SUSTAINABILITY BRIEF

Update from the field **January 2016**

Wilmar's partnership with the Royal Society's South East Asia Rainforest Research Programme

Since 2011, Wilmar has been working with the Southeast Asia Rainforest Research Partnership (SEARRP) in studying our conservation areas especially in our plantations in Sabah, particularly in the Telupid and Lahad Datu districts. Our conservation areas provide an interesting site for researching the impacts of oil palm plantation development on forest biodiversity, and the value of keeping conservation areas in a palm oil plantation.

A summary of SEARRP's findings (refer to enclosed appendices) were condensed and presented in a workshop which was held in Amsterdam on 4 June 2015, at the back of the Roundtable on Sustainable Palm Oil's Roundtable meeting in Europe. The purpose of the workshop was to disseminate the findings, to discuss with producers, consumers, NGOs and other universities the ways of integrating the findings into plantation management. In early November 2015, a session was held in one of Wilmar's plantations in Sabah, to share the same findings to the managers in the plantation. During that session a field trip to the forest patches in and around Wilmar's plantation was also organised to better illustrate the findings from the research.

The success of this partnership will be continued in 2016 for a further 5 years, with more projects related to the assessment and maintenance of conservation values and ecosystem functioning in agricultural landscapes and the sustainable management of oil palm plantations and their embedded forest patches and riparian reserves. This also includes exploring possible greenhouse gas reductions in existing palm oil operations. A memorandum of understanding is expected to be signed by Wilmar and SEARRP in the first quarter of 2016. For more information please visit : http://www.sensorproject.net/knowledge-exchange/

Demonstration in the field on forest quality

Appendix 1

Enhancing biodiversity conservation in the oil palm industry: Translating science into action

Workshop 4th June 2015, Park Plaza Airport Hotel, Amsterdam

Research fact sheet

Key findings

1. **Large tracts of forest are essential to avoid biodiversity losses:** species numbers did not begin to match levels found in continuous forest until patches reached sizes of **more than 10,000 ha.**

2. **To double the number of species found in oil palm plantations** in SE Asia, or achieve 70% of continuous forest species numbers, forest patches need to be in the range of a few **hundred** hectares (ha). In forest patches this size, dipterocarp trees are more likely to be able to **naturally regenerate** thus maintaining the forest in the long term.

3. **Forest patches need to have a core area of at least 20ha** to consistently raise species numbers **above those found in oil palm** plantations**.** In small, low quality forest patches dipterocarp trees may **not be able** to naturally **regenerate.**

4. **Planting tree seedlings could be an effective way to improve forest quality** and boost biodiversity in small, degraded forest patches: early indications suggest **survival and growth** of planted dipterocarp seedlings are **as good** in small forest patches as in continuous forest.

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UNIVERSITY of York SEARRP South East Asia Rainforest Research Programme NERC SCIENCE OF THE ENVIRONMENT

The issue

We know that **oil palm plantations** support **many fewer species** than the natural forest they often replace, and so **the forest patches that remain** within oil palm landscapes could play a **vital role** in the conservation of **biodiversity.** Sustainability standards advocate retaining these **"high conservation value"** areas, but it is unclear what characteristics a forest patch needs in order to support high numbers of species, and to maintain these levels of biodiversity in the longer term.

The key question: How can we maximise the ability of forest patches to support biodiversity?

1. How much biodiversity can a forest patch of a given size support?
2. How big is big enough, and how small is too small?
3. How can we improve levels of biodiversity in forest patches that are too small or degraded?

Rationale

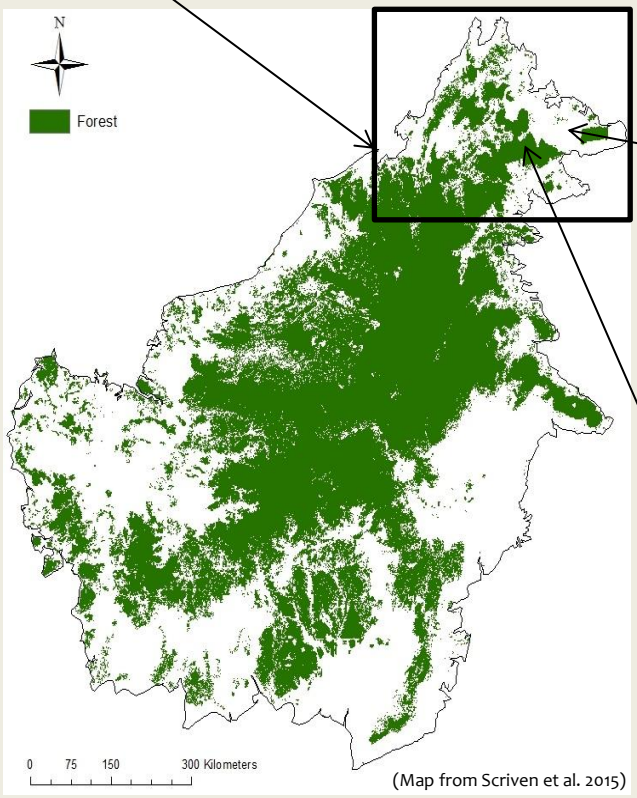
There is a substantial body of research that we can draw upon to help answer these questions, but it is often not presented in a way that can directly help stakeholders to make practical decisions about how to conserve biodiversity. We brought together research on biodiversity and forest processes on Borneo and synthesised the data to provide information which is more directly applicable to conservation policy and practice.

Definitions

Biodiversity: the number of species found in a given area.
Forest processes: important processes which are needed to maintain a healthy forest.
Dipterocarp trees: the dominant family of trees in SE Asia, they form the main structure of the forest and make up 80% of all tree species in these forests.
Core area: the area of forest more than 100m from the edge of the forest patch.

Location

All sampling was conducted in Sabah, Malaysian Borneo



(Map from Scriven et al. 2015)

We used data from 28 forest patches in Eastern Sabah, ranging from 0.7 to 122,500 ha

An example of one of the forest patches that was sampled

All species groups were also sampled in lowland "continuous" forest: forest which was connected to the remaining central spine of forest on Borneo. These values were considered to the highest possible number of species that could be expected for a given area of forest in the region.

Species groups sampled

Birds

Dung beetles

Butterflies

Dipterocarp trees

Ants

Forest processes sampled

Herbivory

Dipterocarp fruit occurrence

Dipterocarp seedling occurrence

Leaf litter decomposition

Dung removal

Results summary

1. The **number of species** declined with decreasing forest patch size.

2. Using the average for all the species groups sampled, we determined that a forest patch needed to be **at least 10,000ha** to support **100%** of continuous forest species numbers.

3. Total species found in the oil palm plantation was around 35% of continuous forest species numbers, but many of these were not forest species.

4. To double the number of species found in oil palm plantations, or to reach 70% of continuous forest species numbers, the results indicated that forest patches needed to be at least **a few hundred ha** (between 250 and 2000ha) in size.

5. In very small patches species numbers were often similar or sometimes even lower than in the oil palm plantation itself. For species numbers in all groups to be consistently higher than the numbers found in oil palm, forest patches needed to have a core area of **over 20ha**.

6. **Forest processes** also declined with decreasing forest patch size.

7. The **most severe effect** was on the **regeneration** of dipterocarp trees, with fruits or seedlings **often totally absent** in small patches.

8. Experiments of **planted dipterocarp seedlings** revealed that **survival** over 18 months was **similar to continuous forest** in patches of all sizes, while **growth rates were sometimes better in smaller patches** because of higher light levels. This suggests that replanting projects to improve forest quality could be successful.

Data used in the synthesis:

Published research:

Benedick, S., Hill, J. K., Mustaffa, N., Chey, V. K., Maryati, M., Searle, J. B., … Hamer, K. C. (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*(5), 967–977.

Edwards, D. P., Hodgson, J. A., Hamer, K. C., Mitchell, S. L., Ahmad, A. H., Cornell, S. J., & Wilcove, D. S. (2010). Wildlife-friendly oil palm plantations fail to protect biodiversity effectively. *Conservation Letters*, *3*(4), 236–242.

Lucey, J. M., & Hill, J. K. (2012). Spillover of insects from rain forest into adjacent oil palm plantations. *Biotropica*, *44*(3), 368–377.

Lucey, J. M., Tawatao, N., Senior, M. J. M., Chey, V. K., Benedick, S., Hamer, K. C., … Hill, J. K. (2014). Tropical forest fragments contribute to species richness in adjacent oil palm plantations. *Biological Conservation*, *169*, 268–276.

Tawatao, N., Lucey, J. M., Senior, M., Benedick, S., Vun Khen, C., Hill, J. K., & Hamer, K. C. (2014). Biodiversity of leaf-litter ants in fragmented tropical rainforests of Borneo: the value of publically and privately managed forest fragments. *Biodiversity and Conservation*, *23*(12), 3113–3126.

Research under review:

Yeong K.L., Reynolds, G. and Hill, J.K. Leaf litter decomposition rates in degraded and fragmented tropical rainforests on Borneo

Yeong K. L., Reynolds, G., Hill, J.K. Enrichment planting to improve forest quality within tropical rainforest fragments

Senior, M.J.M, Edwards, F.A and Hill, J.K. Relating species richness and biomass to ecosystem functioning in fragmented tropical landscapes.

Yeong, K.K., Lucey, J.M. and Hill, J.K. Fragmentation disrupts rainforest regeneration.

Other research cited in the presentations:

Edwards, D. P., Larsen, T. H., Docherty, T. D. S., Ansell, F. A., Hsu, W. W., Derhé, M. A., … Wilcove, D. S. (2011). Degraded lands worth protecting: the biological importance of Southeast Asia's repeatedly logged forests. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1702), 82–90.

Edwards, F. A., Edwards, D. P., Sloan, S., & Hamer, K. C. (2014). Sustainable Management in Crop Monocultures: The Impact of Retaining Forest on Oil Palm Yield. *PLoS ONE*, *9*(3), e91695.

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brulh, C. A., Donald, P. F., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution*, *23*(10), 538–545.

Marshall, A. J., Lacy, R., Ancrenaz, M., Byers, O., Husson, S. J., Leighton, M., … Wich, S. A. (2009). Orangutan population biology, life history, and conservation: Perspectives from population viability analysis models. In S. Wich (Ed.), *Orangutans: geographic variation in behavioral ecology and conservation.* (pp. 311–326). Oxford University press.

Scriven, S. A., Hodgson, J. A., McClean, C. J., & Hill, J. K. (2015). Protected areas in Borneo may fail to conserve tropical forest biodiversity under climate change. *Biological Conservation*, *184*, 414–423.

Outputs of the workshop

"Enhancing biodiversity conservation in the oil palm industry: Translating science into action" Workshop 4th June 2015, Amsterdam

This report provides a summary of the discussion and action points from the workshop. Words in blue italics are additional notes in response to some points to aid further discussion and decision making.

Key research findings presented:

1. **Large tracts of forest are essential to avoid biodiversity losses:** species numbers did not begin to match levels found in continuous forest until patches reached sizes of **more than 10,000 ha.**

2. **To double the number of species found in oil palm plantations** in SE Asia, or achieve 70% of continuous forest species numbers, forest patches need to be in the range of a few **hundred hectares** (ha). In forest patches this size, dipterocarp trees are more likely to be able to **naturally regenerate** thus maintaining the forest in the long term.

3. **Forest patches need to have a core area of at least 20ha** to consistently raise species numbers **above those found in oil palm** plantations**.** In small, low quality forest patches dipterocarp trees may **not be able** to naturally **regenerate.**

4. **Planting tree seedlings could be an effective way to improve forest quality** and boost biodiversity in small, degraded forest patches: early indications suggest **survival and growth** of planted dipterocarp seedlings are **as good** in small forest patches as in continuous forest.

Key points from the morning breakout session: "Understanding the research findings and what they mean for conservation"

Which key message is the most useful?

Some participants found the lowest limit of 20ha core area needed to raise species diversity above oil palm levels a useful lower boundary because below this patches appeared to provide no improvement to background biodiversity levels, however it was highlighted that simply elevating

species numbers above that of oil palm would not address biodiversity losses from the oil palm industry.

Others thought the size needed to maintain double the amount of oil palm biodiversity as well as ensure that forest patches were able to regenerate (a few hundred ha)was the most useful piece of information and might be a sensible target for large estates, although it was highlighted that this would be extremely difficult to achieve for smaller plantations and smallholders.

Still others thought that the highest category of 10,000-450,000ha needed to conserve 100% of continuous forest numbers was the key take home message, and that this should be the ultimate aim if the oil palm industry is to become truly sustainable in terms of biodiversity conservation. It was noted that this will be difficult to achieve under current systems and processes but new zero deforestation policies were a key opportunity.

It was pointed out that some conservation values may be present in very small areas, for example "point endemics", so small fragments may still be important.

In response to this point, it should be noted that while a population may only occupy a very small area, it, or its habitat and vital resources, are likely to be strongly influenced from the wider landscape, so if only a small patch surrounding the population is preserved this will make it highly vulnerable to extinction as edge effects modify conditions within the patch. Therefore a large habitat patch is probably still needed to maintain the population. If an important population of a threatened species is persisting in a very small forest patch within an oil palm landscape, steps should be taken to increase the protection area, buffer edges and prevent human encroachment, or consider translocation to a more stable environment if appropriate.

There was some concern that the findings might threaten small patches if they are deemed to have no value, and it was highlighted that even small patches might facilitate rare dispersal events across the landscape for some important species, but we currently have no empirical evidence for this phenomenon.

In response to this, it should be noted that a precautionary approach is always advised. If the decision is about the value of a pre-existing small fragment, lower thresholds should be adopted, especially in an area where there is already low forest cover, whereas if the decision is about how large an area to set aside, the larger threshold should be adopted. It should also be considered that where there are limited conservation resources, there may be more biodiversity gains in directing resources to conserving or improving a larger patch elsewhere, than maintaining a small, failing patch.

How much biodiversity do you want to conserve?

Many participants ultimately, and unsurprisingly, wanted to conserve all of it, but agreed this would be difficult or impossible within the oil palm concession area as 10s of thousands of ha would be needed to achieve this. Generally participants thought that simply elevating species numbers above oil palm was not sufficient (lower category of 20ha core area), but it was difficult to determine whether 50%, 70% or 90% should be a suitable target instead. One group suggested that biodiversity was not the only important measure, and that ecosystem services and forest processes should also

be considered. To address this point, the threshold for dipterocarp tree regeneration is important to consider alongside biodiversity levels. Another group highlighted that the type of biodiversity was also important: it was suggested that the presence of species of conservation concern should be given highest priority and that weedy, specialist, endangered and forest species should be placed higher than generalist or non-forest species because their ability to persist in altered landscapes means they are least vulnerable to extinction in the oil palm landscape.

How long do you want to conserve biodiversity for?

Participants interpreted this question in two ways: some considered this to mean "what is our ultimate aim?" which was to conserve biodiversity forever. Others considered this to mean the time frame over which a stakeholder is responsible for the biodiversity in the land area, which was generally thought to be one or two life oil palm life cycles (25-50years). Most people agreed that ultimately they would like to see biodiversity conserved in perpetuity, but that a grower would be unable to control continued conservation after the land area had been turned over to another land user.

In response to this it is worth considering the information on patch size and future resilience. The smaller a forest patch the more likely it is to degrade and lose species over time. The research has shown that forest patches needed to be at least a few hundred ha to regenerate properly, so patches smaller than this will likely deteriorate. Smaller patches are also more subject to edge effects which contribute greatly to degradation. Very small patches are likely to need active management to maintain quality and species even within the time frame of responsibility, and will certainly continue to degrade and lose species once they cease to be managed, even if they are retained by future land users. Patches over a few hundred ha or more will not only provide better levels of biodiversity during the time period of responsibility with much less active management, they are more likely to be self-sustaining and continue to support species in the longer term if the new land user continues to protect them. By making patches larger they will be given the best chance of continuing to support functioning and species rich forest beyond the time period of responsibility.

Key points from the afternoon breakout session: "Translating science into actions- How do we apply this knowledge?"

Managing and enhancing existing High Conservation Value (HCV)areas

Challenges and opportunities

- Challenge: The main challenge highlighted was what to do when existing HCV areas are smaller than the thresholds suggested by the research, this may often be the case, and especially so in the smallholder context.
- Challenge: Another major challenge which was highlighted is when areas designated for HCV conservation lose the HCVs they were designed to conserve. In this situation there is a key knowledge gap as to the relative costs and benefits of different responses such as trying to restore the HCV on site e.g. through replanting to improve habitat quality versus options to

offset the loss by conservation activities elsewhere, e.g. by protecting areas of vulnerable continuous forest.

- Opportunity: The research presented suggests replanting could be successful and therefore may boost the capacity of small patches to support biodiversity.
- Challenge: RSPO does not currently have clear guidance on how to respond to this situation, and there is no current option by which a grower could opt for an offsetting solution rather than on sight efforts.
- Opportunity: The major opportunity to deal with this is during replanting where new configuration of the landscape is more possible. In this situation, joining HCVs, increasing connectivity and increasing the size may be possible.

Who are the organisations, initiatives etc. to involve in taking ideas and approaches forward?

- HCV resource network- expand to all regions (Asia, South America and Africa)
- RSPO Biodiversity and High Conservation Value (BHCV) working group
- RSPO Smallholder working group
- Scientists
- Growers
- Policy makers in producing regions

What are the key knowledge gaps for research to target next

- Much more guidance is needed as to the most effective responses to underperforming HCV forest patches (too small/ degraded/ lost the HCV identified in the original assessment) including on connectivity, restoration, offsetting options. Specifically including the economic implications.
- Solutions for smallholders where large HCVs are not possible under the current system
- Impacts on other ecosystems e.g. peat, wetlands, non-forest HCVs
- Possible differences in Latin America and Africa
- Sustainable resource use for local livelihoods in HCVs

What are the next steps for knowledge exchange activities and converting science into action?

- An app to monitor habitat quality
- Present the information to small and large grower forums (MPOB, PIPOC, GAPKI, MPOC)
- Present the information to policy makers (Malaysian ministry of plantations, ISPO)
- Develop practical guidance on reviewing existing HCV areas and appropriate responses to underperforming HCV areas.
- Development of effective monitoring tools and indicators
- Training materials for HCV assessors and auditors.

Planning and designing HCVs for new plantings

Challenges and opportunities

- Opportunity: The HCV licensing scheme provides a means to formally and consistently incorporate the findings of the research into new plantings assessments for HCVs, thus developing HCV areas which will be more effective and robust in future.
- Challenge: Current systems operate within concessions, but to achieve targets for avoiding biodiversity losses the wider landscape context must be incorporated into land planning for HCVs.
- Challenge: Large estates may be able to incorporate larger (a few hundred ha) HCVs into their concession areas, but for smallholders this will be extremely difficult to achieve- what are the alternative solutions?

Who are the organisations, initiatives etc. to involve in taking ideas and approaches forward?

- HCV assessors
- HCS Approach
- HCS Study
- Local scientists
- RSPO BHCV working group
- RSPO Smallholder working group

What are the key knowledge gaps for research to target next?

- Incorporating the social dimension
- Connectivity and resilience under climate change
- Solutions for the smallholder context

What are the next steps for knowledge exchange activities and converting science into action?

- Develop a decision tree/ analytical tool to help with decision making for HCV design which incorporates wider landscape considerations and the costs and benefits of multiple variables including patch size, cost of maintenance, value of connectivity, habitat quality, planted area permeability etc.
- A webinar for assessors, growers and wider audience

Landscape scale conservation

Challenges and opportunities

- Challenge: To achieve the highest category of forest patch size to avoid species extinctions (10,000-450,000ha) landscape scale conservation is necessary, however this is a challenge because it is likely not to be achievable in the current within-concession approach to biodiversity conservation.
- Opportunity: The RSPO is a pool of grower companies who have signed up to the same set commitments towards avoiding biodiversity losses, therefore there is an opportunity for

neighbouring RSPO member companies to collaborate to link HCVs across a larger landscape.

- Opportunity: The RSPO compensation process could provide an opportunity for growers to put conservation resources into projects beyond the boundaries of their concessions creating maximum biodiversity conservation per unit area by conserving hectarage within large forest tracts.
- Opportunity: Land banks were suggested as a mechanism for achieving conservation areas of this order of size, whereby large scale projects are set up which multiple companies and organisations can contribute e.g. for biodiversity credits.
- Opportunity: avoiding further fragmentation of forest land could be achieved if new plantings were directed to degraded land.
- Challenge: often degraded land is used by local communities and developing here can have complex land rights issues.

Who are the organisations, initiatives etc. to involve in taking ideas and approaches forward?

- RSPO member growers
- Other certification standards or initiatives operating in the region, e.g. FSC, Fair Trade, ISEAL, NGO projects etc.
- REDD+
- RSPO BHCV working group and Compensation Task Force

What are the next steps for knowledge exchange activities and converting science into action?

- Developing the business case for putting together a mechanism for conserving large areas of forest
- Hold an HCS-RSPO “Incentives” workshop
- Effective communication channels for scientific information into the development of RSPO+ standards

Monitoring and impact indicators

Challenges and opportunities

- Challenge: Currently no clear guidelines from the RSPO on how to monitor impacts
- Challenge: how do we develop monitoring indicators and protocols which can be analysed consistently in and scientifically, and can be collected by non-specialists in a rapid and cost effective but robust way?
- Challenge: Limited resources and skills base
- Opportunity: Based on the findings presented, can we use a patch size and quality metric as a simple indicator of HCV impact?
- Opportunity: utilising remote sensing technology

Who are the organisations, working groups, initiatives etc. to involve in taking ideas and approaches forward?

- RSPO BHCV working group
- RSPO Head of Impacts
- Scientists
- Practitioners- consultants, growers, auditors who will have to collect and use the information
- HCV resource network

What are the key knowledge gaps for research to target next?

- Identifying effective proxies and indicators for measuring biodiversity and other environmental conditions
- Developing targets and thresholds based on the results of the monitoring indicators
- Incorporating social indicators

What are the next steps for knowledge exchange activities and converting science into action?

- An knowledge gaps analysis of what is known, what is lacking and how to use this information for developing impact indicators
- Development of monitoring indicators and consistent protocols so scientific analysis can be conducted and trends can be drawn and compared across RSPO certified lands
- Training for collectors of these data

Next steps:

HCV assessors licensing scheme

I will engage with the HCV resource network to develop training materials to incorporate this information into HCV assessments.

HCS Approach and HCS Study

I am in communications with both initiatives to incorporate the research into these toolkits and guidelines.

RSPO BHCV Working Group and Compensation Task Force

I plan to present the work at the working group meetings and launch discussion within the RSPO to incorporate the findings into the relevant guidelines.

RSPO Impacts and monitoring

I plan to work with RSPO to develop impacts indicators incorporating the relevant information where possible.

Scientific publication of the research

I intend to publish the synthesis of the research presented at the workshop.

Further collaobration

If you would like to collaborate to take forward any of the action points highlighted during the workshop, or have an idea about how the research findings could be useful to your organisation please get in touch.

Ongoing dialogue between science and industry

Please feel free to comment on the outputs presented and engage in discussions. If you think you would use and benefit from some kind of online forum for discussion, please let me know.

Tell me how you have used the information from the workshop…

Please keep me informed if you have used the information from the workshop in your own reports, projects or initiatives. It's very helpful for future knowledge exchange activities to know where the information ends up, and how it makes a difference.

Contact: Jennifer Lucey, Jennifer.lucey@york.ac.uk

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Appendix 3

Citing the research

"Enhancing biodiversity conservation in the oil palm industry: Translating science into action" Workshop 4th June, Amsterdam

Timeline for availability of research:

Available now:

1. The synthesis presented at the workshop used data from five published papers which are online now. I have compiled a list with the key points to draw from them in relation to forest patch thresholds below and the urls. I have additionally included other key research papers which are relevant to the synthesis.
2. Summary of the synthesis- the handout provided at the workshop is attached- this is not peer reviewed and may be used as reference information but should not be cited as a research paper.

Available in the next 6 months:

1. The synthesis drew on data from a further four publications which are currently under review and these are likely to be available by the end of the year:

    - Yeong K.L., Reynolds, G. and Hill, J.K. Leaf litter decomposition rates in degraded and fragmented tropical rainforests on Borneo
    - Yeong K. L., Reynolds, G., Hill, J.K. Enrichment planting to improve forest quality within tropical rainforest fragments
    - Senior, M.J.M, Edwards, F.A and Hill, J.K. Relating species richness and biomass to ecosystem functioning in fragmented tropical landscapes.
    - Yeong, K.K., Lucey, J.M. and Hill, J.K. Fragmentation disrupts rainforest regeneration

2. The publication of the synthesis: This is currently being drafted for peer review and should follow shortly after the above publications, and hopefully before the end of the year.

Unfortunately we are unable to circulate draft manuscripts prior to publication.

Relevant information from the published papers used in the synthesis:

If you wish to reference the research presented at the workshop in the short term (i.e. before the synthesis is published), the best way to do this is to refer to the papers which are already published. I have collected these together and provided the key points to take from each. Unfortunately due to copyright laws, I cannot provide you with the full library of publications, so if you cannot access the full papers (abstracts should be available) because your organisation does not have a journal subscription, or you would like help to incorporate the information into your work, ***please get in touch, and I can work with you to use the information.***

Benedick, S., Hill, J. K., Mustaffa, N., Chey, V. K., Maryati, M., Searle, J. B., … Hamer, K. C. (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*(5), 967–977.

http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2006.01209.x/full

Key points:

- Study taxon: butterflies
- Looked at a range of fragments from 120 ha to 122500ha in Sabah
- The 2 largest fragments (91587ha and 122500ha) were no different in terms of species richness to continuous forest (Danum and Maliau)
- Derived from the published graph: to reach 70% of continuous forest species richness fragments need to be around ~1000ha
- No endemics in fragments less than 4000ha, but Sundaland restricted species were found in all fragments (i.e. as small as 120ha fragment sampled)

Edwards, D. P., Hodgson, J. A., Hamer, K. C., Mitchell, S. L., Ahmad, A. H., Cornell, S. J., & Wilcove, D. S. (2010). Wildlife-friendly oil palm plantations fail to protect biodiversity effectively. *Conservation Letters*, *3*(4), 236–242.

http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2010.00107.x/full

Key points

- Study taxon: birds
- Looked at fragments ranging from 0.7ha to 88ha
- Fragments of this size were not good at conserving bird species (on average ~30% of continuous forest species richness)
- Bird communities were more similar to oil palm communities than forest communities, and did not increase overall richness in the oil palm landscape

Lucey, J. M., & Hill, J. K. (2012). Spillover of insects from rain forest into adjacent oil palm plantations. *Biotropica*, *44*(3), 368–377.

http://onlinelibrary.wiley.com/doi/10.1111/j.1744-7429.2011.00824.x/abstract

Key points:

- Study taxon: butterflies
- Butterfly species richness in oil palm was increased with proximity to continuous forest with forest dependent species occurring at least a km into oil palm

Lucey, J. M., Tawatao, N., Senior, M. J. M., Chey, V. K., Benedick, S., Hamer, K. C., … Hill, J. K. (2014). Tropical forest fragments contribute to species richness in adjacent oil palm plantations. *Biological Conservation*, *169*, 268–276.

http://www.sciencedirect.com/science/article/pii/S0006320713003935

Key points:

- Study taxon: ants
- Sampled fragments ranging from 5ha to 500ha
- Ant species richness increased with increasing fragment area
- Ant species richness increased in oil palm plantations with proximity to forest
- Fragments over 200ha supported forest assemblages distinct from the oil palm, and boosted richness in the surrounding landscape, but smaller fragments contributed little additional biodiversity

Tawatao, N., Lucey, J. M., Senior, M., Benedick, S., Vun Khen, C., Hill, J. K., & Hamer, K. C. (2014). Biodiversity of leaf-litter ants in fragmented tropical rainforests of Borneo: the value of publically and privately managed forest fragments. *Biodiversity and Conservation*, *23*(12), 3113–3126.

http://link.springer.com/article/10.1007/s10531-014-0768-5

Key points:

- Study taxon: ants
- Virgin jungle reserves (government managed (size ranging from 39h-5529ha, all but 2 over 100ha) supported 70% of continuous forest species richness
- Plantation managed fragments (size ranging from 5-120ha) supported 30% of continuous forest species
- Forest quality was better in VJRs than plantation managed reserves and was correlated with size

Other studies which informed the synthesis:

Edwards, D. P., Larsen, T. H., Docherty, T. D. S., Ansell, F. A., Hsu, W. W., Derhé, M. A., … Wilcove, D. S. (2011). Degraded lands worth protecting: the biological importance of Southeast Asia's repeatedly logged forests. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1702), 82–90.

http://rspb.royalsocietypublishing.org/content/278/1702/82.short

Key points:

- Study taxa: birds and ants

- Continuous forest which is very degraded (logged multiple times) retains over 75% of primary forest species.
- Contains higher overall species richness than primary forest due to mixing of open habitat and forest species
- **Point to take from this**: extensive tracts of forest support crucial biodiversity even if they are very degraded i.e. per unit area, forest which is contiguous with large tracts is more valuable than fragments even if the forest is very low quality in the continuous forest.

Edwards, F. A., Edwards, D. P., Sloan, S., & Hamer, K. C. (2014). Sustainable Management in Crop Monocultures: The Impact of Retaining Forest on Oil Palm Yield. *PLoS ONE*, *9*(3), e91695.

http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0091695

Key points:

- Proximity to forest did not affect oil palm yield
- **Point to take away from this:** Spillover of biodiversity from forest does not apparently have negative impacts on yields

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brulh, C. A., Donald, P. F., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution*, *23*(10), 538–545.

http://www.sciencedirect.com/science/article/pii/S0169534708002528

Key point: oil palm supports 15% of forest species (but around 35% of overall species numbers across taxa except for the bee study which showed a substantial increase in oil palm compared to forest).

Marshall, A. J., Lacy, R., Ancrenaz, M., Byers, O., Husson, S. J., Leighton, M., … Wich, S. A. (2009). Orangutan population biology, life history, and conservation: Perspectives from population viability analysis models. In S. Wich (Ed.), *Orangutans: geographic variation in behavioral ecology and conservation.* (pp. 311–326). Oxford University press.

http://sites.lsa.umich.edu/ajmarsha/wp-content/uploads/sites/162/2014/09/Marshall-et-al.-2009-OU-PVA.pdf

Key point: Orang utans are estimated to need forest areas of 50,000-100,000ha to maintain viable populations.