Relative importance of environmental and biotic factors shaping community assembly of arboreal ants in rubber plantations and rainforests

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Oct 18 2021

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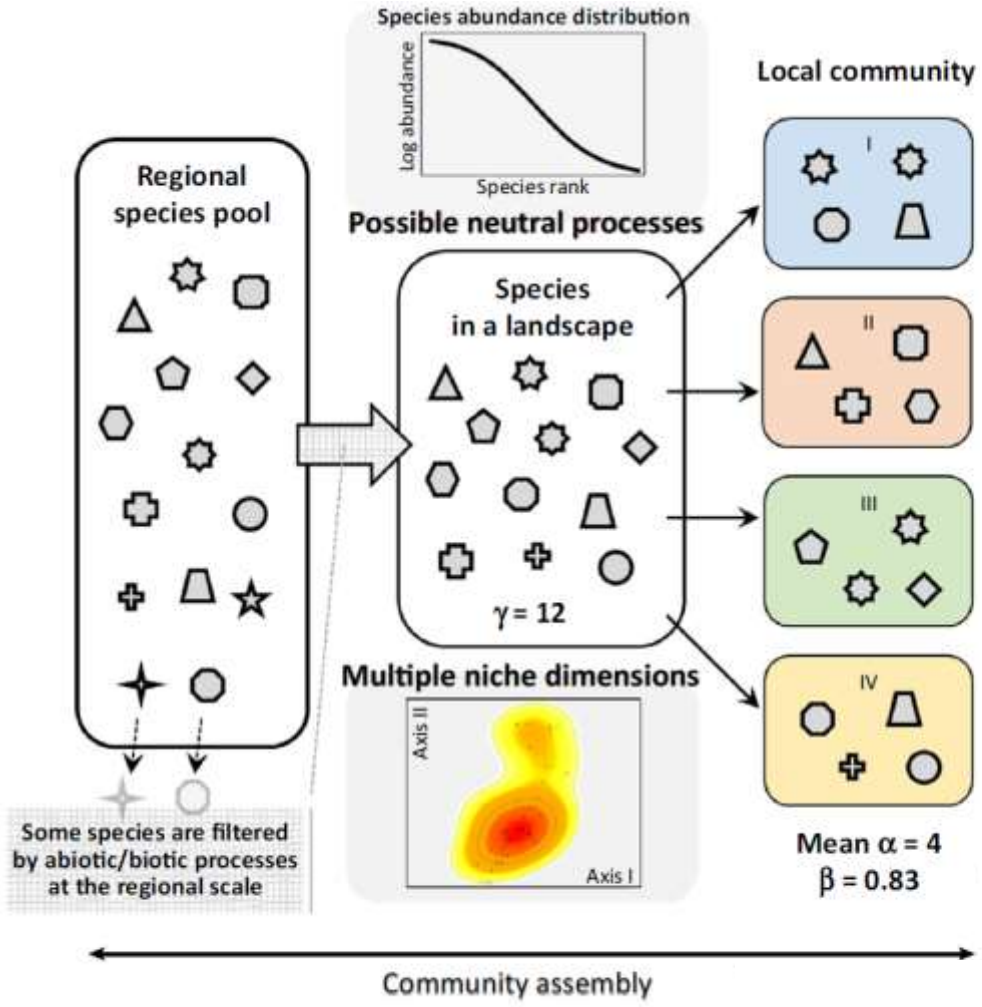
Key Processes of Community Assembly and Biodiversity

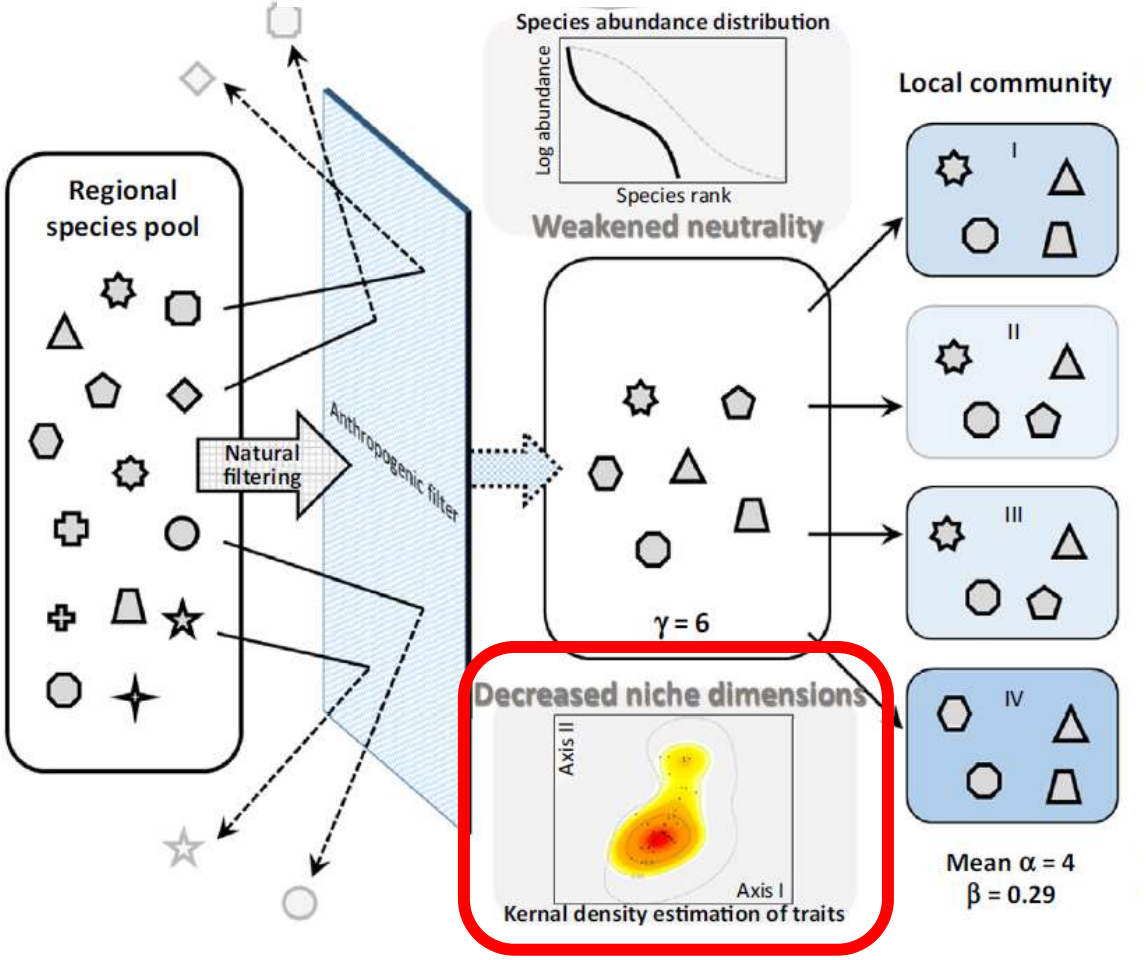


- Reginal species pool -> Species in a landscape (e.g. rainforest trees)
- Coexistence of rare species in a given landscape: may be explained by neutral processes, multiple niche dimensions, stochastic processes and historic contingency
- These mechanisms and local habitat heterogeneity maintain high local β diversity

Trends in Ecology & Evolution

Mori et al. 2018 TREE

Community Assembly and Biodiversity–Ecosystem Functioning with an **"additional" filter**



- An "additional" filter (anthropogenic disturbances) removes available species at a given landscape (e.g., rubber plantations)
- Reduction of both common and rare species results in <u>weakened neutrality</u> and <u>decreased niche dimensions</u>
- Altered mechanisms and homogenised local habitats result in low local β diversity

Decreased niche dimensions = more competition?

Trends in Ecology & Evolution

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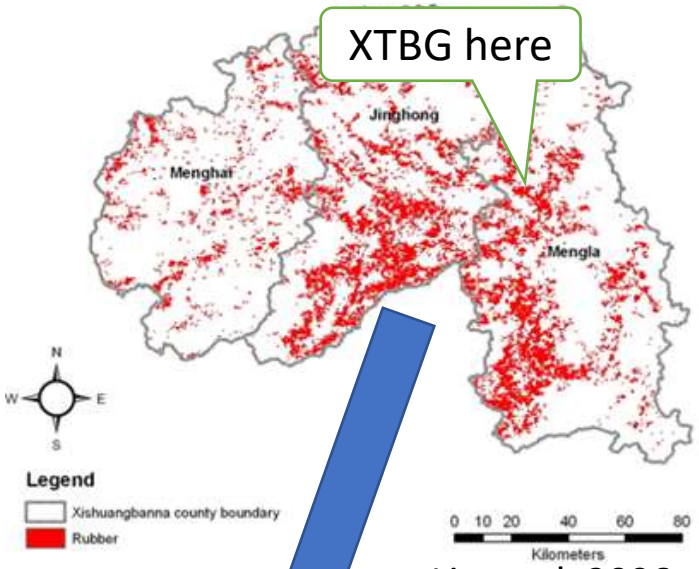
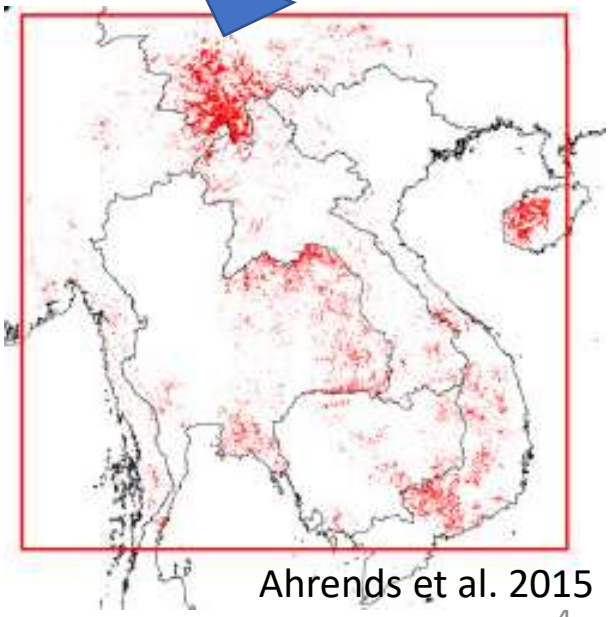
Rubber plantations in Xishuangbanna

- **Rubber plantation: most dominant landscape in Xishuangbanna** (Hammond et al. 2015, ICRAF Working Paper)
- **In Menglun (XTBG), 324% increase in rubber plantation from 1988 to 2003** (Liu et al. 2006 Mountain Research and Development)
- **Subsequent loss of biodiversity** (Ahrends et al. 2015 Global Environmental Change)

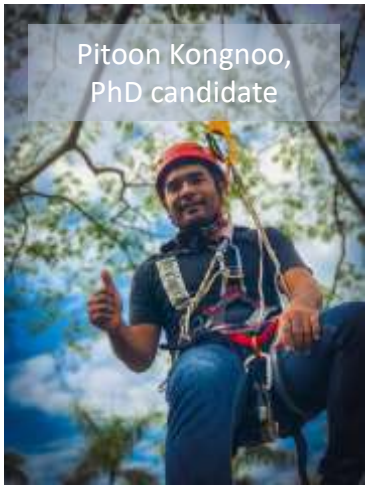


Liu et al. 2006



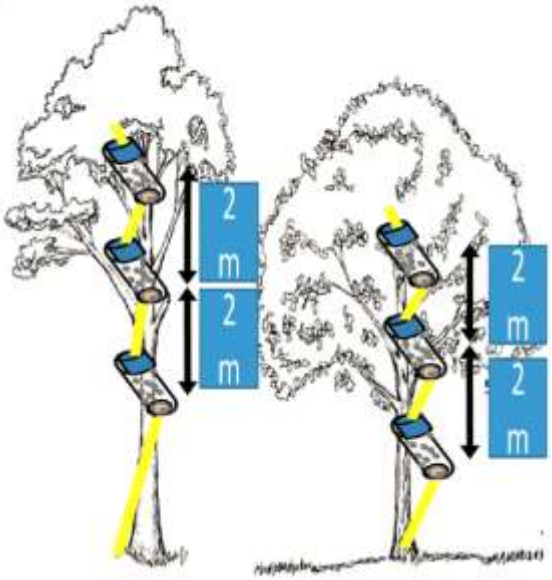
Ahrends et al. 2015

Arboreal ant diversity in rainforests and rubber plantations



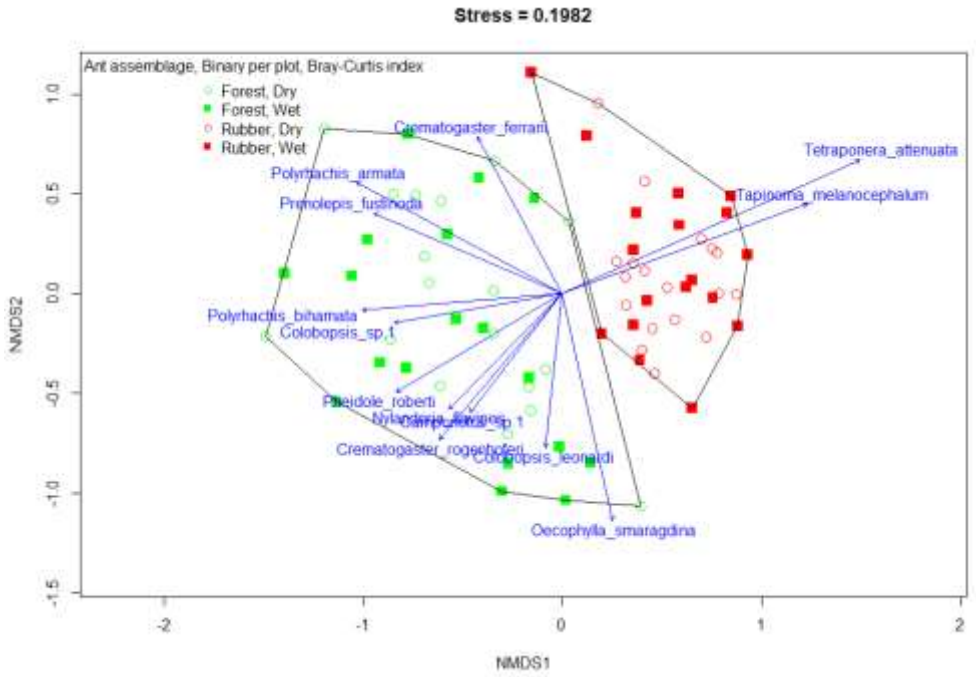
- Spatial structure of arboreal ant assemblages: thought to be driven by **competitive interactions** (Bluthgen and Stork 2007 Austral Eco, Fayle et al. 2013 Ecography)
- **"Ant mosaics"**: competitive interaction explains spatial structure of arboreal ant assemblages (Bluthgen & Stork 2007 Austral Eco)
- Classical studies about ant mosaics primarily came from plantations
- Ant mosaics may or may not work in complex primary forests (Fayle et al. 2013 Ecography)
- We know little about how strength of interactions change across habitats

Arboreal ant baiting in Xishuangbanna



Habitat	Tree species	Sampling seasons	Number of locations	Number of plots per location	Number of trees per plot	Number of traps per tree
Rubber plantation	*Hevea brasiliensis*	2	3	6	10	3
Rain forest	Mix tree species	2	3	6	10	3
					Total number of samples:	**2160**

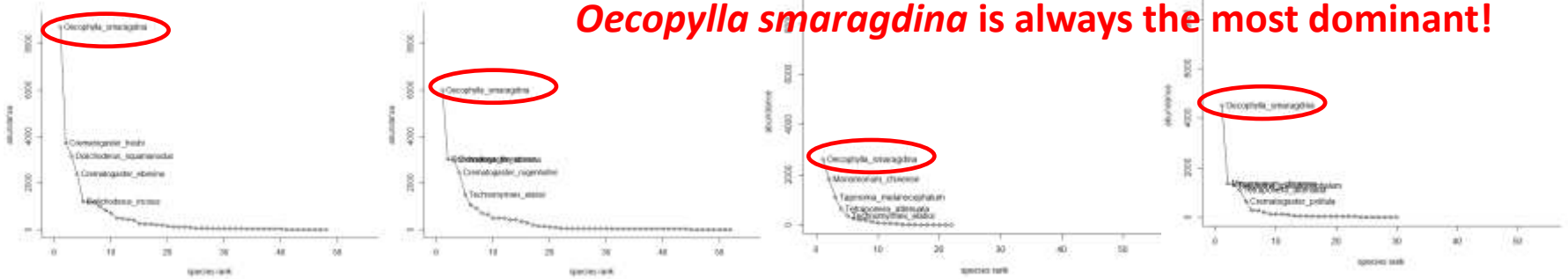
Arboreal ant diversity in rainforests and rubber plantations



- **Lower γ diversity** in rubber plantations:
  Dry season rainforest = 48 species
  Wet season rainforest = 52 species
  Dry season rubber = 22 species
  Wet season rubber = 30 species
- **Lower β diversity** in rubber plantations
  F=19.3 df=3 p<0.001 (from betadisper)
- Significant **differences in ant species composition** between rainforests and rubber but <u>no seasonal differences</u>

- Reduced common and rare species = **weaker neutrality in rubber plantations**

***Oecopylla smaragdina* is always the most dominant!**



Dry rainforest | Wet rainforest | Dry rubber | Wet rubber

Challenges in measuring species interactions (incl. competition)

1. Environmental conditions may confound species interactions (i.e. species that have no interactions appear to have interactions due to their habitat requirements)

2. Indirect vs direct species interactions

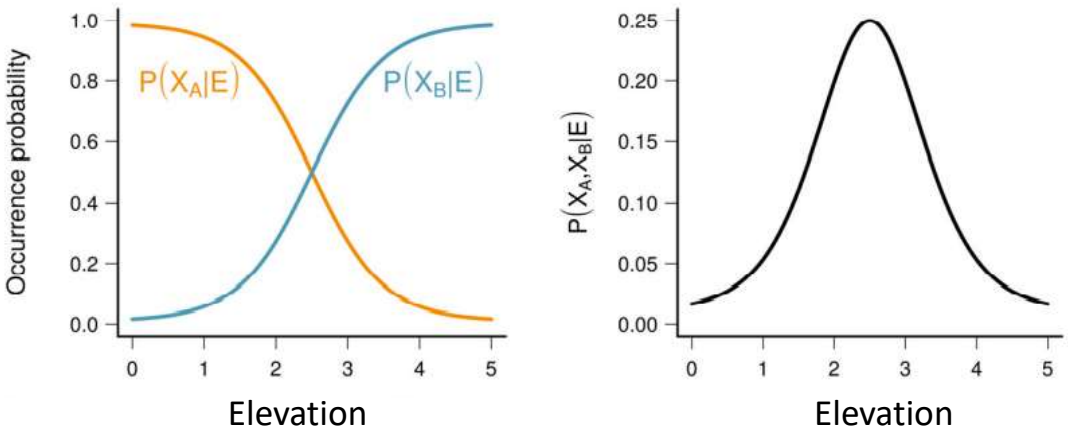
3. Interaction between two species diminish when more species are associated

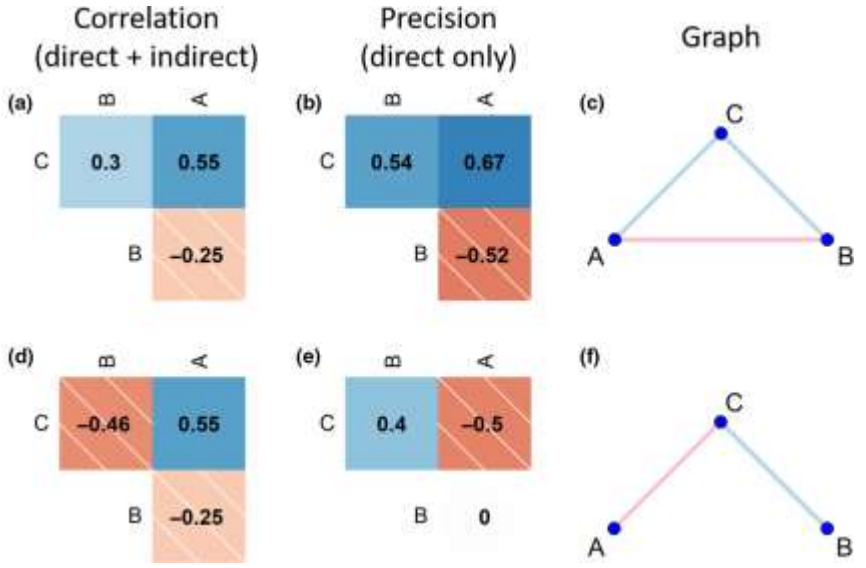
$P(Xa)=P(Xa|Xb)P(Xb)+P(Xa|Xc)P(Xc)+\ldots$

4. Conventionally, probability of species co-occurrence is understood by presence/absence

(X = Bernouilli dist'n)

(Blanchet et al. 2020 Eco Lett)





Popovic et al. 2019 MEE

Gaussian copula graphical model (GCGM)

(Popovic et al. 2019 MEE)

- This model fits generalized linear models for multivariate abundance data (`manyglm`, Wang et al. 2012)
  - Can **accommodate wide variety of data types** (binomial, Poisson, negative binomial, multinomial, Tweedie)
  - Covariance matrices can be obtained **after controlling for environmental variables** (e.g., elevation)

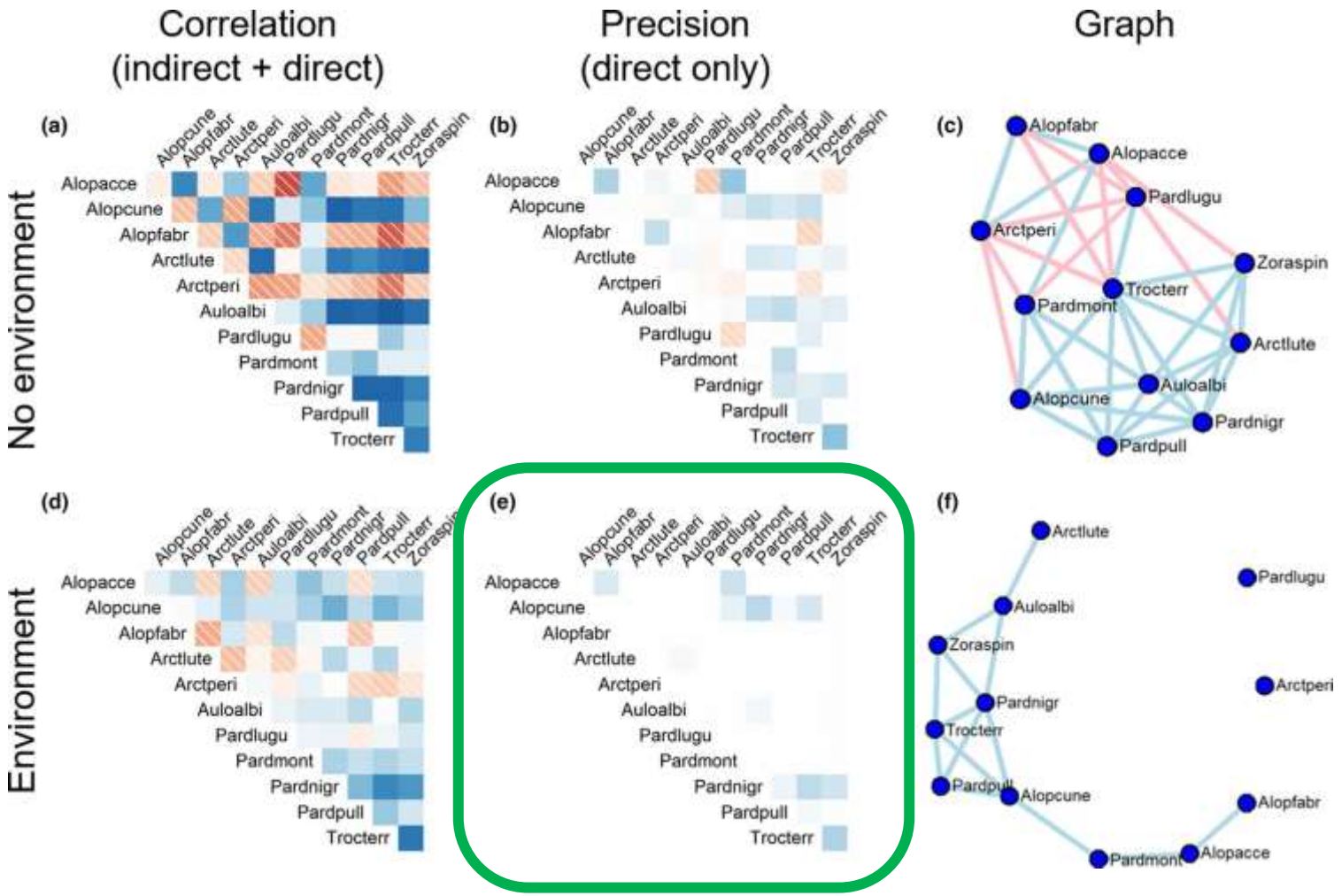
- Indirect vs direct interactions can be teased apart by calculating conditional dependence relationships between species by **examining residual precision matrices** of the focal and other species

- The best model (presence and strength of interactions between species) is modelled iteratively until convergence is achieved

- The R package, `ecoCopula`, is available on `github` (beware – the original R package fails with errors when associations are weak)
  - Bug fix available from `github` written by Buchi (`"mattocci27/ecoCopula@fix"`)

Gaussian copula graphical model (GCGM)

(Popovic et al. 2019 MEE)



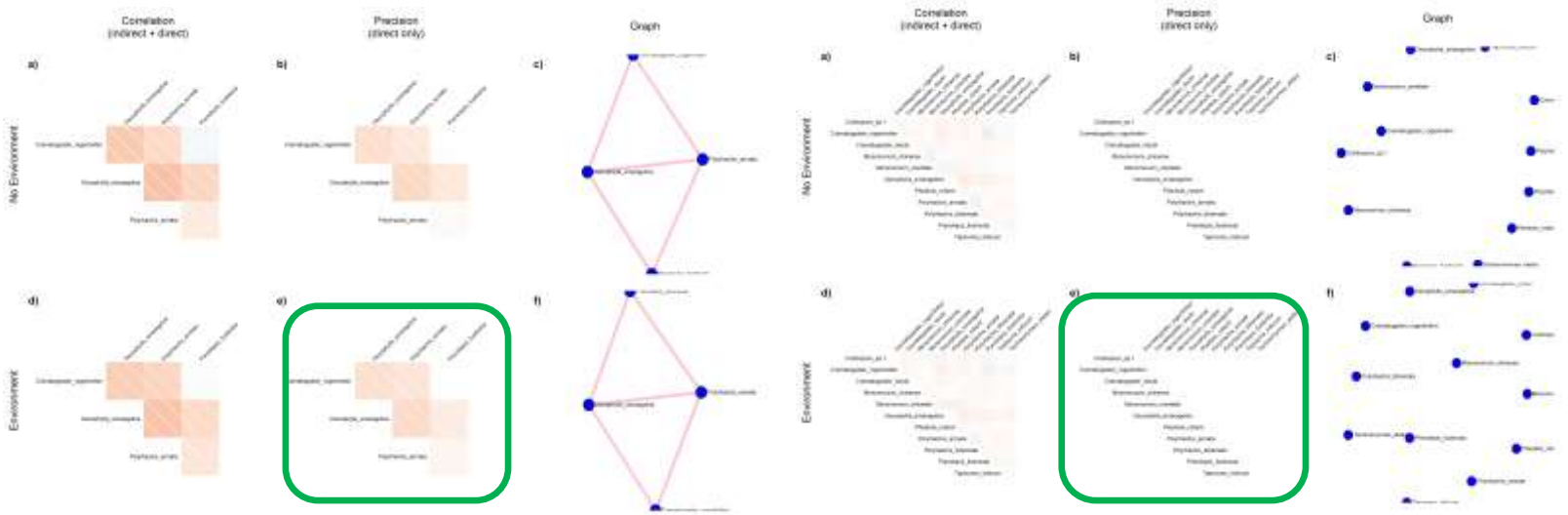
Strength of positive (blue) and negative (pink) associations can be visually assessed

Popovic et al. 2019 MEE

Unsolved problem in GCGMs

- Interaction between two species diminish when more species are associated

$$P(Xa)=P(Xa|Xb)P(Xb)+P(Xa|Xc)P(Xc)+\ldots$$



N=4 N=12

It is unclear whether the interactions do not exist OR interactions were masked by inclusion of many species

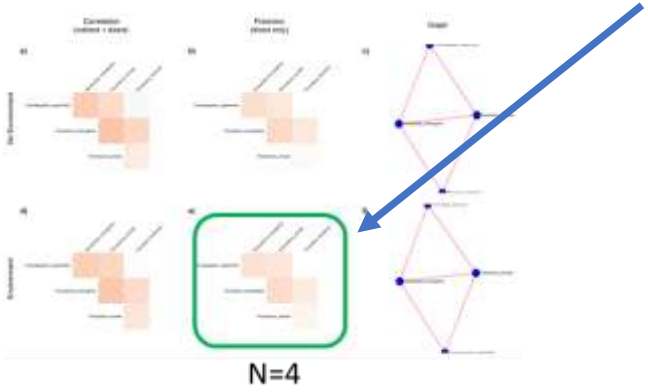
This is the problem when comparing the strength of interactions between two habitats (e.g., primary vs disturbed forests) with different number of species

Unsolved problem in GCGMs – our solution (so far)

Compare the strength of association given a number of species in GCGMs

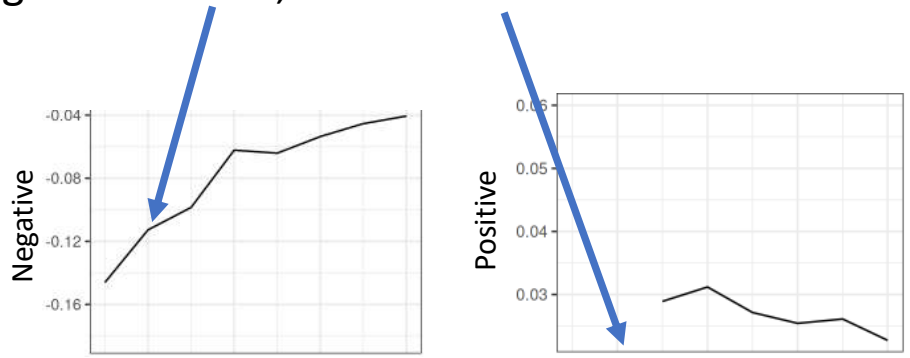
Strength of species interactions between rainforests and rubber plantations

- GCGM models
  1. Select common ant species (n>5 samples)
  2. Use multivariate model averaging (**mglmn**, Katabuchi and Nakamura 2015) to select a set of environmental variables that best explains the ant species compositional variation
  3. PCA to summarise the environmental variables (PC1 and PC2)
  4. Fit GLM (PC1 and PC2 as environmental variables) for multivariate abundance data (**mvabund**, Wang et al. 2012)
  5. Fit Gaussian copula graphical lasso (**ecoCopula**, Popovic 2019)
  6. Calculate the mean values of positive and negative associations between ant species
  7. Repeat the above processes using different number of species (our solution for the unsolved problem in GCGM)



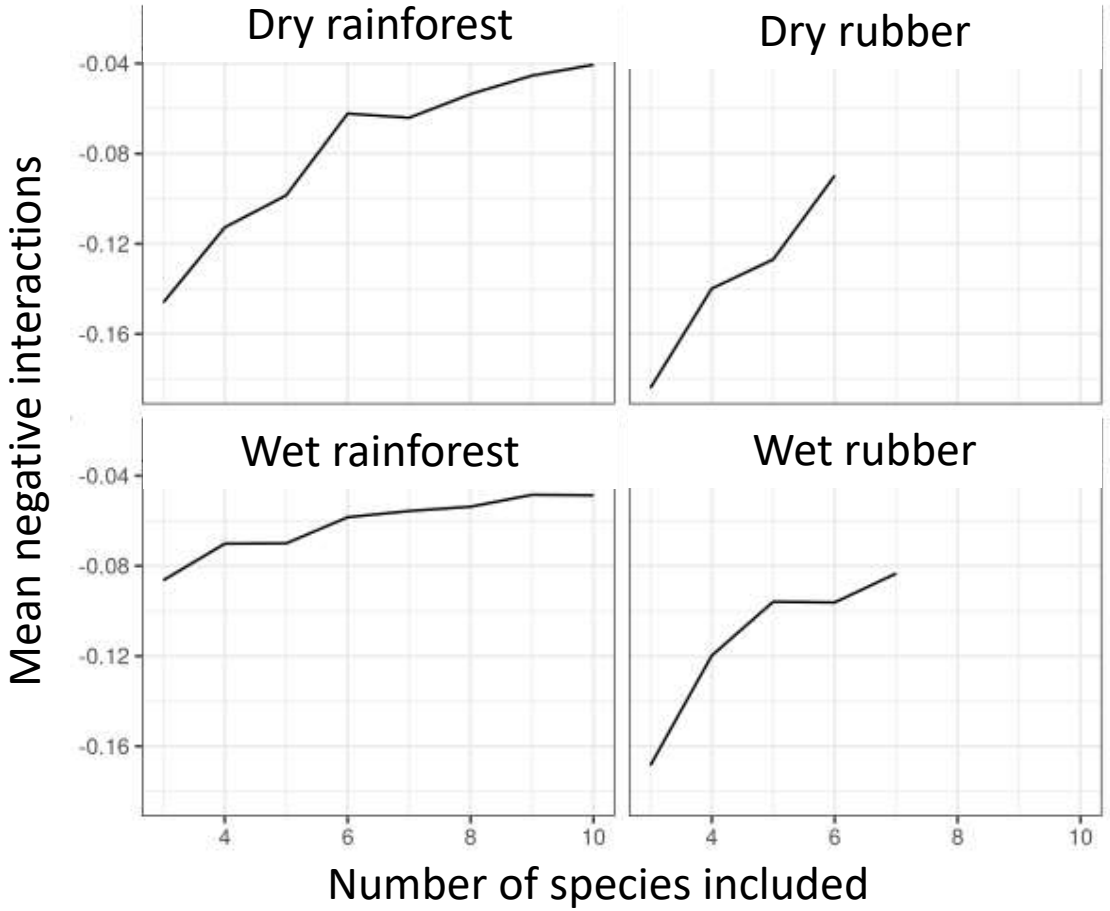
Dry rainforest

Negative = -0.11 ; Positive = 0

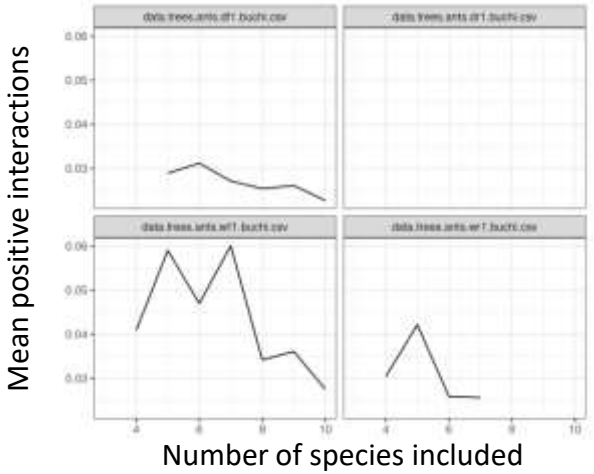


Number of species included

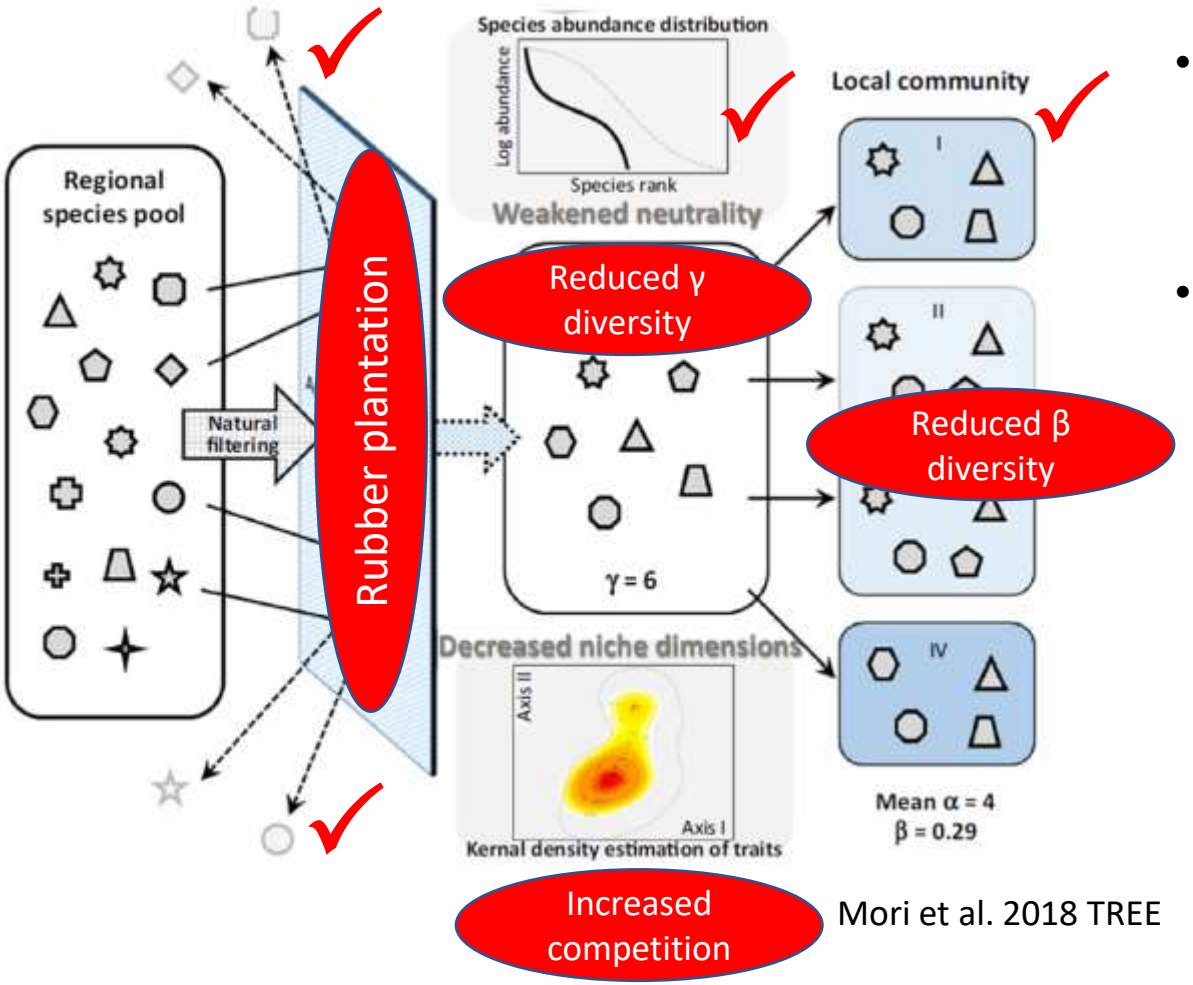
Strength of species interactions between rainforests and rubber plantations



- Stronger negative interactions (competition) during dry season in rainforest
- Competition became stronger in rubber plantation in both dry and wet seasons
- Little positive interactions among all data



Summary



Mori et al. 2018 TREE

- We demonstrated not only the reduction in γ and β diversities (also α)
- Community assembly of ants is likely driven by competition in rubber plantations (same as Fayle et al 2013 Ecography from oil palm plantation)

At local scales (i.e., after the anthropogenic filter)…

Environment drives assembly mechanisms in rainforests

Competition drives assembly mechanisms in rubber plantation

Thank you! 谢谢大家！

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This project is funded by:
BIFA (Biodiversity Information Fund for Asia) Ecological Monitoring Data Mobilization Grant (BIFA5_026)

CAS-SEABRI (Chinese Academy of Sciences South-East Asian Biodiversity Research Institute) Key Area Expansion Projects (Grant number: Y4ZK111B01)

XTBG GBIF CAS SEABRI