DDG Analysis | Supplementary Material

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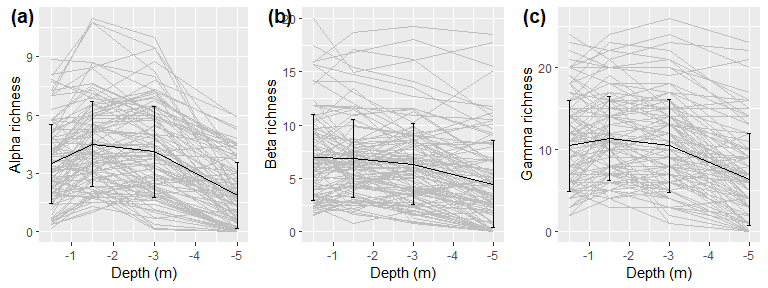
14 Juni 2020

# H1 Pattern

## Depth diversity gradients of macrophytes - overview

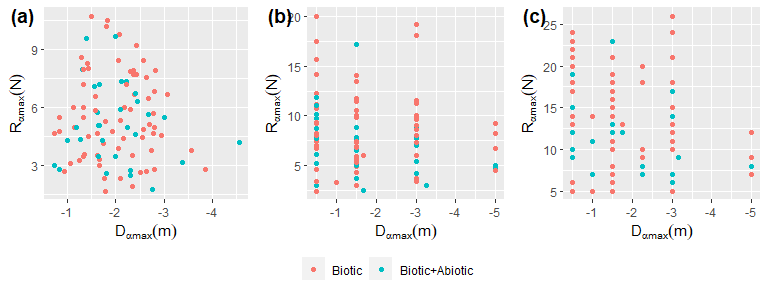
With mean and sd as bars. Single line is one field campaign (lake\*year)

A1<-ggplot(data=Makroph\_Lake\_DepthS)+  
 geom\_line(aes(x=Tiefe, y=ALPHA, group=interaction(Lake, YEAR)),col="grey")+ scale\_x\_reverse()+  
 geom\_line(data=Makroph\_Depth,aes(x=(Tiefe), y=mAlpha))+   
 geom\_errorbar(data=Makroph\_Depth,aes(x=(Tiefe),ymin=mAlpha-sdAlpha, ymax=mAlpha+sdAlpha), width=.1)+  
 ylab("Alpha richness")+xlab(("Depth (m)"))  
B1<-ggplot(data=Makroph\_Lake\_DepthS)+  
 geom\_line(aes(x=Tiefe, y=BETA, group=interaction(Lake, YEAR)),col="grey")+ scale\_x\_reverse()+  
 geom\_line(data=Makroph\_Depth,aes(x=(Tiefe), y=mBeta))+   
 geom\_errorbar(data=Makroph\_Depth,aes(x=(Tiefe),ymin=mBeta-sdBeta, ymax=mBeta+sdBeta), width=.1)+  
 ylab("Beta richness")+xlab(("Depth (m)"))  
C1<-ggplot(data=Makroph\_Lake\_DepthS)+  
 geom\_line(aes(x=Tiefe, y=GAMMA, group=interaction(Lake, YEAR)),col="grey")+ scale\_x\_reverse()+  
 geom\_line(data=Makroph\_Depth,aes(x=(Tiefe), y=mGamma))+   
 geom\_errorbar(data=Makroph\_Depth,aes(x=(Tiefe),ymin=mGamma-sdGamma, ymax=mGamma+sdGamma), width=.1)+  
 ylab("Gamma richness")+xlab(("Depth (m)"))  
ggarrange(A1,B1,C1,ncol=3,nrow=1,labels=c("(a)","(b)","(c)"))



### Peak plots - just to store it

PPalpha<-peakplot(PEAK,PEAK$AlphaPeakDepth,PEAK$AlphaPeakRichness)  
PPbeta<-peakplot(PEAK,PEAK$BetaPeakDepth,PEAK$BetaPeakRichness)  
PPgamma<-peakplot(PEAK,PEAK$GammaPeakDepth,PEAK$GammaPeakRichness)  
  
  
ggarrange(PPalpha,PPbeta,PPgamma, ncol=3,common.legend = T, legend="bottom", labels=c("(a)","(b)","(c)"))



## HERBERICH test

#Did you do GAMMs? Richness ~ Depth, random =transect|lake. Or Herberich tests to check significant differences between depths?   
# gam\_AlphaPeakDepth <- gamm4(ALPHA ~ Tiefe,  
# random= ~(MST\_NR|Lake), # package gamm4  
# data=MakrophS\_ALL)  
# summary(gam\_AlphaPeakDepth$gam)  
# plot(gam\_AlphaPeakDepth$gam)  
#   
#   
#   
# gam\_AlphaPeakDepth <- gamm4(ALPHA ~ s(Tiefe),  
# random=~(YEAR|Lake), # package gamm4  
# data=Makroph\_Lake\_DepthS)  
# summary(gam\_AlphaPeakDepth$gam)  
# plot(gam\_AlphaPeakDepth$gam)  
  
#Herberich Test  
library(multcomp)  
library(multcompView)  
library(sandwich)  
library(broom)  
  
  
Makroph\_Lake\_DepthS$TiefeFact <- as.factor(Makroph\_Lake\_DepthS$Tiefe)  
  
aov1 = aov(ALPHA ~ (TiefeFact), data=Makroph\_Lake\_DepthS) #Fit an Analysis of Variance Model  
Heteroaov1 <- glht(aov1,mcp(TiefeFact="Tukey") , vcov=vcovHC)  
summary(Heteroaov1) #Studies sites do not significantly differ in ....

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = ALPHA ~ (TiefeFact), data = Makroph\_Lake\_DepthS)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## -3 - -5 == 0 2.2407 0.2894 7.742 < 0.001 \*\*\*  
## -1.5 - -5 == 0 2.6427 0.2787 9.483 < 0.001 \*\*\*  
## -0.5 - -5 == 0 1.6206 0.2666 6.080 < 0.001 \*\*\*  
## -1.5 - -3 == 0 0.4020 0.3224 1.247 0.59584   
## -0.5 - -3 == 0 -0.6201 0.3120 -1.987 0.19326   
## -0.5 - -1.5 == 0 -1.0221 0.3021 -3.383 0.00419 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- single-step method)

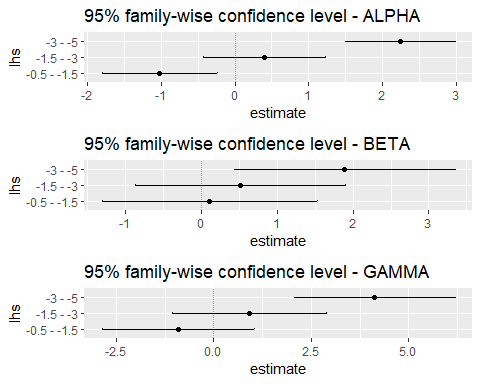
#plot(Heteroaov1, main="95% family-wise confidence level - ALPHA")  
Herb1<-confint(Heteroaov1) %>%   
 tidy %>%   
 filter(lhs %in% c("-0.5 - -1.5","-1.5 - -3","-3 - -5"))%>% #to select just neighboring groups  
 ggplot(aes(lhs, y=estimate, ymin=conf.low, ymax=conf.high)) +  
 geom\_hline(yintercept=0, linetype="11", colour="grey60") +  
 geom\_errorbar(width=0.1) +   
 geom\_point() +  
 coord\_flip()+  
 ggtitle("95% family-wise confidence level - ALPHA")  
  
  
aov2 = aov(BETA ~ (TiefeFact), data=Makroph\_Lake\_DepthS) #Fit an Analysis of Variance Model  
Heteroaov2 <- glht(aov2,mcp(TiefeFact="Tukey") , vcov=vcovHC)  
summary(Heteroaov2) #Studies sites do not significantly differ in ....

##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = BETA ~ (TiefeFact), data = Makroph\_Lake\_DepthS)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## -3 - -5 == 0 1.8893 0.5633 3.354 0.00474 \*\*   
## -1.5 - -5 == 0 2.4073 0.5534 4.350 < 0.001 \*\*\*  
## -0.5 - -5 == 0 2.5194 0.5767 4.369 < 0.001 \*\*\*  
## -1.5 - -3 == 0 0.5180 0.5341 0.970 0.76653   
## -0.5 - -3 == 0 0.6301 0.5582 1.129 0.67173   
## -0.5 - -1.5 == 0 0.1121 0.5482 0.204 0.99697   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- single-step method)

#plot(Heteroaov2, main="95% family-wise confidence level - BETA")  
Herb2<-confint(Heteroaov2) %>%   
 tidy %>%   
 filter(lhs %in% c("-0.5 - -1.5","-1.5 - -3","-3 - -5"))%>% #to select just neighboring groups  
 ggplot(aes(lhs, y=estimate, ymin=conf.low, ymax=conf.high)) +  
 geom\_hline(yintercept=0, linetype="11", colour="grey60") +  
 geom\_errorbar(width=0.1) +   
 geom\_point() +  
 coord\_flip()+  
 ggtitle("95% family-wise confidence level - BETA")  
  
  
aov3 = aov(GAMMA ~ (TiefeFact), data=Makroph\_Lake\_DepthS) #Fit an Analysis of Variance Model  
Heteroaov3 <- glht(aov3,mcp(TiefeFact="Tukey") , vcov=vcovHC)  
summary(Heteroaov3) #Studies sites do not significantly differ in ....

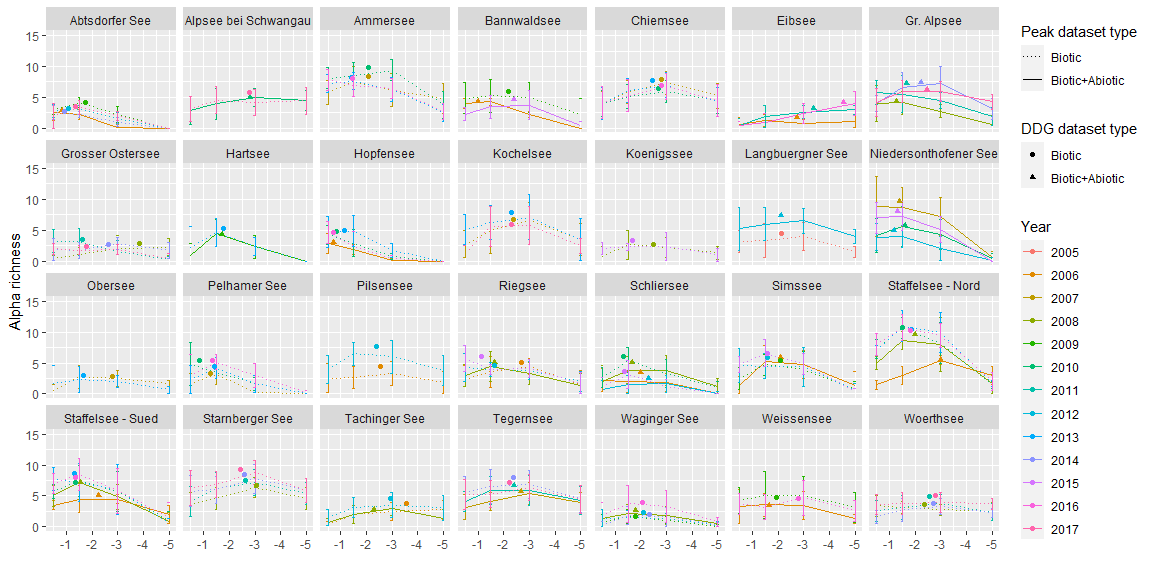
##   
## Simultaneous Tests for General Linear Hypotheses  
##   
## Multiple Comparisons of Means: Tukey Contrasts  
##   
##   
## Fit: aov(formula = GAMMA ~ (TiefeFact), data = Makroph\_Lake\_DepthS)  
##   
## Linear Hypotheses:  
## Estimate Std. Error t value Pr(>|t|)   
## -3 - -5 == 0 4.1300 0.7969 5.183 <1e-04 \*\*\*  
## -1.5 - -5 == 0 5.0500 0.7593 6.651 <1e-04 \*\*\*  
## -0.5 - -5 == 0 4.1400 0.7889 5.248 <1e-04 \*\*\*  
## -1.5 - -3 == 0 0.9200 0.7635 1.205 0.624   
## -0.5 - -3 == 0 0.0100 0.7929 0.013 1.000   
## -0.5 - -1.5 == 0 -0.9100 0.7551 -1.205 0.624   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## (Adjusted p values reported -- single-step method)

#plot(Heteroaov3, main="95% family-wise confidence level - GAMMA")  
Herb3<-confint(Heteroaov3) %>%   
 tidy %>%   
 filter(lhs %in% c("-0.5 - -1.5","-1.5 - -3","-3 - -5"))%>% #to select just neighboring groups  
 ggplot(aes(lhs, y=estimate, ymin=conf.low, ymax=conf.high)) +  
 geom\_hline(yintercept=0, linetype="11", colour="grey60") +  
 geom\_errorbar(width=0.1) +   
 geom\_point() +  
 coord\_flip() +  
 ggtitle("95% family-wise confidence level - GAMMA")  
  
ggarrange(Herb1,Herb2,Herb3, nrow = 3)

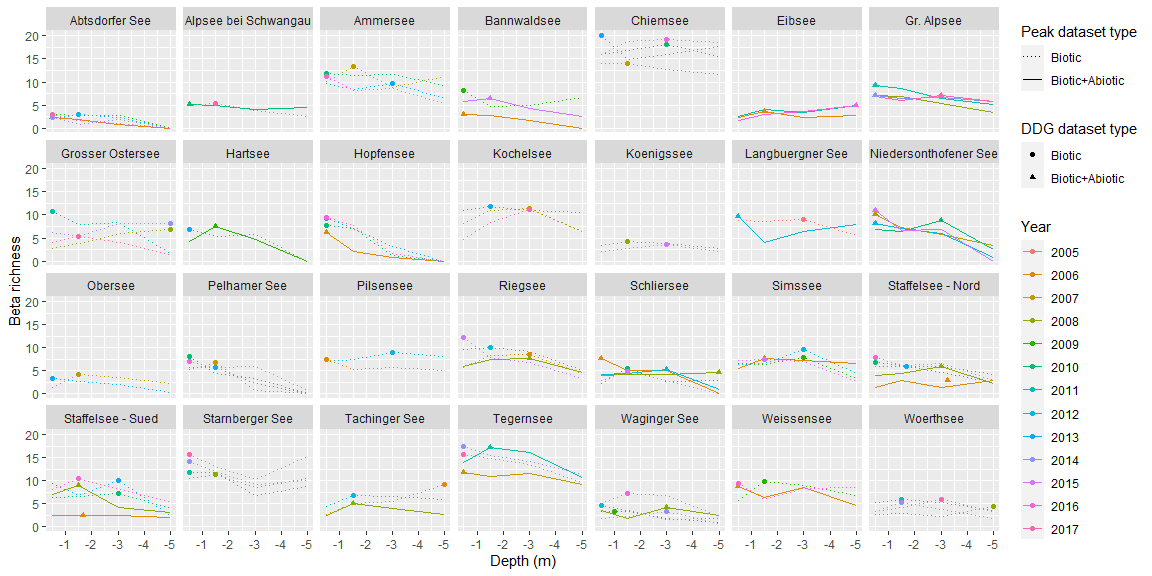


Depth pattern of Alpha, Beta and Gamma Richness for full dataset. For Alpha Richness, lines show the mean Alpha Richness per lake and year with their corresponding standard deviation; the single Richness Peaks are depicted as points. The different dataset levels can be distinguished by line type and point shape: Points and dashed line=Biotic dataset of all available macrophyte mapping; triangles and solid line=subset of biotic dataset, where also abiotic data is available.

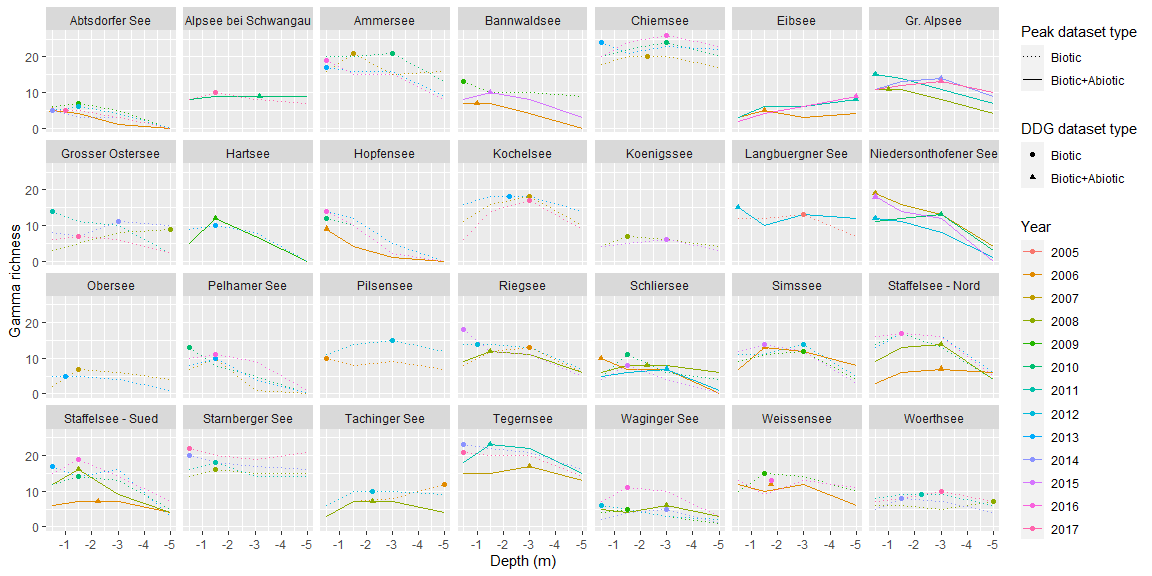
### ALPHA & Peak Plot  
ggplot(data=Makroph\_Lake\_DepthS, aes(x=(Tiefe), y=ALPHA, col=factor(YEAR), group=interaction(Lake,YEAR)))+   
 geom\_line(aes(linetype=datasettotsimpl))+#interaction(dataset,datasetWLF)  
 scale\_linetype\_manual(values=c("dotted", "solid"))+  
 facet\_wrap(~ Lake, ncol=7)+  
 ylab("Alpha richness")+ xlab("")+labs(fill = "Pattern type")+ylim(0,15)+  
 geom\_errorbar(data=Makroph\_Lake\_DepthS,aes(ymin=ALPHA-ALPHAsd, ymax=ALPHA+ALPHAsd), width=.1)+  
 geom\_point(data=PEAK, aes(x=(AlphaPeakDepth), y=AlphaPeakRichness, shape=datasettotsimpl))+ scale\_x\_reverse()+  
 labs(linetype="Peak dataset type",shape="DDG dataset type", colour="Year")



### BETA & Peak Plot  
ggplot(Makroph\_Lake\_DepthS, aes(x=Tiefe, y=BETA, group=interaction(Lake,YEAR), col=factor(YEAR), linetype=datasettotsimpl))+   
 geom\_line()+facet\_wrap(~ Lake, ncol=7)+  
 scale\_linetype\_manual(values=c("dotted", "solid"))+  
 ylab("Beta richness")+ xlab("Depth (m)")+labs(fill = "Pattern type")+  
 geom\_point(data=PEAK, aes(x=BetaPeakDepth, y=BetaPeakRichness, shape=datasettotsimpl))+ scale\_x\_reverse()+  
 labs(linetype="Peak dataset type",shape="DDG dataset type", colour="Year")



### GAMMA & Peak Plot  
ggplot(Makroph\_Lake\_DepthS, aes(x=Tiefe, y=GAMMA, group=interaction(Lake,YEAR), col=factor(YEAR), linetype=datasettotsimpl))+   
 geom\_line()+facet\_wrap(~ Lake, ncol=7)+  
 scale\_linetype\_manual(values=c("dotted", "solid"))+  
 ylab("Gamma richness")+ xlab("Depth (m)")+labs(fill = "Pattern type")+  
 geom\_point(data=PEAK, aes(x=GammaPeakDepth, y=GammaPeakRichness, shape=datasettotsimpl))+ scale\_x\_reverse()+  
 labs(linetype="Peak dataset type",shape="DDG dataset type", colour="Year")



## Representativeness

As full environmental data is only accessible for a subset of the full Biodiversity dataset we compare the richness components for Biodiversity dataset and Environmental & biodiversity dataset with a PERMANOVA. The results show that the Environmental & biodiversity dataset (N=27) is highly significant (p<0.001) representative for the Biodiversity dataset (N=100) (see Supplementary material X).

library(vegan)  
adonis2(PEAK[,c(3,5)]~datasettotsimpl, data=PEAK, by = NULL) #ALPHAPEAK

## 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 0.537  
## Residual 98 130.361 0.99337   
## Total 99 131.231 1.00000

adonis2((PEAK[,c(14,15)])~datasettotsimpl, data=PEAK, by = NULL) #GammaPEAK

## 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 0.138  
## Residual 98 8.2047 0.97982   
## Total 99 8.3738 1.00000

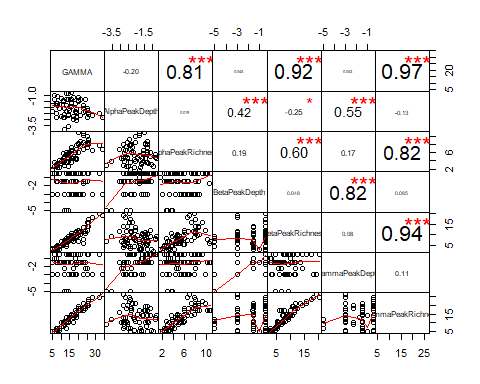
adonis2(scale(PEAK[,c(16,17)])~datasettotsimpl, data=PEAK, by = NULL) #BetaPEAK

## 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 0.656  
## Residual 98 218744 1.26182   
## Total 99 173355 1.00000

## Correlations between metrices

Correlations between diversity metrices #TODO Umbenennen! # Problem with greek letters

library(PerformanceAnalytics)  
chart.Correlation(PEAK\_Chem\_norm[c(33,20,22,31,32,29,30)], histogram=F, pch=9, method = "pearson")



# H2 Driver

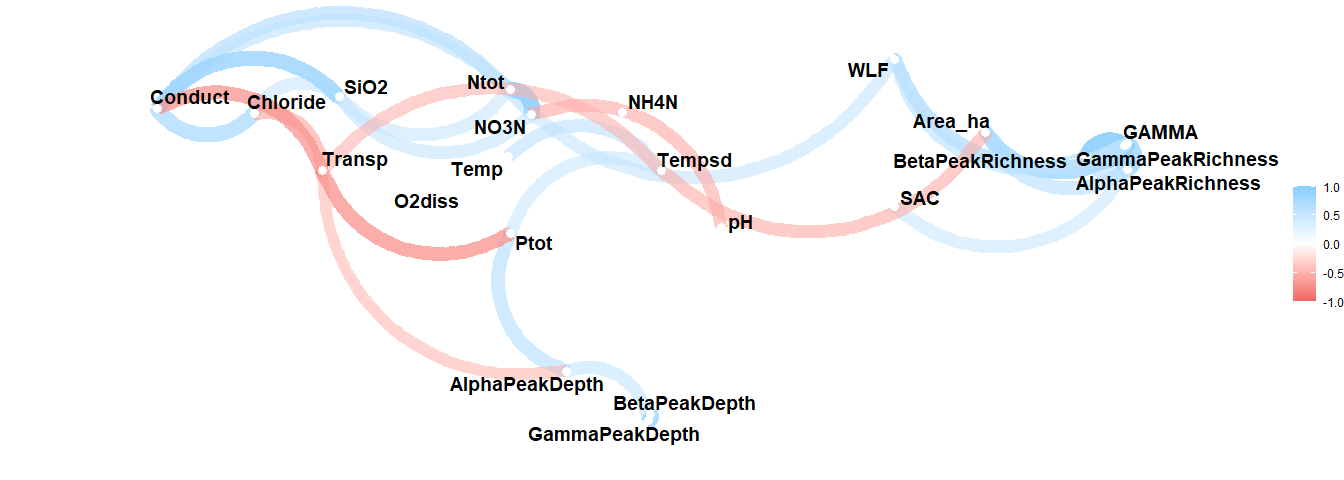
## Correlations | Drivers

Correlation between normalized chemical-physical values (!Achtung Level2 Dataset) & Richness measures #TODO: umbenennen: Greek letters?

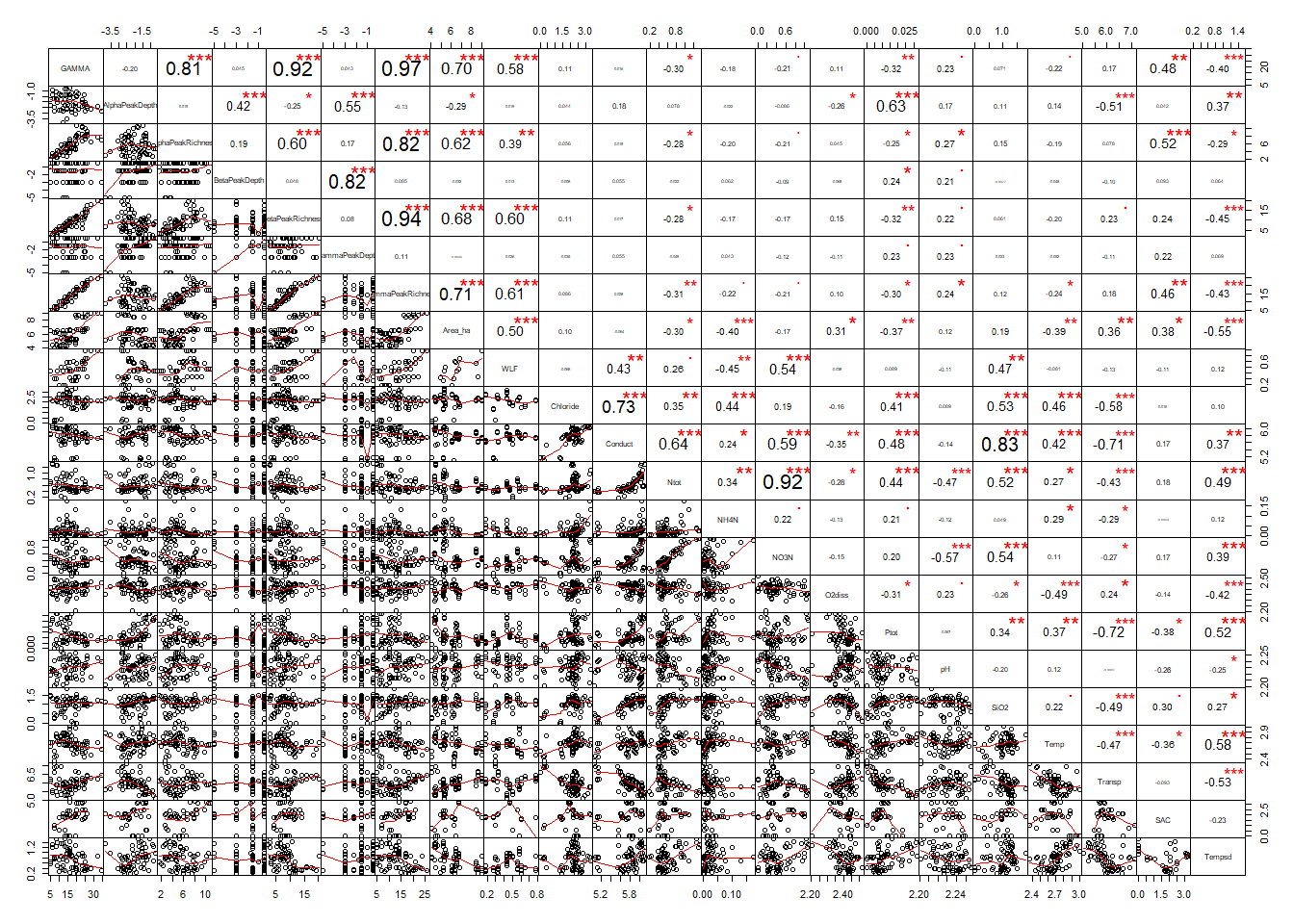
### Correlations

Fig. 3 Correlations (negative: red; positive: blue) between abiotic variables and richness measures displayed as correlation network plot. Proximity between points and colours of the connecting line show the strength of correlation (see colour legend). We show only connections with absolute correlation coefficient > ±0.5. A table with the full correlations in given in see also Supplementary material SX

library(corrr)  
PEAK\_Chem\_norm[c(33,20,22,31,32,29,30,16,19,3:15)] %>%   
 correlate(use="pairwise.complete.obs", method = "pearson") %>%   
 network\_plot(min\_cor=0.50, repel=TRUE, legend=TRUE)

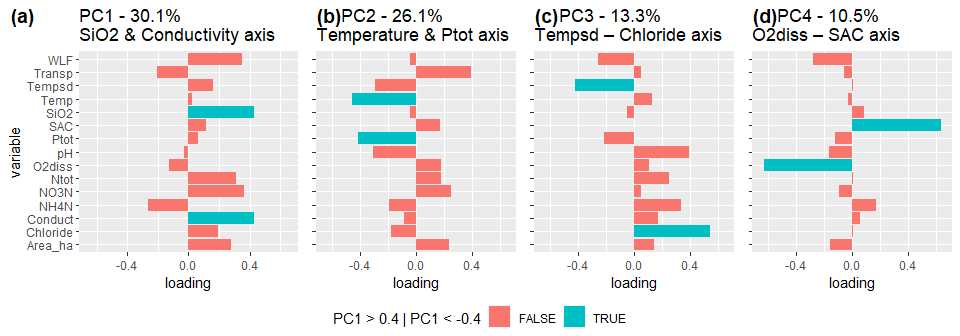


library(PerformanceAnalytics)  
chart.Correlation(PEAK\_Chem\_norm[c(33,20,22,31,32,29,30,16,19,3:15)], histogram=F, pch=9, method = "pearson")



### PCA # CHANGE that PLOT

################ PCA ###############################################  
label\_lake<- PEAK\_Chem\_norm[complete.cases(PEAK\_Chem\_norm[,c(3:16,19)]),] #LEVEL 3 data #[,c(3:16,19)] #[,c(8:10,12:16,19)]  
lak.pca <- prcomp(na.omit(label\_lake[,c(3:16,19)]),center = TRUE, scale. = TRUE)  
#print(lak.pca)  
#summary(lak.pca)   
  
PCA <- (data.frame(label\_lake$Lake))  
PCA$YEAR <- label\_lake$YEAR  
PCA$PC1 <- lak.pca$x[,1]  
PCA$PC2 <- lak.pca$x[,2]  
PCA$PC3 <- lak.pca$x[,3]  
PCA$PC4 <- lak.pca$x[,4]  
  
names(PCA)[1]<-"Lake"  
  
PEAK\_PCA<-merge(PCA, PEAK\_Chem\_norm, by=c("Lake", "YEAR"))  
  
  
Rotation <-lak.pca$rotation %>% as.data.frame()  
Rotation$variable <- row.names(Rotation)  
R1<-ggplot(data=Rotation)+geom\_bar(aes(y=variable,x=PC1,fill = PC1 > 0.4 | PC1< -0.4), stat='identity')+xlim(-0.65,0.65)+ggtitle("PC1 - 30.1% \nSiO2 & Conductivity axis")+xlab("loading")  
R2<-ggplot(data=Rotation)+geom\_bar(aes(y=variable,x=PC2,fill = PC2 > 0.4 | PC2< -0.4), stat='identity')+xlim(-0.65,0.65)+ylab("")+theme(axis.title.y=element\_blank(),axis.text.y=element\_blank())+ggtitle(" PC2 - 26.1%\nTemperature & Ptot axis")+xlab("loading")  
R3<-ggplot(data=Rotation)+geom\_bar(aes(y=variable,x=PC3,fill = PC3 > 0.4 | PC3< -0.4), stat='identity')+xlim(-0.65,0.65)+ylab("")+theme(axis.title.y=element\_blank(),axis.text.y=element\_blank())+ggtitle(" PC3 - 13.3%\nTempsd – Chloride axis")+xlab("loading")  
R4<-ggplot(data=Rotation)+geom\_bar(aes(y=variable,x=PC4,fill = PC4 > 0.4 | PC4< -0.4), stat='identity')+xlim(-0.65,0.65)+ylab("")+theme(axis.title.y=element\_blank(),axis.text.y=element\_blank())+ggtitle(" PC4 - 10.5%\nO2diss – SAC axis")+xlab("loading")  
  
ggarrange(R1,R2,R3,R4, ncol=4, common.legend = T, legend="bottom", labels = c("(a)","(b)","(c)","(d)"), widths = c(1.4,1,1,1))



## GAMM for Beta and Gamma richness

#Beta  
gam\_BetaPeakDepth <- gamm4(BetaPeakDepth ~ s(PC1)+s(PC2)+s(PC3)+s(PC4),  
 random= ~(1|Lake), # package gamm4  
 data=PEAK\_PCA)  
summary(gam\_BetaPeakDepth$gam)

##   
## Family: gaussian   
## Link function: identity   
##   
## Formula:  
## BetaPeakDepth ~ s(PC1) + s(PC2) + s(PC3) + s(PC4)  
##   
## Parametric coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.7938 0.2481 -7.23 3.44e-07 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Approximate significance of smooth terms:  
## edf Ref.df F p-value  
## s(PC1) 1.000 1.000 0.079 0.782  
## s(PC2) 1.000 1.000 0.754 0.395  
## s(PC3) 1.000 1.000 0.433 0.518  
## s(PC4) 1.457 1.457 0.723 0.590  
##   
## R-sq.(adj) = -0.0928   
## lmer.REML = 85.261 Scale est. = 1.1908 n = 27

gam\_BetaPeakRichness <- gamm4(BetaPeakRichness ~ s(PC3),  
 random= ~(1|Lake), # package gamm4  
 data=PEAK\_PCA)  
summary(gam\_BetaPeakRichness$gam)

##   
## Family: gaussian   
## Link function: identity   
##   
## Formula:  
## BetaPeakRichness ~ s(PC3)  
##   
## Parametric coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 9.3549 0.8106 11.54 2.48e-11 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Approximate significance of smooth terms:  
## edf Ref.df F p-value   
## s(PC3) 1.775 1.775 5.436 0.0352 \*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## R-sq.(adj) = 0.0124   
## lmer.REML = 112.91 Scale est. = 1.513 n = 27

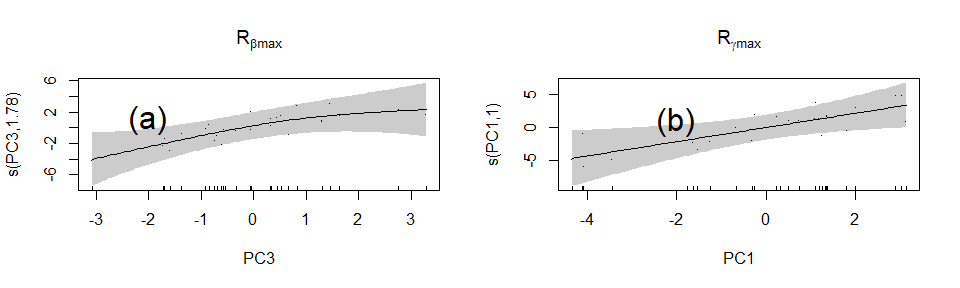
#Gamma  
gam\_GammaPeakDepth <- gamm4(GammaPeakDepth ~ s(PC1)+s(PC2)+s(PC3)+s(PC4),  
 random= ~(1|Lake), # package gamm4  
 data=PEAK\_PCA)  
summary(gam\_GammaPeakDepth$gam)

##   
## Family: gaussian   
## Link function: identity   
##   
## Formula:  
## GammaPeakDepth ~ s(PC1) + s(PC2) + s(PC3) + s(PC4)  
##   
## Parametric coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -1.8173 0.2313 -7.857 7.95e-08 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Approximate significance of smooth terms:  
## edf Ref.df F p-value  
## s(PC1) 1 1 0.001 0.973  
## s(PC2) 1 1 0.024 0.877  
## s(PC3) 1 1 0.002 0.967  
## s(PC4) 1 1 1.487 0.235  
##   
## R-sq.(adj) = -0.0966   
## lmer.REML = 80.984 Scale est. = 0.99175 n = 27

gam\_GammaPeakRichness <- gamm4(GammaPeakRichness ~ s(PC1),  
 random= ~(1|Lake), # package gamm4  
 data=PEAK\_PCA)  
summary(gam\_GammaPeakRichness$gam)

##   
## Family: gaussian   
## Link function: identity   
##   
## Formula:  
## GammaPeakRichness ~ s(PC1)  
##   
## Parametric coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 15.0795 0.9628 15.66 1.97e-14 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Approximate significance of smooth terms:  
## edf Ref.df F p-value   
## s(PC1) 1 1 6.053 0.021 \*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## R-sq.(adj) = 0.265   
## lmer.REML = 128.23 Scale est. = 3.731 n = 27

par(mfrow=c(1,2))  
  
plot(gam\_BetaPeakRichness$gam,residuals=TRUE, main = expression(R[beta][max]), shade = T,seWithMean=T)  
text(-2, 1.0, "(a)", cex=2)  
plot(gam\_GammaPeakRichness$gam,residuals=TRUE, main = expression(R[gamma][max]), shade = T,seWithMean=T)  
text(-2, 1.0, "(b)", cex=2)

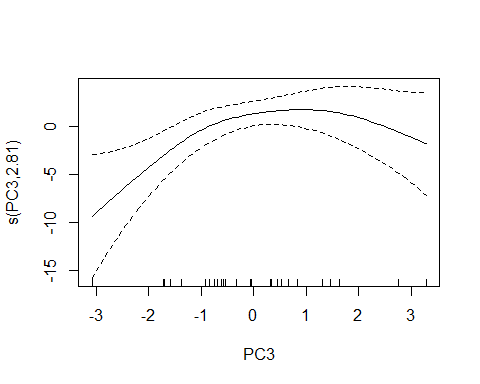


# Gamm for Gamma

gam\_Gamma <- gamm4(GAMMA ~ s(PC3), #s(PC1)+s(PC2)+s(PC3)+s(PC4)  
 random= ~(1|Lake), # package gamm4  
 data=PEAK\_PCA)  
summary(gam\_Gamma$gam)

##   
## Family: gaussian   
## Link function: identity   
##   
## Formula:  
## GAMMA ~ s(PC3)  
##   
## Parametric coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 18.639 1.233 15.12 1.67e-13 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Approximate significance of smooth terms:  
## edf Ref.df F p-value   
## s(PC3) 2.808 2.808 3.881 0.0199 \*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## R-sq.(adj) = 0.213   
## lmer.REML = 140.14 Scale est. = 4.6943 n = 27

plot(gam\_Gamma$gam)



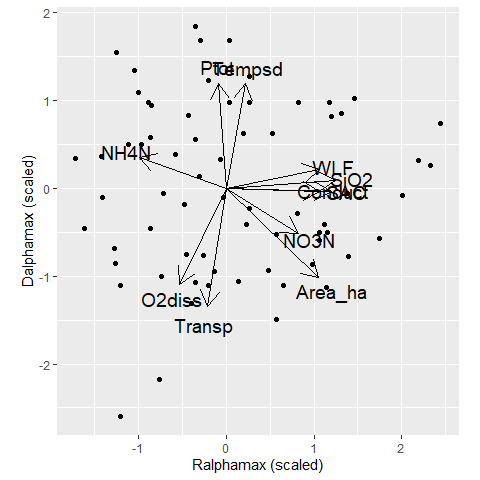
## Environmental fitting

Als Ergänzende Analyse #TODO Umbenennen Environmental fitting for normalized abiotic data and scales DDG measures Dalphamax & Ralphamax

library(vegan)  
ord <- PEAK\_Chem\_norm[c(25,26)]  
vec.sp\_Alpha<-envfit(ord, PEAK\_Chem\_norm[c(16,19,3:15)], permu = 999,na.rm = TRUE)#26:38,  
vec.sp\_Alpha

##   
## \*\*\*VECTORS  
##   
## AlphaPeakDepth\_sc AlphaPeakRichness\_sc r2 Pr(>r)   
## Area\_ha -0.69522 0.71879 0.5331 0.001 \*\*\*  
## WLF 0.19589 0.98063 0.2948 0.019 \*   
## Chloride -0.88056 0.47393 0.0424 0.621   
## Conduct -0.02768 0.99962 0.2837 0.021 \*   
## Ntot -0.62425 0.78122 0.1609 0.116   
## NH4N 0.34062 -0.94020 0.2754 0.019 \*   
## NO3N -0.52624 0.85034 0.2324 0.049 \*   
## O2diss -0.89986 -0.43618 0.3675 0.005 \*\*   
## Ptot 0.99726 -0.07398 0.3630 0.007 \*\*   
## pH 0.94708 -0.32100 0.0550 0.503   
## SiO2 0.07685 0.99704 0.3909 0.007 \*\*   
## Temp 0.92404 -0.38230 0.1558 0.132   
## Transp -0.98751 -0.15754 0.4660 0.001 \*\*\*  
## SAC -0.03035 0.99954 0.3564 0.004 \*\*   
## Tempsd 0.98319 0.18261 0.3685 0.004 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## Permutation: free  
## Number of permutations: 999  
##   
## 41 observations deleted due to missingness

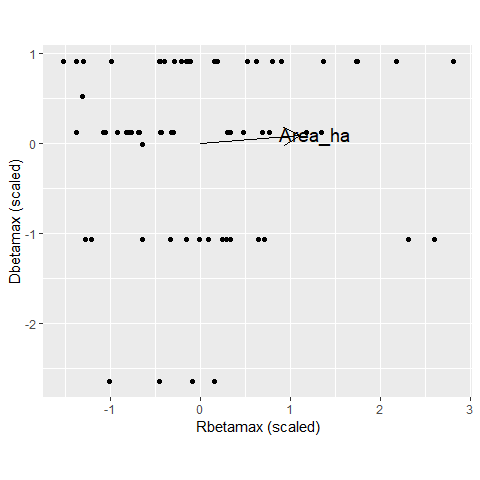
vec.sp.df\_Alpha<-as.data.frame(vec.sp\_Alpha$vectors$arrows\*sqrt(vec.sp\_Alpha$vectors$r))  
vec.sp.df\_Alpha$param<-rownames(vec.sp.df\_Alpha)  
vec.sp.df\_Alpha <- vec.sp.df\_Alpha %>% filter(param %in% (c("Area\_ha","WLF","Conduct","NH4N","NO3N","O2diss","Ptot","SiO2","Tempsd","Transp","SAC")))#"Temp\_0\_6\_sd",  
ggplot(PEAK\_Chem\_norm, aes(y=AlphaPeakDepth\_sc, x=AlphaPeakRichness\_sc))+  
 geom\_point(aes())+ theme(legend.title=element\_blank())+#scale\_fill\_discrete(name = "Groups")+  
 geom\_segment(data=vec.sp.df\_Alpha,aes(y=0,yend=2\*AlphaPeakDepth\_sc,x=0,xend=2\*AlphaPeakRichness\_sc),  
 arrow = arrow(length = unit(0.5, "cm")),colour="black",inherit\_aes=FALSE) +  
 geom\_text(data=vec.sp.df\_Alpha,aes(y=2.3\*AlphaPeakDepth\_sc,x=2.3\*AlphaPeakRichness\_sc,label=param),size=5)+  
 coord\_fixed() + xlab("Ralphamax (scaled)") + ylab("Dalphamax (scaled)")+  
 theme(legend.position = c(0.9, 0.1))

 Dbetamax & Rbetamax

ord <- scale(PEAK\_Chem\_norm[c(31,32)])  
vec.sp\_Beta<-envfit(ord, PEAK\_Chem\_norm[c(16,19,3:15)], permu = 999,na.rm = TRUE)#26:38,  
vec.sp\_Beta

##   
## \*\*\*VECTORS  
##   
## BetaPeakDepth BetaPeakRichness r2 Pr(>r)   
## Area\_ha 0.07857 0.99691 0.3081 0.014 \*  
## WLF -0.27718 0.96082 0.1763 0.093 .  
## Chloride -0.78611 0.61809 0.0194 0.790   
## Conduct -0.52579 0.85062 0.0434 0.603   
## Ntot -0.39239 0.91980 0.1585 0.117   
## NH4N 0.21228 -0.97721 0.0872 0.330   
## NO3N -0.24366 0.96986 0.1265 0.190   
## O2diss -0.71246 0.70171 0.0369 0.634   
## Ptot -0.87776 -0.47911 0.0375 0.614   
## pH 0.68703 0.72663 0.0215 0.759   
## SiO2 0.76891 0.63936 0.0121 0.884   
## Temp -0.53163 -0.84698 0.0638 0.452   
## Transp 0.92831 0.37180 0.0712 0.378   
## SAC 0.79453 0.60723 0.0540 0.510   
## Tempsd -0.05177 -0.99866 0.1542 0.130   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## Permutation: free  
## Number of permutations: 999  
##   
## 41 observations deleted due to missingness

vec.sp.df\_Beta<-as.data.frame(vec.sp\_Beta$vectors$arrows\*sqrt(vec.sp\_Beta$vectors$r))  
vec.sp.df\_Beta$param<-rownames(vec.sp.df\_Beta)  
vec.sp.df\_Beta <- vec.sp.df\_Beta %>% filter(param %in% (c("Area\_ha")))#"Temp\_0\_6\_sd",  
ggplot(PEAK\_Chem\_norm, aes(y=scale(BetaPeakDepth), x=scale(BetaPeakRichness)))+  
 geom\_point(aes())+ theme(legend.title=element\_blank())+#scale\_fill\_discrete(name = "Groups")+  
 geom\_segment(data=vec.sp.df\_Beta,aes(y=0,yend=2\*(BetaPeakDepth),x=0,xend=2\*(BetaPeakRichness)),  
 arrow = arrow(length = unit(0.5, "cm")),colour="black",inherit\_aes=FALSE) +  
 geom\_text(data=vec.sp.df\_Beta,aes(y=2.3\*(BetaPeakDepth),x=2.3\*(BetaPeakRichness),label=param),size=5)+  
 coord\_fixed() + xlab("Rbetamax (scaled)") + ylab("Dbetamax (scaled)")+  
 theme(legend.position = c(0.9, 0.1))

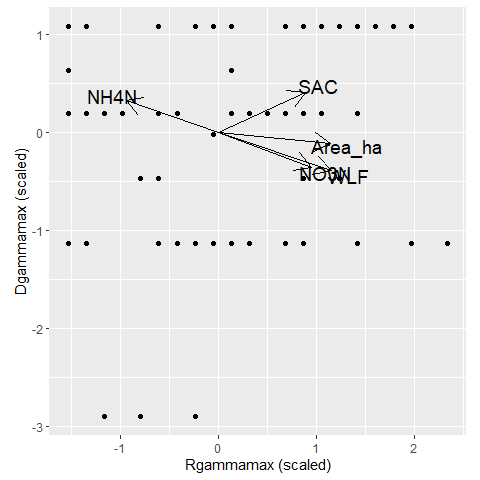


Dgammamax & Rgammamax

ord <- scale(PEAK\_Chem\_norm[c(29,30)])  
vec.sp\_Gamma<-envfit(ord, PEAK\_Chem\_norm[c(16,19,3:15)], permu = 999,na.rm = TRUE)#26:38,  
vec.sp\_Gamma

##   
## \*\*\*VECTORS  
##   
## GammaPeakDepth GammaPeakRichness r2 Pr(>r)   
## Area\_ha -0.09935 0.99505 0.3297 0.008 \*\*  
## WLF -0.31756 0.94824 0.3694 0.005 \*\*  
## Chloride -0.92693 0.37524 0.0416 0.577   
## Conduct -0.41152 0.91140 0.1905 0.087 .   
## Ntot -0.36639 0.93046 0.1983 0.082 .   
## NH4N 0.32526 -0.94562 0.2481 0.032 \*   
## NO3N -0.34907 0.93710 0.2573 0.032 \*   
## O2diss -0.79512 -0.60646 0.0761 0.395   
## Ptot 0.95095 0.30935 0.0009 0.991   
## pH 0.95766 -0.28792 0.0362 0.636   
## SiO2 0.01811 0.99984 0.1530 0.143   
## Temp -0.17471 -0.98462 0.0461 0.545   
## Transp 0.61896 -0.78542 0.0180 0.802   
## SAC 0.42261 0.90631 0.2386 0.034 \*   
## Tempsd 0.65037 -0.75962 0.0129 0.861   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
## Permutation: free  
## Number of permutations: 999  
##   
## 41 observations deleted due to missingness

vec.sp.df\_Gamma<-as.data.frame(vec.sp\_Gamma$vectors$arrows\*sqrt(vec.sp\_Gamma$vectors$r))  
vec.sp.df\_Gamma$param<-rownames(vec.sp.df\_Gamma)  
vec.sp.df\_Gamma <- vec.sp.df\_Gamma %>% filter(param %in% (c("Area\_ha","WLF","NH4N","NO3N","SAC")))#"Temp\_0\_6\_sd",  
ggplot(PEAK\_Chem\_norm, aes(y=scale(GammaPeakDepth), x=scale(GammaPeakRichness)))+  
 geom\_point(aes())+ theme(legend.title=element\_blank())+#scale\_fill\_discrete(name = "Groups")+  
 geom\_segment(data=vec.sp.df\_Gamma,aes(y=0,yend=2\*(GammaPeakDepth),x=0,xend=2\*(GammaPeakRichness)),  
 arrow = arrow(length = unit(0.5, "cm")),colour="black",inherit\_aes=FALSE) +  
 geom\_text(data=vec.sp.df\_Gamma,aes(y=2.3\*(GammaPeakDepth),x=2.3\*(GammaPeakRichness),label=param),size=5)+  
 coord\_fixed() + xlab("Rgammamax (scaled)") + ylab("Dgammamax (scaled)")+  
 theme(legend.position = c(0.9, 0.1))



## Represetitvity of small dataset

Comparing the environmental data for the two dataset levels Level3 and Level2 with a permanova test shows that Level3 data (N=27) is highly significant (p<0.001) representative for full dataset.

##TEST for Represantativity #Permanova  
adonis2(PEAK[,c(3,5)]~datasettotsimpl, data=PEAK, by = NULL) #ALPHAPEAK

## 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 0.531  
## Residual 98 130.361 0.99337   
## Total 99 131.231 1.00000

adonis2(PEAK[,c(14,15)]~datasettotsimpl, data=PEAK, by = NULL) #GammaPEAK

## 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 0.146  
## Residual 98 8.2047 0.97982   
## Total 99 8.3738 1.00000

#adonis2(PEAK[,c(16,17)]~datasettotsimpl, data=PEAK, by = NULL) #BetaPEAK

No significant influence of dataset type

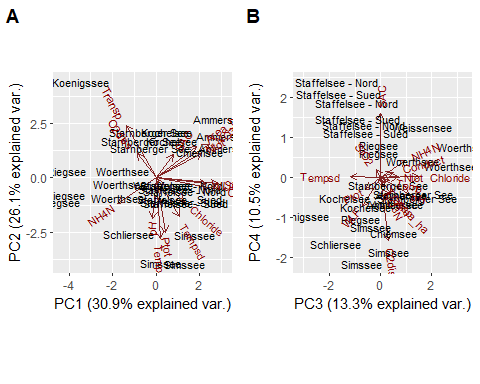
## PCA

PCA for all abiotic data. Multiple years for lakes

library(ggbiplot)  
  
label\_lake<- PEAK\_Chem\_norm[complete.cases(PEAK\_Chem\_norm[,c(3:16,19)]),] #LEVEL 3 data #19 #  
lak.pca <- prcomp(na.omit(label\_lake[,c(3:16,19)]),center = TRUE, scale. = TRUE)  
#print(lak.pca)  
#plot(lak.pca, type="l")  
summary(lak.pca)

## Importance of components:  
## PC1 PC2 PC3 PC4 PC5 PC6 PC7  
## Standard deviation 2.1542 1.9791 1.4106 1.2579 0.89524 0.78922 0.67224  
## Proportion of Variance 0.3094 0.2611 0.1327 0.1055 0.05343 0.04152 0.03013  
## Cumulative Proportion 0.3094 0.5705 0.7032 0.8086 0.86207 0.90359 0.93372  
## PC8 PC9 PC10 PC11 PC12 PC13  
## Standard deviation 0.60783 0.53218 0.37405 0.32663 0.20941 0.16798  
## Proportion of Variance 0.02463 0.01888 0.00933 0.00711 0.00292 0.00188  
## Cumulative Proportion 0.95835 0.97723 0.98656 0.99367 0.99659 0.99848  
## PC14 PC15  
## Standard deviation 0.13554 0.06711  
## Proportion of Variance 0.00122 0.00030  
## Cumulative Proportion 0.99970 1.00000

p1<- ggbiplot(lak.pca, choices = 1:2, obs.scale = 1, var.scale = 1,labels=label\_lake$Lake, arrow.color = "#FF0000",  
 ellipse = TRUE, cicle = TRUE)  
p2<- ggbiplot(lak.pca, choices = 3:4, obs.scale = 1, var.scale = 1,labels=label\_lake$Lake, arrow.color = "#FF0000",  
 ellipse = TRUE, cicle = TRUE)   
figure <- ggarrange(p1,p2,  
 labels = c("A","B"),  
 ncol = 2, nrow = 1, common.legend = TRUE, legend = "bottom", align = "hv")  
figure

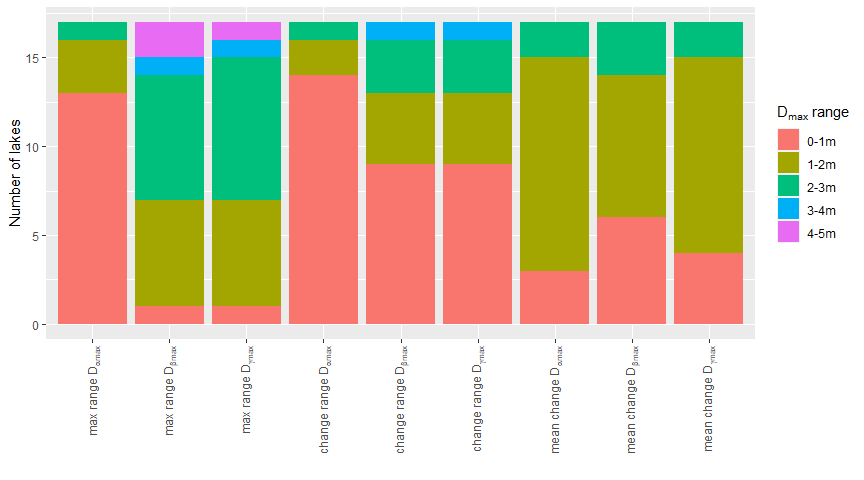


# PCA <- (data.frame(label\_lake$Lake))  
# PCA$YEAR <- label\_lake$YEAR  
# PCA$Morph\_PC1 <- lak.pca$x[,1]  
# PCA$Morph\_PC2 <- lak.pca$x[,2]  
# PCA$Morph\_PC3 <- lak.pca$x[,3]  
# PCA$Morph\_PC4 <- lak.pca$x[,4]  
# PCA$Morph\_PC5 <- lak.pca$x[,5]  
# names(PCA)[1]<-"Lake"

# H3 Temporal change

## Range

LAKECHANGE<-PEAK%>% dplyr::group\_by(Lake) %>% #summarize informtion for lakes (over timeseries)  
 dplyr::summarise(NYEAR=n\_distinct(YEAR),  
 AlphaPeakDepthmean=mean(AlphaPeakDepth), #Mean AlphaPeakDepth over timeseries  
 AlphaPeakDepthRange=max(AlphaPeakDepth)-min(AlphaPeakDepth), #Maximal range of Alphapeakdepth  
 AlphaPeakDepthFirstLastRange=last(AlphaPeakDepth)-first(AlphaPeakDepth), #Change from beginning to end  
 AlphaPeakDepthMeanChange=sum(abs(lag(AlphaPeakDepth)),na.rm =TRUE)/n\_distinct(YEAR), #abs=Betrag; mean difference   
   
 AlphaPeakDepthsd=sd(AlphaPeakDepth),  
 AlphaPeakRichnessnmean=mean(AlphaPeakRichness),  
 AlphaPeakRichnessRange=max(AlphaPeakRichness)-min(AlphaPeakRichness),  
 AlphaPeakRichnessFirstLastRange=last(AlphaPeakRichness)-first(AlphaPeakRichness),  
 AlphaPeakRichnessMeanChange=sum(abs(lag(AlphaPeakRichness)),na.rm =TRUE)/n\_distinct(YEAR),  
   
 BetaPeakDepthmean=mean(BetaPeakDepth),  
 BetaPeakDepthRange=max(BetaPeakDepth)-min(BetaPeakDepth),   
 BetaPeakDepthFirstLastRange=last(BetaPeakDepth)-first(BetaPeakDepth),  
 BetaPeakDepthMeanChange=sum(abs(lag(BetaPeakDepth)),na.rm =TRUE)/n\_distinct(YEAR),  
   
 BetaPeakRichnessnmean=mean(BetaPeakRichness),  
 BetaPeakRichnessRange=max(BetaPeakRichness)-min(BetaPeakRichness),  
 BetaPeakRichnessFirstLastRange=last(BetaPeakRichness)-first(BetaPeakRichness),  
 BetaPeakRichnessMeanChange=sum(abs(lag(BetaPeakRichness)),na.rm =TRUE)/n\_distinct(YEAR),  
   
 GammaPeakDepthmean=mean(GammaPeakDepth),  
 GammaPeakDepthRange=max(GammaPeakDepth)-min(GammaPeakDepth),  
 GammaPeakDepthsd=sd(GammaPeakDepth),  
 GammaPeakDepthFirstLastRange=last(GammaPeakDepth)-first(GammaPeakDepth),  
 GammaPeakDepthMeanChange=sum(abs(lag(GammaPeakDepth)),na.rm =TRUE)/n\_distinct(YEAR),  
   
 GammaPeakRichnessnmean=mean(GammaPeakRichness),  
 GammaPeakRichnessRange=max(GammaPeakRichness)-min(GammaPeakRichness),  
 GammmaPeakRichnessFirstLastRange=last(GammaPeakRichness)-first(GammaPeakRichness),  
 GammaPeakRichnessMeanChange=sum(abs(lag(GammaPeakRichness)),na.rm =TRUE)/n\_distinct(YEAR)  
   
 )%>%  
 filter(NYEAR>3) #For timeseries dataset  
  
giveDepthclass <- function(parameter){  
 ifelse(parameter<1,"0-1m",  
 ifelse(parameter<2,"1-2m",  
 ifelse(parameter<3,"2-3m",  
 ifelse(parameter<4,"3-4m",  
 ifelse(parameter<5,"4-5m",99)))))  
}  
  
giveRichnessclass <- function(parameter){  
 ifelse(parameter<1,"0-1",  
 ifelse(parameter<2,"1-2",  
 ifelse(parameter<3,"2-3",  
 ifelse(parameter<4,"3-4",  
 ifelse(parameter<5,"4-5m",99)))))  
}  
  
  
 LAKECHANGE2<-LAKECHANGE %>%  
 mutate(AlphaPeakDepthRangeClass=giveDepthclass(AlphaPeakDepthRange),  
 BetaPeakDepthRangeClass=giveDepthclass(BetaPeakDepthRange),  
 GammaPeakDepthRangeClass=giveDepthclass(GammaPeakDepthRange),  
 AlphaPeakDepthFirstLastRangeClass=giveDepthclass(AlphaPeakDepthFirstLastRange),  
 BetaPeakDepthFirstLastRangeClass=giveDepthclass(BetaPeakDepthFirstLastRange),  
 GammaPeakDepthFirstLastRangeClass=giveDepthclass(GammaPeakDepthFirstLastRange),  
 AlphaPeakDepthMeanChangeRangeClass=giveDepthclass(AlphaPeakDepthMeanChange),  
 BetaPeakDepthMeanChangeRangeClass=giveDepthclass(BetaPeakDepthMeanChange),  
 GammaPeakDepthMeanChangeRangeClass=giveDepthclass(GammaPeakDepthMeanChange)  
 )  
  
  
  
AA<-LAKECHANGE2%>%  
 group\_by(AlphaPeakDepthRangeClass)%>%  
 dplyr::summarise(AlphaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=AlphaPeakDepthRangeClass)  
AAfirstlast<-LAKECHANGE2%>%  
 group\_by(AlphaPeakDepthFirstLastRangeClass)%>%  
 dplyr::summarise(AlphaPeakDepthRangeFirstLast=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=AlphaPeakDepthFirstLastRangeClass)  
AAmeanrange<-LAKECHANGE2%>%  
 group\_by(AlphaPeakDepthMeanChangeRangeClass)%>%  
 dplyr::summarise(AlphaPeakDepthMeanRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=AlphaPeakDepthMeanChangeRangeClass)  
BA<-LAKECHANGE2%>%  
 group\_by(BetaPeakDepthRangeClass)%>%  
 dplyr::summarise(BetaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=BetaPeakDepthRangeClass)  
BAfirstlast<-LAKECHANGE2%>%  
 group\_by(BetaPeakDepthFirstLastRangeClass)%>%  
 dplyr::summarise(BetaPeakDepthRangeFirstLast=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=BetaPeakDepthFirstLastRangeClass)  
BAmeanrange<-LAKECHANGE2%>%  
 group\_by(BetaPeakDepthMeanChangeRangeClass)%>%  
 dplyr::summarise(BetaPeakDepthMeanRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=BetaPeakDepthMeanChangeRangeClass)  
GA<-LAKECHANGE2%>%  
 group\_by(GammaPeakDepthRangeClass)%>%  
 dplyr::summarise(GammaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=GammaPeakDepthRangeClass)  
GAfirstlast<-LAKECHANGE2%>%  
 group\_by(GammaPeakDepthFirstLastRangeClass)%>%  
 dplyr::summarise(GammaPeakDepthRangeFirstLast=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=GammaPeakDepthFirstLastRangeClass)  
GAmeanrange<-LAKECHANGE2%>%  
 group\_by(GammaPeakDepthMeanChangeRangeClass)%>%  
 dplyr::summarise(GammaPeakDepthMeanRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=GammaPeakDepthMeanChangeRangeClass)  
  
ABG<-full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(  
 AA,  
 AAfirstlast,by=c("PeakDepthRangeClass")),  
 AAmeanrange,by=c("PeakDepthRangeClass")),  
 BA,by=c("PeakDepthRangeClass")),  
 BAfirstlast,by=c("PeakDepthRangeClass")),  
 BAmeanrange,by=c("PeakDepthRangeClass")),  
 GA,by=c("PeakDepthRangeClass")),  
 GAfirstlast,by=c("PeakDepthRangeClass")),  
 GAmeanrange,by=c("PeakDepthRangeClass")  
 )  
  
ABGs<-ABG %>% tidyr::gather("Type", "Nlakes", -PeakDepthRangeClass)  
  
positions <- c("GammaPeakDepthRangeFirstLast","GammaPeakDepthMeanRange","GammaPeakDepthRange",  
 "BetaPeakDepthRangeFirstLast","BetaPeakDepthMeanRange","BetaPeakDepthRange",   
 "AlphaPeakDepthRangeFirstLast","AlphaPeakDepthMeanRange","AlphaPeakDepthRange" )  
  
positions <- c("AlphaPeakDepthRange","BetaPeakDepthRange" ,"GammaPeakDepthRange",  
 "AlphaPeakDepthRangeFirstLast","BetaPeakDepthRangeFirstLast","GammaPeakDepthRangeFirstLast",  
 "AlphaPeakDepthMeanRange","BetaPeakDepthMeanRange","GammaPeakDepthMeanRange"  
 )  
  
ggplot(ABGs,aes(x=(Type),y=Nlakes,fill=PeakDepthRangeClass))+  
 geom\_col(position = position\_stack(reverse = T))+  
 xlab("")+ylab("Number of lakes")+  
 #coord\_flip()+  
 scale\_x\_discrete(limits = positions,labels=c("AlphaPeakDepthRange" = bquote("max range D"[alpha][max]),  
 "AlphaPeakDepthMeanRange" = bquote("mean change D"[alpha][max]),  
 "AlphaPeakDepthRangeFirstLast" = bquote("change range D"[alpha][max]),  
 "BetaPeakDepthRange" = bquote("max range D"[beta][max]),  
 "BetaPeakDepthMeanRange" = bquote("mean change D"[beta][max]),  
 "BetaPeakDepthRangeFirstLast" = bquote("change range D"[beta][max]),  
 "GammaPeakDepthRange" = bquote("max range D"[gamma][max]),  
 "GammaPeakDepthMeanRange" = bquote("mean change D"[gamma][max]),  
 "GammaPeakDepthRangeFirstLast" = bquote("change range D"[gamma][max])))+   
 scale\_fill\_discrete(name = bquote("D"[max] ~"range" ))+   
 theme(axis.text.x = element\_text(angle = 90, vjust = 0.5, hjust=1))



## GENERAL: Gamma change

Temporal change of Gamma richness for Temporal change dataset

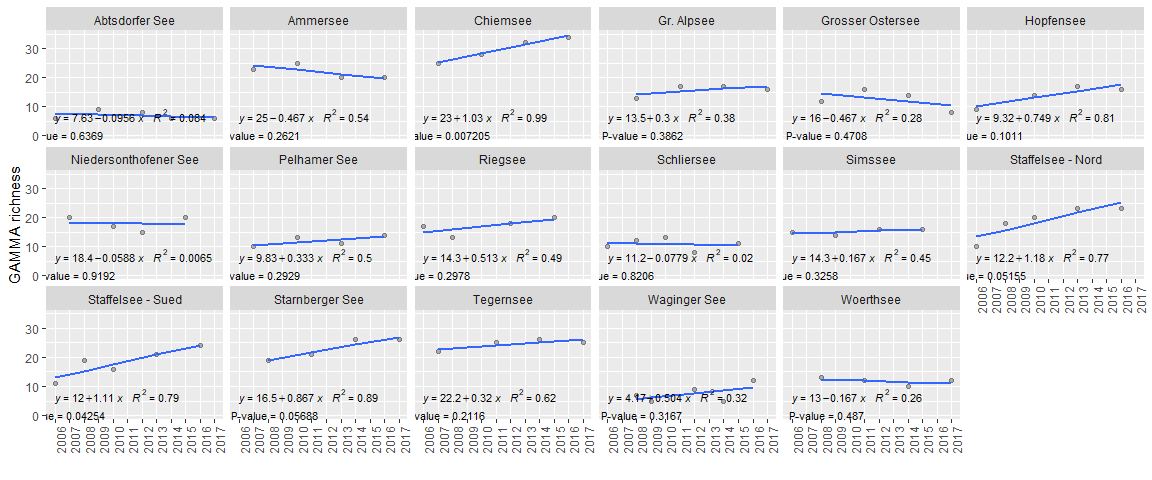
library(ggpmisc)  
formula <- y ~ x  
ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=GAMMA)) +  
 xlab("")+ylab("GAMMA richness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)



## SINGLE LAKES: Gamma change

Temporal change of Gamma richness for Temporal change dataset

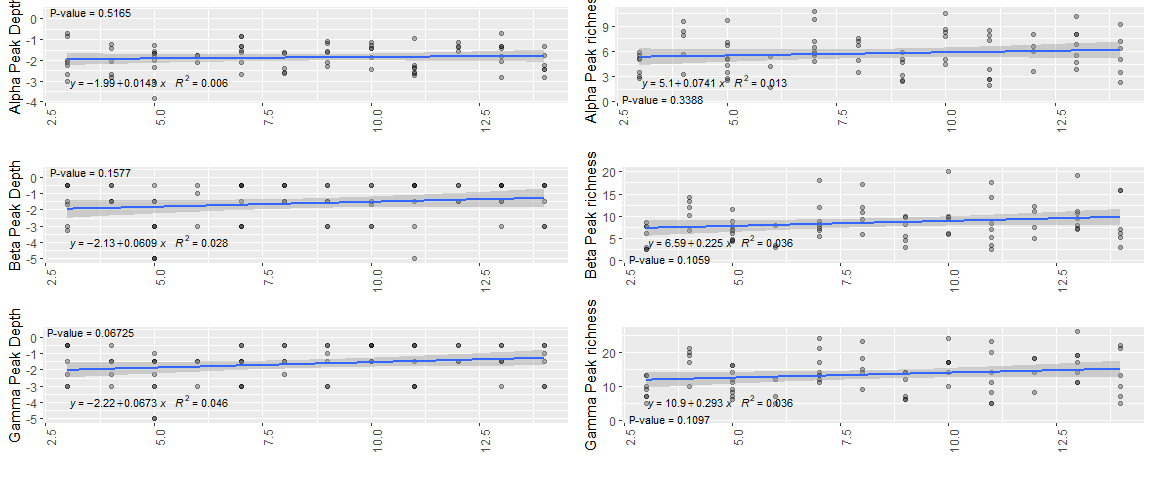
library(ggpmisc)  
formula <- y ~ x  
ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=GAMMA, group=factor(Lake))) +  
 xlab("")+ylab("GAMMA richness")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F, formula = y~x) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)



## GENERAL: PEAK CHANGE

Temporal change of Gamma richness for Temporal change dataset

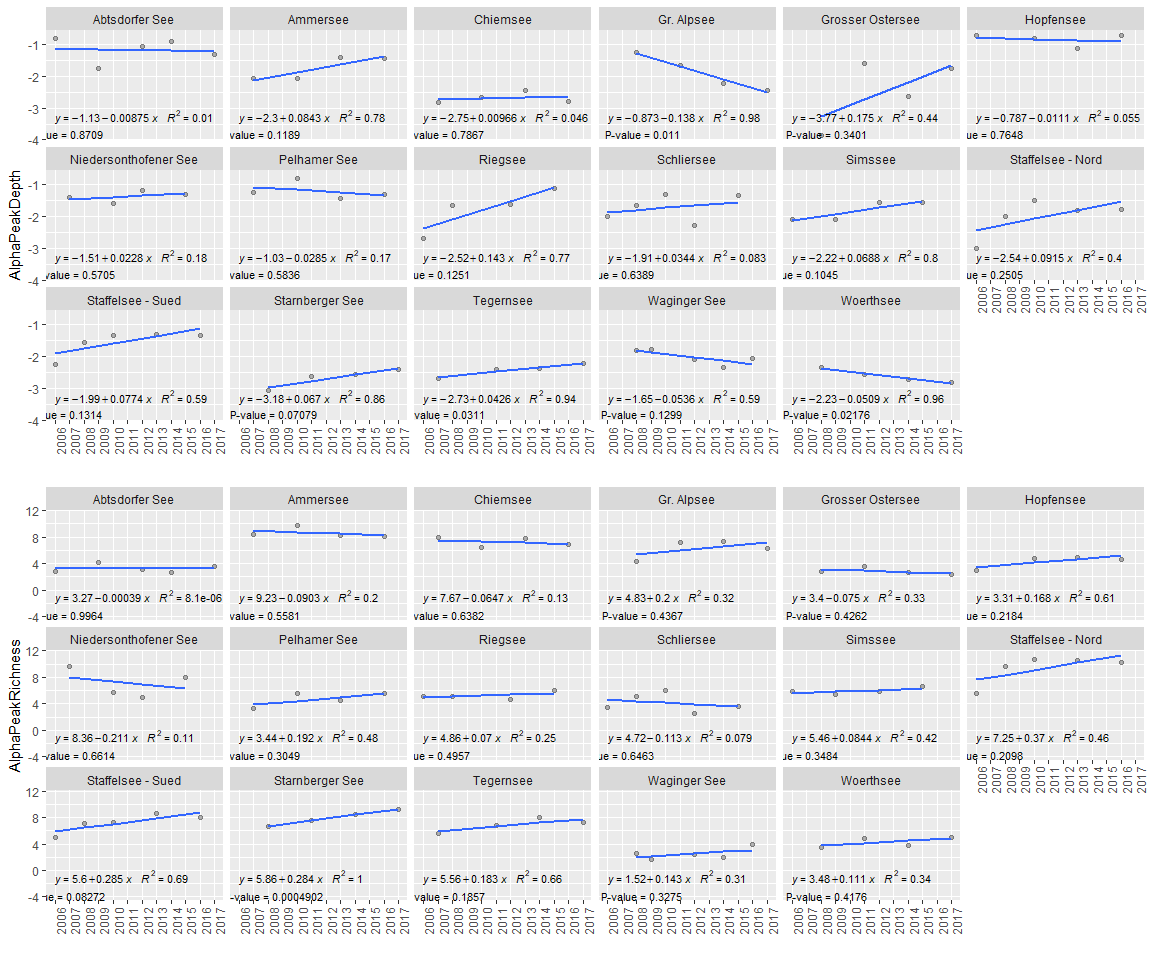
library(ggpmisc)  
formula <- y ~ x  
A1<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=AlphaPeakDepth)) +  
 xlab("")+ylab("Alpha Peak Depth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
A2<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=AlphaPeakRichness)) +  
 xlab("")+ylab("Alpha Peak richness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
B1<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=BetaPeakDepth)) +  
 xlab("")+ylab("Beta Peak Depth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
B2<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=BetaPeakRichness)) +  
 xlab("")+ylab("Beta Peak richness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
C1<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=GammaPeakDepth)) +  
 xlab("")+ylab("Gamma Peak Depth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
C2<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=as.numeric(YEAR), y=GammaPeakRichness)) +  
 xlab("")+ylab("Gamma Peak richness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+  
 geom\_point(alpha = 0.3) +  
 geom\_smooth(method = "lm", se = T) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),  
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = 0.35, size = 3)  
  
ggarrange(A1,A2,B1,B2,C1,C2, ncol=2, nrow = 3)



## Single lakes: Peak change

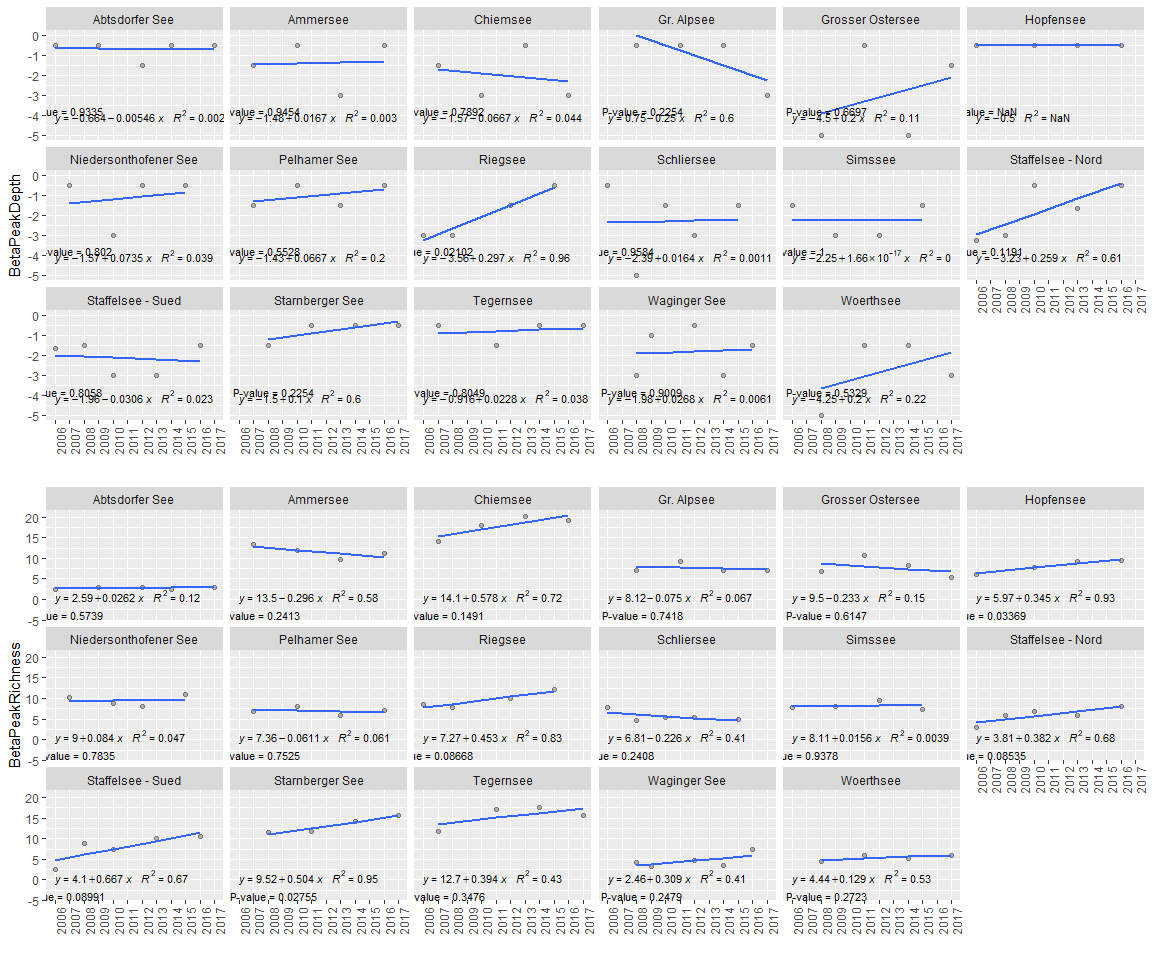
Temporal change for Dalphamax and Ralphamax

library(ggpmisc)  
formula <- y ~ x  
T1<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=AlphaPeakDepth, group=factor(Lake)))+  
 xlab("")+ylab("AlphaPeakDepth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
  
  
T2<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=AlphaPeakRichness, group=factor(Lake)))+  
 xlab("")+ylab("AlphaPeakRichness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
ggarrange(T1,T2, nrow=2)



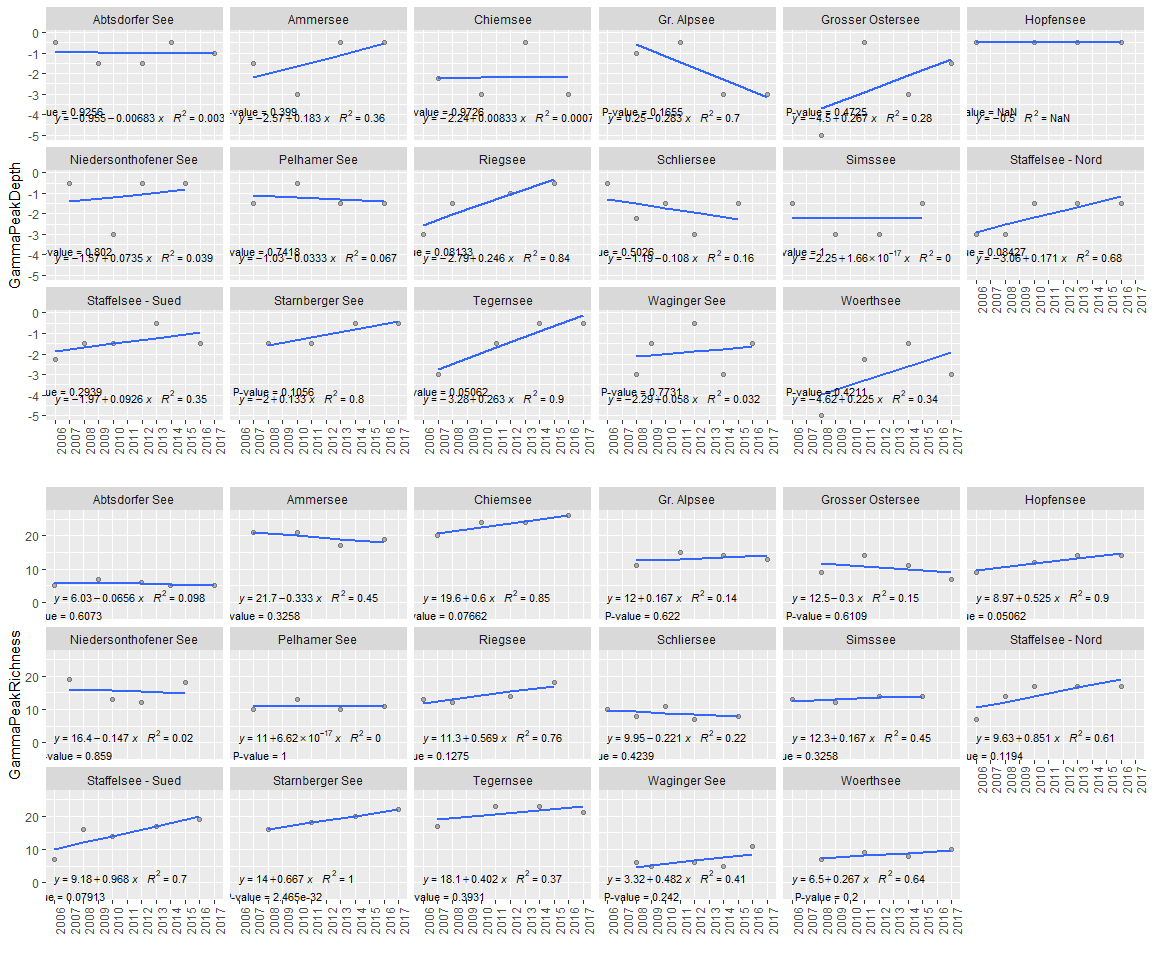
Temporal change for Dbetamax and Rbetamax

formula <- y ~ x  
T3<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=BetaPeakDepth, group=factor(Lake)))+  
 xlab("")+ylab("BetaPeakDepth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
T4<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=BetaPeakRichness, group=factor(Lake)))+  
 xlab("")+ylab("BetaPeakRichness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
ggarrange(T3,T4, nrow=2)



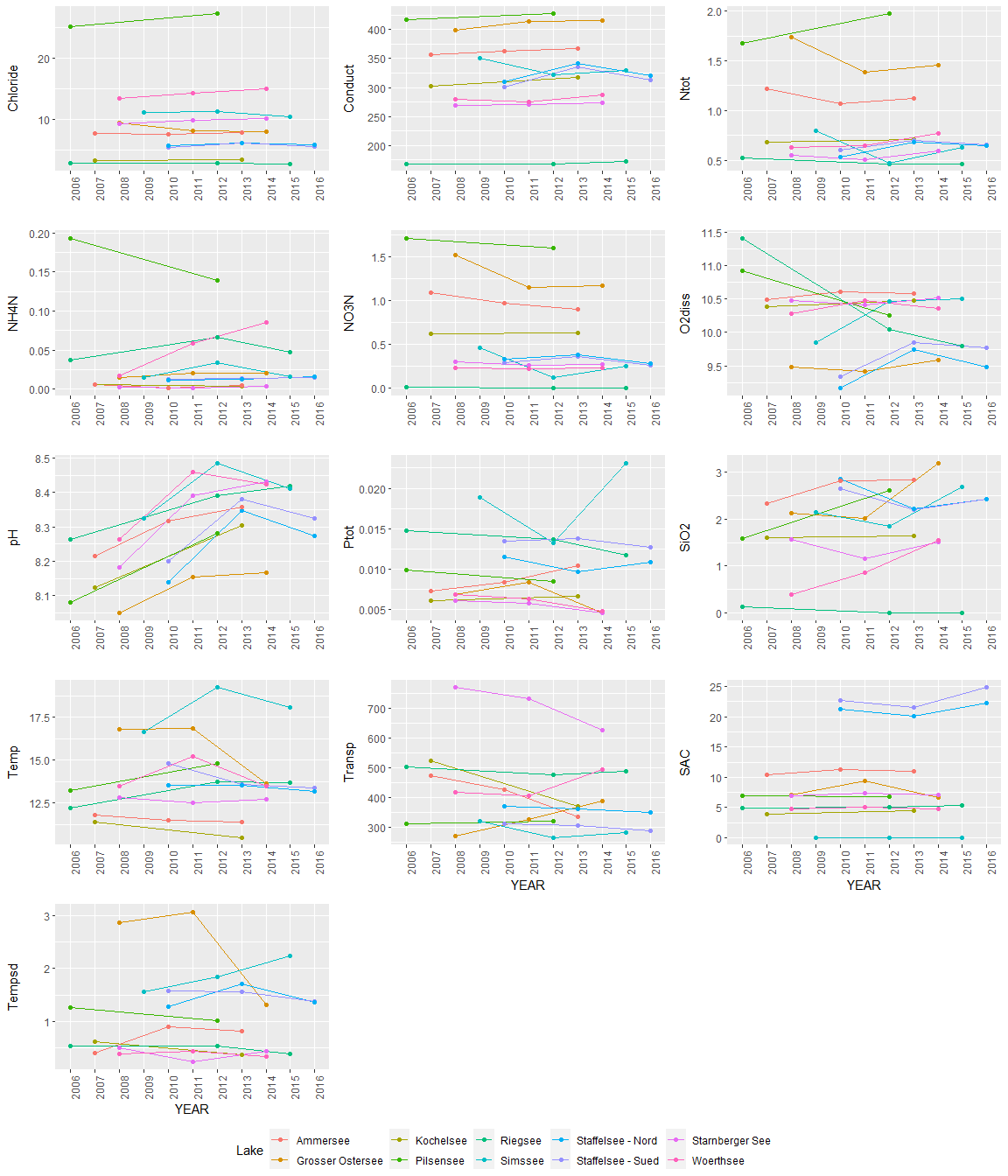
Temporal change for Dgammamax and Rgammamax

formula <- y ~ x  
T5<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=GammaPeakDepth, group=factor(Lake)))+  
 xlab("")+ylab("GammaPeakDepth")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
T6<-ggplot(PEAK%>%group\_by(Lake)%>%filter(n\_distinct(YEAR)>3), aes(x=factor(YEAR), y=GammaPeakRichness, group=factor(Lake)))+  
 xlab("")+ylab("GammaPeakRichness")+  
 theme(axis.text.x = element\_text(angle = 90, hjust = 1))+   
 geom\_point(alpha = 0.3) +facet\_wrap(vars(Lake),nrow=3) +  
 geom\_smooth(method = "lm", se = F) +  
 stat\_poly\_eq(aes(label = paste(..eq.label.., ..rr.label.., sep = "~~~")),   
 label.x.npc = "left", label.y.npc = 0.15,  
 formula = formula, parse = TRUE, size = 3)+  
 stat\_fit\_glance(method = 'lm',  
 method.args = list(formula = formula),  
 geom = 'text',  
 aes(label = paste("P-value = ", signif(..p.value.., digits = 4), sep = "")),  
 label.x = 'left', label.y = -3.8, size = 3)  
  
ggarrange(T5,T6, nrow=2)



## Abiotic change

Chem\_0\_6m\_mean\_STAFF <- Chem\_uniform\_LOIx[rowSums(is.na(Chem\_uniform\_LOIx[,c(3:15)]))==0,] %>%   
 group\_by(Lake) %>%  
 filter(n\_distinct(YEAR)>1)  
   
STAFF1<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Chloride, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF2<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Conduct, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF3<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Ntot, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF4<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=NH4N, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF5<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=NO3N, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF6<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=O2diss, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF7<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=pH, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF7A<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Ptot, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
  
STAFF8<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=SiO2, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF9<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Temp, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF10<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Transp, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("YEAR")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF11<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=SAC, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("YEAR")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
STAFF12<-ggplot(Chem\_0\_6m\_mean\_STAFF,aes(x=factor(YEAR), y=Tempsd, group=(Lake), col=Lake))+  
 geom\_line()+geom\_point()+xlab("YEAR")+theme(axis.text.x = element\_text(angle = 90, hjust = 1))  
  
ggarrange(STAFF1,STAFF2,STAFF3,STAFF4,STAFF5,STAFF6,STAFF7,STAFF7A,STAFF8,STAFF9,STAFF10,STAFF11,STAFF12, nrow = 5, ncol = 3, common.legend = TRUE, legend = "bottom", align = "hv")



### Range analysis

LAKECHANGE<-PEAK%>% dplyr::group\_by(Lake) %>% #summarize informtion for lakes (over timeseries)  
 dplyr::summarise(NYEAR=n\_distinct(YEAR),  
 AlphaPeakDepthRange=max(AlphaPeakDepth)-min(AlphaPeakDepth), #Maximal range of Alphapeakdepth  
 AlphaPeakRichnessRange=max(AlphaPeakRichness)-min(AlphaPeakRichness),  
 BetaPeakDepthRange=max(BetaPeakDepth)-min(BetaPeakDepth),   
 BetaPeakRichnessRange=max(BetaPeakRichness)-min(BetaPeakRichness),  
 GammaPeakDepthRange=max(GammaPeakDepth)-min(GammaPeakDepth),  
 GammaPeakRichnessRange=max(GammaPeakRichness)-min(GammaPeakRichness)  
   
 )%>%  
 filter(NYEAR>3) #For timeseries dataset  
  
giveDepthclass <- function(parameter){  
 ifelse(parameter<1,"0-1m",  
 ifelse(parameter<2,"1-2m",  
 ifelse(parameter<3,"2-3m",  
 ifelse(parameter<4,"3-4m",  
 ifelse(parameter<5,"4-5m",99)))))  
}  
  
giveRichnessclass <- function(parameter){  
 ifelse(parameter<1,"0-2",  
 ifelse(parameter<4,"2-4",  
 ifelse(parameter<6,"4-6",  
 ifelse(parameter<8,"6-8",  
 ifelse(parameter<15,"8-15",  
 ifelse(parameter<25,"15-25",99))))))  
}  
  
  
 LAKECHANGE2<-LAKECHANGE %>%  
 mutate(AlphaPeakDepthRangeClass=giveDepthclass(AlphaPeakDepthRange),  
 BetaPeakDepthRangeClass=giveDepthclass(BetaPeakDepthRange),  
 GammaPeakDepthRangeClass=giveDepthclass(GammaPeakDepthRange),  
 AlphaPeakRichnessRangeClass=giveRichnessclass(AlphaPeakRichnessRange),  
 BetaPeakRichnessRangeClass=giveRichnessclass(BetaPeakRichnessRange),  
 GammaPeakRichnessRangeClass=giveRichnessclass(GammaPeakRichnessRange)  
 )  
  
  
  
AA<-LAKECHANGE2%>%  
 group\_by(AlphaPeakDepthRangeClass)%>%  
 dplyr::summarise(AlphaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=AlphaPeakDepthRangeClass)  
  
AR<-LAKECHANGE2%>%  
 group\_by(AlphaPeakRichnessRangeClass)%>%  
 dplyr::summarise(AlphaPeakRichnessRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakRichnessRangeClass=AlphaPeakRichnessRangeClass)  
  
BA<-LAKECHANGE2%>%  
 group\_by(BetaPeakDepthRangeClass)%>%  
 dplyr::summarise(BetaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=BetaPeakDepthRangeClass)  
BR<-LAKECHANGE2%>%  
 group\_by(BetaPeakRichnessRangeClass)%>%  
 dplyr::summarise(BetaPeakRichnessRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakRichnessRangeClass=BetaPeakRichnessRangeClass)  
  
GA<-LAKECHANGE2%>%  
 group\_by(GammaPeakDepthRangeClass)%>%  
 dplyr::summarise(GammaPeakDepthRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakDepthRangeClass=GammaPeakDepthRangeClass)  
GR<-LAKECHANGE2%>%  
 group\_by(GammaPeakRichnessRangeClass)%>%  
 dplyr::summarise(GammaPeakRichnessRange=n\_distinct(Lake))%>%  
 dplyr::rename(PeakRichnessRangeClass=GammaPeakRichnessRangeClass)  
  
  
ABG<-full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(full\_join(  
 AA,  
 AAfirstlast,by=c("PeakDepthRangeClass")),  
 AAmeanrange,by=c("PeakDepthRangeClass")),  
 BA,by=c("PeakDepthRangeClass")),  
 BAfirstlast,by=c("PeakDepthRangeClass")),  
 BAmeanrange,by=c("PeakDepthRangeClass")),  
 GA,by=c("PeakDepthRangeClass")),  
 GAfirstlast,by=c("PeakDepthRangeClass")),  
 GAmeanrange,by=c("PeakDepthRangeClass")  
 )  
  
ABG<-full\_join(full\_join(  
 AA,   
 BA,by=c("PeakDepthRangeClass")),  
 GA,by=c("PeakDepthRangeClass"))  
   
ABGRich<-full\_join(full\_join(  
 AR,   
 BR,by=c("PeakRichnessRangeClass")),  
 GR,by=c("PeakRichnessRangeClass"))  
  
ABGs<-ABG %>% tidyr::gather("Type", "Nlakes", -PeakDepthRangeClass)  
ABGRichs<-ABGRich %>% tidyr::gather("Type", "Nlakes", -PeakRichnessRangeClass)  
  
  
positions1 <- c("GammaPeakDepthRange","BetaPeakDepthRange" ,"AlphaPeakDepthRange")  
positions2 <- c("GammaPeakRichnessRange","BetaPeakRichnessRange","AlphaPeakRichnessRange")  
  
P1<-ggplot(ABGs,aes(x=(Type),y=Nlakes,fill=PeakDepthRangeClass))+  
 geom\_col(position = position\_stack(reverse = T))+  
 xlab("")+ylab("Number of lakes")+  
 coord\_flip()+  
 scale\_x\_discrete(limits = positions1,labels=c("AlphaPeakDepthRange" = bquote("max range D"[alpha][max]),  
 #"AlphaPeakDepthMeanRange" = bquote("mean change D"[alpha][max]),  
 #"AlphaPeakDepthRangeFirstLast" = bquote("change range D"[alpha][max]),  
 "BetaPeakDepthRange" = bquote("max range D"[beta][max]),  
 #"BetaPeakDepthMeanRange" = bquote("mean change D"[beta][max]),  
 #"BetaPeakDepthRangeFirstLast" = bquote("change range D"[beta][max]),  
 "GammaPeakDepthRange" = bquote("max range D"[gamma][max])  
 #"GammaPeakDepthMeanRange" = bquote("mean change D"[gamma][max]),  
 #"GammaPeakDepthRangeFirstLast" = bquote("change range D"[gamma][max])  
 ))+  
 scale\_fill\_discrete(name = bquote("D"[max] ~"range" ))+   
 theme(axis.text.x = element\_text(angle = 90, vjust = 0.5, hjust=1))  
  
P2<-ggplot(ABGRichs,aes(x=(Type),y=Nlakes,fill=PeakRichnessRangeClass))+  
 geom\_col(position = position\_stack(reverse = T))+  
 xlab("")+ylab("Number of lakes")+  
 coord\_flip()+  
 scale\_x\_discrete(limits = positions2,labels=c("AlphaPeakRichnessRange" = bquote("max range R"[alpha][max]),  
 "BetaPeakRichnessRange" = bquote("max range R"[beta][max]),  
 "GammaPeakRichnessRange" = bquote("max range R"[gamma][max])  
 ))+  
 scale\_fill\_discrete(name = bquote("R"[max] ~"range" ))+   
 theme(axis.text.x = element\_text(angle = 90, vjust = 0.5, hjust=1))  
  
ggarrange(P1,P2,nrow=2)

