Appendix 3 RScript

```
#load packages
library(vegan)
library(adespatial)
library(tidyverse)
library(reshape)
library(ade4)
library(readxl)

##get quickMEM function (replacement of old quickPCNM function)
source ('http://www.davidzeleny.net/anadat-r/doku.php/en:numecolr:sr.value?do=export_code&codeblock=1')
source ('http://www.davidzeleny.net/anadat-r/doku.php/en:numecolr:sr.value?do=export_code&codeblock=1')
source ('https://raw.githubusercontent.com/zdealveindy/anadat-r/master/scripts/NumEcolR2/quickMEM.R')
source ('https://raw.githubusercontent.com/zdealveindy/anadat-r/master/scripts/NumEcolR2/scalog.R')

#Lakes data
#Time 90 steps, 30 years with 3 steps per year (1990-2019); this time vector is use for the individual time series models of all lakes
Timesteps <- read_excel("file_location_on_disk.xlsx", sheet = "Time vector 90 steps")
#Lakes: Example of data import with explanatroy (water quality) variables
Lake <- read_excel("file_location_on_disk.xlsx.xlsx", sheet = "Lake_name")

#Standardization of water quality variables
Lake_scaled <- scale(Lake, center = TRUE, scale = TRUE)

# TIME SERIES MODELING
#creating AEM variables
out <- aem.time(90, moran = TRUE)

#AEM-RDA models using quickMEM function
modelLake <- quickMEM(Lake_scaled, Timesteps, myspat=out$aem[,1:70], alpha=0.05, perm.max=999, detrend = FALSE)

#Extract lc scores for significant RDA axes; note: choices=1:X refers to significant RDA axes in the models, where X stands for the number of significant axes
fitted.scores.Lake <- data.frame(scores(modelLake$RDA,display="lc",choices=1:X))

#LINEAR MODEL
#ANOVA for significant RDA axes, folllowing https://rcompanion.org/handbook/I_09.html
rmANOVA_RDA1 <- read_excel("file_(significant_axes)_import_from_file_location_on_disk.xlsx", sheet = "rm-ANOVA RDA1")
rmANOVA_RDA2 <- read_excel("file_(significant_axes)_import_from_file_location_on_disk.xlsx", sheet = "rm-ANOVA RDA2")
rmANOVA_RDA3 <- read_excel("file_(significant_axes)_import_from_file_location_on_disk.xlsx", sheet = "rm-ANOVA RDA3")
rmANOVA_RDA4 <- read_excel("file_(significant_axes)_import_from_file_location_on_disk.xlsx", sheet = "rm-ANOVA RDA4")

library(nlme)
if(!require(psych)){install.packages("psych")}
if(!require(nlme)){install.packages("nlme")}
if(!require(car)){install.packages("car")}
if(!require(multcompView)){install.packages("multcompView")}
if(!require(lsmeans)){install.packages("lsmeans")}
if(!require(ggplot2)){install.packages("ggplot2")}
if(!require(rcompanion)){install.packages("rcompanion")}
```

```
#accounting for temporal autocorrelation structure; finds value for corAR1 function
#RDA1
model.RDA1 = gls(RDA1 ~ Type + Time + Type*Time,data=rmANOVA_RDA1)
ACF(model.RDA1, form = ~ Time | Lake)
#RDA2
model.RDA2 = gls(RDA2 ~ Type + Time + Type*Time, data=rmANOVA_RDA2)
ACF(model.RDA2,form = ~ Time | Lake)
#RDA3
model.RDA3 = gls(RDA3 ~ Type + Time + Type*Time, data=rmANOVA_RDA3)
ACF(model.RDA3, form = ~ Time | Lake)
#RDA4
model.RDA4 = gls(RDA4 ~ Type + Time + Type*Time, data=rmANOVA_RDA4)
ACF(model.RDA4,form = ~ Time | Lake)

#Lake (i.e. replicates) treated as random variable, using lme function; without random effects the gls function can be used
model.RDA1 = lme(RDA1 ~ Type + Time + Type*Time, random = ~1|Lake, correlation = corAR1(form = ~ Time | Lake, value = 0.8210608), data=rmANOVA_RDA1, method="REML")
model.RDA2 = lme(RDA2 ~ Type + Time + Type*Time, random = ~1|Lake, correlation = corAR1(form = ~ Time | Lake, value = 0.17883266), data=rmANOVA_RDA2, method="REML")
model.RDA3 = lme(RDA3 ~ Type + Time + Type*Time, random = ~1|Lake, correlation = corAR1(form = ~ Time | Lake, value = 0.059594695), data=rmANOVA_RDA3, method="REML")
model.RDA4 = lme(RDA4 ~ Type + Time + Type*Time, random = ~1|Lake, correlation = corAR1(form = ~ Time | Lake, value = 0.0328), data=rmANOVA_RDA4, method="REML")

#car package not working without loading data.table package
install.packages("data.table")
library(data.table)
install.packages("car")
library(car)

#display ANOVA tables
Anova(model.RDA1)
Anova(model.RDA2)
Anova(model.RDA3)
Anova(model.RDA4)

Anova(model.RDA1.gls)
Anova(model.RDA2.gls)
Anova(model.RDA3.gls)
Anova(model.RDA4.gls)


# adj. R2 of RDA axes
RsquareAdj(modelLake)$r.squared
coef(modelLake)

##CORRELATION ANALYSES
#All analyses carried out at: https://www.socscistatistics.com/tests/spearman/default2.aspx
```