	remains mostly fertile	e.g. mostly from incoming seed rain	remnants remains as seed source	mostly small species dispersing small seeds	high
Maximum Diversity Planting	Herbaceous weeds dominate	erosion risk increasing	few	absent within seed dispersal distances of site	mostly gone	high
Nurse crop or foster ecosystem	Sparse: herbaceous weeds	significant soil erosion	very few	absent within seed dispersal distances of site	mostly gone	high

Considering this preliminary results, one may conclude that the first important step in restoring forest in the study area is to avoid further habitat changes/disturbances. This is an important step but also a difficult part to be implemented. Illegal encroachment is still happening in the study area (as proof, one of my bird survey transect in early 2011 was destroyed due to illegal encroachment in the last quarter of 2011).

The probability of seed dispersal was positively correlated with frugivorous species richness (Garcia & Martinez, 2012). Relatively high frugivorous species richness in each transect might still indicate that presence of seed dispersal service. However, most of the frugivorous birds recorded were small frugivorous bird species hence partially reflected the limited number of large seeds that were being dispersed in the study area. Moreover, from the seed trap data, most of the seeds being dispersed were small seeds (mostly from pioneer tree species such as *Bellucia pentamera* and *Callicarpa pentandra*). In this sense forest structure improvement can also be conducted in order to facilitate larger frugivorous species such as Rhinoceros hornbill *Buceros rhinoceros*, hence enabling dispersal of large seeds. Planting of fast-growing large seeded native tree species might be an option to attract large seed dispersal into the degraded forest.

6. NEXT STEPS

The current preliminary analysis highlighted that seed dispersal service was still operating, even in the most degraded habitat. However, further analysis is required to further verify the effect of habitat structure on frugivorous bird assemblage particularly by incorporating detection history and taking into account the spatial aggregation of points in transects (avoiding 'pseudoreplication', Hurlbert 1984). In this case, linear mixed-effects model will be used in teasing out what habitat factors influence the richness and abundance of frugivorous bird species. Incorporating spatial scale might also be interested to look at, i.e. whether local, site or landscape scale have influence in frugivorous bird species richness and abundance.

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