Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

# Dominated taxonomic and phylogenetic turnover but functional nestedness of wetland bird beta diversity in North China

Fan Yang[1], Zhuoen Liu[1], Guisheng Yang[1], and Gang Feng[1]

[1]Inner Mongolia University

June 9, 2022

## Abstract

Decomposition of taxonomic, phylogenetic, and functional beta diversity into their turnover and nestedness component could provide novel insight for biodiversity conservation, e.g., provide implications for the Single Large Or Several Small reserves debate (SLOSS debate). This study applied this beta diversity decomposition in wetland bird communities in North China, aiming to propose scientific and comprehensive suggestions for bird diversity conservation in this region. Paired t test was used to compare the differences between taxonomic, phylogenetic, functional turnover and their nestedness component. In addition, spearman correlation analysis was used to assess the associations between each explanatory variable and each beta diversity index. The results showed that taxonomic and phylogenetic beta diversity among wetland bird communities in North China was dominated by turnover, while functional beta diversity was dominated by nestedness. Importantly, the phylogenetic and functional results showed similar patterns even after control the effects of taxonomic beta diversity. In addition, the taxonomic and phylogenetic turnover was more associated with both climate variables and spatial distances than other component. The contrasting patterns between taxonomic, phylogenetic decomposition and functional decomposition of wetland bird communities in North China indicate that distinctive conservation strategies should be considered for different biodiversity dimensions. Specifically, the conservation of taxonomic and phylogenetic bird diversity in this region should focus on multiple wetlands, while the conservation of bird functional diversity should focus on single wetland with high functional diversity.

## Research Papers

## Dominated taxonomic and phylogenetic turnover but functional nestedness of wetland bird beta diversity in North China

Fan Yang[1#], Zhuoen Liu[2#], Guisheng Yang[1], Gang Feng[2*]

[1]School of Life Sciences, Inner Mongolia University, Hohhot 010070, China

[2]Ministry of Education Key Laboratory of Ecology and Resource Use of the Mongolian Plateau & Inner Mongolia Key Laboratory of Grassland Ecology, School of Ecology and Environment, Inner Mongolia University, Hohhot 010021, China

[*] Corresponding author: Gang Feng (qaufenggang@163.com; +86 13674881568)

Fan Yang and Zhuoen Liu contributed equally to this work.

## Abstract

Decomposition of taxonomic, phylogenetic, and functional beta diversity into their turnover and nestedness component could provide novel insight for biodiversity conservation, e.g., provide implications for the Single Large Or Several Small reserves debate (SLOSS debate). This study applied this beta diversity decomposition in wetland bird communities in North China, aiming to propose scientific and comprehensive suggestions

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

for bird diversity conservation in this region. Paired t test was used to compare the differences between taxonomic, phylogenetic, functional turnover and their nestedness component. In addition, spearman correlation analysis was used to assess the associations between each explanatory variable and each beta diversity index. The results showed that **t** axonomic and phylogenetic beta diversity among wetland bird communities in North China was dominated by turnover, while functional beta diversity was dominated by nestedness. Importantly, the phylogenetic and functional results showed similar patterns even after control the effects of taxonomic beta diversity. In addition, the taxonomic and phylogenetic turnover was more associated with both climate variables and spatial distances than other component. The contrasting patterns between taxonomic, phylogenetic decomposition and functional decomposition of wetland bird communities in North China indicate that distinctive conservation strategies should be considered for different biodiversity dimensions. Specifically, the conservation of taxonomic and phylogenetic bird diversity in this region should focus on multiple wetlands, while the conservation of bird functional diversity should focus on single wetland with high functional diversity.

**Key words:**biodiversity conservation; functional diversity; nestedness; phylogenetic diversity; turnover; wetland bird diversity.

## Introduction

Wetland ecosystems are of crucial importance in terms of both harboring extremely high biodiversity and providing valuable ecosystem functioning and services (Reid et al. 2019; Tickner et al. 2020; Albert et al. 2021). Although only covering very low proportion (less than 1%) of the Earth's surface, the wetland ecosystems are home of about one-third of vertebrate species and many species of other groups (Strayer and Dudgeon 2010; Fricke et al. 2019; Tickner et al. 2020). 2.In addition, the wetland ecosystems could sequester and store high proportion of carbon, and play an important role in mitigating the accelerated climate change (Mitsch et al. 2013). Lastly, the wetland ecosystems also provide many other ecosystem services, e.g., human health, cultural and educational services (Albert et al. 2021).

However, the unprecedented global changes in the Anthropocene, including climate change, land use changes, invasion and pollution, have posed great threat and damage to the wetland ecosystems (Reid et al. 2019; WWF 2020). Specifically, the wetland ecosystems are disappearing at a rate three times faster than the forest ecosystems (Gardner and Finlayson 2018; Tickner et al. 2020). Compared with the terrestrial and marine ecosystems, the freshwater Living Planet Index has fallen more steeply from 1970 to 2016, declined by 84% (ranges from 77% to 89%), about 4% per year since 1970 (WWF 2020). There is also higher proportion of freshwater associated threatened vertebrate species, according to the International Union for Conservation of Nature Red List (Ricciardi and Rasmussen 1999; Collen et al. 2014).

Consistent with these global patterns, China's lakes are also experiencing dramatic changes in the past decades (Tao et al. 2015; Jeelani et al. 2020; Tao et al. 2020). Notably, most of China's lakes are distributed in North China, i.e., Heilongjiang, Inner Mongolia, Xinjiang, Qinghai, and Tibet provinces (Jeelani et al. 2020; Mao et al. 2020). More importantly, both number and area of lakes in these regions have decreased significantly in the past decades, mainly driven by anthropogenic activities, e.g., irrigation and mining (Tao et al. 2015, 2020). These massive changes would have serious adverse effects on the wetlands biodiversity as well as ecosystem functioning and services. However, so far few studies have investigated biodiversity distribution patterns in these lakes, especially from perspective of phylogenetic and functional beta diversity (including the turnover and nestedness component), which could provide novel insight for the biodiversity conservation (Baselga 2010; Baselga and Orme 2012; Li et al. 2021b).

Compared with taxonomic diversity, which treats different species as ecological equivalent, phylogenetic diversity and functional diversity could reflect the evolutionary and functional differences among species, respectively (Swenson 2011; Liang et al. 2019). In addition, beta diversity could also be decomposed into turnover and nestedness, which mean the species replacement and species gain or less between biotic communities, respectively (Baselga 2010; Baselga and Orme 2012). The relative importance of turnover and nestedness could inform strategies for biodiversity conservation. Specifically, the dominance of turnover sug-

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

gests that different sites or communities need to be protected, while the dominance of nestedness emphasizes the need of protection of a single important site or community (Baselga and Orme 2012; Li et al. 2021b).

Therefore, to better conserve wetland bird diversity in North China, this study will assess the turnover and nestedness component of bird communities among different wetlands in this region. We aim to (a) test if the phylogenetic and functional decomposition of beta diversity shows consistent patterns with taxonomic decomposition; (b) how is the taxonomic, phylogenetic, and functional beta diversity component affected by climate differences and spatial distances? (c) provide comprehensive and scientific suggestions for wetlands bird diversity conservation in North China.

## Materials and Methods

### 2.1 Bird community data in wetlands in North China

Bird community data in wetlands in North China was collected from published scientific papers. These papers were selected and downloaded from xueshu.baidu.com, which includes databases of both English and Chinese scientific journals. "wetland bird diversity", "river bird diversity", and "lake bird diversity" were the keywords used for the searching of these related papers. Only the papers with bird investigations lasting more than one year (or covering at least four seasons) were kept for further diversity analyses to ensure sufficient sampling efforts. Finally, bird community data of 38 wetlands from 34 papers was kept (Fig. 1).

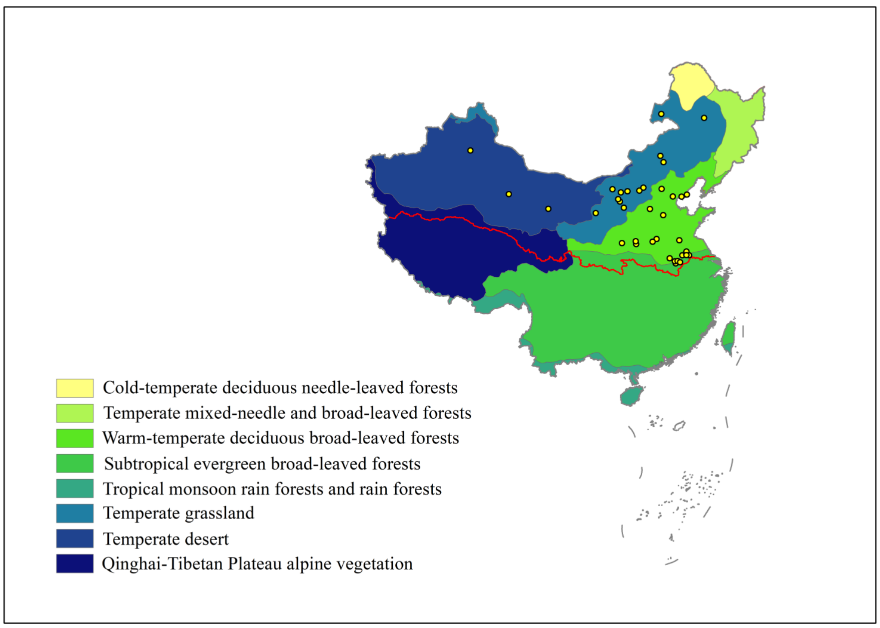


**Figure 1.** Distribution of the 38 wetlands (yellow points) in North China. The red line is the border of North and South China.

### 2.2 Functional traits and phylogeny

Body size, trophic level and habitat specificity of the 438 breeding birds found in the 38 wetlands were used for the functional diversity analyses. These key functional traits are closely related with birds' energy requirements, resource utilization, sensitivity to habitat change. Gower's distances (could deal with both continuous and categorical traits) of these traits among all pairs of species were used to represent the functional dissimilarity of all species pairs. The functional distance matrix was then used in a principal coordinate analysis (PCoA). And a matrix composed by the first three axes of the PCoA was finally used to calculate the functional diversity.

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

A phylogeny including 432 breeding birds (six species could not be found) was built from a global bird phylogeny (Jetz et al. 2014). The option of 'Hackett All Species: a set of 10,000 trees with 9,993 OUTs each' was selected. 5,000 trees from the pseudo-posterior distribution were then sampled and a maximum clade credibility tree using mean node heights was calculated in TreeAnnotator in BEAST package (Bouckaert et al., 2014).

**2.3 Environmental variables**

Contemporary climate variables of each wetland, including mean annual precipitation (MAP) and mean annual temperature (MAT), were collected from WorldClim database (https://www.worldclim.org/; Hijmans et al. 2005). The Euclidean distances of the MAT and MAP were used to represent the environmental filtering. The spatial distances among all wetland pairs were calculated to represent the dispersal limitation.

**2.4 Statistics**

Taxonomic, functional, and phylogenetic beta diversity as well as their turnover and nestedness component was calculated based on pairwise-site dissimilarity methods, using the Sorensen index (Baselga, 2013). To control the effects of taxonomic beta diversity on functional and phylogenetic beta diversity, the standardized effect size (SES) of functional and phylogenetic beta diversity was also calculated using the following formula:

$\mathrm{SES}_{beta} = (\mathrm{beta}_{obs} - \mathrm{mean}(\mathrm{beta}_{rnd}))/\mathrm{sd}(\mathrm{beta}_{rnd})$

Where $\mathrm{beta}_{obs}$ is the observed functional/phylogenetic beta diversity (includes their turnover and nestedness component); $\mathrm{beta}_{rnd}$ is the functional/phylogenetic beta diversity (includes their turnover and nestedness component) of null modeled bird communities (randomly shuffle species labels in bird community data while maintain species richness and species numbers shared among bird communities for 999 times).

Paired t test was used to compare the differences between taxonomic turnover and taxonomic nestedness, between functional turnover and functional nestedness, between phylogenetic turnover and phylogenetic nestedness, between standardized functional turnover and standardized functional nestedness, as well as between standardized phylogenetic turnover and standardized phylogenetic nestedness. Spearman correlation analysis was used to assess the associations between each explanatory variable and each beta diversity index.

**Results**

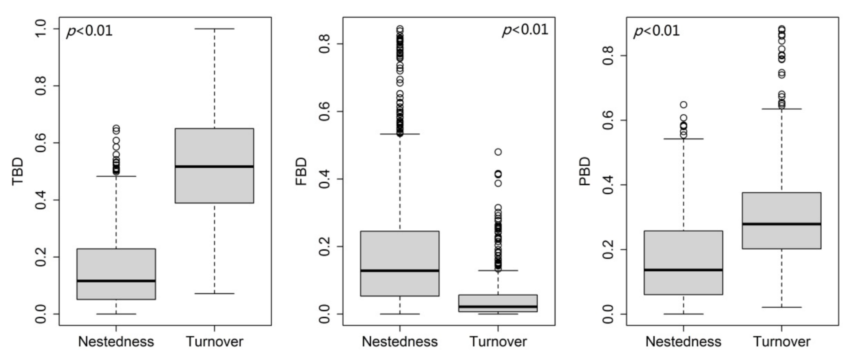


**Figure 2.** Results of paired t-test of taxonomic (TBD), functional (FBD), phylogenetic (PBD) turnover against their nestedness component.

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

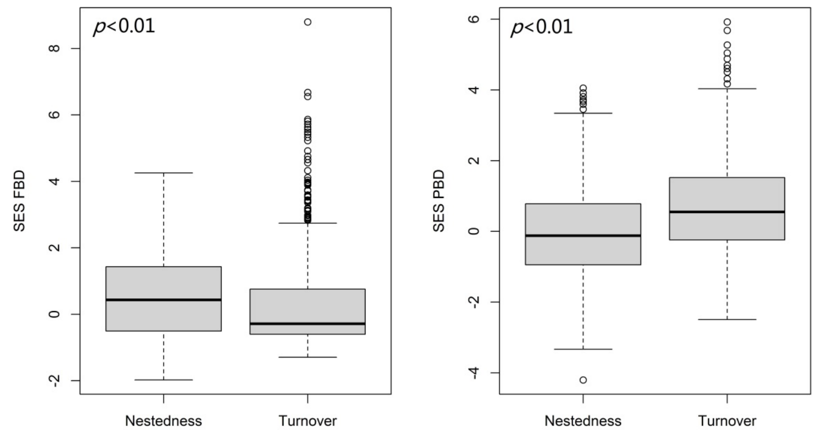


**Figure 3.** Results of paired t test of standardized functional (SES FBD), standardized phylogenetic (SES PBD) turnover against their nestedness component.

### 3.1 Comparisons of taxonomic, functional, phylogenetic turnover against their nestedness component

The mean pairwise taxonomic beta diversity was 0.68, while the mean taxonomic turnover component was 0.52 and the mean taxonomic nestedness component was 0.15. The mean pairwise functional beta diversity was 0.24, while the mean functional turnover component was 0.04 and the mean functional nestedness component was 0.19. The mean pairwise phylogenetic beta diversity was 0.47, while the mean phylogenetic turnover component was 0.30, and the mean phylogenetic nestedness component was 0.17.

Paired t test showed that taxonomic turnover was significantly higher than taxonomic nestedness (t=33.95, p<0.01, mean differences=0.37); phylogenetic turnover was also significantly higher than phylogenetic nestedness (t=13.69, p<0.01, mean differences=0.12); but functional turnover was significantly lower than functional nestedness (t=-18.80, p<0.01, mean differences=0.15, Fig. 2). The standardized functional and phylogenetic beta diversity showed similar patterns (Fig. 3). Specifically, the standardized phylogenetic turnover was also significantly higher than the standardized phylogenetic nestedness (t=7.82, p<0.01, mean differences=0.70); but standardized functional turnover was significantly lower than standardized functional nestedness (t=-3.38, p<0.01, mean differences=0.30, Fig. 3).

### 3.2 Associations between different beta diversity component and explanatory variables

Spearman correlation analysis indicated that taxonomic and phylogenetic turnover was significantly and positively correlated with the three explanatory variables, while functional turnover was poorly associated with the explanatory variables (Table 1). In addition, taxonomic nestedness was significantly but negatively correlated with the explanatory variables, while functional nestedness was significantly but positively correlated with the climate variables (Table 1).

**Table 1.** Spearman correlations between explanatory variables and taxonomic (TBD), functional (FBD), phylogenetic (PBD) turnover and nestedness. MAT is differences in mean annual temperature; MAP is differences in mean annual precipitation; Dispersal is spatial distance.$^{*}$, $p < 0.05$; $^{**}$,$p < 0.01$.

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

| | TBD | TBD | FBD | FBD | PBD | PBD |
|---|---|---|---|---|---|---|
| | Turnover | Nestedness | Turnover | Nestedness | Turnover | Nestedness |
| MAT | $0.45^{**}$ | $-0.08^{*}$ | -0.03 | $0.10^{**}$ | $0.41^{**}$ | 0.01 |
| MAP | $0.54^{**}$ | $-0.11^{**}$ | 0.04 | $0.14^{**}$ | $0.47^{**}$ | 0.04 |
| Dispersal | $0.43^{**}$ | $-0.10^{**}$ | 0.01 | 0.05 | $0.35^{**}$ | -0.01 |

## Discussion

Being the first study on the decomposition of turnover and nestedness component of wetland bird beta diversity in North China, the results showed that taxonomic and phylogenetic beta diversity of bird communities among 38 wetlands was dominated by turnover, while functional beta diversity was dominated by nestedness. Notably, the phylogenetic and functional patterns did not change even after control the effects of taxonomic beta diversity. In addition, the taxonomic and phylogenetic turnover was highly associated with both climate differences and spatial distances.

### 4.1 Higher taxonomic and phylogenetic turnover, but lower functional turnover

Higher taxonomic and phylogenetic turnover than their nestedness component indicated that changes of wetland bird community composition in North China were mainly driven by species and lineage replacement, rather than species and lineage loss (Naka et al. 2020; Li et al. 2021b). This finding suggests that conservation of all wetlands is needed to protect the bird taxonomic and phylogenetic diversity in this region (Baselga 2010; Li et al. 2021b). In contrast, the lower functional turnover than functional nestedness indicated that changes of wetland bird functional composition were mainly caused by functional diversity loss, rather than functional replacement (Li et al. 2021ab). Therefore, a different conservation strategy is needed for protecting the wetlands bird functional diversity in North China, i.e., to protect the few wetlands with high functional diversity (Baselga 2010; Li et al. 2021b).

Our results were consistent with many previous studies (Naka et al. 2020; Li et al. 2021ab). For example, a study about plant diversity in Inner Mongolia grassland also found that the taxonomic and phylogenetic beta diversity was dominated by turnover, while functional beta diversity was dominated by nestedness, emphasizing the necessity of different conservation strategies for different biodiversity dimensions (Li et al. 2021b). Dominated taxonomic replacement and functional nestedness was also found for waterbird communities across anthropogenic subsidence wetlands in North China Plain, suggesting that the taxonomic turnover maybe mainly driven by functionally redundant species (Li et al. 2021a). In addition, an avian study in riparian Amazonian habitats also found dominated taxonomic and phylogenetic replacements, highlighting the crucial role of transition zones and ecotones for avian taxonomic and phylogenetic diversity conservation (Naka et al. 2020).

### 4.2 Better explained taxonomic and phylogenetic turnover

Distribution patterns of beta diversity are mainly shaped by two mechanisms, i.e., environmental filtering and dispersal limitation (Shen et al. 2009; Daniel et al. 2019; Li et al. 2021b). These two mechanisms are usually represented by climate differences and spatial distances at large scales (Chi et al. 2014; Li et al. 2021b). The results in this study showed that the dominated taxonomic turnover and phylogenetic turnover was highly associated with temperature and precipitation differences as well as spatial distances, indicating that both environmental filtering and dispersal limitation have affected the bird diversity distributions in wetlands in North China. Consistent with this finding, the study in riparian Amazonian habitats also found that taxonomic replacement and phylogenetic replacement was significantly correlated with the climate gradient (Naka et al. 2020). In contrast to the high associations between explanatory variables and taxonomic, phylogenetic turnover, the low correlations between functional beta diversity and each predictor as well as

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

the relatively lower functional beta diversity (in terms of both turnover and nestedness component) may suggest that the strong environmental filtering in North China has left significant legacy on the functional diversity of wetland bird communities in this region.

## Conclusions

North China has most of China's lakes, which have decreased in terms of both number and area in the past decades due to both climate change and anthropogenic activities, e.g., irrigation and mining (Tao et al. 2015, 2020). These changes in lakes would further affect their high biodiversity, indicating the importance of scientific biodiversity conservation in this region. The contrasting patterns of decomposition of taxonomic, phylogenetic and functional beta diversity suggest that different conservation strategies should be implemented to protect the multiple dimension of bird diversity in North China. The high associations between climate differences and taxonomic and phylogenetic turnover also indicate that the adverse effects of future climate change on bird diversity should also be considered for the biodiversity conservation in this region.

## Acknowledgments

GF was supported by the National Key R&D Program of China (2019YFA0607103) and the National Natural Science Foundation of China (41861004).

## Competing interests

The authors declare that they have no competing interests

## References

Albert SJ, Destouni G, Duke-Sylvester MS, Magurran EA, Oberdorff T, Reis ER, et al. Scientists' warning to humanity on the freshwater biodiversity crisis. Ambio. 2021;50(1):85-94.

Baselga A. Partitioning the turnover and nestedness components of beta diversity. Global Ecol Biogeogr. 2010;19:134-143.

Baselga A, Orme CDL. betapart: An R package for the study of beta diversity. Methods Ecol Evol. 2012;3:808-812.

Baselga A. Separating the two components of abundance-based dissimilarity: balanced changes in abundance vs. abundance gradients. Methods Ecol Evol. 2013;4:552–557.

Bouckaert R, Heled J, Kuehnert D, Vaughan T, Wu CH, Xie D, et al. BEAST 2: A software platform for Bayesian evolutionary analysis. PLoS Comput Biol. 2014;10(4):e1003537.

Chi XL, Tang ZY, Fang JY. Patterns of phylogenetic beta diversity in China's grasslands in relation to geographical and environmental distance. Basic Appl Ecol. 2014;15:416-425.

Collen B, Whitton F, Dyer EE, Baillie EMJ, Cumberlidge N, Darwall RTW, et al. Global patterns of freshwater species diversity, threat and endemism. Global Ecol Biogeogr. 2014;23:40-51.

Daniel J, Gleason JE, Cottenie K, Rooney RC. Stochastic and deterministic processes drive wetland community assembly across a gradient of environmental filtering. Oikos. 2019;128:1158-1169.

Fricke R, Eschmeyer W, Laan RVD. Catalog of fishes: Genera, species, references. California Academy of Sciences; 2019.

Gardner RC, Finlayson C. Global Wetland Outlook: State of the World's Wetlands and Their Services to People. Ramsar Convention Secretariat. 2018;9:89.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. Very high resolution interpolated climate surfaces for global land areas. Int J Climatol. 2005;25(15): 1965-1978.

Posted on Authorea 9 Jun 2022 — The copyright holder is the author/funder. All rights reserved. No reuse without permission. — https://doi.org/10.22541/au.165477260.05314847/v1 — This a preprint and has not been peer reviewed. Data may be preliminary.

Jeelani N, Yang W, Xia L, Zhu HL, An S. Ecosystem threats and management strategies for wetlands in China. Mar Freshw Res. 2020;71:1557-1563.

Jetz W, Thomas HG, Joy BJ, Redding WD, Hartmann K, Mooers OA. Global distribution and conservation of evolutionary distinctness in birds. Curr Biol. 2014;24(9):919-930.

Li C, Wang X, Zhang B, Cui P, Feng G, Svenning JC. Decomposing multiple β-diversity reveals non-random assembly of the waterbird communities across anthropogenic subsidence wetlands. Divers Distrib. 2021a;00:1-12.

Li F, Yan Y, Zhang J, Zhang Q, Niu J. Taxonomic, functional, and phylogenetic beta diversity in the Inner Mongolia grassland. Global Ecol Conserv. 2021b;28:e01634.

Liang C, Yang G, Wang N, Feng G, Yang F, Svenning JC, et al. Taxonomic, phylogenetic and functional homogenization of bird communities due to land use change. Biol Conserv. 2019;236:37-43.

Mao D, Wang Z, Du B, Li L, Tian Y, Jia M, et al. National wetland mapping in china: a new product resulting from object-based and hierarchical classification of landsat 8 oli images. ISPRS J Photogramm. 2020;164:11-25.

Mitsch JW, Bernal B, Nahlik MA, Mander U, Zhang L, Anderson JC, et al. Wetlands, carbon, and climate change. Landscape Ecol. 2013;28(4):583-597.

Naka LN, Laranjeiras TO, Rodrigues Lima G, Plaskievicz A, Pinto F, Gonçalves-Souza T. Climate as a major driver of avian diversity in riparian Amazonian habitats along an environmental gradient. J Biogeogr. 2020;47:2328-2340.

Reid JA, Carlson KA, Creed FI, Eliason JE, Gell AP, Johnson TJP, et al. Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol Rev. 2019;94:849-873.

Ricciardi A, Rasmussen JB. Extinction rates of North American freshwater fauna. Conserv Biol. 1999;13:1220-1222.

Shen G, Yu M, Hu X, Mi X, Ren H, Sun IF, et al. Species-area relationships explained by the joint effects of dispersal limitation and habitat heterogeneity. Ecology. 2009;90:3033-3041.

Strayer LD, Dudgeon D. Freshwater biodiversity conservation: Recent progress and future challenges. J N Am Benthol Soc. 2010;29:344-358.

Swenson, GN. Phylogenetic beta diversity metrics, trait evolution and inferring the functional beta diversity of communities. PLoS One. 2011;6:e21264-e21264.

Tickner D, Opperman JJ, Abell R, Acreman M, Arthington HA, Bunn ES, et al. Bending the curve of global freshwater biodiversity loss-an emergency recovery plan. BioScience. 2020;70(4):330-342.

Tao S, Fang J, Zhao X, Zhao S, Shen H, Hu H, et al. Rapid loss of lakes on the Mongolian plateau. Proc Natl Acad Sci USA. 2015;112:2281-6.

Tao S, Fang J, Ma S, Cai Q, Xiong X, Tian D, et al. Changes in China's lakes: climate and human impacts. Natl Sci Rev. 2020;7(1):132-140.

Almond REA, Grooten M, Petersen T. WWF (2020) Living Planet Report 2020-Bending the curve of biodiversity loss. WWF, Gland, Switzerland