Depth diversity gradients of macrophytes: shape, drivers and recent shifts

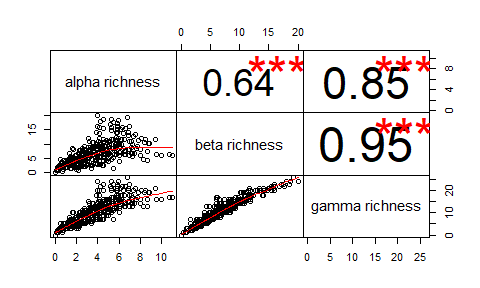
Supporting information I

22 December 2020

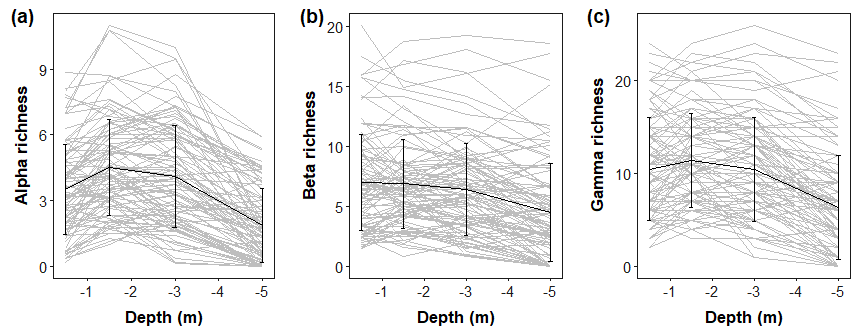
Table of Contents

# Depth diversity gradients (DDG) of macrophytes: shape

## Correlations between richness components

 Figure 1: Correlations between diversity metrices (method = pearson). Significance levels of p-values: \*p<0.1;\*\*p<0.05;\*\*\*p<0.01

## DDG of all field campaigns

 Figure 2: Depth diversity gradients of macrophytes for alpha (a), beta (b) and gamma richness (c) with mean as black line and sd as black bars. Each single grey line is one field campaign (lake\*year).

## DDG per lake

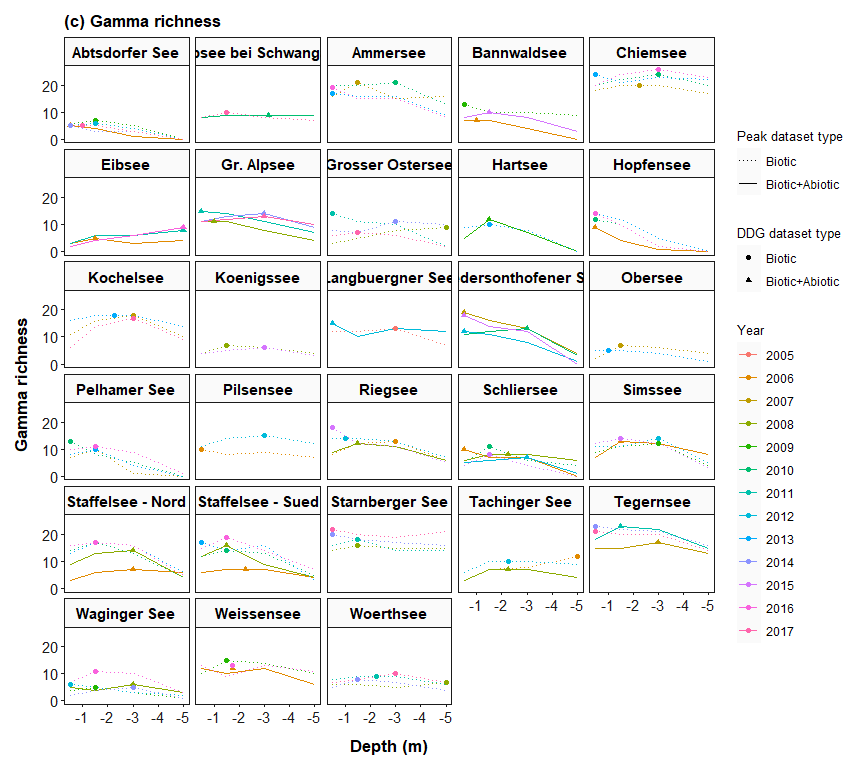
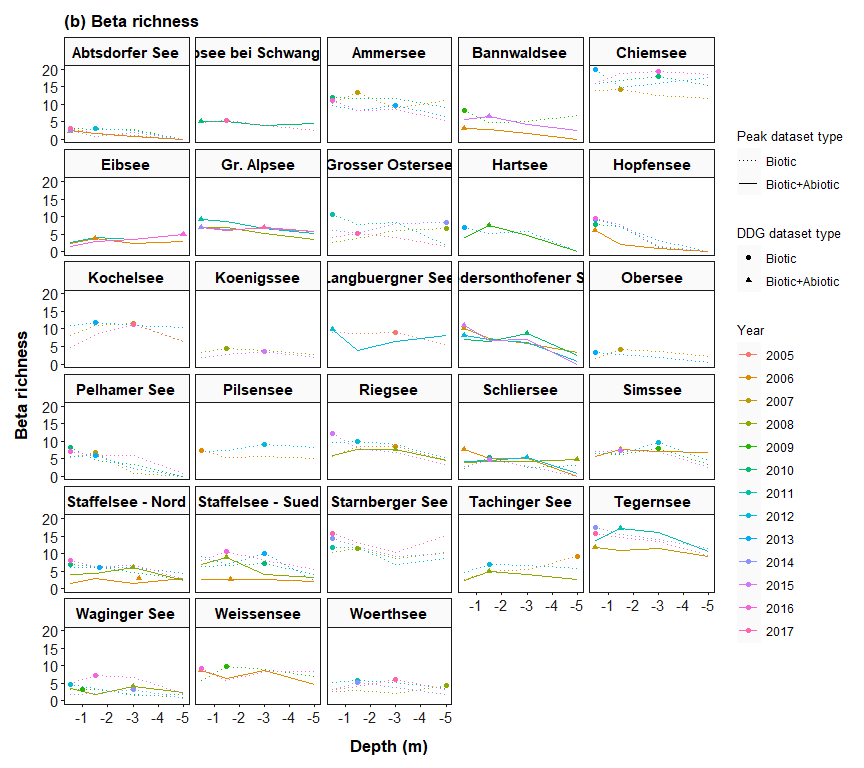
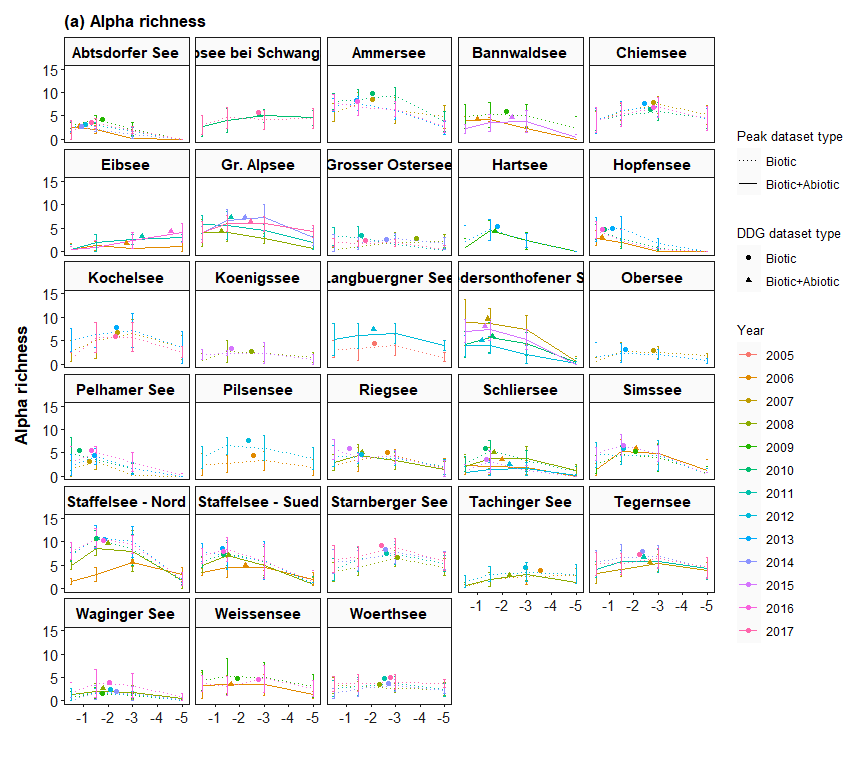
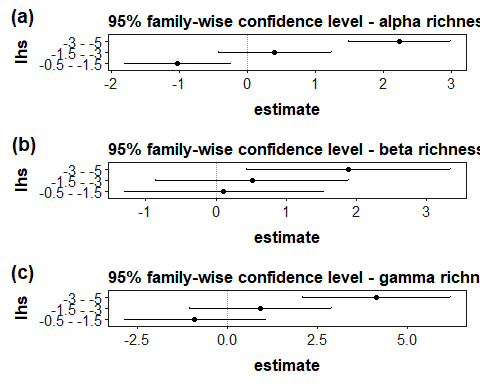


Figure 3: DDG of submerged macrophytes for alpha (a), beta (b) and gamma richness (c). For alpha richness, lines show the mean alpha richness per lake and year with their corresponding standard deviation; the single richness peaks (=DGG measures) are depicted as points. The different dataset levels can be distinguished by line type and point shape. Points and dashed line: Biotic dataset of all available macrophyte mapping (biodiversity dataset); triangles and solid line: subset of biotic dataset, where also abiotic data is available (environmental & biodiversity dataset).

## Herberich test

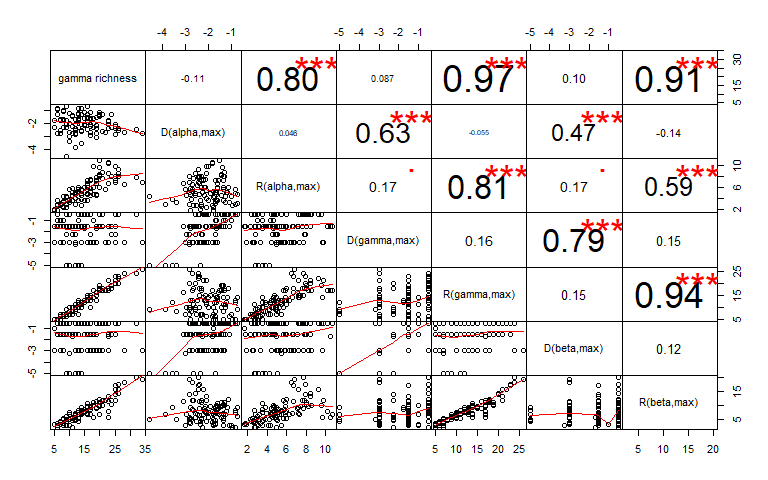
 Figure 4: Simultaneous tests for linear models with multiple comparisons of means using Tukey contrasts that are robust under non-normality, heteroscedasticity and variable sample size (Herberich et al. 2010) to check significant differences between depths within richness components. Results are plotted for alpha richness (a), beta richness (b) and gamma richness(c).

## DDG pattern types

Table 1: Overview about DDG patterns of decreasing curves, hump-shaped curves (different peak depths) and increasing curves. Shows number of field campaigns (lake\*year) showing a distinct depth pattern for each richness component.

## Decreasing curve (Peak: >-1m) Hump-shaped (Peak: -1- -2m)  
## Alpha\_N 6 41  
## Beta\_N 40 31  
## Gamma\_N 26 39  
## Hump-shaped (Peak: -2- -4m) Increasing curve (Peak: <-4m)  
## Alpha\_N 52 1  
## Beta\_N 22 7  
## Gamma\_N 30 5

## Correlations between DDG metrices

 Figure 5: Pearson correlations between DDG measures of different species richness components. Significance levels of p-values: \*p<0.1;\*\*p<0.05;\*\*\*p<0.01

## Chi-square test of DDG pattern

Chi-square is done to see siginificant differences in frequency among the DDG pattern types (Table 1) to see if they are significantly different for each richness component.

##   
## Pearson's Chi-squared test with simulated p-value (based on 2000  
## replicates)  
##   
## data: PEAKCLASS  
## X-squared = 44.078, df = NA, p-value = 0.0004998

# Depth diversity gradients of macrophytes: drivers

## Data representativeness of nested subsets

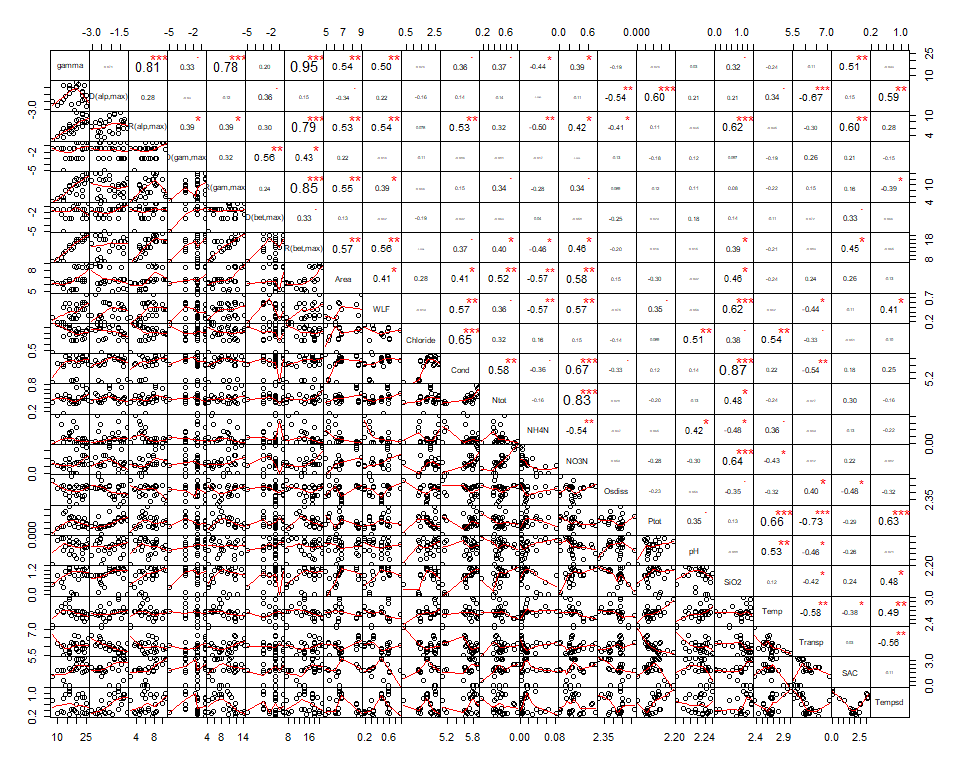
To show that the diversity metrics of the environmental & biodiversity dataset are representative for the diversity metrics of biodiversity dataset we applied the PERMANOVA test adonis2, using the R package ‘vegan’ which compares centroids and the variance (Oksanen et al. 2019). A non-significant result (p>0.05) confirms that centroids and variance of two groups are not different. The results show that the Environmental & biodiversity dataset (N=27) is representative for the Biodiversity dataset (N=100).

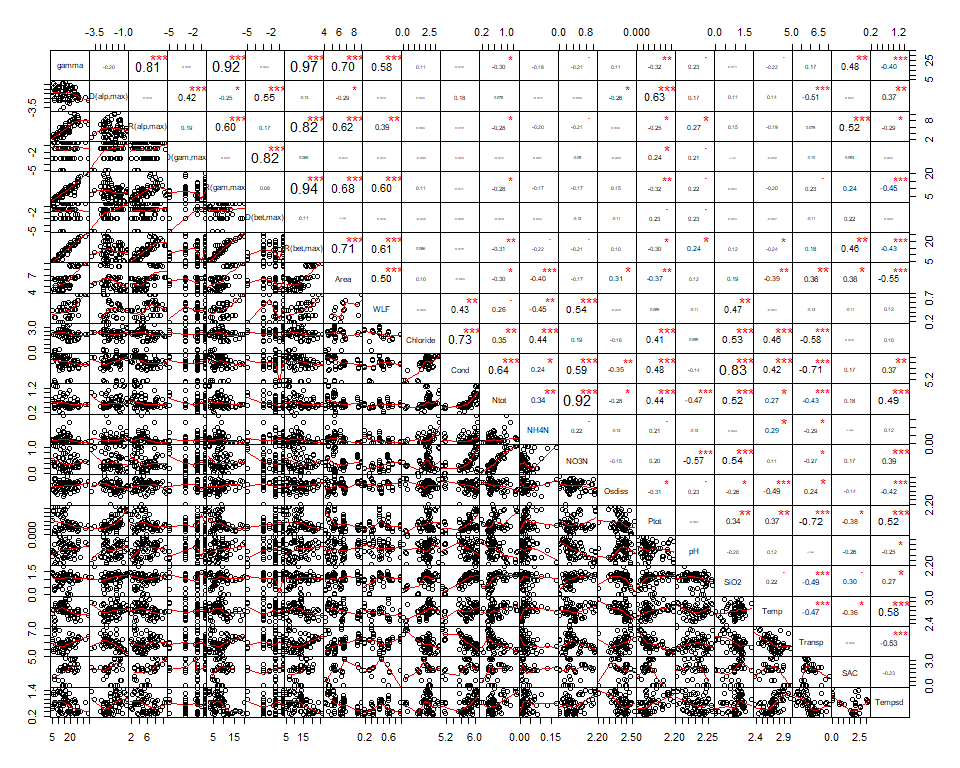
## Permutation test for adonis under reduced model  
## Permutation: free  
## Number of permutations: 999  
##   
## adonis2(formula = PEAK[, c(3, 5)] ~ datasettotsimpl, data = PEAK, by = NULL)  
## Df SumOfSqs R2 F Pr(>F)  
## Model 1 0.871 0.00663 0.6545 0.551  
## Residual 98 130.361 0.99337   
## Total 99 131.231 1.00000

## Permutation test for adonis under reduced model  
## Permutation: free  
## Number of permutations: 999  
##   
## adonis2(formula = (PEAK[, c(14, 15)]) ~ datasettotsimpl, data = PEAK, by = NULL)  
## Df SumOfSqs R2 F Pr(>F)  
## Model 1 0.1690 0.02018 2.0189 0.131  
## Residual 98 8.2047 0.97982   
## Total 99 8.3738 1.00000

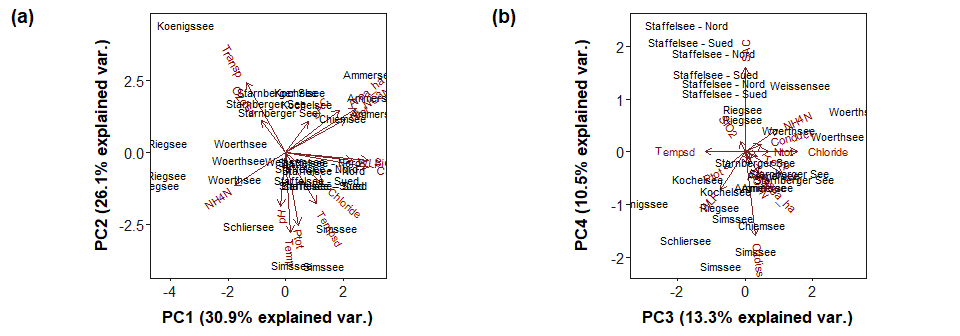
## Permutation test for adonis under reduced model  
## Permutation: free  
## Number of permutations: 999  
##   
## adonis2(formula = scale(PEAK[, c(16, 17)]) ~ datasettotsimpl, data = PEAK, by = NULL)  
## Df SumOfSqs R2 F Pr(>F)  
## Model 1 -45388 -0.26182 -20.335 0.667  
## Residual 98 218744 1.26182   
## Total 99 173355 1.00000

## Correlations between drivers

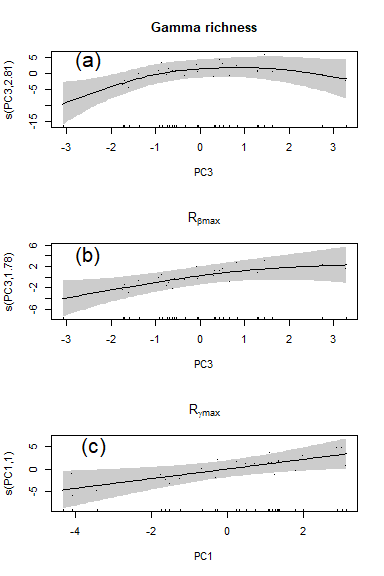
 Figure 6: Pearson correlation between normalized chemical-physical values & DDG measures for all richness components. Environmental & biodiversity dataset is used. Significance levels of p-values: \*p<0.1;\*\*p<0.05;\*\*\*p<0.01

 Figure 7: Pearson correlation between normalized chemical-physical values & DDG measures for all richness components. Biodiversity dataset is used, zero values are ignored. Significance levels of p-values: \*p<0.1;\*\*p<0.05;\*\*\*p<0.01

## Principle component analysis

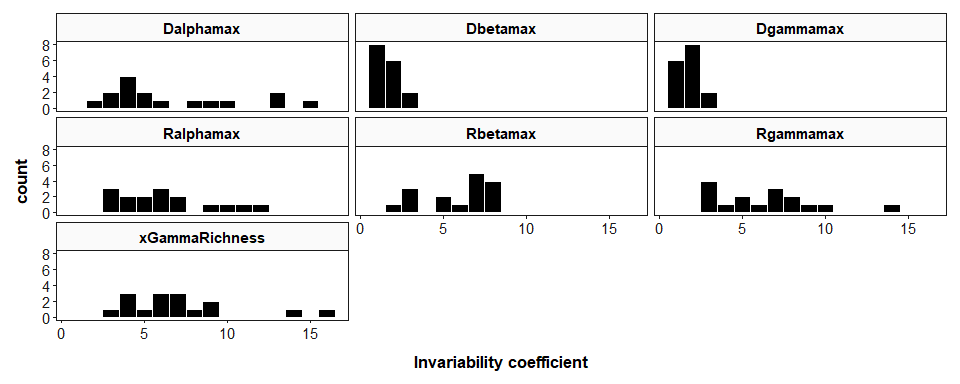
 Figure 8: PCA with all environmental parameters of the environemnatal & biodiversity dataset. PCA axes 1-4 cover 0.8086% of variation. Axes 1 & 2 are plotted in panel (a), axes 3 & 4 in panel (b).

## GAMM for gamma richness & beta and gamma DDG measures

 Figure 9: Minimal GAMMs for response variables Gamma richness (a), R(beta,max) (b) and R(gamma, max) (c). Low r\_square (adj) were found: 0.213 (a); 0.0124 (b); 0.265 (c).

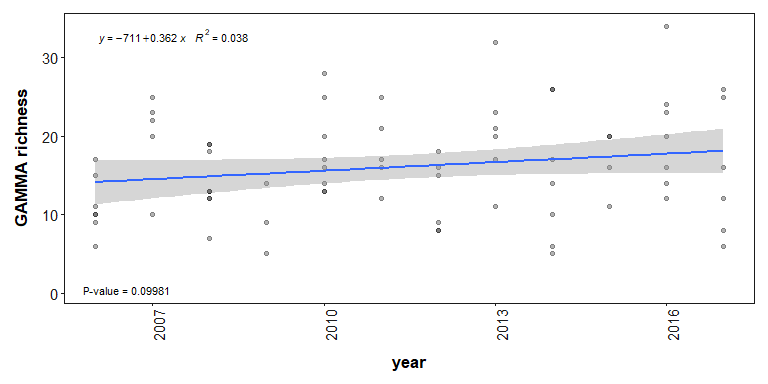
# Depth diversity gradients of macrophytes: recent shifts

## Invariability analysis

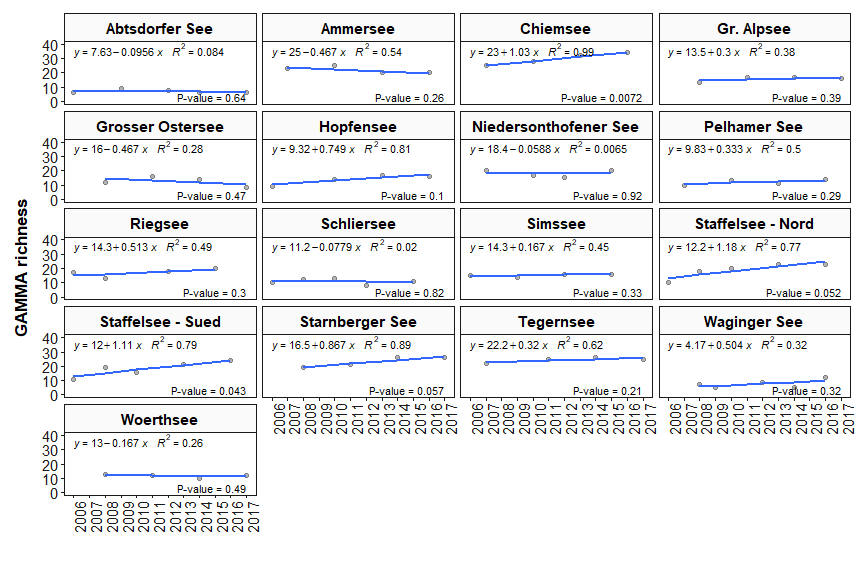
 Figure 10: Histograms for Invariability coefficients for single DDG measures (Dmax and Rmax of alpha, beta and gamma richness) and gamma richness for the biodiversity timeseries dataset. High invariability means a high stability within the timeseries.

## Temporal trend of gamma richness

### General

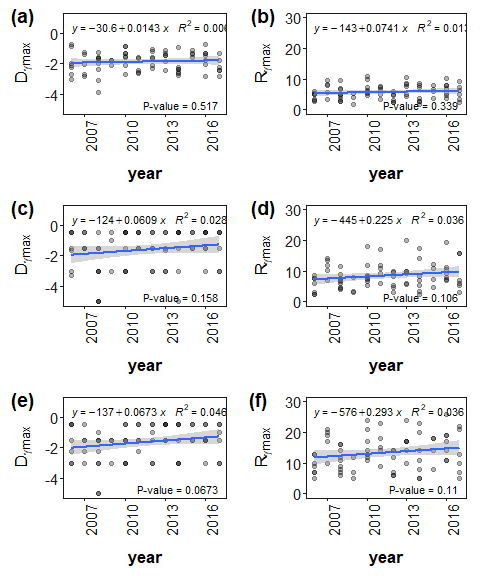
 Figure 11: Temporal change of gamma richness from biodiversity time series dataset for all lakes together. Points show individual values and the blue line is a linear model.

### Individual lakes

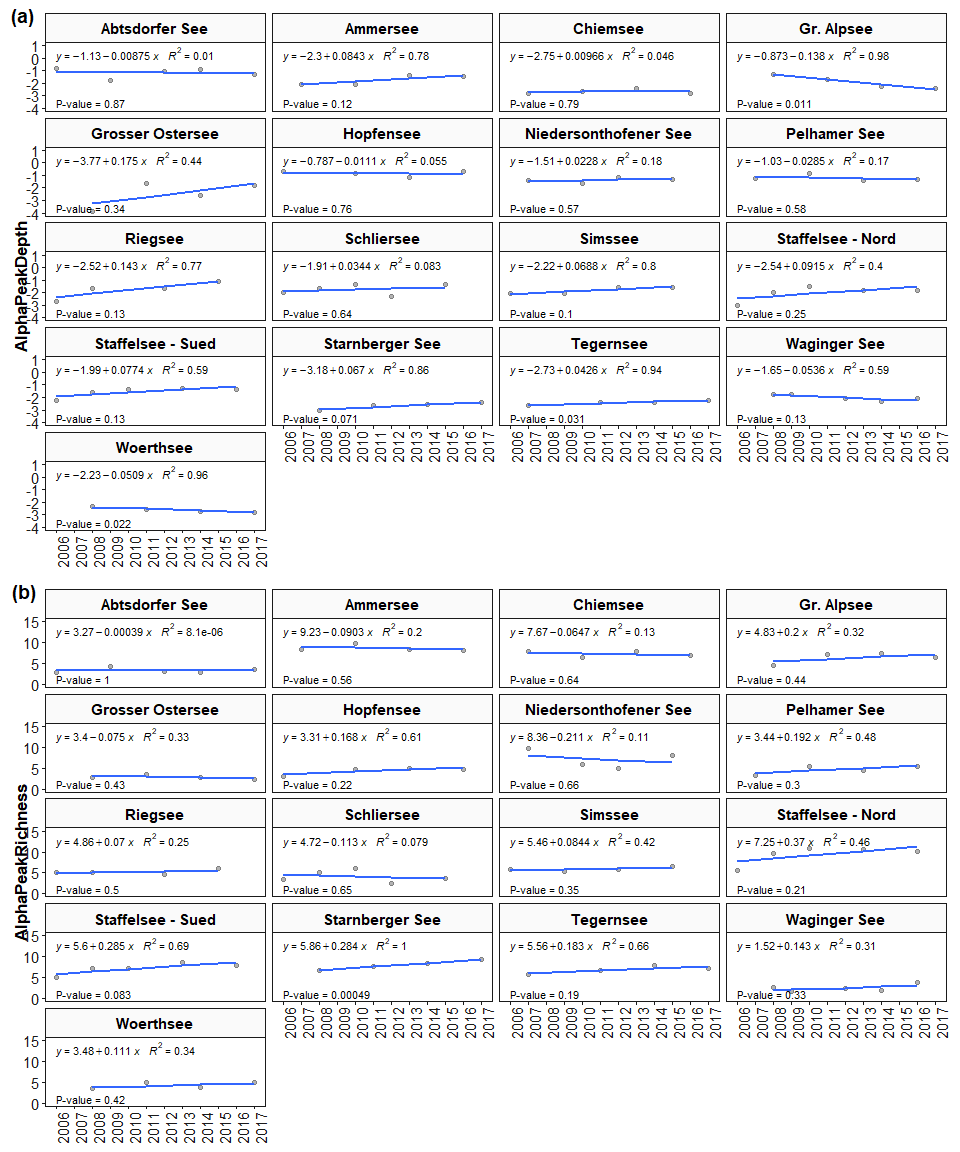
 Figure 12: Temporal change of gamma richness from biodiversity time series dataset for all individual lakes. Points show single values and the blue line is a linear model per lake.

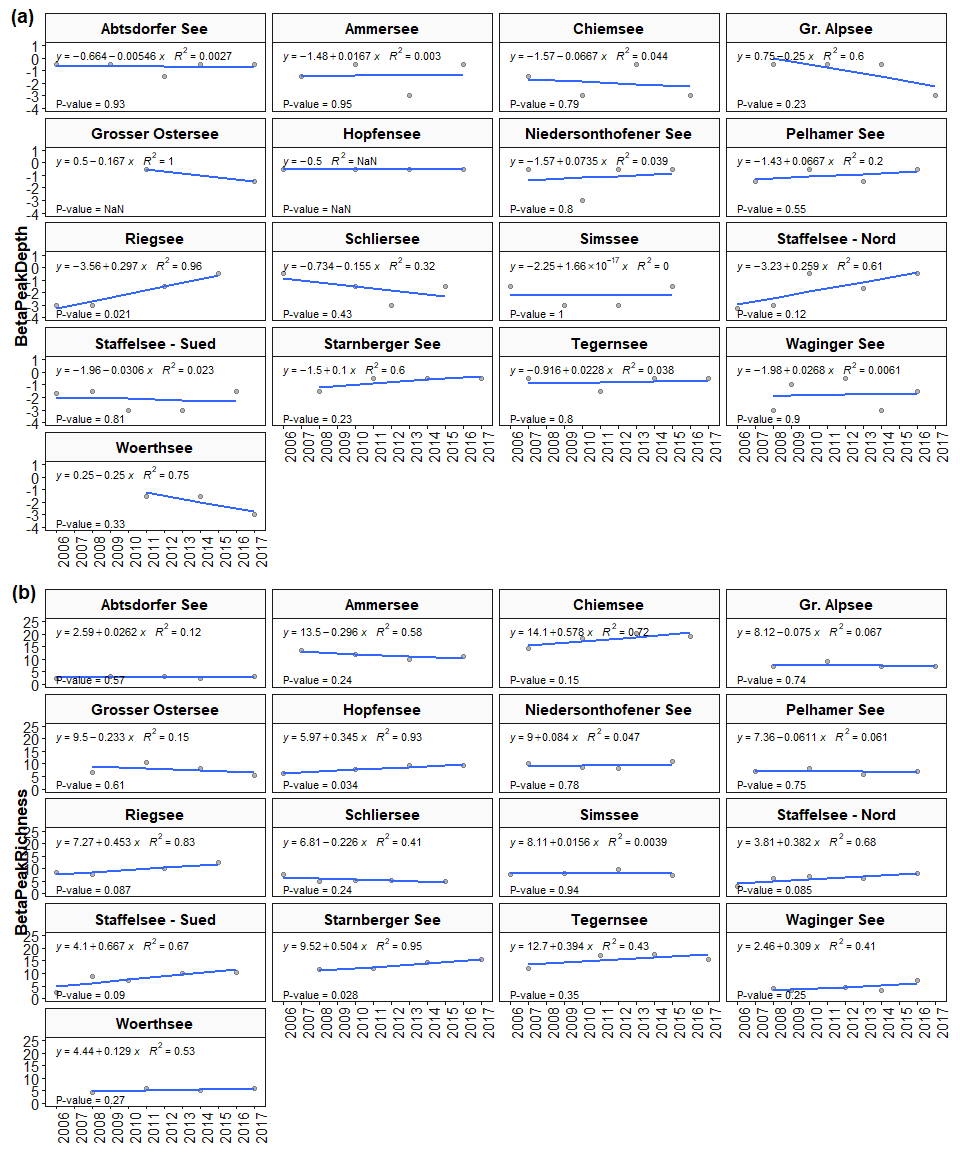
## Temporal trend of DDG measures

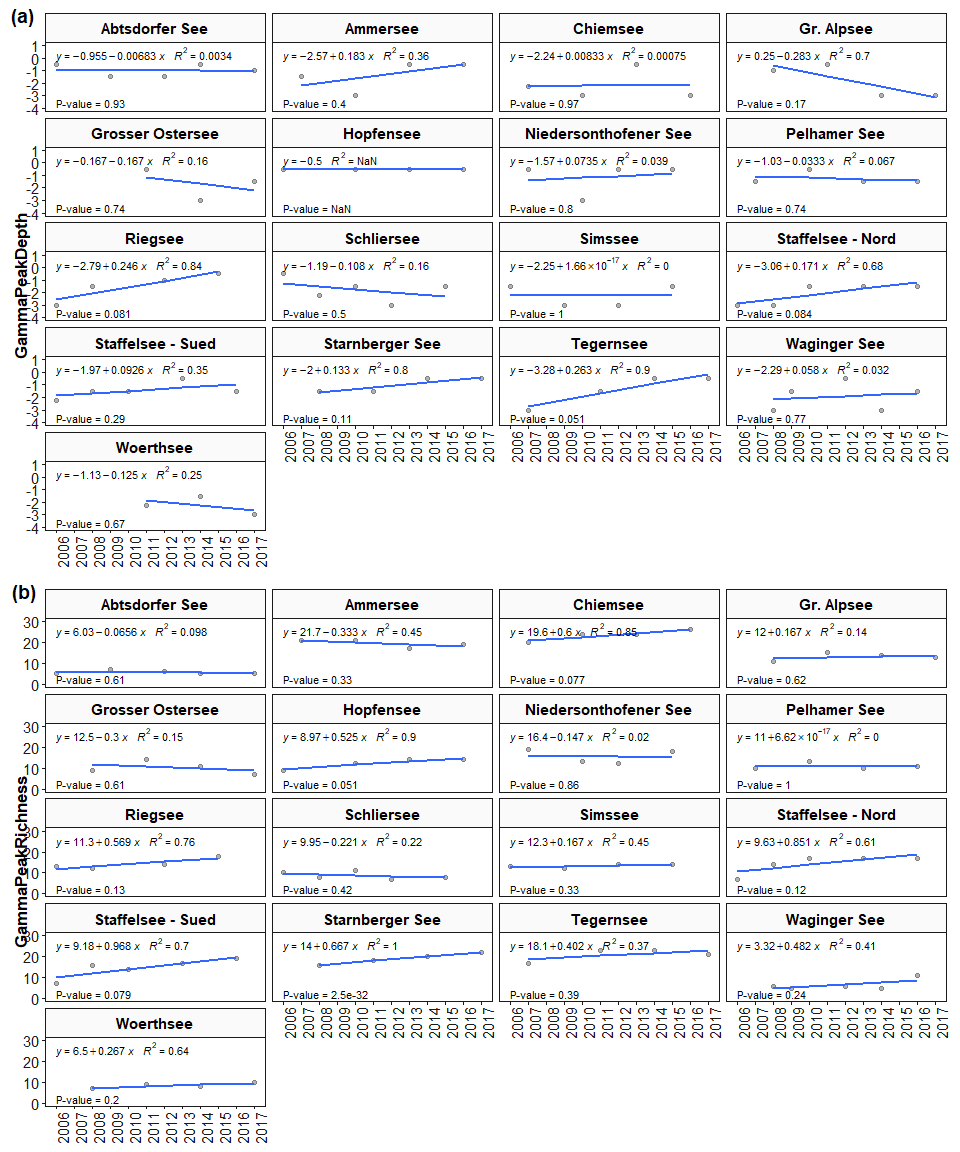
### General

 Figure 13: Temporal change of DDG metrices from biodiversity time series dataset for all lakes at once. Points show single values and the blue line is a linear model. In panel (a,c,e) temporal change of D(max) is shown and in panel (b,d,f) the corresponding course of R(max) is depicted.

### Individual lakes

 Figure 14: Temporal change of DDG metrices from biodiversity time series dataset for all lakes. Points show annual values and the blue line is a linear model. In panel (a) temporal change of D(alpha,max) is shown for all lakes and in panel (b) the corresponding course of R(alpha,max) is depicted.

 Figure 15: Temporal change of DDG metrices from biodiversity time series dataset for all lakes. Points show annual values and the blue line is a linear model. In panel (a) temporal change of D(beta,max) is shown for all lakes and in panel (b) the corresponding course of R(beta,max) is depicted.

 Figure 16: Temporal change of DDG metrices from biodiversity time series dataset for all lakes. Points show annual values and the blue line is a linear model. In panel (a) temporal change of D(gamma,max) is shown for all lakes and in panel (b) the corresponding course of R(gamma,max) is depicted.

# Literature

Herberich, E. et al. 2010. A Robust Procedure for Comparing Multiple Means under Heteroscedasticity in Unbalanced Designs (F Rapallo, Ed.). - PLoS ONE 5: e9788.

# Session info

Sys.time()

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## [8] base   
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