

Does protected area connectivity moderate the efficacy of protection on tropical biodiversity

Evidence from a replication of Brodie et al. (2023)

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30x30

Target 3 of the Kunming-Montreal Global Biodiversity Framework

Ensure and enable that by 2030 at least 30% of terrestrial and inland water areas, and of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem functions and services, are effectively conserved and managed through *ecologically representative, well-connected and equitably governed systems of protected areas and other effective area-based conservation measures, ...*

Brodie et al. (2023)

Analysis and key claims of the original study

Brodie et al. demonstrated the efficacy of terrestrial protected areas (PA) for conserving bird biodiversity while accounting for the confounding effects of 3D forest structure and accessibility.

Predictors

PA	Sample site inside/outside Protected Area
Forest	Canopy height (<i>habitat quality</i>)
Access	Circuit theory derived measure (<i>hunting pressure</i>)
HDI	Human development index

Response

Diversity	Functional Richness, Species Richness, Phylogenetic Diversity
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ED Fig. 2 | Directed acyclic graph of bird and mammal diversity in relation to exposure variables and covariates

Brodie et al. (2023)

Analysis and key claims of the original study

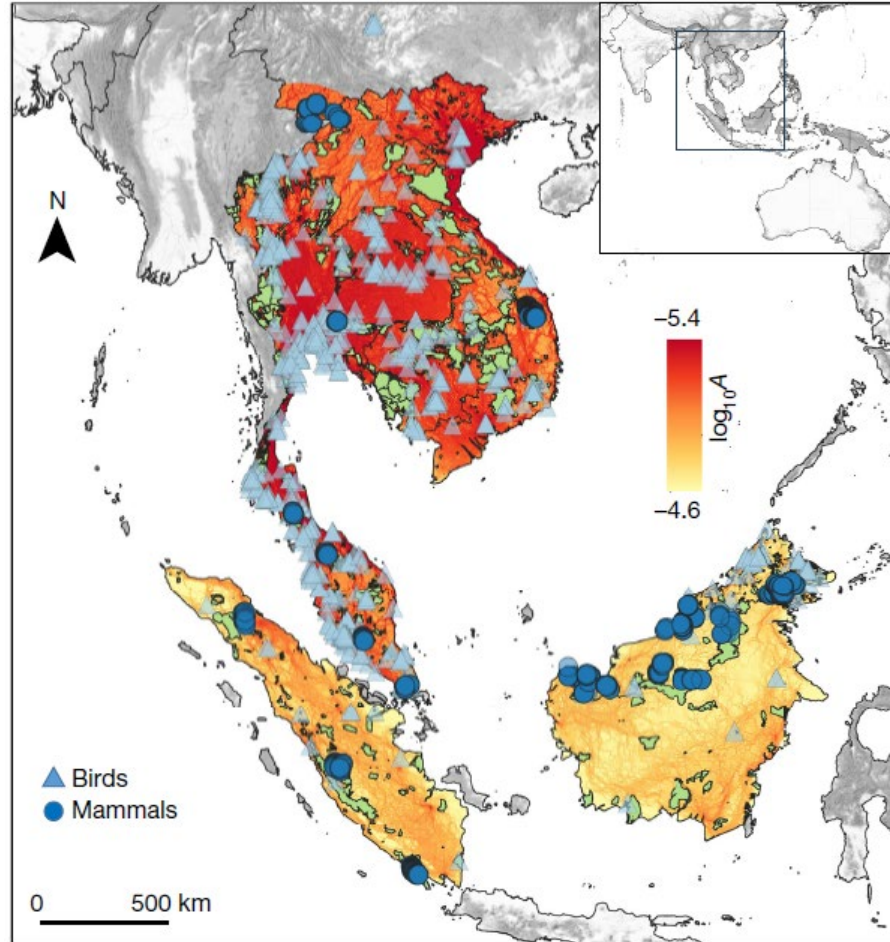


Fig. 2 | Site accessibility across Southeast Asia. The accessibility of locations (for example, to hunters) is estimated from circuit theoretic movement models.

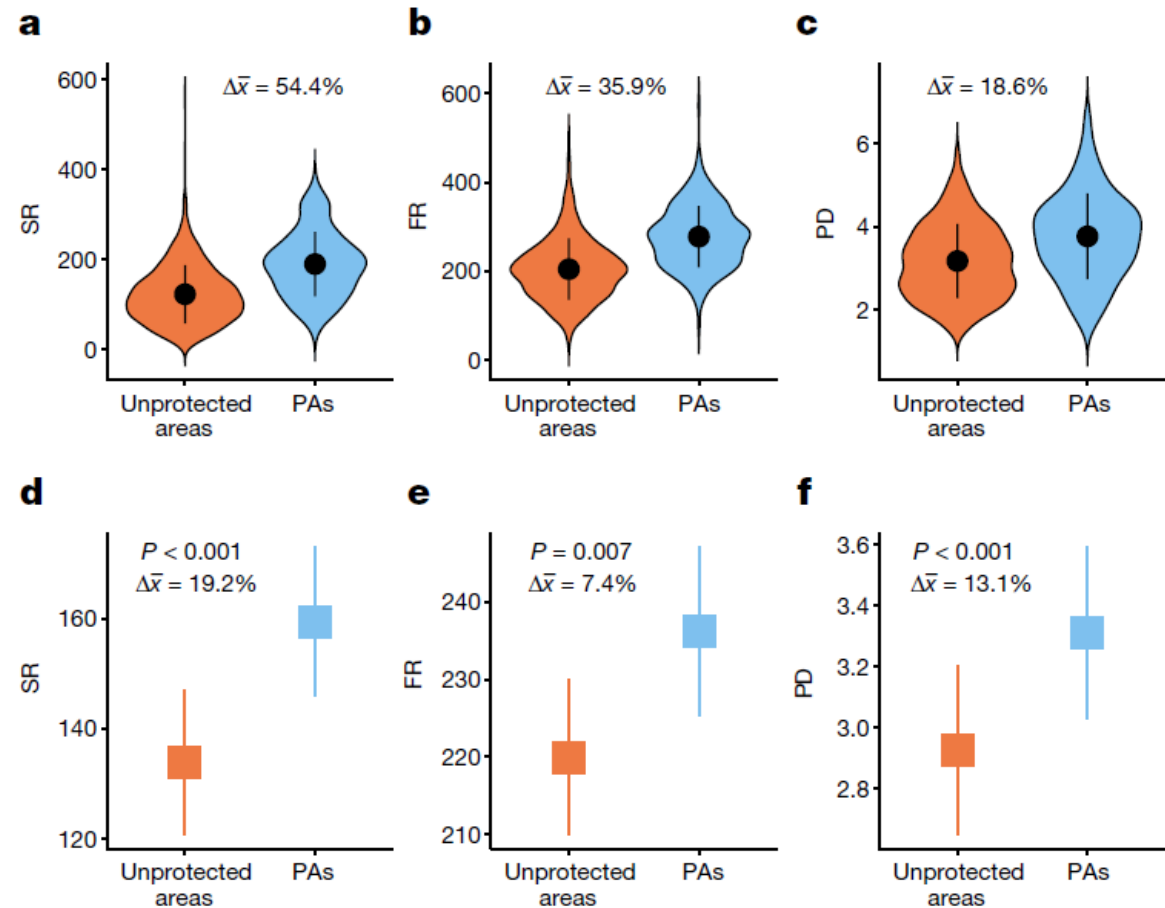


Fig. 3 | All facets of bird diversity are higher inside PAs than outside PAs.

(a-c) violin plots of biodiversity, (d-f) Spatial mixed effects regression on propensity score matched data

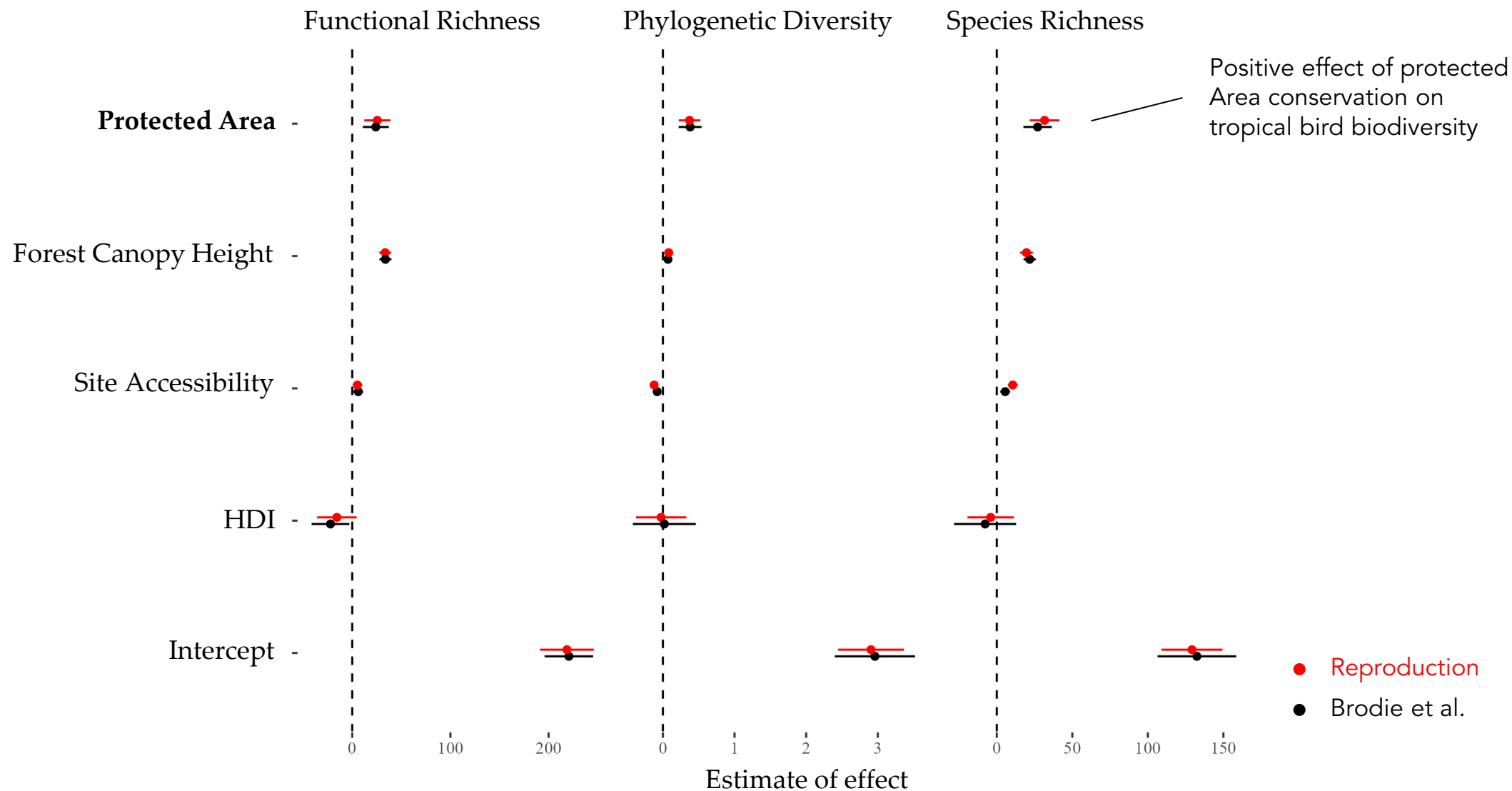
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Computational Reproduction

Matching effect estimates observed across studies



Reproducibility Check

We identified a series of minor issues and areas of concern in the original analysis

Minor Concern

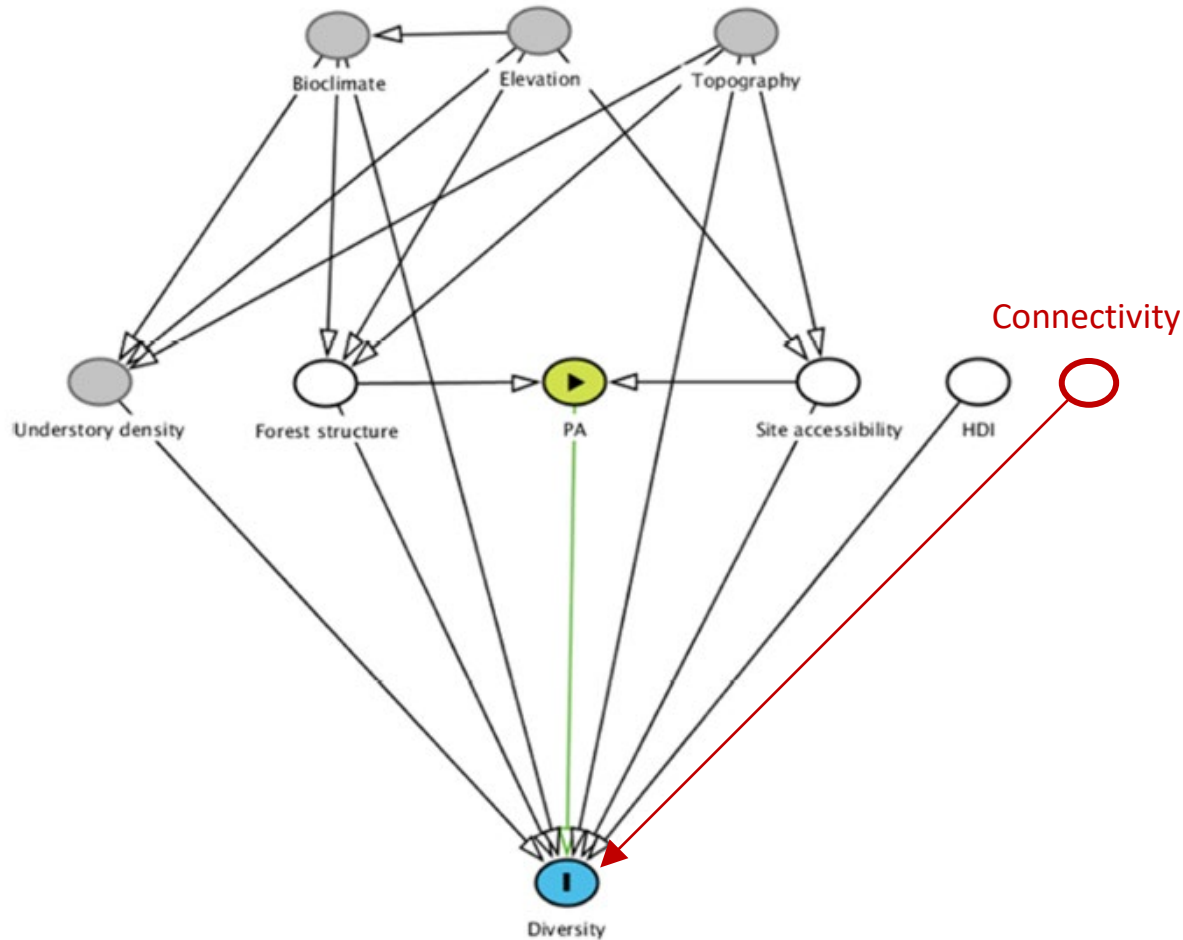
Omission	<i>Brodie et al. did not include HDI measures in the public data file</i>
Construction	<i>Procedures to construct GEDI predictors were not provided in public code</i>
Spatial	<i>Information about projections and distance calculations was omitted</i> <i>Accounted for, but did not test for remaining spatial structure in model residuals</i>

Moderate Concern

Standardization	<i>Brodie et al. centered variables on complete dataset, but regressed on subset</i>
Leverage	<i>Removed outliers based on complete dataset, but regressed on subset</i>

Replication Design

Introduce connectivity as a predictor of biodiversity and moderator of PA efficacy



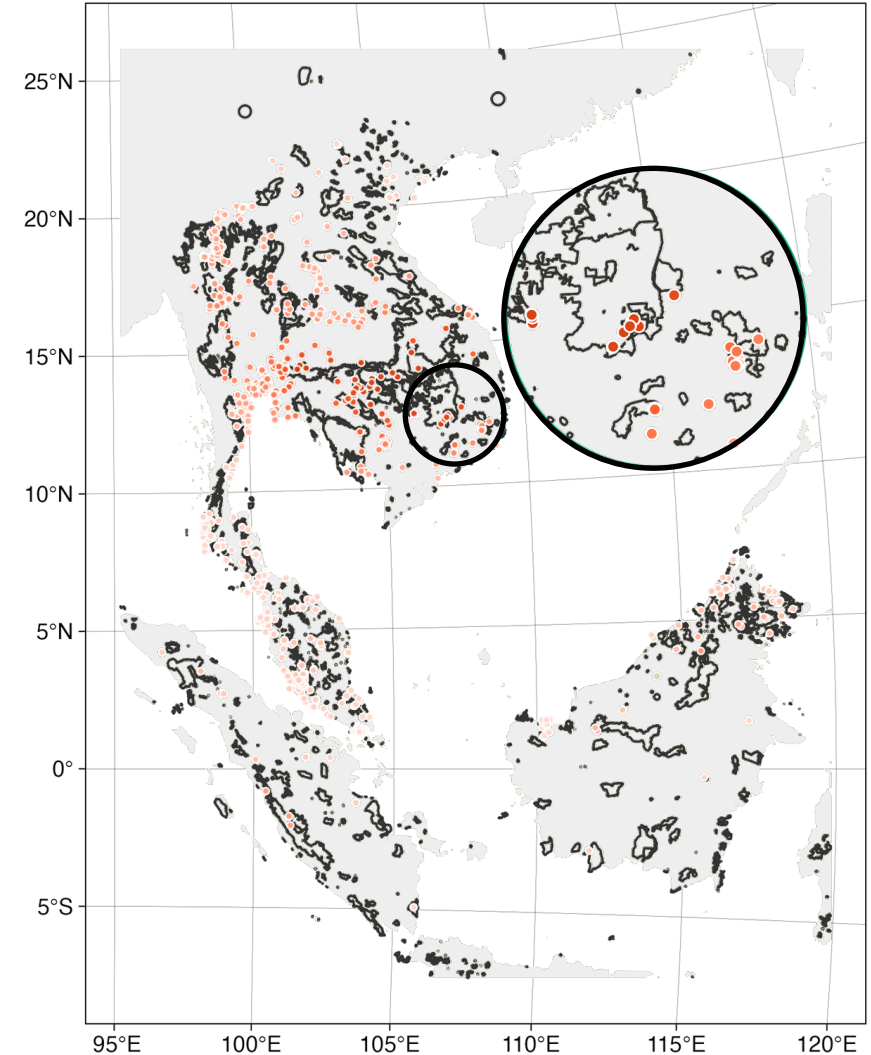
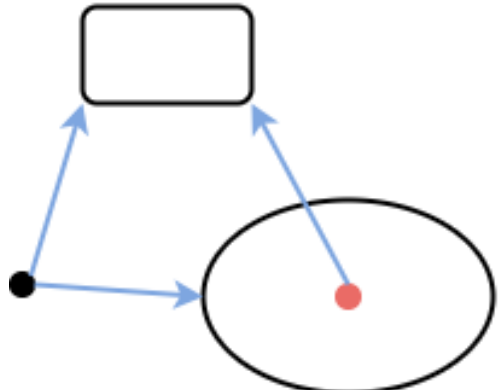
```
lme(Diversity ~ Brodie + conn + conn:PA,  
  random = list(~1 | country),  
  data = dat_matched,  
  weights = ~1(1/weights),  
  correlation = corExp(form = ~utm_east + utm_north,  
    nugget = TRUE)  
)
```

ED Fig. 2 | Modified DAG of bird diversity in southeast Asia

Replication Design

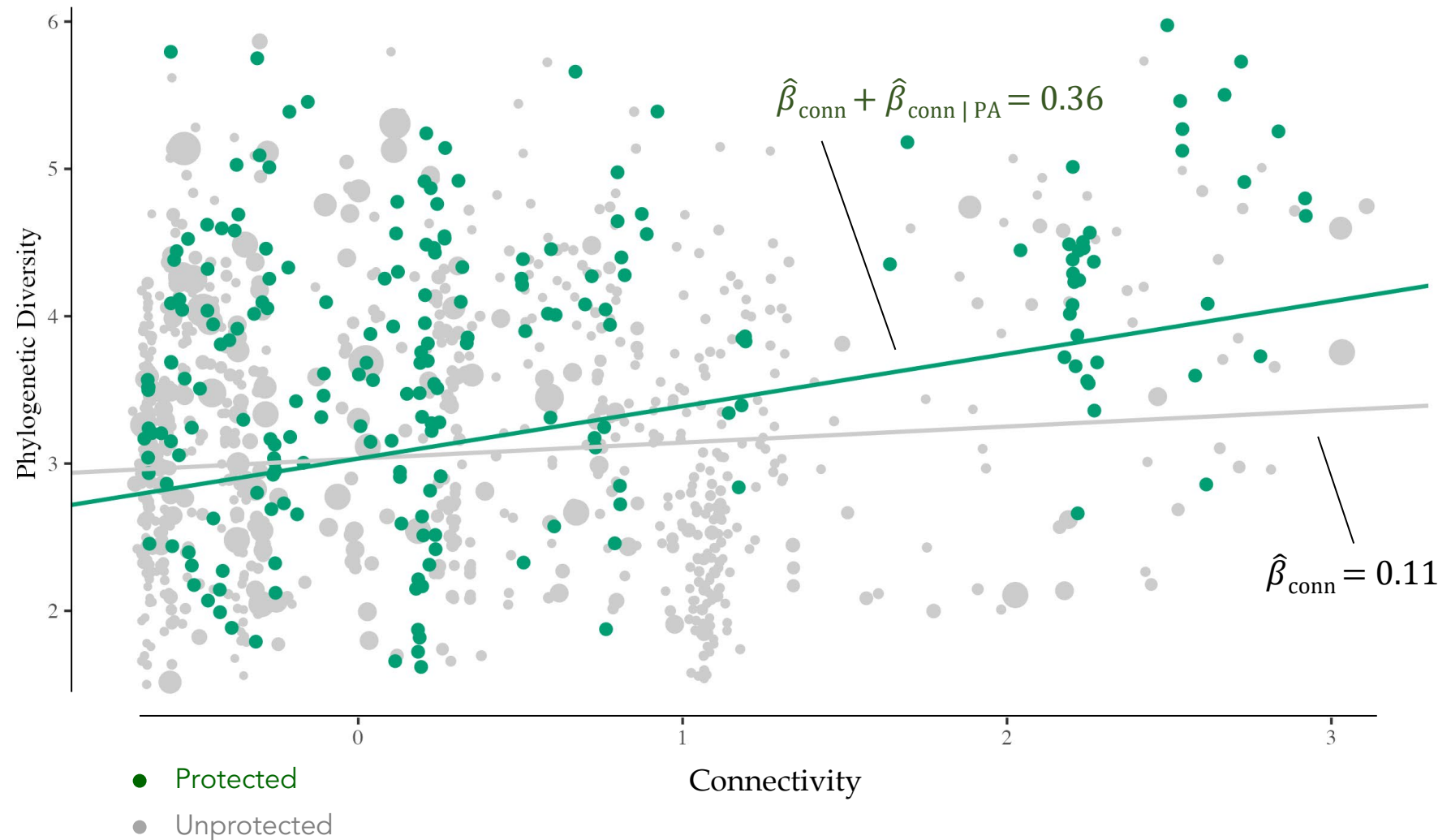
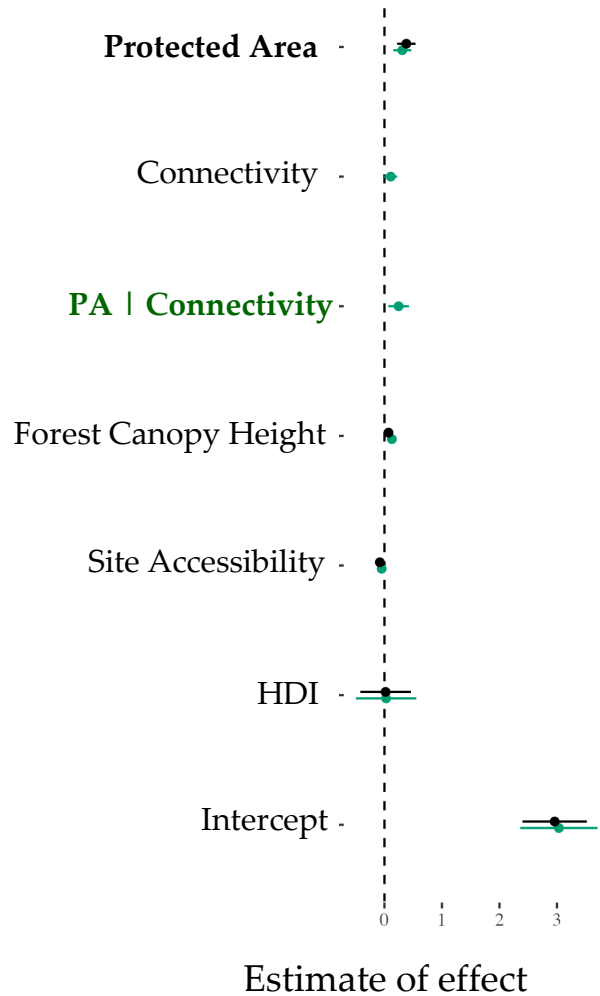
Introduce connectivity as a predictor of biodiversity and moderator of PA efficacy

$$AWFlux = \sum_{i=1}^n \sum_{j=1, i \neq j}^n \exp(-\theta * d_{ij}) \cdot a_i \cdot a_j$$



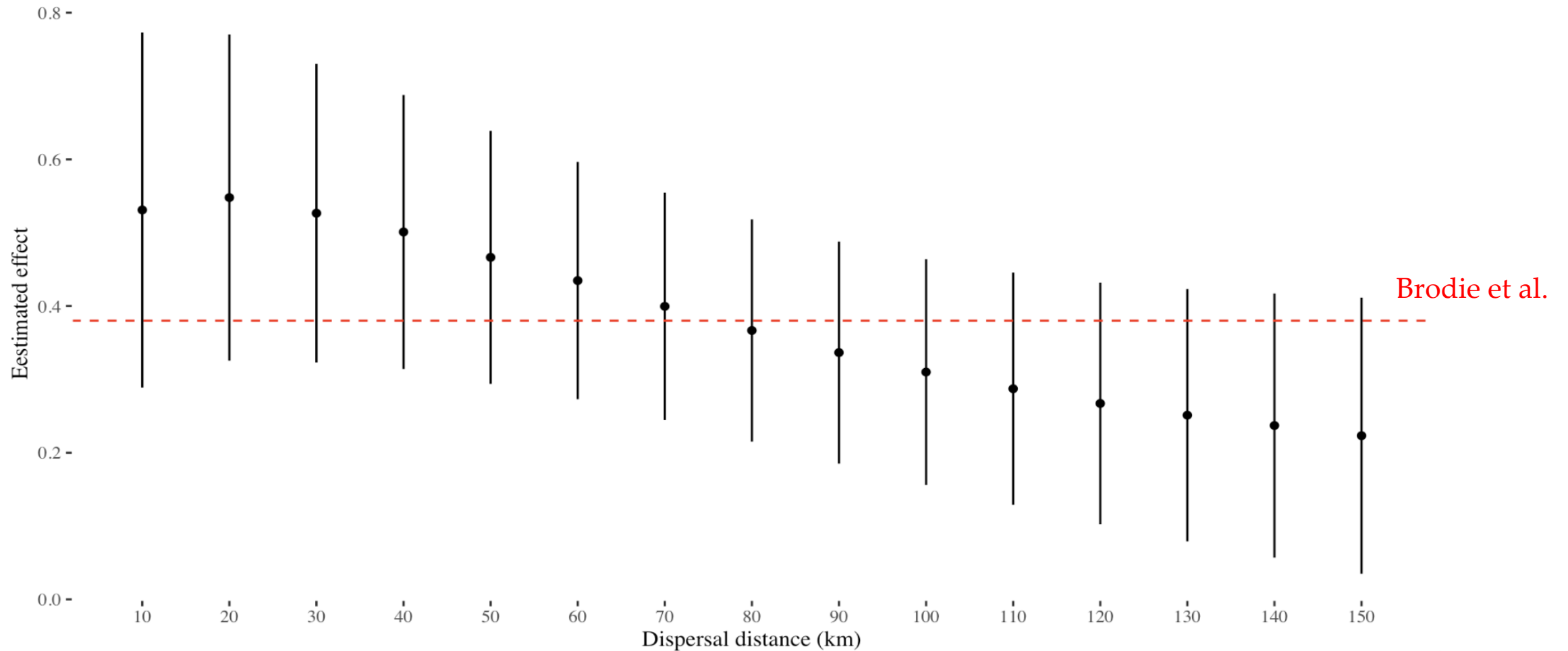
Connectivity Moderates PA Efficacy

On phylogenetic diversity, at a dispersal distance of 100km



Robustness Check of PA Efficacy

PA efficacy has some sensitivity to dispersal distance selection, but statistically indistinguishable



Further Modifications

Conducting additional analyses before pre-print publication and submission

Primary Findings

Extension	Identified potential direct and moderating effects of connectivity, while preserving protective effect of PA conservation
Reproduction	Computationally reproduced effect estimates and supported conclusion and internal validity of Brodie et al.

Ongoing Work

Corrections	Check adjustments & extensions of original procedure (e.g., outliers, DAG)
Spatial	Consider ways to address remaining spatial structure
Consistency	Consistent positive direct and moderating effects of connectivity were only observed for phylogenetic diversity of birds

Questions and Comments

The many paths we didn't explore, the researcher degrees of freedom we used



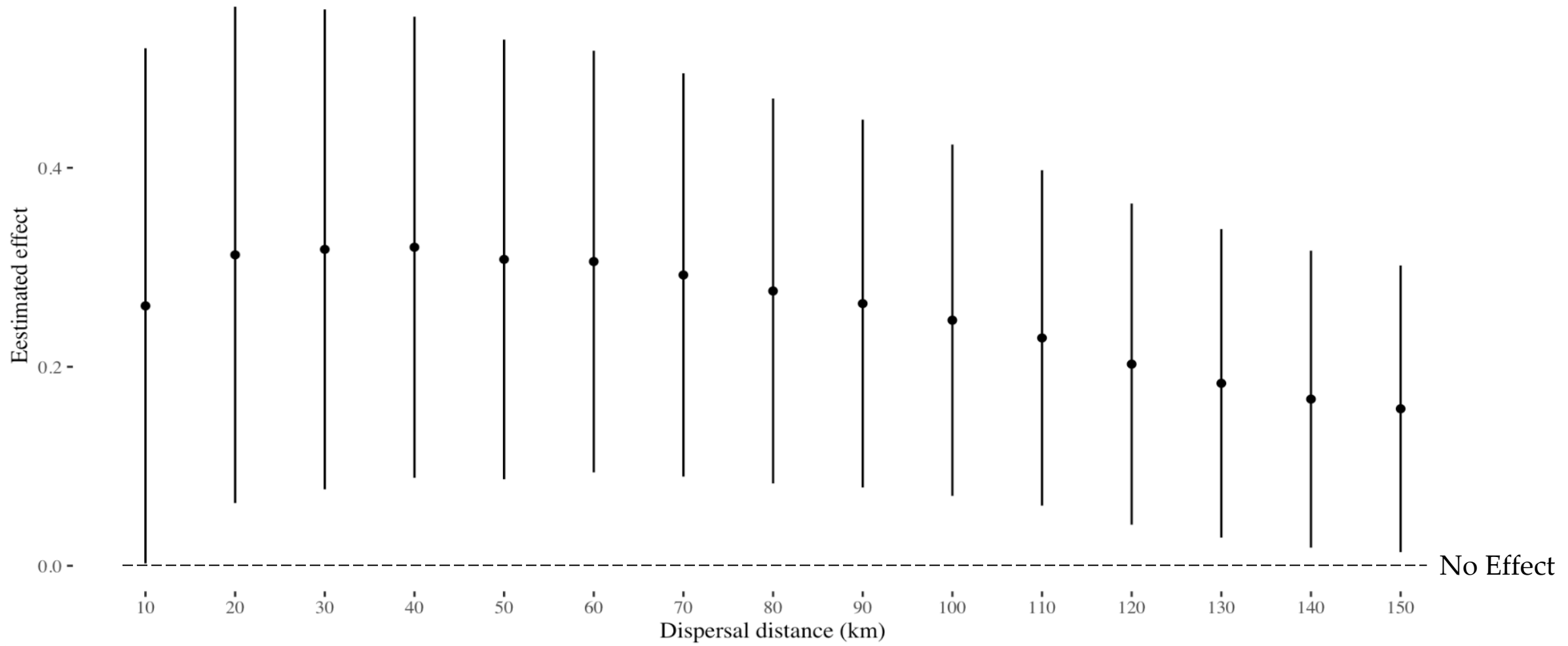
Please contact me at peterkedron@ucsb.edu for the data and code used in this analysis. Our GitHub repository is currently under development and quite messy. However, we should have a clean repository (with messy development history tracked through version control) available soon along with a preprint summarizing our findings.

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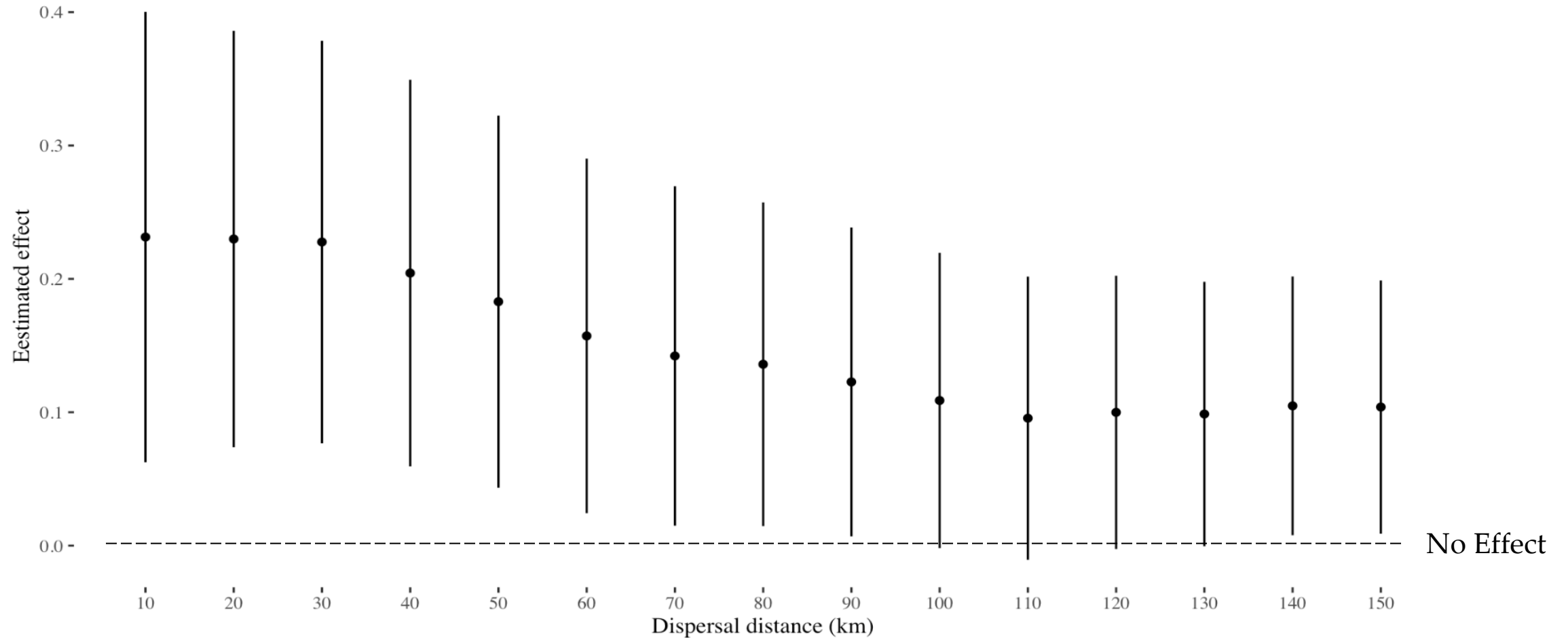
Robustness Check of PA Efficacy

The effect of connectivity is consistently positive across dispersal distances for Bird Phylogenetic Diversity



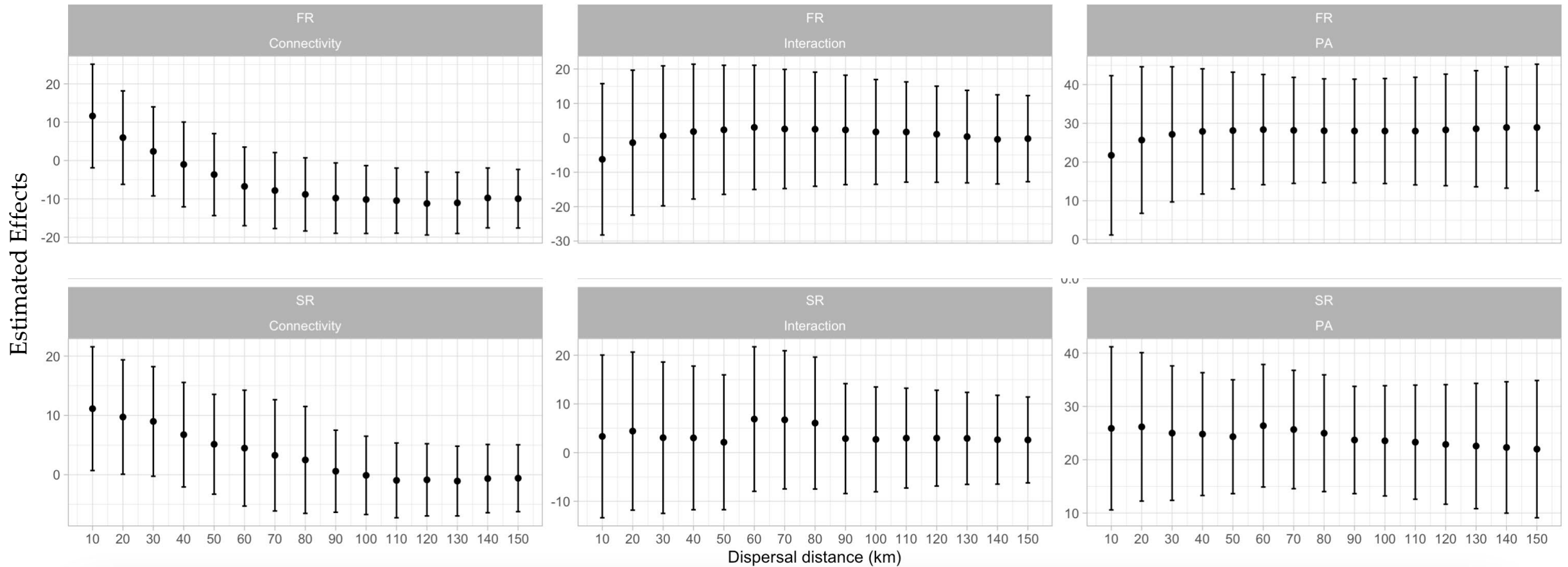
Robustness Check of Moderating Effect

The moderating effect of connectivity on PA is generally consistent across dispersal distances for Bird Phylogenetic Diversity

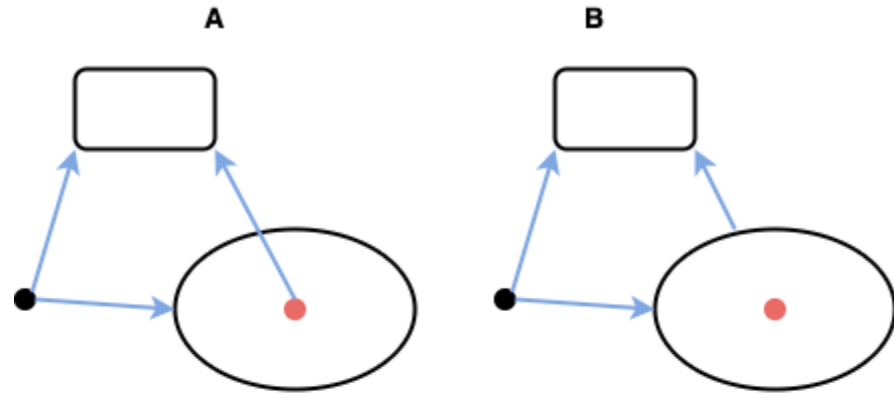


Further Robustness Checks

Inconsistency in effect estimates observed across dispersal distances for functional and species richness measures

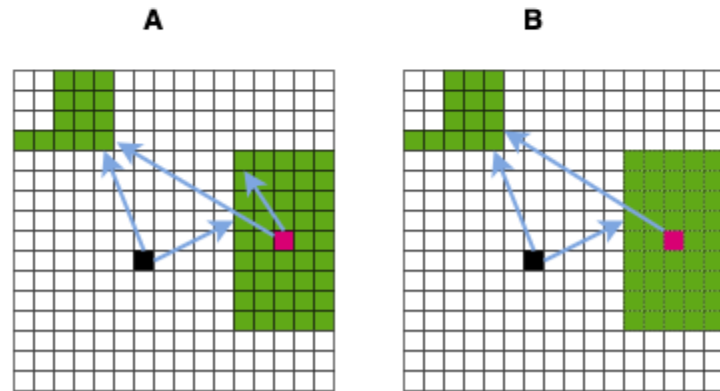


Vector-based method



Final flux value is the sum of the pixel (or intersected polygon) to all valid PA polygons. The area weighted flux is weighted by the area of valid PA polygons..

Raster-based method



Final flux value is the sum of the pixel to all valid PA pixels. The area weighted flux is weighted by number of valid PA pixels.

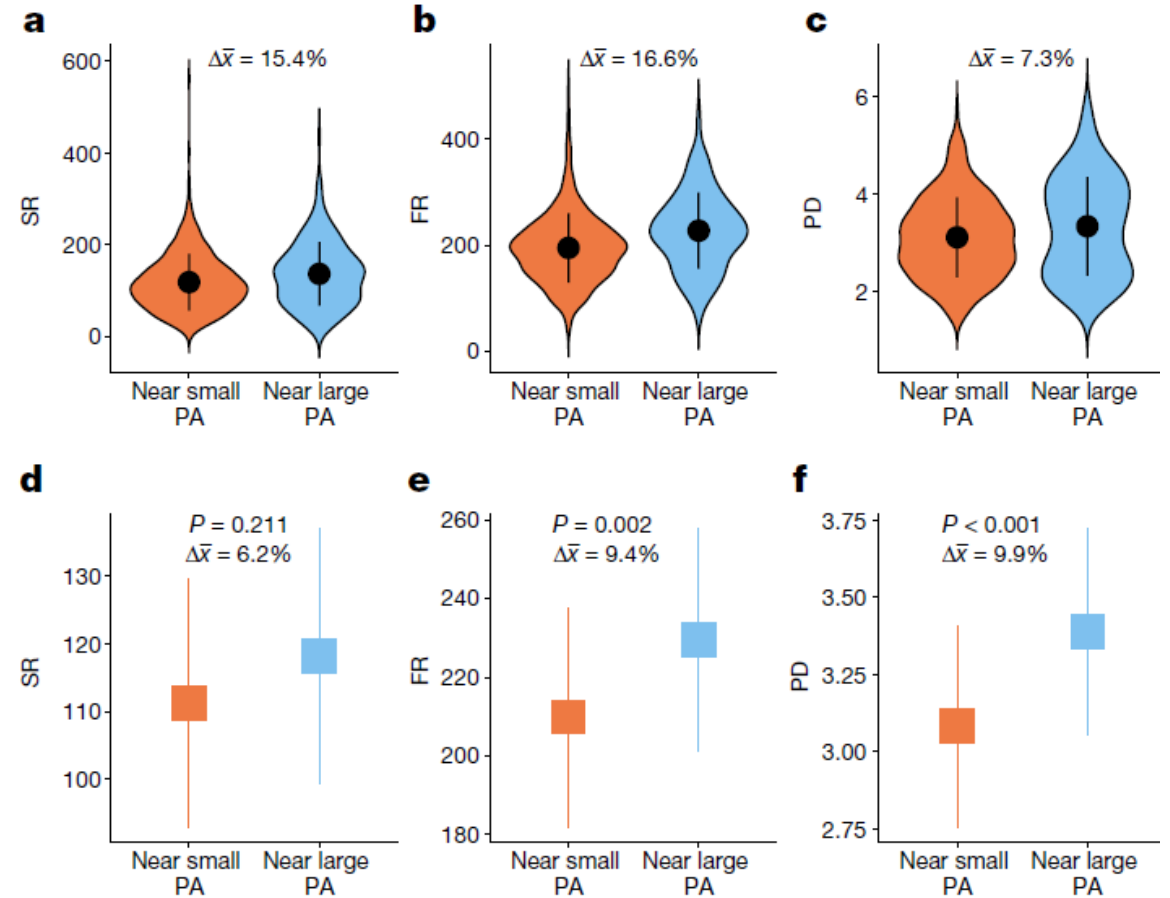


Fig. 5 | All facets of bird diversity outside PAs are higher near large PAs than near small PAs, but these differences are smaller than for mammals.