**Code for logistic regression analyses**

## Load required libraries

library(MASS)

library(nnet)

library(tidyverse)

library(ggplot2)

## Read data and make some minor corrections for consistency

nzje<-read.csv("nzje\_data.csv")

nzje$I\_cats[nzje$I\_cats=="Plant"] <- "Weed"

nzje$B\_cats[nzje$B\_cats=="Birds"] <- "Bird"

## Specify factor levels

nzje$I\_cats<-factor(nzje$I\_cats,

levels=c("Mammal predator","Mammal herbivore",

"Weed","Other"))

nzje$B\_cats<-factor(nzje$B\_cats,

levels=c("Bird","Invert","Plant","Other"))

nzje$P1<-factor(nzje$P1)

nzje$P2<-factor(nzje$P2)

nzje$P3<-factor(nzje$P3)

nzje$P4<-factor(nzje$P4)

nzje$P5<-factor(nzje$P5)

nzje$P6<-factor(nzje$P6)

nzje$P7<-factor(nzje$P7)

nzje$P8<-factor(nzje$P8)

nzje$P9<-factor(nzje$P9)

summary(nzje)

## Use Ordinal LR for principles 1:6

## Combine 2nd and 3rd level and use LR for principles 7 and 8

## Principle 9 is all 1's, so not analysed

## Ordinal logistic regression for principles 1:6

mods<-lapply(paste0("P",1:6),function(yy){

# define models

m1<-formula(paste0(yy,"~1"))

m2<-formula(paste0(yy,"~I\_cats"))

m3<-formula(paste0(yy,"~B\_cats"))

m4<-formula(paste0(yy,"~I\_cats+B\_cats"))

# fit models

olr1<-polr(m1,data=nzje,Hess=TRUE)

olr2<-polr(m2,data=nzje,Hess=TRUE)

olr3<-polr(m3,data=nzje,Hess=TRUE)

olr4<-polr(m4,data=nzje,Hess=TRUE)

# collate results and create AIC table

aic<-AIC(olr1,olr2,olr3,olr4)

res<-list(olr1=olr1,olr2=olr2,olr3=olr3,olr4=olr4)

aic$neg2ll<-sapply(res,function(mm) -2\*logLik(mm))

aic$Daic<-aic$AIC-min(aic$AIC[1:3])

aic$wgt<-exp(-0.5\*aic$Daic)/sum(exp(-0.5\*aic$Daic[1:3]))

# table of regression coefficients

col\_names<-rownames(coef(summary(olr4)))

coefs<-ses<-array(NA,dim=c(4,length(col\_names)))

for(ii in 1:4){

temp<-coef(summary(res[[ii]]))

idx<-match(rownames(temp),col\_names)

coefs[ii,idx]<-temp[,"Value"]

ses[ii,idx]<-temp[,"Std. Error"]

colnames(coefs)<-colnames(ses)<-col\_names

}

# calculate 95% CIs

lower<-exp(coefs-1.96\*ses)

upper<-exp(coefs+1.96\*ses)

return(list(aic=cbind(aic,coefs,ses,lower,upper),

res=res))

})

## Principles 7 & 8

# combine levels

nzje$P7b<-nzje$P7

nzje$P7b[nzje$P7b==3]<-2

nzje$P7b<-factor(nzje$P7b)

nzje$P8b<-nzje$P8

nzje$P8b[nzje$P8b==3]<-2

nzje$P8b<-factor(nzje$P8b)

mods\_b<-lapply(paste0("P",7:8,"b"),function(yy){

# define models

m1<-formula(paste0(yy,"~1"))

m2<-formula(paste0(yy,"~I\_cats"))

m3<-formula(paste0(yy,"~B\_cats"))

m4<-formula(paste0(yy,"~I\_cats+B\_cats"))

# fit models

lr1<-glm(m1,data=nzje,family = binomial)

lr2<-glm(m2,data=nzje,family = binomial)

lr3<-glm(m3,data=nzje,family = binomial)

lr4<-glm(m4,data=nzje,family = binomial)

# collate results and create AIC table

aic<-AIC(lr1,lr2,lr3,lr4)

res<-list(lr1=lr1,lr2=lr2,lr3=lr3,lr4=lr4)

aic$neg2ll<-sapply(res,function(mm) -2\*logLik(mm))

aic$Daic<-aic$AIC-min(aic$AIC[1:3])

aic$wgt<-exp(-0.5\*aic$Daic)/sum(exp(-0.5\*aic$Daic[1:3]))

# table of regression coefficients

col\_names<-rownames(coef(summary(lr4)))

coefs<-ses<-array(NA,dim=c(4,length(col\_names)))

for(ii in 1:4){

temp<-coef(summary(res[[ii]]))

idx<-match(rownames(temp),col\_names)

coefs[ii,idx]<-temp[,"Estimate"]

ses[ii,idx]<-temp[,"Std. Error"]

colnames(coefs)<-colnames(ses)<-col\_names

}

# calculate 95% CIs

lower<-exp(coefs-1.96\*ses)

upper<-exp(coefs+1.96\*ses)

return(list(aic=cbind(aic,coefs,ses,lower,upper),

res=res))

})

## Sumary of AIC model weights for all analyses

wgt\_summ<-sapply(mods,function(mod)mod$aic$wgt)

wgt\_summ<-cbind(wgt\_summ,sapply(mods\_b,function(mod)mod$aic$wgt))

colnames(wgt\_summ)<-paste0("P",1:8)

rownames(wgt\_summ)<-paste0("mod\_",1:4)

round(wgt\_summ,3)

###################################################################

### Collate results from best models for plotting

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res\_summ<-lapply(mods,function(mod){

idx<-which.min(mod$aic$Daic[1:3])

temp<-mod$aic[idx,-(1:5)]

prin<-names(attr(mod$res[[1]]$terms,"dataClasses"))

data.frame(principle=prin,param=colnames(temp),

value=as.numeric(temp),

type=rep(c("est","se","lower","upper"),each=8))

})

res\_summ<-c(res\_summ,

lapply(mods\_b,function(mod){

idx<-which.min(mod$aic$Daic[1:3])

temp<-mod$aic[idx,-(1:5)]

prin<-names(attr(mod$res[[1]]$terms,"dataClasses"))

data.frame(principle=prin,param=colnames(temp),

value=as.numeric(temp),

type=rep(c("est","se","lower","upper"),each=7))

}))

res\_summ<-do.call("rbind",res\_summ)

## Tidy up some parameter names

res\_summ<-res\_summ %>% filter(!is.na(value))

res\_summ$param<-gsub(".1","",res\_summ$param,fixed = TRUE)

res\_summ$param<-gsub(".2","",res\_summ$param,fixed = TRUE)

res\_summ$param<-gsub(".3","",res\_summ$param,fixed = TRUE)

res\_summ$principle<-gsub("b","",res\_summ$principle,fixed = TRUE)

res\_summ$principle<-gsub("P","Principle ",res\_summ$principle,fixed = TRUE)

## Convert to wide format

res\_summ<-res\_summ %>% pivot\_wider(names\_from = "type",values\_from = "value")

## More name tidying

res\_summ <-res\_summ %>% filter(!(param %in% c("(Intercept)","1|2","2|3") ))

res\_summ$par2<-res\_summ$param

res\_summ$par2<-gsub("I\_cats","",res\_summ$par2,fixed = TRUE)

res\_summ$par2<-gsub("B\_cats","",res\_summ$par2,fixed = TRUE)

res\_summ$par2<-gsub(" ","\n",res\_summ$par2,fixed = TRUE)

res\_summ$lower[res\_summ$lower==0]<-NA

res\_summ$upper[is.infinite(res\_summ$upper)]<-NA

res\_summ$par2<-factor(res\_summ$par2,

levels=sort(unique(res\_summ$par2))[c(1,2,4,5,3)])

## Plots of results

ggplot(subset(res\_summ,principle!="Principle 1"),aes(x=par2,y=exp(est))) +

geom\_hline(yintercept = 1,colour="red")+

geom\_point()+

geom\_linerange(aes(ymin=lower,ymax=upper)) +

ylab("Odds ratio") + xlab("Invasive species category") +

theme\_bw()+theme(axis.text.x = element\_text(angle = 90)) +

facet\_wrap(~principle,scales="free\_y",ncol = 2)

ggsave("Invasive species effects.pdf",width=12,height=6)

ggsave("Invasive species effects.jpg",width=8,height=9)

ggplot(subset(res\_summ,principle=="Principle 1"),aes(x=par2,y=exp(est))) +

geom\_hline(yintercept = 1,colour="red")+

geom\_point()+

geom\_linerange(aes(ymin=lower,ymax=upper)) +

ylab("Odds ratio") + xlab("Biodiversity response category") +

theme\_bw()+theme(axis.text.x = element\_text(angle = 90)) +

facet\_wrap(~principle,scales="free\_y")

ggsave("Biodiversity response effects.pdf",width=4,height=3)

ggsave("Biodiversity response effects.jpg",width=4,height=3)

## Save AIC tables for analyses

for(ii in 1:6){

write.csv(mods[[ii]]$aic[1:3,1:5],paste0("AIC\_P",ii,".csv"))

}

for(ii in 1:2){

write.csv(mods\_b[[ii]]$aic[1:3,1:5],paste0("AIC\_P",ii+6,".csv"))

}