Supporting information

**Selective logging intensification and time since logging drive tropical fauna biodiversity: a case study from Brazilian Amazon**

França & Beiroz et al. (2024) – *Environmental Conservation*

**Appendix S1**. Inclusion criteria for studies used in the literature review.

Using Web of Science (<http://webofscience.com>), we searched for publications assessing the impacts of selective logging on the functional diversity of tropical forests. We performed this search on January 4th 2023 by using the terms “logging” AND “functional diversity” AND “tropic\*” and “forest\*” (query link: <https://www.webofscience.com/wos/woscc/summary/f8e846cb-fe20-4d66-848e-1b2a41319d35-68a3ede1/relevance/1>). We did not specify where these terms should occur in the publications (field tag = “ALL”, for all fields).

Web of Science returned 44 publications, which were then examined and filtered to ensure we considered all studies reporting the impacts of logging on the functional diversity of Tropical America forests. We assessed the pertinence of each publication according to its title, abstract and methods. All field-based studies were retained, while reviews, conference and modelling studies were excluded. In total 35 articles were considered for final assessment.

**Table S1**. List of studies examining the impacts of selective logging on the functional diversity of tropical forests. Table shows the Author, Year of publication, Journal Abbreviation, DOI link, Document type, Inclusion in the assessment (Y = Yes; N = No), Region, Taxa, Group, and Country of the study.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Authors** | **Year** | **Journal**  | **DOI Link** | **Type** | **Included** | **Region** | **Taxa** | **Country** |
| Mestre, LAM et al | 2020 | ANIM CONSERV | <http://dx.doi.org/10.1111/acv.12592> | Article | Y | Tropical Americas | Birds | Brazil |
| Ernst, R et al | 2006 | BIOL CONSERV | <http://dx.doi.org/10.1016/j.biocon.2006.05.028> | Article | Y | Americas/Afrotropics | Amphibians | Ivory Coast/Guyana |
| Carreno-Rocabado et al | 2012 | J ECOL | <http://dx.doi.org/10.1111/j.1365-2745.2012.02015.x> | Article | Y | Tropical Americas | Trees | Bolivia |
| Ding, Y et al | 2019 | ECOL INDIC | <http://dx.doi.org/10.1016/j.ecolind.2018.10.030> | Article | Y | Australasia | Trees | China |
| Chapman, PM et al | 2018 | J APPL ECOL | <http://dx.doi.org/10.1111/1365-2664.13073> | Article | Y | Australasia | Birds | Borneo |
| Edwards, FA et al | 2014 | ANIM CONSERV | <http://dx.doi.org/10.1111/acv.12074> | Article | Y | Australasia | Dung beetles | Borneo |
| Mahayani, NPD et al | 2022 | FOREST ECOL MANAG | <http://dx.doi.org/10.1016/j.foreco.2021.119948> | Article | Y | Australasia | Trees | Borneo |
| Costantini, D et al | 2016 | BIOL CONSERV | <http://dx.doi.org/10.1016/j.biocon.2016.02.020> | Meta-analyses | N | Australasia | Mammals/Birds | Borneo |
| Ross, SRPJ et al | 2017 | METHODS ECOL EVOL | <http://dx.doi.org/10.1111/2041-210X.12769> | Article | Y | Australasia | Birds | Borneo |
| Baraloto, C et al | 2012 | J APPL ECOL | <http://dx.doi.org/10.1111/j.1365-2664.2012.02164.x> | Article | Y | Tropical Americas | Trees | French Guyana |
| Tripathi, BM et al | 2016 | MOL ECOL | <http://dx.doi.org/10.1111/mec.13620> | Article | Y | Australasia | Soil microorganisms | Borneo |
| Lameris, DW et al | 2020 | ANIM CONSERV | <http://dx.doi.org/10.1111/acv.12526> | Article | Y | Afrotropics | Mammals | Cameroon |
| Edwards, FA et al | 2013 | IBIS | <http://dx.doi.org/10.1111/ibi.12027> | Article | Y | Australasia | Birds | Borneo |
| Both, S et al | 2019 | NEW PHYTOL | <http://dx.doi.org/10.1111/nph.15444> | Article | Y | Australasia | Trees | Borneo |
| Cosset, CCP & Edwards, DP | 2017 | ECOL APPL | <http://dx.doi.org/10.1002/eap.1578> | Article | Y | Australasia | Birds | Borneo |
| Jacob, LL et al | 2021 | HYDROBIOLOGIA | <http://dx.doi.org/10.1007/s10750-020-04508-3> | Article | Y | Tropical Americas | Fish | Brazil |
| Cerullo, GR et al | 2019 | FOREST ECOL MANAG | <http://dx.doi.org/10.1016/j.foreco.2019.04.025> | Article | Y | Australasia | Dung beetles | Borneo |
| Matuoka, MA et al | 2020 | ECOL INDIC | <http://dx.doi.org/10.1016/j.ecolind.2020.106471> | Meta-analyses | N | Global | Birds | Global |
| Osazuwa-Peters, OL et al | 2015 | CONSERV PHYSIOL | <http://dx.doi.org/10.1093/conphys/cov012> | Article | Y | Afrotropics | Trees | Uganda |
| Ford, H et al | 2018 | AGR ECOSYST ENVIR | <http://dx.doi.org/10.1016/j.agee.2018.02.025> | Article | N | Non-tropical | Trees | Wales |
| Kpan, TF et al | 2021 | FOREST ECOL MANAG | <http://dx.doi.org/10.1016/j.foreco.2021.119489> | Article | Y | Afrotropics | Amphibians | Ivory Coast |
| Schaaf, AA et al | 2021 | SCI REP-UK | <http://dx.doi.org/10.1038/s41598-021-03756-0> | Article | N | Non-tropical | Birds | Argentina |
| Bui, V et al | 2022 | ECOL RES | <http://dx.doi.org/10.1111/1440-1703.12308> | Article | Y | Australasia | Dung beetles | Vietnam |
| Carlson et al | 2017 | GLOBAL CHANGE BIOL | <http://dx.doi.org/10.1111/gcb.13453> | Article | Y | Afrotropics | Trees | Gabon |
| Ross, SRPJ et al | 2018 | BIOTROPICA | <http://dx.doi.org/10.1111/btp.12569> | Article | Y | Afrotropics | Ants | Kenya |
| Schleuning, M et al | 2011 | PLOS ONE | <http://dx.doi.org/10.1371/journal.pone.0027785> | Article | Y | Afrotropics | Ecological functions | Kenya |
| Souza, AF & Longhi, SJ | 2019 | ECOL EVOL | <http://dx.doi.org/10.1002/ece3.5289> | Article | Y | Tropical Americas | Trees | Brazil |
| Pyles, MV et al | 2018 | BIODIVERS CONSERV | <http://dx.doi.org/10.1007/s10531-018-1598-7> | Article | Y | Tropical Americas | Trees | Brazil |
| Hamer, KC et al | 2015 | BIOL CONSERV | <http://dx.doi.org/10.1016/j.biocon.2014.09.026> | Article | Y | Australasia | Birds | Borneo |
| Both, S | 2019 | NEW PHYTOL | <http://dx.doi.org/10.1111/nph.16120> | Correction | N | Australasia | Trees | Borneo |
| Woodcock, P et al | 2011 | PHILOS T R SOC B | <http://dx.doi.org/10.1098/rstb.2011.0031> | Article | Y | Australasia | Ants | Borneo |
| Chapman, PM et al | 2018 | BIODIVERS CONSERV | <http://dx.doi.org/10.1007/s10531-018-1594-y> | Article | Y | Australasia | Mammals | Borneo |
| Harrison, RD & Swinfield, T | 2015 | TROP CONSERV SCI | <http://dx.doi.org/10.1177/194008291500800103> | Article | Y | Australasia | Trees | Indonesia |
| Hawes, JE et al | 2020 | J ECOL | <http://dx.doi.org/10.1111/1365-2745.13358> | Article | Y | Tropical Americas | Trees | Brazil |
| Luke, SH et al | 2014 | BIODIVERS CONSERV | <http://dx.doi.org/10.1007/s10531-014-0750-2> | Article | Y | Australasia | Ants/Termites | Borneo |
| Ernst, R et al | 2007 | ENVIRON SCI ENG | <https://doi.org/10.1007/978-3-540-30290-2_4>  | Book chapter | Y | Americas/Afrotropics | Frogs | Guinea/Guyana |
| Bregman, TP et al | 2016 | P ROY SOC B-BIOL SCI | <http://dx.doi.org/10.1098/rspb.2016.1289>  | Article | Y | Tropical Americas | Birds | Brazil |
| Edwards, DP et al | 2013 | CONSERV BIOL | <http://dx.doi.org/10.1111/cobi.12059>  | Article | Y | Australasia | Birds | Borneo |
| Vasquez-Grandon, A et al | 2018 | FORESTS | <http://dx.doi.org/10.3390/f9110726> | Review | N | NA | NA | NA |
| Liu, XF et al | 2019 | SCI REP-UK | <http://dx.doi.org/10.1038/s41598-018-35963-7> | Meta-analyses | N | Australasia | Trees | China |
| Pachit, P et al | 2020 | PEDOBIOLOGIA | <http://dx.doi.org/10.1016/j.pedobi.2020.150661> | Article | Y | Australasia | Soil microorganisms | Thailand |
| Neoh, KB et al | 2015 | ECOL RES | <http://dx.doi.org/10.1007/s11284-015-1289-8> | Review | N | Australasia | Termites | Indo-Malaysia |
| Depecker, J et al | 2022 | J TROP ECOL | <http://dx.doi.org/10.1017/S0266467422000347> | Article | Y | Afrotropics | Trees | Congo |
| Cordier, JM et al | 2021 | BIOL CONSERV | <http://dx.doi.org/10.1016/j.biocon.2020.108863> | Review | N | Global | Amphibians/Reptiles | Global |

**Appendix S2**. Supplementary Tables and Figures.

**Table S2**. Number of sites included into estimate dung beetle and bird functional and taxonomic responses to selective logging intensification and time since logging in the Brazilian Amazon.

|  |  |
| --- | --- |
|   | **Number of sites** |
| **Response variables** | **Birds** | **Dung beetles** |
| Abundance | 48 (4 controls) | 51 (7 controls) |
| Richness |
| Body mass |
| Rao's entropy |
| Functional specialization |
| Functional originality |
| Bray-Curtis dissimilarity |
| Bray-Curtis balanced variation |
| Bray-Curtis abundance gradient |
| Species rarity | 99 | 93 |

**Table S3**. Beta-diversity between and within our study regions\*.

|  |  |  |
| --- | --- | --- |
| **Dung beetles – Beta-diversity (Jaccard)** |  | **Dung beetles – Beta-diversity (Brazy-Curtis)** |
|  | Bituba C1 | Bituba C2 | Gueti C1 |  |  | Bituba C1 | Bituba C2 | Gueti 1 |
| Bituba C2 | 0.346 |  |  |  | Bituba C2 | 0.376 |  |  |
| Gueti C1 | 0.375 | 0.370 |  |  | Gueti C1 | 0.351 | 0.314 |  |
| Gueti C2 | 0.360 | 0.296 | 0.444 |  | Gueti C2 | 0.312 | 0.439 | 0.317 |

|  |  |  |
| --- | --- | --- |
| **Birds – Beta-diversity (Jaccard)** |  | **Birds – Beta-diversity (Brazy-Curtis)** |
|  | Bituba C1 | Bituba C2 | Gueti C1 |  |  | Bituba C1 | Bituba C2 | Gueti C1 |
| Bituba C2 | 0.346 |  |  |  | Bituba C2 | 0.580 |  |  |
| Gueti C1 | 0.375 | 0.370 |  |  | Gueti C1 | 0.690 | 0.596 |  |
| Gueti C2 | 0.360 | 0.296 | 0.444 |  | Gueti C2 | 0.524 | 0.651 | 0.634 |

\*We used the R packages ‘vegan’ (Oksanen et al., 2015) and ‘betapart’ (Baselga, Orme, 2012) to assess beta-diversity based on species’ presence/absence (Jaccard dissimilarity) and abundances (Bray-Curtis dissimilarity) in our control sites (**C**; i.e. unlogged) both within and between our study regions. Dissimilarity values were very close across unlogged sites for both study regions.

**Table S4**. Summary of models’ structure, response and explanatory variables used to address our research question (Q). Depending on the family error, we used generalized linear models (GLM) or linear models (LM).

|  |  |  |  |
| --- | --- | --- | --- |
| **Questions** | **Variables** | **Family error** | **Model type** |
| **Response** | **Explanatory** |
| Q1 | Species richness | Logging intensity + Region + Logging intensity\*Region | Quasi-Poisson | GLM |
| Abundance | Negative binomial | GLM |
| CWM biomass | Gaussian | LM |
| FDq | Gaussian | LM |
| Functional originality | Gaussian | LM |
| Functional specialization | Gaussian | LM |
| Q2 | Bray-Curtis dissimilarity | Gaussian (dung beetles) / Gamma (birds) | LM (dung beetles) /GLM (birds) |
| Bray-Curtis abundance gradient | Gamma | GLM |
| Bray-Curtis balanced variation | Gamma | GLM |
| Q3 | CMW species rarity | Gaussian | LM |



**Figure S1**. Bray-Curtis dissimilarity components can be partitioned into (A) abundance gradients, which quantify the individual loss of all species from one site to another (top panel); and (B) Balanced variation in abundance, which assess if individuals lost by one species are substituted by individuals from other species when between sites (bottom panel). The size of the circles represent relative abundances (i.e. population size or number of individuals) from each specie (columns) between sites (rows).

**Appendix S3**. Rarity index calculation

We followed the same approach previously used by Leitão *et al*. 2016 (Leitão et al., 2016), where the rarity index for a species $z$ ($RI\_{z}$) was calculated as:

$$RI\_{z}=\frac{[\left(LA\_{z}×w\_{LA}\right)+\left(GR\_{z}×w\_{GR}\right)+ \left(HB\_{z}×w\_{HB}\right)]}{w\_{LA}+w\_{GR}+w\_{HB}}$$

Here, $w\_{LA}$, $w\_{GR}$, and $w\_{HB} $are the weighted parameters that represent the independence degree of each rarity metric for local abundance ($LA$), geographical range ($GR$) and habitat breath ($HB$), respectively. These rarity’s weighted parameters for local abundance ($w\_{LA}$) were calculated as:

$$w\_{LA}=\frac{1}{2}+\left[\left(\frac{1-\left| r\_{LAGR}\right|}{2}\right)+\left(\frac{1-\left| r\_{LAHB}\right|}{2}\right)\right]$$

Where $ r\_{LAGR} $and $ r\_{LAHB} $are the Pearson’s correlation coefficients between $LA$ with $GR$ or $HB$, respectively.

**REFERENCES**

Baselga A, Orme CDL (2012) betapart : an R package for the study of beta diversity. *Methods in Ecology and Evolution* 3: 808–812.

Leitão RP, Zuanon J, Villéger S, Williams SE, Baraloto C, Fortunel C, et al. (2016) Rare species contribute disproportionately to the functional structure of species assemblages. *Proceedings of the Royal Society B: Biological Sciences* 283: 20160084.

Oksanen AJ, Blanchet FG, Kindt R, Legendre P, Minchin PR, Hara RBO, et al. (2015) Package ‘ vegan ’.