Q1: Are lake and terrestrial primary productivity coherent?

Jonathan Walter, Grace Wilkinson, Rachel Fleck, Michael Pace

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This document organizes for openness and reproducibility analyses of the temporal coherence of interannual variation in lake primary productivity with terrestrial primary productivity in the landscape surrounding the lake.

Data import

Data produced in 'ms1_prep.Rmd' are loaded.

```
load("/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/RData files/ms1_analysis_inprogress1.RData
```

```
any(sapply(analysislakes$lakedata, function(x){any(is.infinite(x))}))
```

```
## [1] FALSE
```

```
any(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))
```

```
## [1] FALSE
```

```
which(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))
```

```
## named integer(0)
```

```
analysislakes$lakeinfo[which(sapply(analysislakes$lakedata, function(x){any(is.na(x))})),]
```

```
##  [1] lagoslakeid       gnis_name         nhd_lat
##  [4] nhd_long          lake_area_ha      lake_perim_meters
##  [7] nhd_ftype         nhd_fcode         hu4_zoneid
## [10] hu12_zoneid       state_zoneid      elevation_m
## [13] start             end
## <0 rows> (or 0-length row.names)
```

```
# image(accndvi)
# points(lakepts.prj[which(sapply(analysislakes$lakedata, function(x){any(is.na(x))})),])

dbuff[which(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))]
```

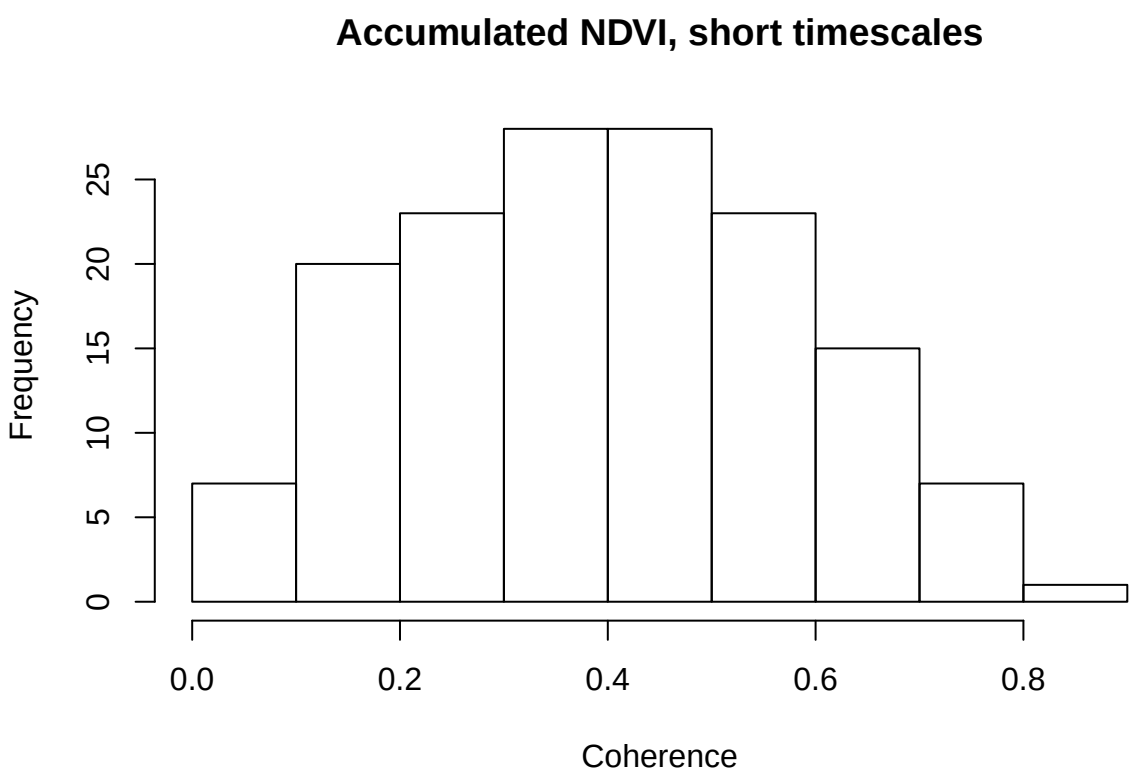
```
## numeric(0)
```

```
analysislakes$lakeinfo<-analysislakes$lakeinfo[!sapply(analysislakes$lakedata, function(x){any(is.na(x)
analysislakes$lakedata<-analysislakes$lakedata[!sapply(analysislakes$lakedata, function(x){any(is.na(x)
```

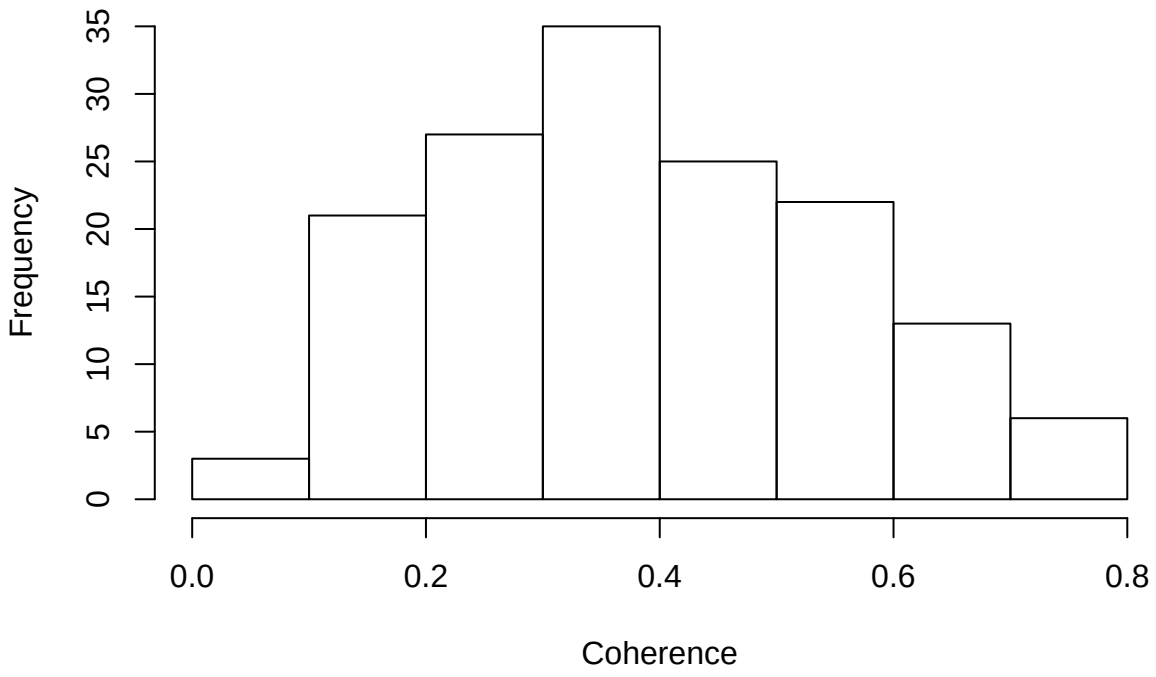
```
source("~/GitHub/AquaTerrSynch/AnalysisCode/bandtest_coh.R")

tsranges<-rbind(c(2,4),c(4,Inf),c(2,Inf))

coh.chlaXaccndvi<-NULL
coh.chlaXmaxndvi<-NULL
```

```
for(lind in 1:length(analysislakes$lakedata)){
  lakedat.ii<-cleandat(analysislakes$lakedata[[lind]], as.numeric(colnames(analysislakes$lakedata[[lind]
  chlaXaccndvi<-coh(lakedat.ii[1,], lakedat.ii[2,], as.numeric(colnames(analysislakes$lakedata[[lind]]))
                    norm="powall", sigmethod="fast", nrand=10000)
  chlaXmaxndvi<-coh(lakedat.ii[1,], lakedat.ii[3,], as.numeric(colnames(analysislakes$lakedata[[lind]]))
                    norm="powall", sigmethod="fast", nrand=10000)
  for(rind in 1:nrow(tsranges)){
    chlaXaccndvi<-bandtest.coh(chlaXaccndvi, tsranges[rind,])
    chlaXmaxndvi<-bandtest.coh(chlaXmaxndvi, tsranges[rind,])
  }
  coh.chlaXaccndvi<-rbind(coh.chlaXaccndvi, c(t(as.matrix(chlaXaccndvi$bandp[,3:5]))))
  coh.chlaXmaxndvi<-rbind(coh.chlaXmaxndvi, c(t(as.matrix(chlaXmaxndvi$bandp[,3:5]))))

}

coh.chlaXaccndvi<-as.data.frame(coh.chlaXaccndvi)
coh.chlaXmaxndvi<-as.data.frame(coh.chlaXmaxndvi)

colnames(coh.chlaXaccndvi)<-paste0("accndvi",c("p.ts1","phi.ts1","coh.ts1","p.ts2","phi.ts2","coh.ts2",
colnames(coh.chlaXmaxndvi)<-paste0("maxndvi",c("p.ts1","phi.ts1","coh.ts1","p.ts2","phi.ts2","coh.ts2",

coh.chlaXaccndvi$lagoslakeid<-analysislakes$lakeinfo$lagoslakeid
coh.chlaXmaxndvi$lagoslakeid<-analysislakes$lakeinfo$lagoslakeid
```

```
#short timescales
hist(coh.chlaXaccndvi$accndvicoh.ts1, main="Accumulated NDVI, short timescales", xlab="Coherence", ylab=
```




```
hist(coh.chlaXmaxndvi$maxndvicoh.ts1, main="Maximum NDVI, short timescales", xlab="Coherence", ylab="Fr
```




```
quantile(coh.chlaXaccndvi$accndvicoh.ts1)
```

```
##         0%        25%        50%        75%       100%
## 0.03540956 0.24309615 0.39391782 0.52458761 0.81625251
```

```
quantile(coh.chlaXmaxndvi$maxndvicoh.ts1)
```

```
##         0%        25%        50%        75%       100%
## 0.04514692 0.25124895 0.35877767 0.50983226 0.77145899
```

```
alpha=0.05
sum(coh.chlaXaccndvi$accndvip.ts1<alpha)/nrow(coh.chlaXaccndvi)
```

```
## [1] 0.05921053
```

```
sum(coh.chlaXmaxndvi$maxndvip.ts1<alpha)/nrow(coh.chlaXmaxndvi)
```

```
## [1] 0.05921053
```

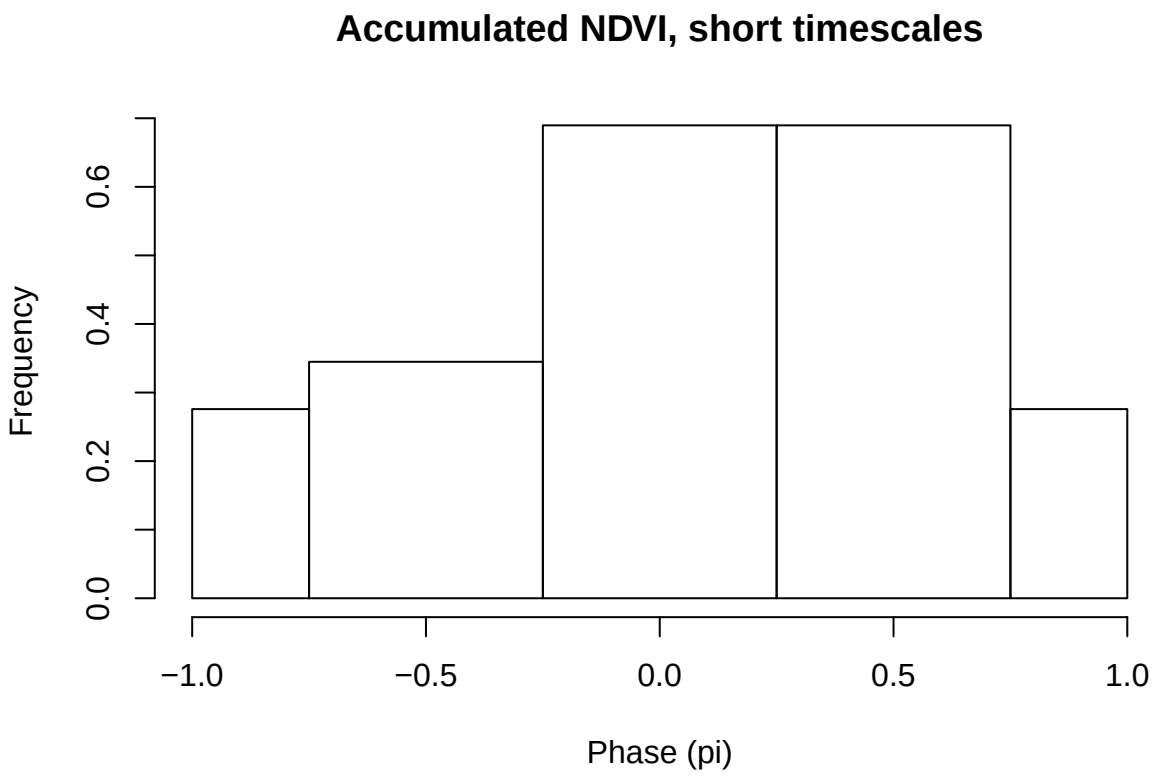
```
print(coh.chlaXaccndvi$accndviphi.ts1[coh.chlaXaccndvi$accndvip.ts1<alpha]/pi) #only pattern is that la
```

```
## [1]  0.70415901  0.33224850 -0.97156054 -0.04413595  0.56356061 -0.86709075
## [7] -0.05260276  0.12416199  0.92429361
```

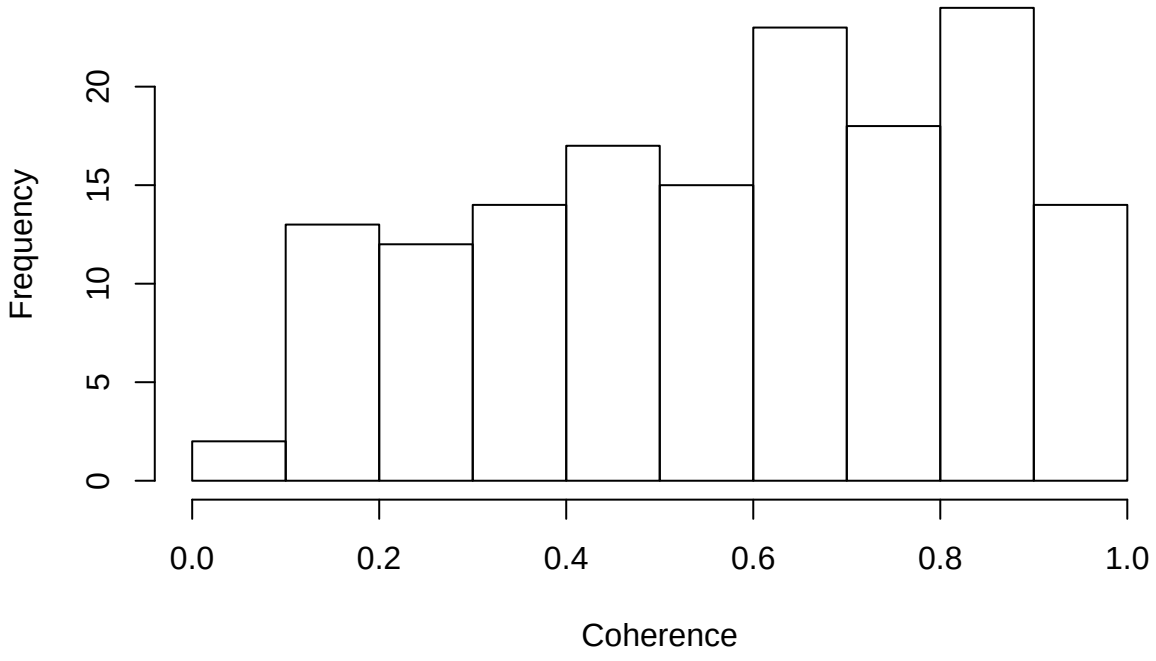
```
print(coh.chlaXmaxndvi$maxndviphi.ts1[coh.chlaXmaxndvi$maxndvip.ts1<alpha]/pi)
```

```
## [1] -0.1573764 -0.8240104 -0.7892870 -0.7185325 -0.9310910 -0.8435071
## [7] -0.2280369  0.5324496 -0.2123467
```

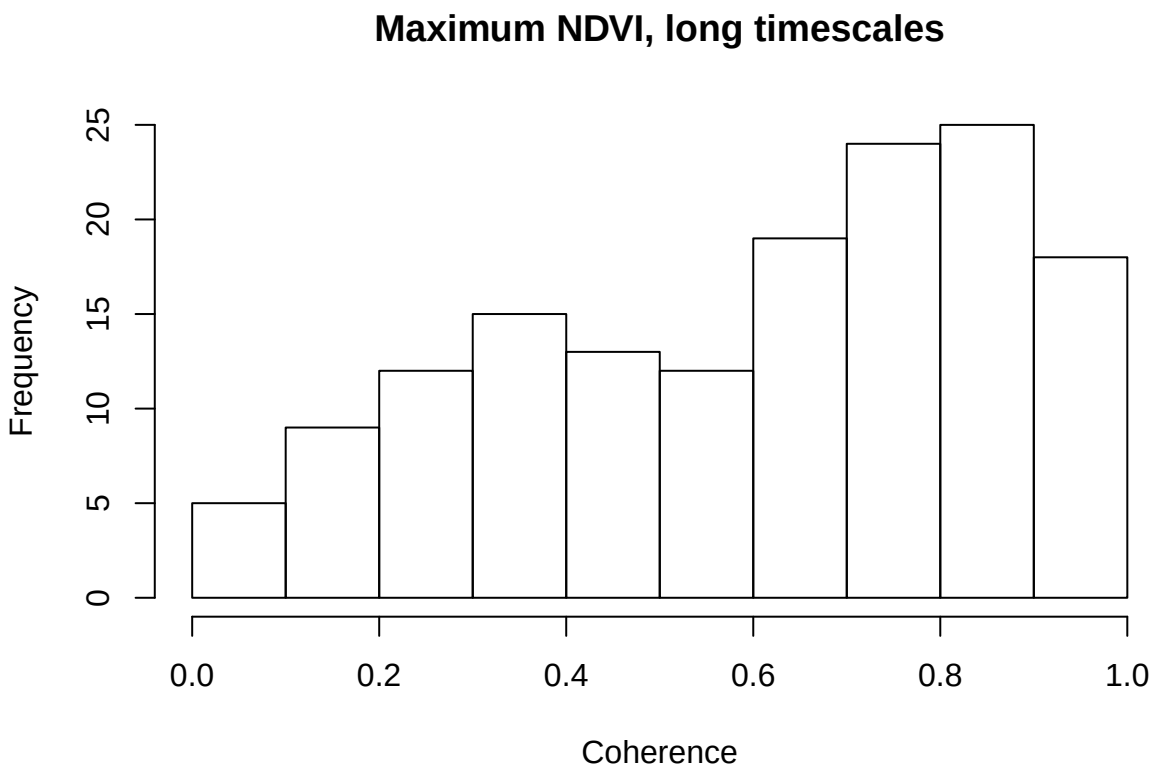
```
phicls<-c(-1,-.75,-0.25,0.25,0.75,1)

hist(coh.chlaXaccndvi$accndviphi.ts1[coh.chlaXaccndvi$accndvip.ts1<0.2]/pi, main="Accumulated NDVI, sho
```




```
#hist(coh.chlaXmaxndvi$maxndviphi.ts1[coh.chlaXmaxndvi$maxndvip.ts1<0.2]/pi, main="Maximum NDVI, short

#long timescales
hist(coh.chlaXaccndvi$accndvicoh.ts2, main="Accumulated NDVI, long timescales", xlab="Coherence", ylab=
```



```
hist(coh.chlaXmaxndvi$maxndvicoh.ts2, main="Maximum NDVI, long timescales", xlab="Coherence", ylab="Fre
```




```
quantile(coh.chlaXaccndvi$accndvicoh.ts2)
```

```
##         0%        25%        50%        75%       100%
## 0.06700155 0.38228617 0.60468470 0.79725568 0.97780892
```

```
quantile(coh.chlaXmaxndvi$maxndvicoh.ts2)
```

```
##         0%        25%        50%        75%       100%
## 0.04123391 0.38061632 0.65820308 0.81106846 0.96962207
```

```
alpha=0.05
sum(coh.chlaXaccndvi$accndvip.ts2<alpha)/nrow(coh.chlaXaccndvi)
```

```
## [1] 0.04605263
```

```
sum(coh.chlaXmaxndvi$maxndvip.ts2<alpha)/nrow(coh.chlaXmaxndvi)
```

```
## [1] 0.05263158
```

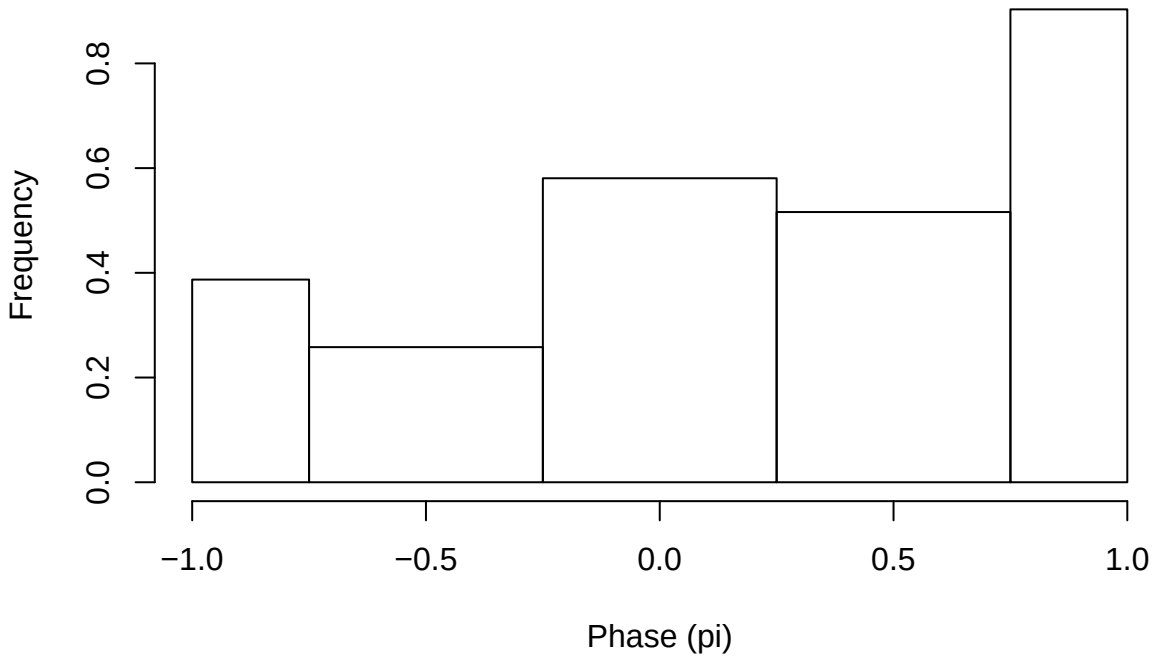
```
print(coh.chlaXaccndvi$accndviphi.ts2[coh.chlaXaccndvi$accndvip.ts2<alpha]/pi)
```

```
## [1] -0.43893809  0.25315167 -0.04386325 -0.65597599 -0.58346970  0.36382168
## [7]  0.89471121
```

```
print(coh.chlaXmaxndvi$maxndviphi.ts2[coh.chlaXmaxndvi$maxndvip.ts2<alpha]/pi)
```

```
## [1]  0.69982097 -0.97179292 -0.04190360  0.02097044 -0.67004320 -0.58501674
## [7] -0.31373024 -0.33804686
```

```
hist(coh.chlaXaccndvi$accndviphi.ts1[coh.chlaXaccndvi$accndvip.ts2<0.2]/pi, main="Accumulated NDVI, lon
```



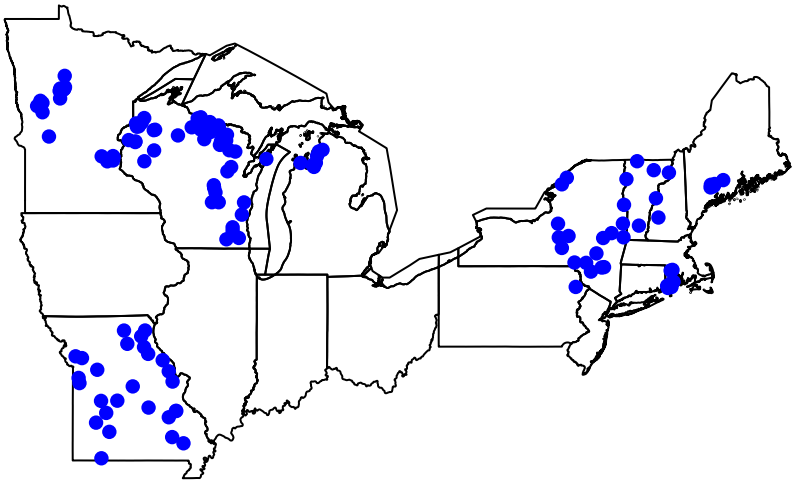

```
#hist(coh.chlaXmaxndvi$maxndviphi.ts1[coh.chlaXmaxndvi$maxndvicoh.ts2>0.6]/pi, main="Maximum NDVI, shor
```

```
states<-readOGR("~/Box Sync/NSF EAGER Synchrony/Data/statesp020.shp")
```

```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/statesp020.shp", layer: "statesp020
## with 2895 features
## It has 9 fields
## Integer64 fields read as strings:  STATESP020 DAY_ADM YEAR_ADM
```

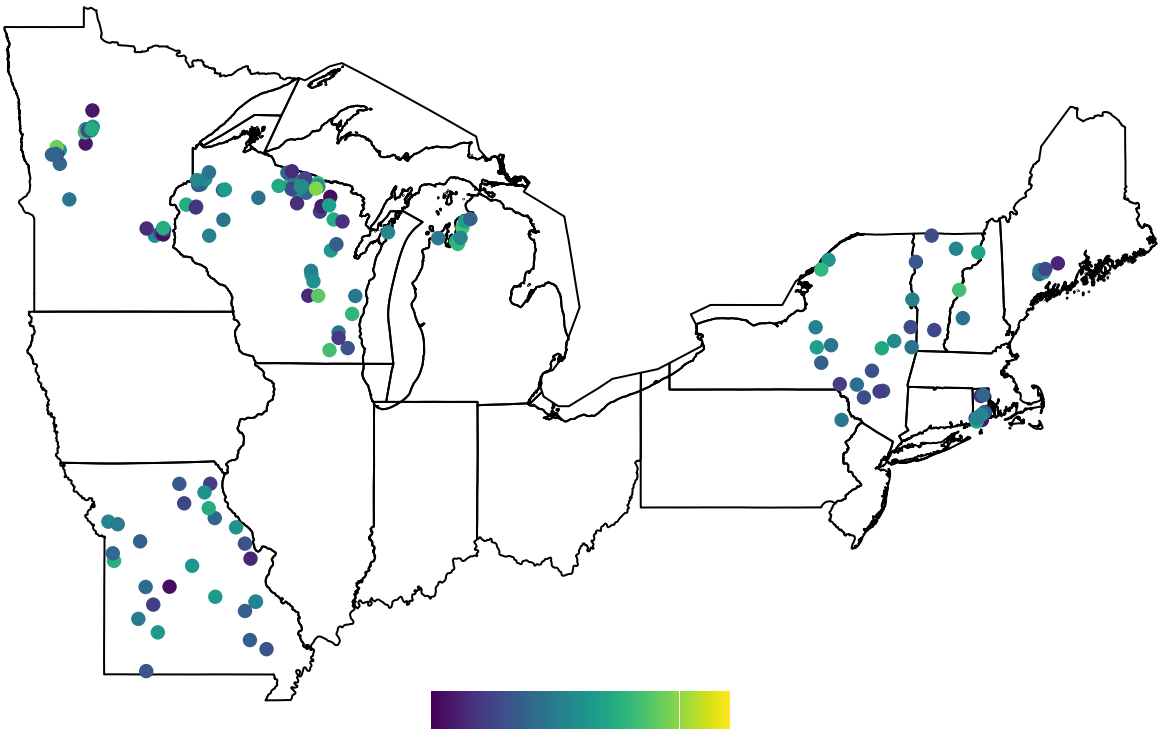
```
getstates<-c("Minnesota", "Iowa", "Wisconsin", "Illinois", "Missouri", "Michigan", "Indiana", "Ohio", "
lagosstates<-states[states@data$STATE %in% getstates,]

plot(lagosstates, main="Lakes selected for analysis")
points(analysislakes$lakeinfo$nhd_long, analysislakes$lakeinfo$nhd_lat, pch=16, cex=1, col="blue")
```

Lakes selected for analysis

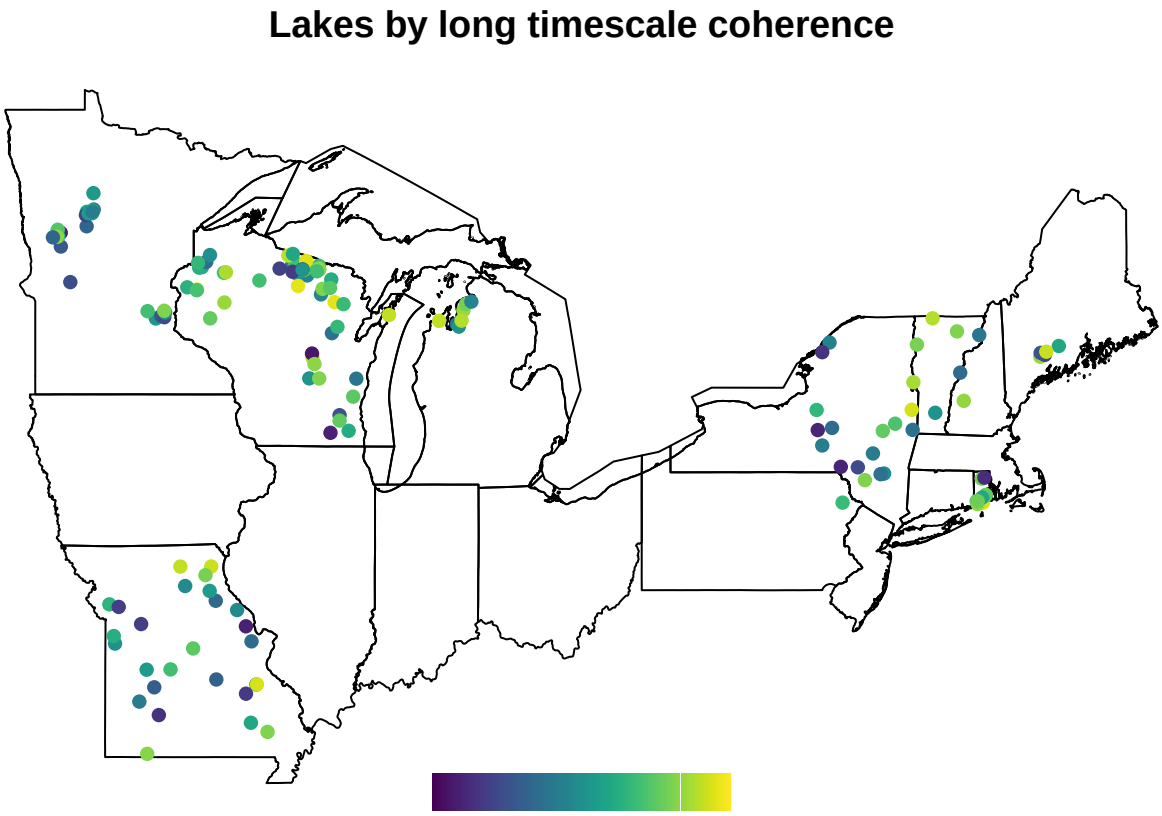


```
cohplotdata<-left_join(analysislakes$lakeinfo, coh.chlaXaccndvi, by="lagoslakeid")

pal<-viridis(100)

par(mar=c(1,0,2,0))

plot(lagosstates, main="Lakes by short timescale coherence")
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1, col=pal[round(cohplotdata$accndvicoh.ts
colorbar.plot(x=mean(par("usr")[1:2]),y=par("usr")[3],strip=1:100,col=pal,horizontal = T)
```

Lakes by short timescale coherence



```
plot(lagosstates, main="Lakes by long timescale coherence")
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1, col=pal[round(cohplotdata$accndvicoh.ts
colorbar.plot(x=mean(par("usr")[1:2]),y=par("usr")[3],strip=1:100,col=pal,horizontal = T)
```




```
#Need to add: depth, average growing season Chlorophyll-a, TSI(chla) categories, pct ag

#agriculture -- is 500m buffer best? Other options include 100m buffer (probably too small) and hu12 wa
# pct.ag<-lagosne_select(table="buffer500m.lulc", vars=c("lagoslakeid","buffer500m_nlcd2001_pct_82","bu
pct.ag<-lagosne_select(table="hu12.lulc", vars=c("hu12_zoneid","hu12_nlcd2001_pct_82","hu12_nlcd2006_pc
pct.ag<-pct.ag[pct.ag$hu12_zoneid %in% analysislakes$lakeinfo$hu12_zoneid,]
pct.ag.avg<-data.frame(hu12_zoneid=pct.ag$hu12_zoneid, pct.ag=rowMeans(pct.ag[,2:4]))

#depth
depth<-lagosne_select(table="lakes_limno", vars=c("lagoslakeid","maxdepth"))
depth<-depth[depth$lagoslakeid %in% analysislakes$lakeinfo$lagoslakeid,] #use max depth because it's mo

#growing season Chlorophyll-a
chla<-lagosne_select(table="epi_nutr", vars=c("lagoslakeid","samplemonth","chla"))
chla<-chla[chla$lagoslakeid %in% analysislakes$lakeinfo$lagoslakeid,]
gs.chla<-chla[chla$samplemonth %in% 5:9,]
avg.chla<-aggregate(chla ~ lagoslakeid, data=gs.chla, FUN=mean, na.rm=T)

#Chlorophyll-a TSI class
#TSI(CHL) = 9.81 ln(CHL) + 30.6
tsi.chl<-data.frame(lagoslakeid=avg.chla$lagoslakeid, tsi=9.81 * log(avg.chla$chla) + 30.6)
tsi.chl$tsi.cat<-rep("lake",nrow(tsi.chl))

tsi.chl$tsi.cat[tsi.chl$tsi < 40]<-"oligotrophic"
```

```
tsi.chl$tsi.cat[tsi.chl$tsi >=40 & tsi.chl$tsi < 50]<-"mesotrophic"
tsi.chl$tsi.cat[tsi.chl$tsi >=50 & tsi.chl$tsi < 70]<-"eutrophic"
tsi.chl$tsi.cat[tsi.chl$tsi >= 70] <-"hypereutrophic"

#huc2 and huc4 watershed codes
huc_codes<-read.csv("/Users/jonathanwalter/GitHub/AquaTerrSynch/AnalysisCode/match_huc_codes.csv", colCl

#state info
states<-lagosne_select(table="state", vars=c("state_zoneid","state_name"))

predictors<-analysislakes$lakeinfo
predictors$tslength<-predictors$end-predictors$start+1
predictors<-left_join(predictors, depth, by="lagoslakeid")
predictors<-left_join(predictors, pct.ag.avg, by="hu12_zoneid")
```

```
## Warning: Column `hu12_zoneid` joining factors with different levels,
## coercing to character vector
```

```
predictors<-left_join(predictors, avg.chla, by="lagoslakeid")
predictors<-left_join(predictors, tsi.chl, by="lagoslakeid")
predictors<-left_join(predictors, states, by="state_zoneid")
```

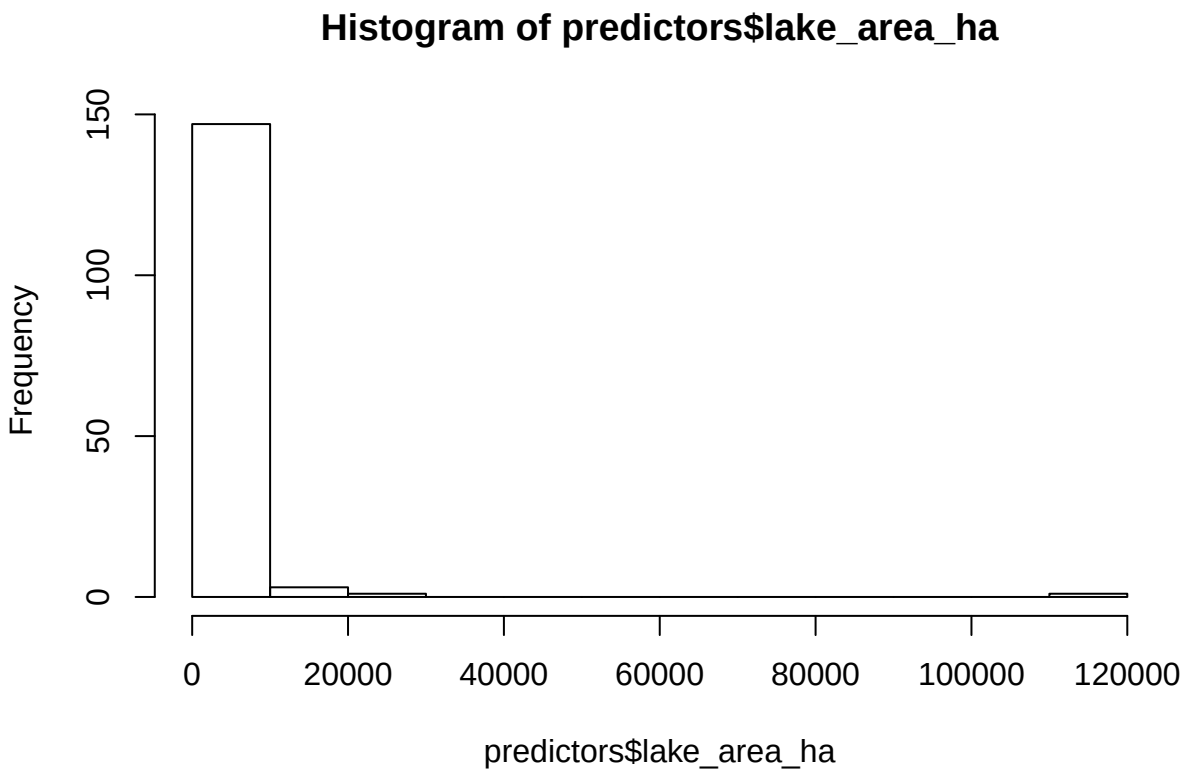
```
## Warning: Column `state_zoneid` joining factors with different levels,
## coercing to character vector
```

```
#predictors<-left_join(predictors, huc_codes, by="hu4_zoneid")

for(nn in 1:ncol(predictors)){

  if(is.factor(predictors[,nn])){
    predictors[,nn]<-factor(predictors[,nn])
  }

}

str(predictors)
```

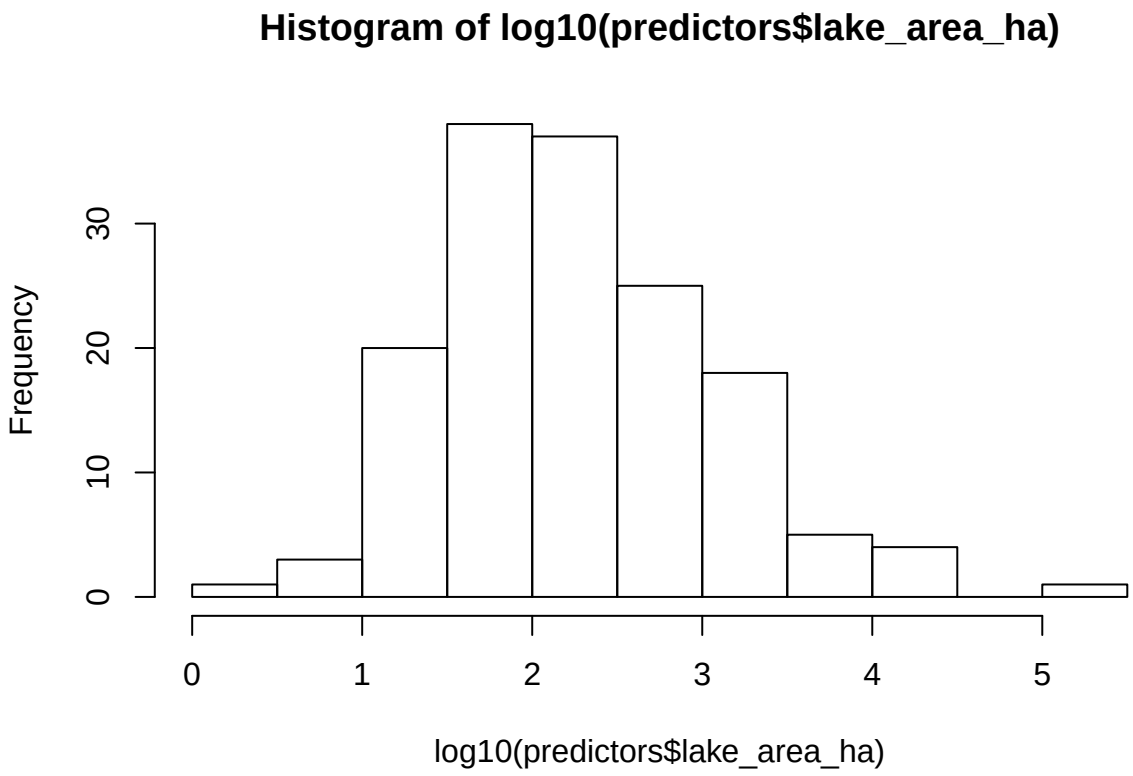
```
## 'data.frame':    152 obs. of  21 variables:
##  $ lagoslakeid      : int  211 249 618 906 969 1109 1505 2062 2714 2851 ...
##  $ gnis_name        : chr  NA NA "Butternut Lake" "Sparkling Lake" ...
##  $ nhd_lat          : num  44.5 43.7 45.9 46 45.8 ...
##  $ nhd_long         : num  -73.3 -73.4 -89 -89.7 -89.3 ...
##  $ lake_area_ha     : num  113496.4 30 504.7 63.7 210.2 ...
##  $ lake_perim_meters: num  1042251 3494 13134 3777 9402 ...
##  $ nhd_ftype        : int  390 390 390 390 390 390 390 390 390 390 ...
##  $ nhd_fcode        : int  39004 39004 39004 39004 39004 39004 39004 39004 39004 39004 ...
##  $ hu4_zoneid       : Factor w/ 28 levels "HU4_10","HU4_12",..: 17 17 11 8 12 10 10 10 10 10 ...
##  $ hu12_zoneid      : chr  "HU12_17646" "HU12_16835" "HU12_13309" "HU12_13098" ...
##  $ state_zoneid     : chr  "State_17" "State_5" "State_9" "State_9" ...
##  $ elevation_m      : num  28.8 28.2 514.5 494.7 503.3 ...
##  $ start            : num  1989 1990 1993 1989 1994 ...
##  $ end              : num  2010 2010 2013 2011 2013 ...
##  $ tslength         : num  22 21 21 23 20 21 18 21 21 21 ...
##  $ maxdepth         : num  97 NA 12.8 20 11.6 ...
##  $ pct.ag           : num  2.5298 0.4199 0.0976 0.3029 6.6886 ...
```

```
##  $ chla             : num  5.39 7.94 2.44 1.86 2.04 ...
##  $ tsi              : num  47.1 50.9 39.4 36.7 37.6 ...
##  $ tsi.cat          : chr  "mesotrophic" "eutrophic" "oligotrophic" "oligotrophic" ...
##  $ state_name       : Factor w/ 10 levels "Maine","Michigan",..: 9 6 10 10 10 2 2 2 2 2 ...
```

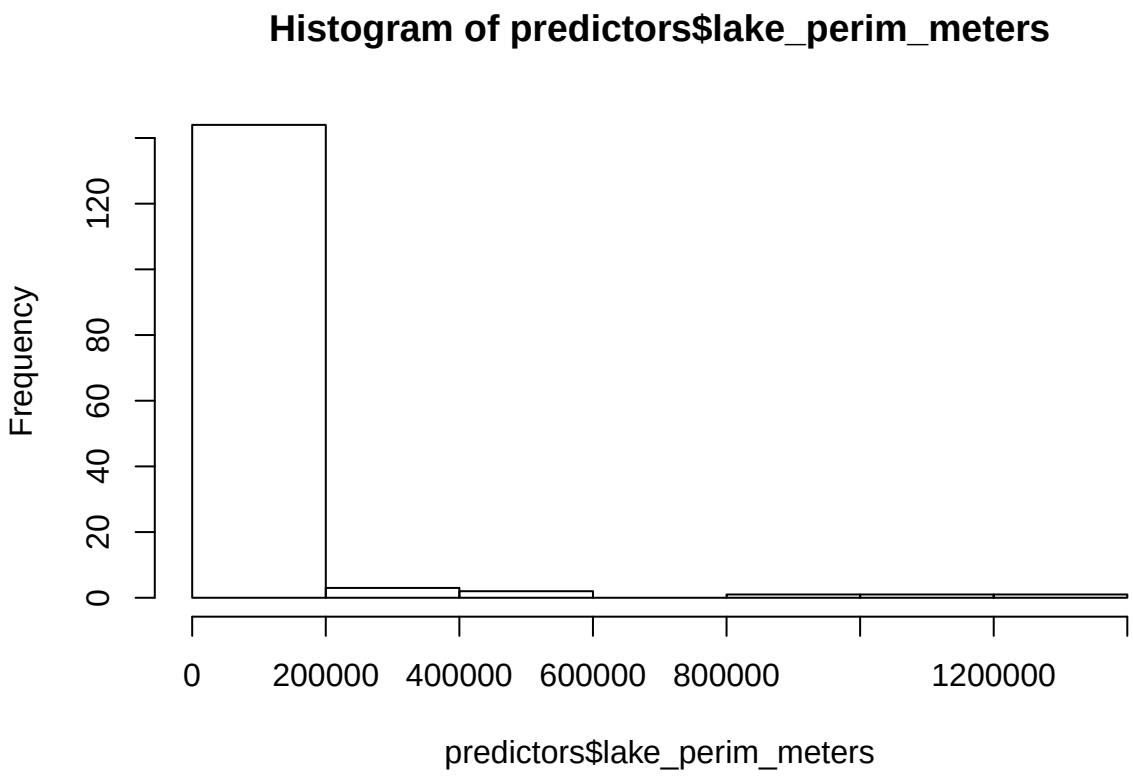
```
hist(predictors$lake_area_ha)
```



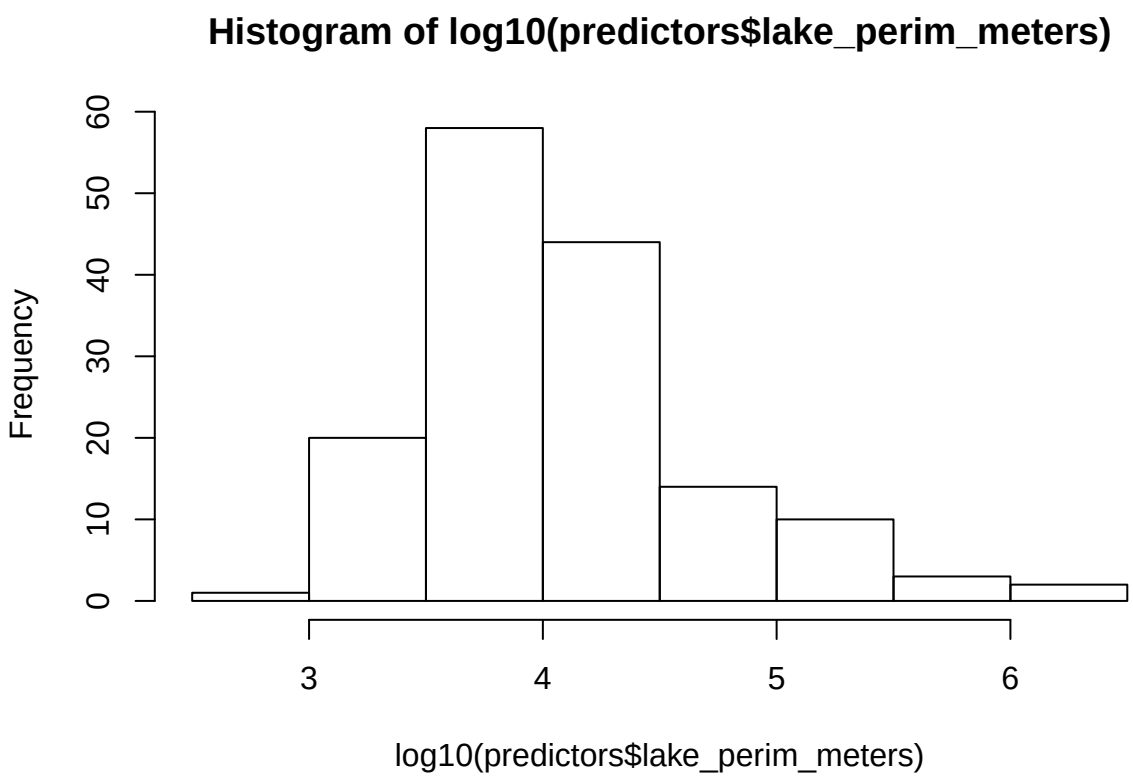

```
hist(log10(predictors$lake_area_ha))
```




```
hist(predictors$lake_perim_meters)
```




```
hist(log10(predictors$lake_perim_meters))
```




```
table(predictors$nhd_fcode)
```

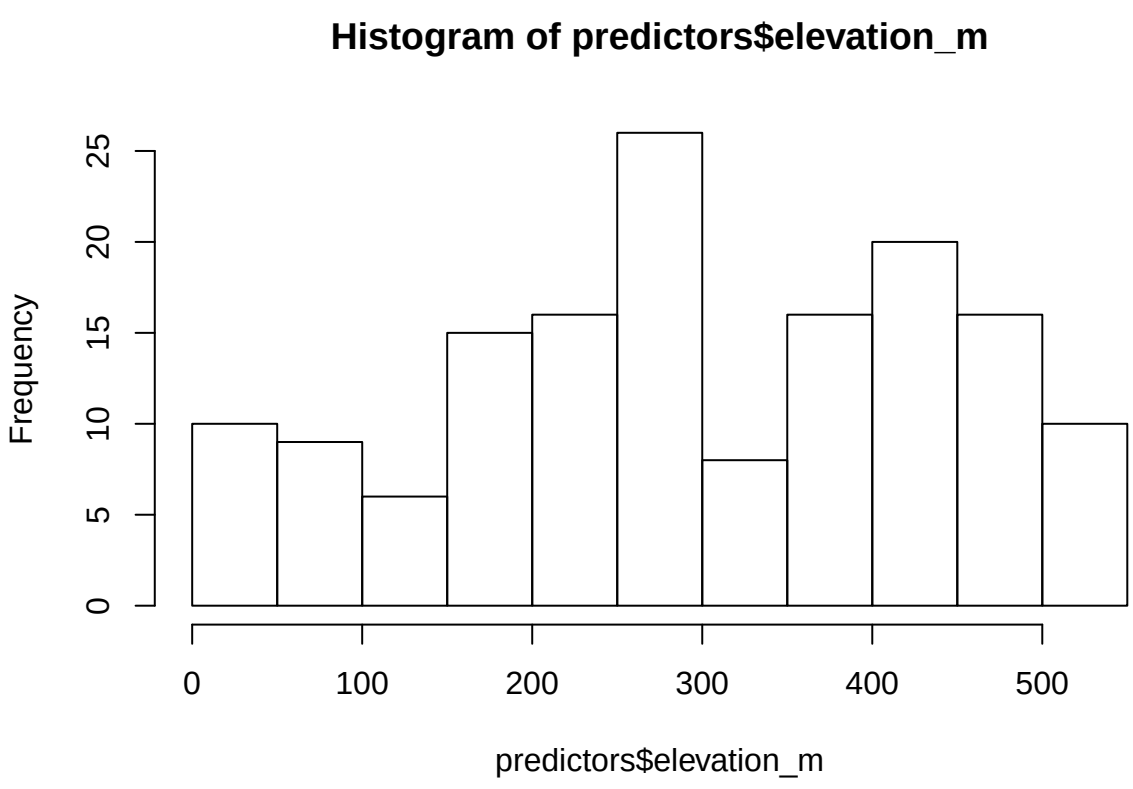
```
##
## 39000 39004 39009 39010 39012 43601
##     1   123    17     4     6     1
```

```
table(predictors$hu12_zoneid)
```

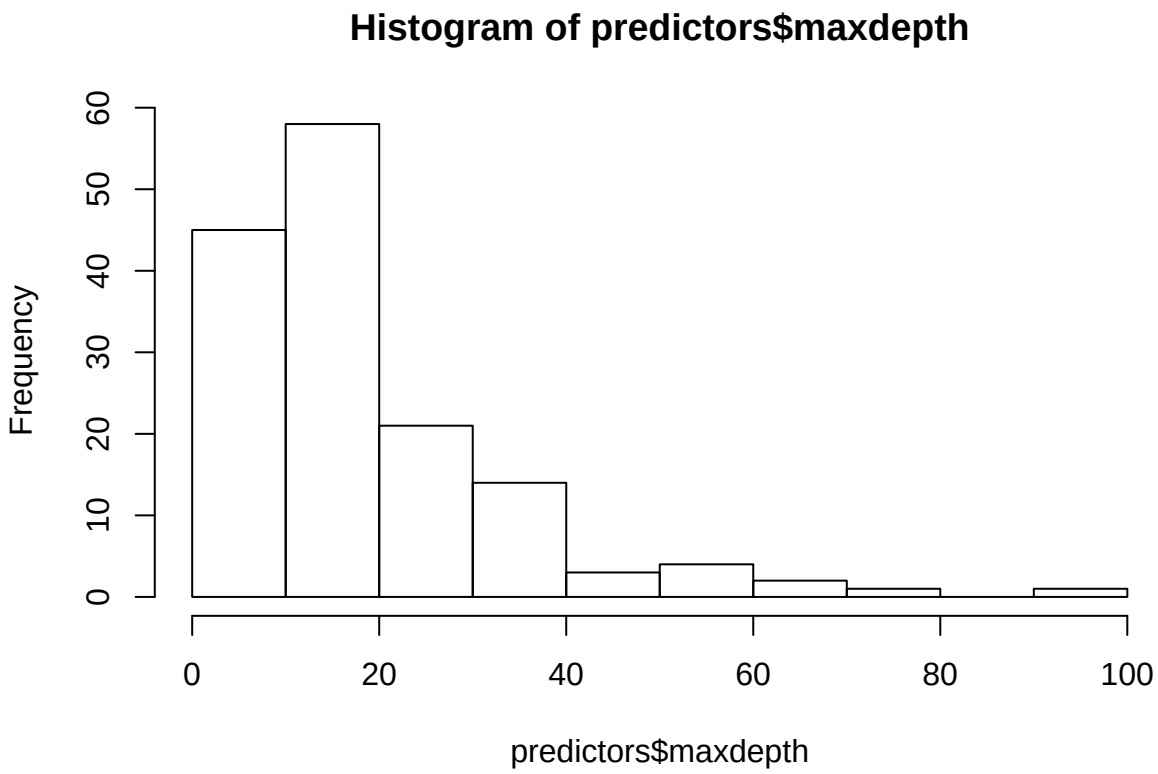
```
##
## HU12_10463 HU12_10471 HU12_10488 HU12_10493 HU12_10499 HU12_10676
##          1          2          1          1          1          1
## HU12_10700 HU12_10785 HU12_10862 HU12_10863 HU12_10865 HU12_11197
##          1          1          1          4          1          2
## HU12_11465 HU12_11495 HU12_11508 HU12_11509 HU12_11514 HU12_11515
##          1          1          1          1          2          1
## HU12_11522 HU12_11529 HU12_11768 HU12_11816 HU12_11826 HU12_11829
##          1          2          1          1          1          1
## HU12_11889 HU12_11938 HU12_11978 HU12_11981 HU12_12113 HU12_12125
##          1          1          1          1          1          1
## HU12_12225 HU12_13098 HU12_13100 HU12_13125 HU12_13128 HU12_13164
##          1          5          1          1          1          1
## HU12_13189 HU12_13192 HU12_13214 HU12_13234 HU12_13241 HU12_13244
##          1          1          1          1          1          1
## HU12_13261 HU12_13300 HU12_13304 HU12_13309 HU12_13354 HU12_13360
##          1          1          1          2          1          1
## HU12_13363 HU12_13370 HU12_13374 HU12_13376 HU12_13388 HU12_13413
##          1          3          1          1          1          1
## HU12_13612 HU12_13616 HU12_13624 HU12_13625 HU12_13628 HU12_13633
##          1          1          1          1          1          1
## HU12_13634 HU12_14494 HU12_14495 HU12_14496 HU12_14497 HU12_14533
```

```
##          1          1          1          1          4          1
##   HU12_148  HU12_1494 HU12_15183 HU12_15197 HU12_15280 HU12_15296
##          1          1          1          1          1          1
## HU12_15315 HU12_15329  HU12_1537 HU12_15856 HU12_16122 HU12_16125
##          1          1          1          1          1          1
##  HU12_1615  HU12_1621 HU12_16347 HU12_16746 HU12_16747 HU12_16749
##          1          2          1          1          2          2
## HU12_16835 HU12_16882 HU12_17143 HU12_17178 HU12_17235 HU12_17379
##          1          1          1          1          2          1
## HU12_17401 HU12_17407 HU12_17433 HU12_17477 HU12_17488 HU12_17504
##          1          1          1          1          2          2
## HU12_17512 HU12_17513 HU12_17515 HU12_17541 HU12_17646 HU12_17651
##          1          2          1          1          1          1
## HU12_17655  HU12_1802 HU12_18174  HU12_1819  HU12_1828 HU12_18730
##          1          1          1          1          1          1
##  HU12_1896 HU12_19726  HU12_1980 HU12_19842 HU12_20279  HU12_2173
##          1          1          1          1          1          1
##  HU12_2200  HU12_2239  HU12_2350  HU12_2410  HU12_2412  HU12_2429
##          1          1          1          1          1          1
##  HU12_4337  HU12_4347   HU12_442   HU12_488   HU12_509   HU12_542
##          1          1          1          1          1          1
##   HU12_581   HU12_829
##          1          1
```

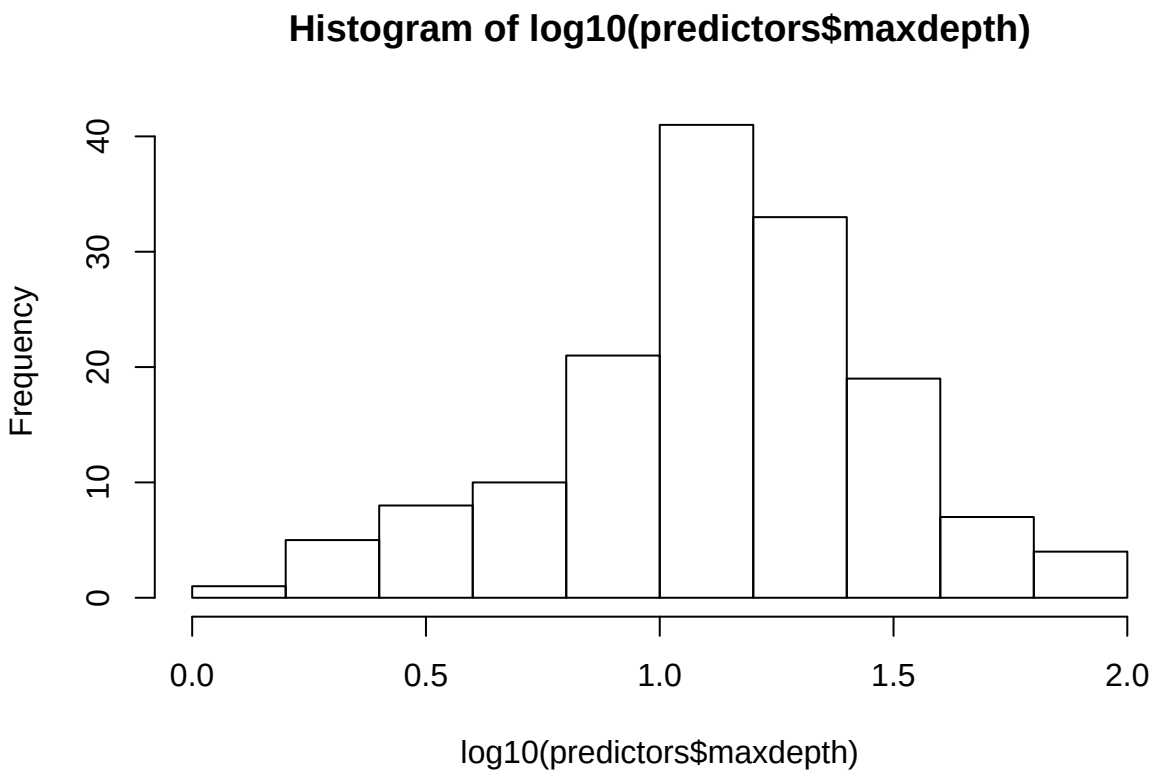
```
hist(predictors$elevation_m)
```



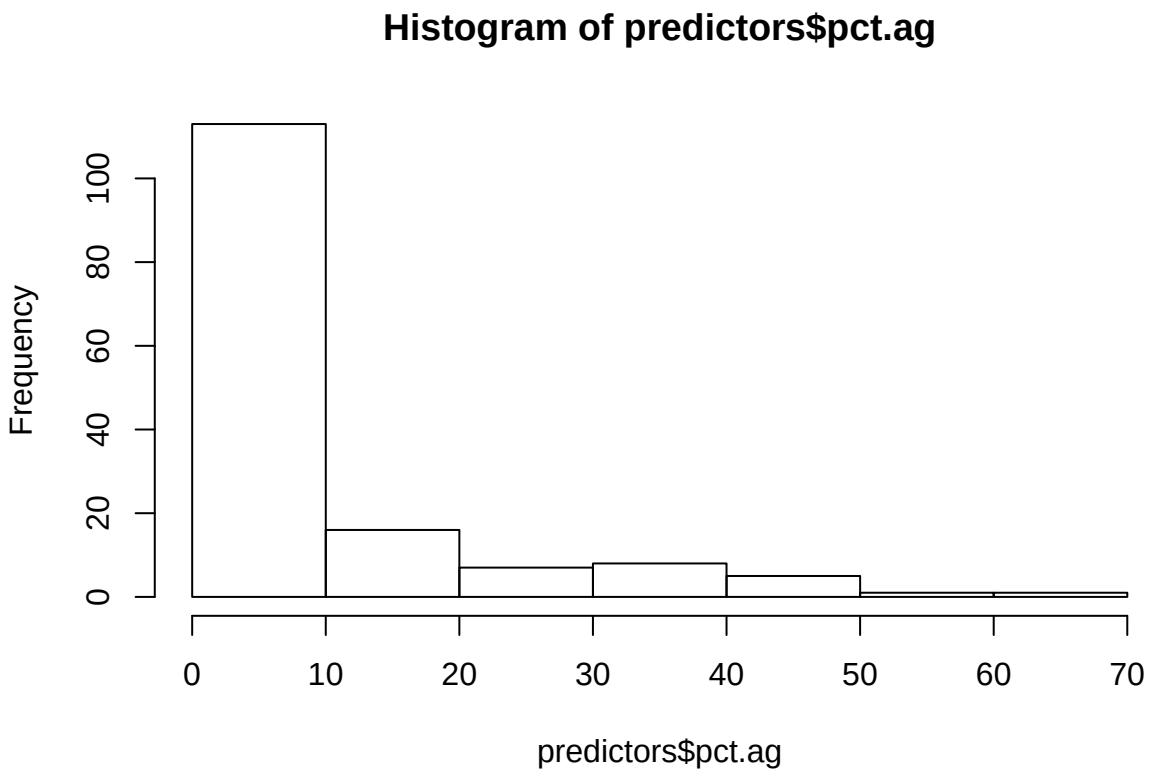

```
hist(predictors$maxdepth)
```



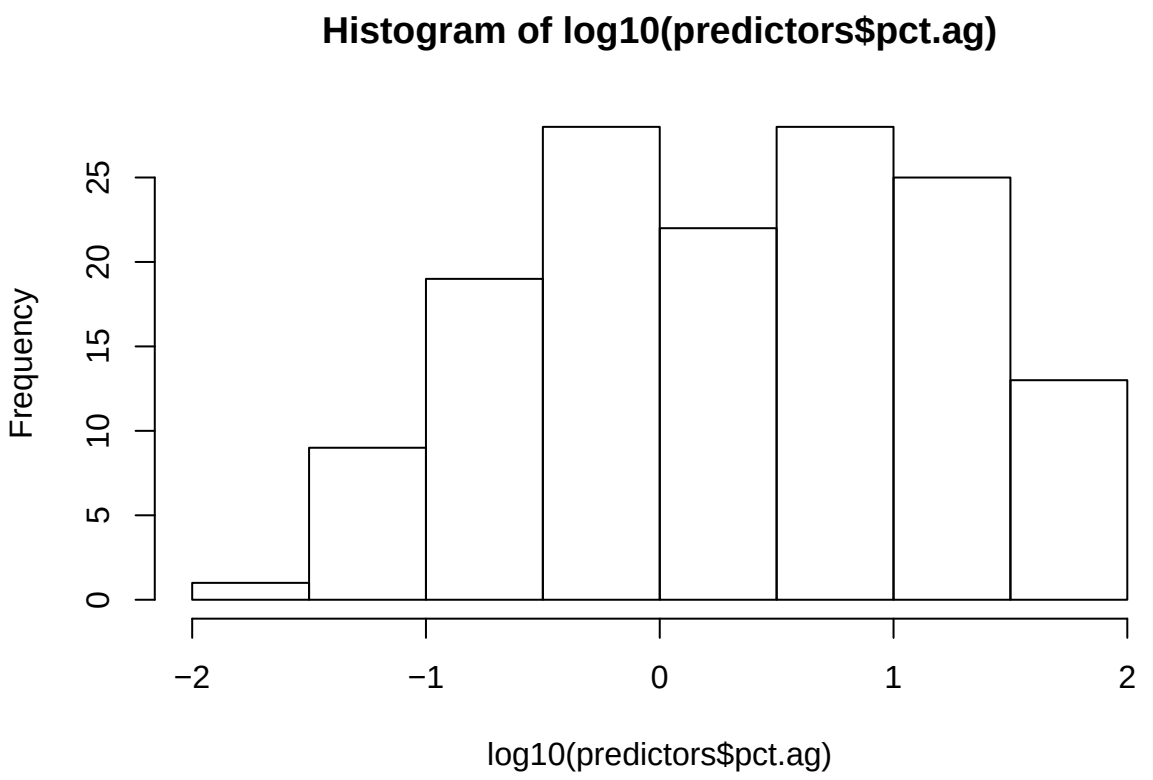

```
hist(log10(predictors$maxdepth))
```



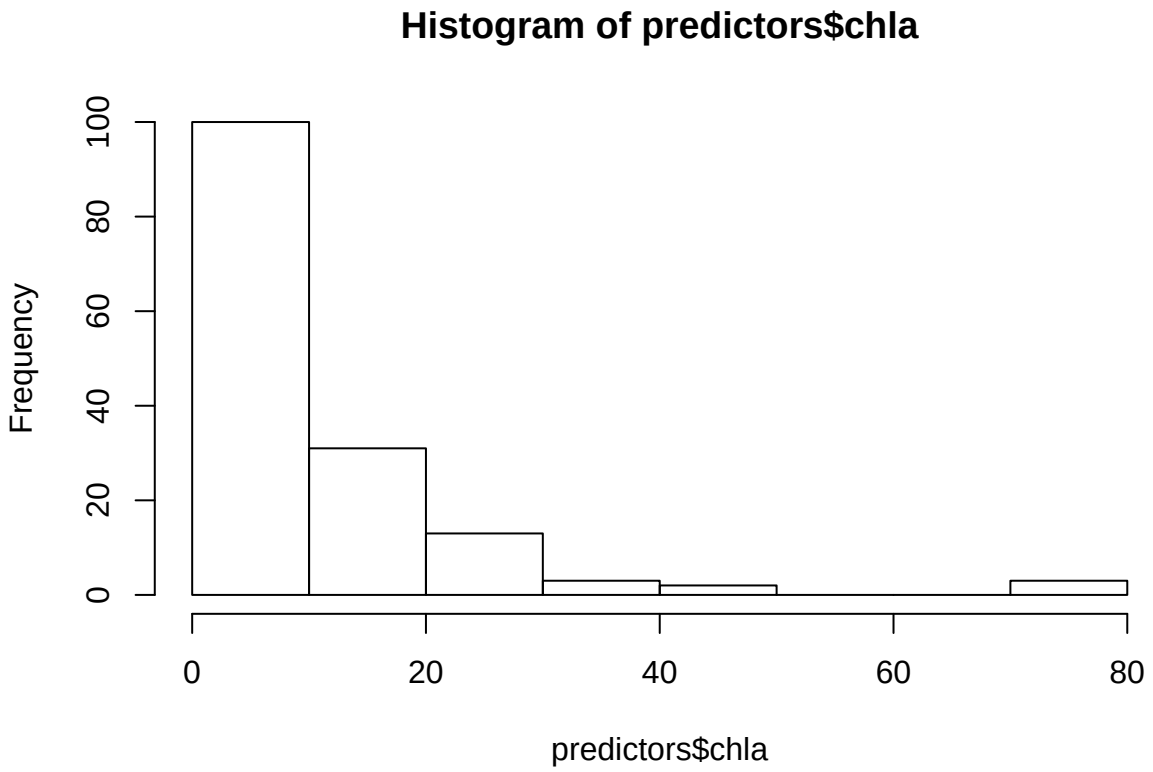

```
hist(predictors$pct.ag)
```



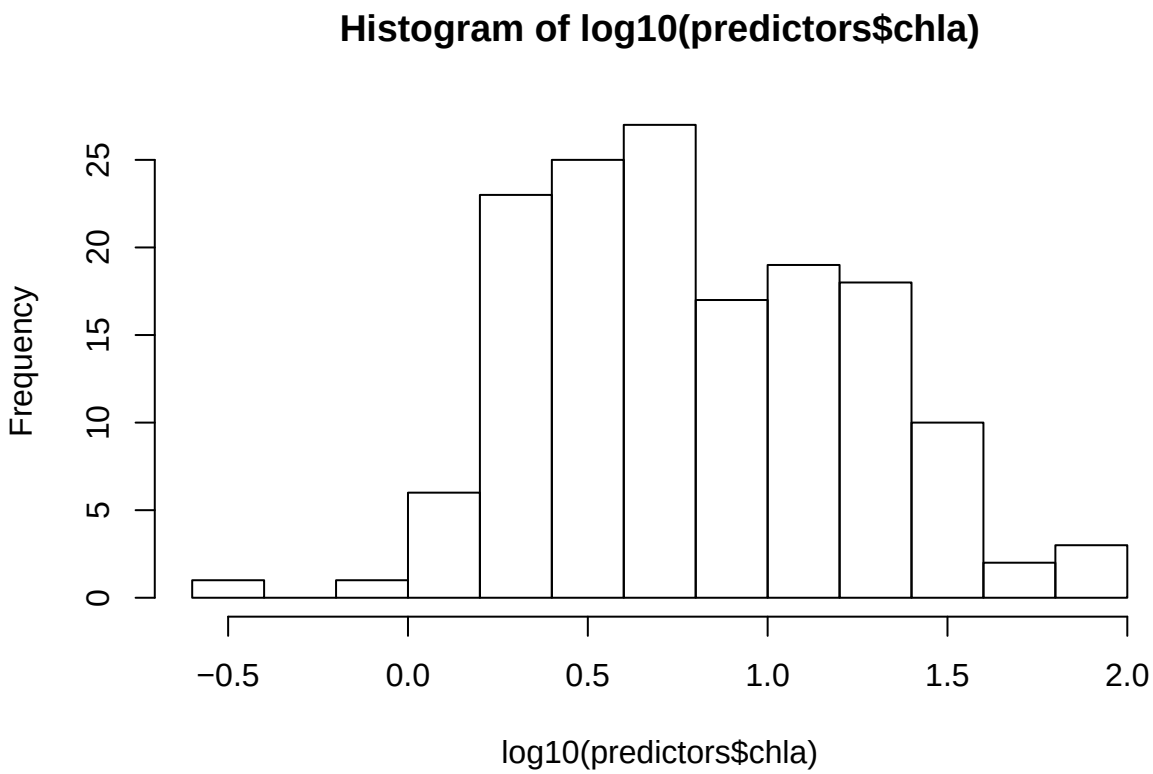

```
hist(log10(predictors$pct.ag))
```



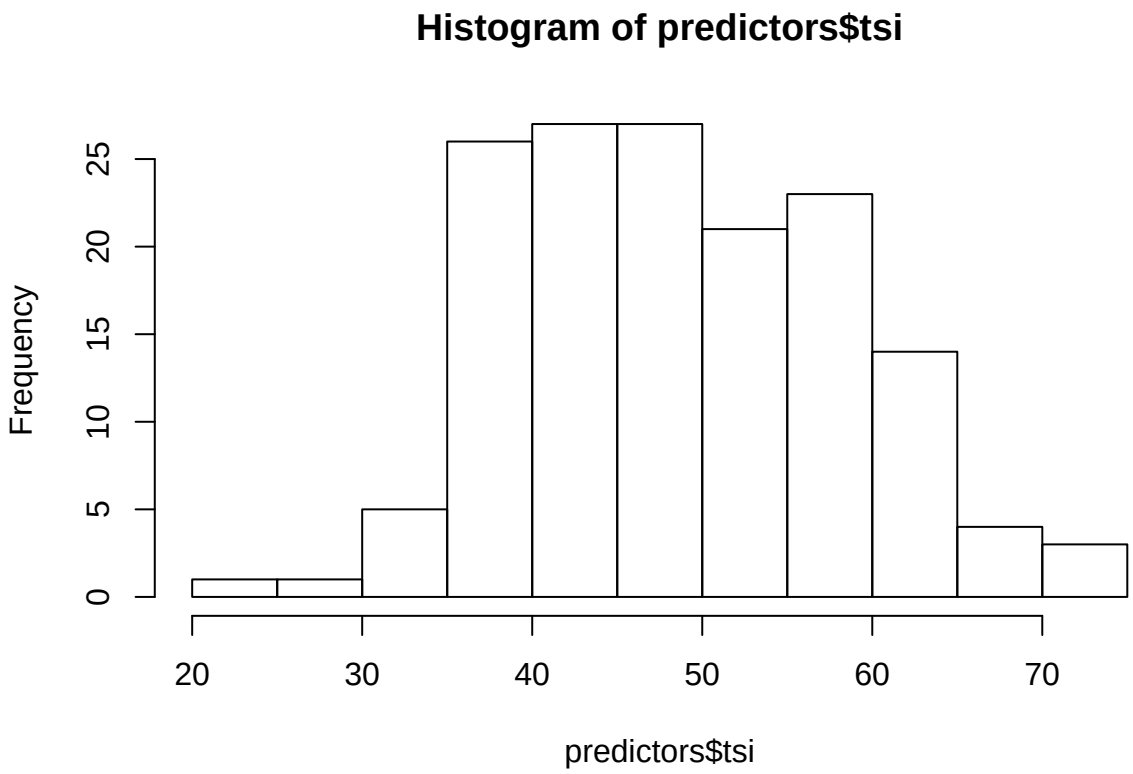

```
hist(predictors$chla)
```




```
hist(log10(predictors$chla))
```




```
hist(predictors$tsi)
```




```
table(predictors$tsi.cat)
```

```
##
##      eutrophic hypereutrophic    mesotrophic   oligotrophic
##             62              3             54             33
```

```
predictors$log10_lake_area_ha<-log10(predictors$lake_area_ha)
predictors$log10_lake_perim_meters<-log10(predictors$lake_perim_meters)
predictors$log10_maxdepth<-log10(predictors$maxdepth)
predictors$log10_pct.ag<-log10(predictors$pct.ag+1)
predictors$log10_chla<-log10(predictors$chla)

modvars.accndvi<-left_join(predictors, coh.chlaXaccndvi, by="lagoslakeid")
modvars.accndvi$nhd_ftype<-factor(modvars.accndvi$nhd_ftype)
modvars.accndvi$tsi.cat<-factor(modvars.accndvi$tsi.cat)
modvars.accndvi$tslength<-modvars.accndvi$end-modvars.accndvi$start + 1

modvars.accndvi<-modvars.accndvi[!is.na(modvars.accndvi$maxdepth),]
modvars.accndvi<-modvars.accndvi[!is.na(modvars.accndvi$pct.ag),]

modvars.accndvi.phist<-modvars.accndvi[modvars.accndvi$accndvip.ts1<0.2,]
modvars.accndvi.philt<-modvars.accndvi[modvars.accndvi$accndvip.ts2<0.2,]
```

```
#short timescales
gls.coh.accndvi.st<-gls(accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.st)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
```

```
##   Data: modvars.accndvi
##         AIC       BIC   logLik
##   -34.86545 -5.449022 27.43272
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.02637732
##
## Coefficients:
##                            Value  Std.Error    t-value p-value
## (Intercept)            0.3780751 0.13387883  2.8240093  0.0054
## log10_maxdepth        -0.0064893 0.05970988 -0.1086801  0.9136
## log10_lake_area_ha     0.0067299 0.02452810  0.2743734  0.7842
## log10_pct.ag           0.0599450 0.03049924  1.9654601  0.0513
## log10_chla            -0.0399933 0.09500935 -0.4209404  0.6744
## tsi.cathypereutrophic -0.0802583 0.12799397 -0.6270472  0.5316
## tsi.catmesotrophic    -0.0104314 0.06229034 -0.1674635  0.8672
## tsi.catoligotrophic   -0.0022963 0.09664989 -0.0237586  0.9811
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.334
## log10_lake_area_ha    -0.121 -0.614
## log10_pct.ag          -0.039 -0.175  0.181
## log10_chla            -0.885  0.169 -0.052 -0.128
## tsi.cathypereutrophic  0.365  0.080 -0.064 -0.160 -0.454
## tsi.catmesotrophic    -0.800  0.028  0.062 -0.054  0.834 -0.337
## tsi.catoligotrophic   -0.826  0.030  0.044 -0.086  0.902 -0.386  0.860
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -1.88930497 -0.68232316 -0.00388693  0.76108472  2.52612247
##
## Residual standard error: 0.1847216
## Degrees of freedom: 148 total; 140 residual
```

```
suppressWarnings(dredge.coh.accndvi.st<-dredge(gls.coh.accndvi.st, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.st))
```

```
## Global model call: gls(model = accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##     (Int)  l10_chl l10_lak_are_ha l10_mxd l10_pct.ag df logLik  AICc delta
## 1  0.3878                                            3 40.107 -74.0  0.00
## 9  0.3541                                  0.04997   4 38.977 -69.7  4.37
## 2  0.4144 -0.03251                                   4 38.096 -67.9  6.14
## 5  0.3616                        0.02281             4 38.043 -67.8  6.24
## 3  0.3840                0.00165                     4 37.069 -65.9  8.19
```

```
## 10 0.3851 -0.04156                          0.05461  5 37.243 -64.1  9.99
##    weight
## 1   0.815
## 9   0.092
## 2   0.038
## 5   0.036
## 3   0.014
## 10  0.006
## Models ranked by AICc(x)
```

```
gls.phi.accndvi.st<-gls(cos(accndviphi.ts1) ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10
                        data=modvars.accndvi.phist,
                        correlation=corExp(form = ~ nhd_lat + nhd_long)) #remove ftype b/c only lakes
summary(gls.phi.accndvi.st)
```

```
## Generalized least squares fit by REML
##   Model: cos(accndviphi.ts1) ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla +
##   Data: modvars.accndvi.phist
##        AIC      BIC    logLik
##   75.62843 85.44781 -28.81422
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##     range
## 0.1175311
##
## Coefficients:
##                           Value Std.Error    t-value p-value
## (Intercept)           0.1557571 1.3530049  0.1151194  0.9094
## log10_maxdepth        0.2331647 0.4601153  0.5067528  0.6174
## log10_lake_area_ha    0.0201684 0.2489976  0.0809985  0.9362
## log10_pct.ag          0.3375757 0.3076398  1.0973083  0.2844
## log10_chla           -0.2348224 0.7343608 -0.3197643  0.7522
## tsi.catmesotrophic   -0.5072231 0.5577661 -0.9093832  0.3730
## tsi.catoligotrophic -0.3037483 0.8258868 -0.3677844  0.7165
##
##  Correlation:
##                      (Intr) lg10_m l10___ lg10_. lg10_c ts.ctm
## log10_maxdepth       -0.476
## log10_lake_area_ha   -0.320 -0.437
## log10_pct.ag         -0.235  0.098  0.009
## log10_chla           -0.853  0.438 -0.030  0.083
## tsi.catmesotrophic   -0.808  0.219  0.170  0.037  0.791
## tsi.catoligotrophic -0.784  0.272  0.011  0.046  0.883  0.889
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -1.62466317 -0.64963316  0.02210254  0.78296527  1.46238879
##
## Residual standard error: 0.7207362
## Degrees of freedom: 29 total; 22 residual
```

```
suppressWarnings(dredge.phi.accndvi.st<-dredge(gls.phi.accndvi.st, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.phi.accndvi.st))
```

```
## Global model call: gls(model = cos(accndviphi.ts1) ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.phist,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##       (Int) l10_chl l10_lak_are_ha l10_mxd l10_pct.ag df  logLik AICc
## 1   0.21630                                          3 -29.959 66.9
## 5  -0.17910                         0.3238           4 -29.667 69.0
## 9   0.02983                                   0.3004  4 -29.755 69.2
## 2   0.30200 -0.1132                                  4 -30.195 70.1
## 3  -0.24650                 0.1793                   4 -30.261 70.2
## 13 -0.41000                         0.3492    0.3224  5 -29.386 71.4
##    delta weight
## 1   0.00  0.462
## 5   2.12  0.160
## 9   2.30  0.146
## 2   3.18  0.094
## 3   3.31  0.088
## 13  4.50  0.049
## Models ranked by AICc(x)
```

```
#long timescales
gls.coh.accndvi.lt<-gls(accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.lt)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi
##        AIC      BIC    logLik
##   49.63532 79.05175 -14.81766
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.01090697
##
## Coefficients:
##                             Value  Std.Error   t-value p-value
## (Intercept)             0.6922566 0.18000001  3.845870  0.0002
## log10_maxdepth         -0.1049311 0.07857613 -1.335407  0.1839
## log10_lake_area_ha      0.0192790 0.03276030  0.588485  0.5572
## log10_pct.ag            0.0134578 0.03998785  0.336546  0.7370
## log10_chla             -0.0604638 0.12783712 -0.472976  0.6370
## tsi.cathypereutrophic -0.1157395 0.17123018 -0.675929  0.5002
## tsi.catmesotrophic    -0.0467804 0.08449234 -0.553665  0.5807
## tsi.catoligotrophic    0.0384610 0.13075777  0.294139  0.7691
```

```
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.329
## log10_lake_area_ha    -0.124 -0.617
## log10_pct.ag          -0.032 -0.184  0.179
## log10_chla            -0.891  0.178 -0.050 -0.124
## tsi.cathypereutrophic  0.371  0.072 -0.063 -0.160 -0.456
## tsi.catmesotrophic    -0.806  0.038  0.066 -0.044  0.827 -0.333
## tsi.catoligotrophic   -0.836  0.040  0.049 -0.077  0.903 -0.388  0.854
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -1.9726454 -0.7675194  0.1494407  0.7859815  1.7504324
##
## Residual standard error: 0.2470175
## Degrees of freedom: 148 total; 140 residual
```

```
suppressWarnings(dredge.coh.accndvi.lt<-dredge(gls.coh.accndvi.lt, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.lt))
```

```
## Global model call: gls(model = accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##    (Int)  l10_chl l10_lak_are_ha  l10_mxd l10_pct.ag df logLik AICc delta
## 1 0.5654                                             3 -4.621 15.4  0.00
## 2 0.6098 -0.05450                                    4 -6.104 20.5  5.08
## 5 0.6149                          -0.04338           4 -6.261 20.8  5.39
## 9 0.5668                                   -0.002248  4 -6.968 22.2  6.81
## 3 0.5789               -0.005868                     4 -7.341 23.0  7.55
## 6 0.7015 -0.07061                 -0.06897           5 -7.347 25.1  9.71
##   weight
## 1  0.826
## 2  0.065
## 5  0.056
## 9  0.027
## 3  0.019
## 6  0.006
## Models ranked by AICc(x)
```

```
gls.phi.accndvi.lt<-gls(cos(accndviphi.ts2) ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log1
                        data=modvars.accndvi.philt,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.phi.accndvi.lt)
```

```
## Generalized least squares fit by REML
##   Model: cos(accndviphi.ts2) ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla +
##   Data: modvars.accndvi.philt
##        AIC      BIC    logLik
##   64.75967 74.16037 -23.37983
##
```

```
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##    range
## 3.997892
##
## Coefficients:
##                         Value Std.Error   t-value p-value
## (Intercept)         -3.873933 1.0447684 -3.707935  0.0013
## log10_maxdepth       0.278713 0.2813057  0.990782  0.3331
## log10_lake_area_ha   0.656921 0.1346603  4.878359  0.0001
## log10_pct.ag        -0.225035 0.3011773 -0.747183  0.4632
## log10_chla           1.989585 0.7443527  2.672906  0.0142
## tsi.catmesotrophic   0.933829 0.4902553  1.904781  0.0706
## tsi.catoligotrophic  2.338714 0.6105442  3.830540  0.0010
##
##  Correlation:
##                     (Intr) lg10_m l10___ lg10_. lg10_c ts.ctm
## log10_maxdepth      -0.343
## log10_lake_area_ha  -0.161 -0.221
## log10_pct.ag        -0.172  0.121 -0.174
## log10_chla          -0.803  0.123 -0.100  0.064
## tsi.catmesotrophic  -0.710 -0.010 -0.062  0.125  0.825
## tsi.catoligotrophic -0.756 -0.013  0.103 -0.026  0.856  0.901
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -1.6622861 -0.9233702 -0.2285615  0.4186192  1.5661025
##
## Residual standard error: 0.9602299
## Degrees of freedom: 28 total; 21 residual
```

```
suppressWarnings(dredge.phi.accndvi.lt<-dredge(gls.phi.accndvi.lt, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.phi.accndvi.lt))
```

```
## Global model call: gls(model = cos(accndviphi.ts2) ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.philt,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##       (Int) l10_chl l10_lak_are_ha l10_mxd l10_pct.ag tsi.cat df  logLik
## 1   0.02521                                                    3 -29.788
## 20 -3.61700  1.9150         0.6653                          +  7 -23.610
## 3  -0.59900                 0.2778                             4 -29.301
## 5  -0.38600                         0.3624                     4 -29.360
## 9   0.21070                                  -0.3133           4 -29.573
## 2  -0.17250  0.2997                                             4 -29.624
##    AICc delta weight
## 1  66.6  0.00  0.303
## 20 66.8  0.24  0.268
## 3  68.3  1.77  0.125
## 5  68.5  1.88  0.118
```

```
## 9  68.9  2.31  0.095
## 2  69.0  2.41  0.091
## Models ranked by AICc(x)
```

That turned up astonishingly little, so now try breaking down by region. The regions are: 1) Missouri; 2) Minnesota, Wisconsin, and Michigan; 3) Pennsylvania, New York, Rhode Island, Vermont, New Hampshire, Maine.

```
#Region 1: Missouri

modvars.accndvi.r1<-modvars.accndvi[modvars.accndvi$state_name=="Missouri",]
# modvars.accndvi.philt.r1<-modvars.accndvi.philt[modvars.accndvi.philt$state_name=="Missouri",]
# modvars.accndvi.phist.r1<-modvars.accndvi.phist[modvars.accndvi.phist$state_name=="Missouri",]

#short timescales
gls.coh.accndvi.st<-gls(accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r1,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.st)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r1
##        AIC      BIC   logLik
##   8.995435 18.43983 5.502282
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.04237466
##
## Coefficients:
##                              Value Std.Error    t-value p-value
## (Intercept)             0.5274299 0.3418418  1.5429064  0.1393
## log10_maxdepth          0.0825125 0.2176013  0.3791915  0.7088
## log10_lake_area_ha     -0.0881376 0.0564694 -1.5608041  0.1351
## log10_pct.ag           -0.0043755 0.0739419 -0.0591742  0.9534
## log10_chla             -0.0246044 0.1913508 -0.1285829  0.8990
## tsi.cathypereutrophic -0.2698166 0.1904339 -1.4168520  0.1727
## tsi.catmesotrophic     -0.0511146 0.1455996 -0.3510631  0.7294
## tsi.catoligotrophic    -0.0690611 0.2003904 -0.3446327  0.7342
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.738
## log10_lake_area_ha     0.320 -0.704
## log10_pct.ag          -0.039 -0.161  0.575
## log10_chla            -0.753  0.377 -0.414 -0.379
## tsi.cathypereutrophic  0.162  0.119  0.077  0.182 -0.488
## tsi.catmesotrophic    -0.361 -0.099  0.138 -0.005  0.517 -0.299
## tsi.catoligotrophic   -0.529 -0.044  0.133  0.093  0.681 -0.396  0.582
##
## Standardized residuals:
##           Min            Q1           Med            Q3           Max
```

```
## -1.8764938490 -0.5841693937 -0.0005826097  0.6383170091  1.4584586195
##
## Residual standard error: 0.1487541
## Degrees of freedom: 27 total; 19 residual
```

```
suppressWarnings(dredge.coh.accndvi.st<-dredge(gls.coh.accndvi.st, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.st))
```

```
## Global model call: gls(model = accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r1,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##    (Int)  l10_chl l10_lak_are_ha  l10_mxd l10_pct.ag df logLik  AICc delta
## 1 0.3637                                             3 10.280 -13.5  0.00
## 3 0.5223                -0.06426                     4 10.105 -10.4  3.12
## 5 0.4597                         -0.07548            4  9.309  -8.8  4.72
## 2 0.4658 -0.08931                                    4  9.294  -8.8  4.75
## 9 0.3261                                      0.0479 4  8.663  -7.5  6.01
## 7 0.3727                -0.08780  0.16280            5  9.689  -6.5  7.00
##   weight
## 1  0.677
## 3  0.142
## 5  0.064
## 2  0.063
## 9  0.034
## 7  0.020
## Models ranked by AICc(x)
```

```
#long timescales
gls.coh.accndvi.lt<-gls(accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r1,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.lt)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r1
##        AIC      BIC   logLik
##   30.68938 40.13377 -5.34469
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##        range
## 0.0007748676
##
## Coefficients:
##                            Value Std.Error    t-value p-value
## (Intercept)            0.8410986 0.6033686  1.3940045  0.1794
## log10_maxdepth        -0.2114190 0.3837089 -0.5509880  0.5881
## log10_lake_area_ha     0.0493772 0.0984220  0.5016886  0.6217
## log10_pct.ag           0.0197342 0.1279348  0.1542520  0.8790
```

```
## log10_chla            -0.1216361 0.3352222 -0.3628521  0.7207
## tsi.cathypereutrophic -0.2031081 0.3289865 -0.6173754  0.5443
## tsi.catmesotrophic    -0.4459652 0.2516045 -1.7724848  0.0923
## tsi.catoligotrophic   -0.0753487 0.3413207 -0.2207564  0.8276
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.750
## log10_lake_area_ha     0.341 -0.711
## log10_pct.ag          -0.027 -0.167  0.577
## log10_chla            -0.760  0.397 -0.430 -0.384
## tsi.cathypereutrophic  0.163  0.111  0.081  0.185 -0.486
## tsi.catmesotrophic    -0.361 -0.087  0.128 -0.009  0.517 -0.301
## tsi.catoligotrophic   -0.562 -0.019  0.121  0.087  0.715 -0.412  0.606
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -1.46764955 -0.48581053 -0.07318649  0.64200328  1.65345475
##
## Residual standard error: 0.2568536
## Degrees of freedom: 27 total; 19 residual
```

```
suppressWarnings(dredge.coh.accndvi.lt<-dredge(gls.coh.accndvi.lt, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.lt))
```

```
## Global model call: gls(model = accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r1,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##     (Int) l10_chl l10_lak_are_ha  l10_mxd l10_pct.ag tsi.cat df logLik
## 1  0.5211                                                    3 -2.790
## 5  0.5767                        -0.04332                    4 -3.413
## 2  0.4388 0.07277                                            4 -3.840
## 9  0.5195                                    0.002141        4 -4.380
## 3  0.4430                0.03212                             4 -4.675
## 17 0.5668                                                +   6 -1.805
##    AICc delta weight
## 1  12.6  0.00  0.748
## 5  16.6  4.02  0.100
## 2  17.5  4.87  0.065
## 9  18.6  5.95  0.038
## 3  19.2  6.54  0.028
## 17 19.8  7.19  0.021
## Models ranked by AICc(x)
```

```
#Region 2: Minnesota, Wisconsin, Michigan

modvars.accndvi.r2<-modvars.accndvi[modvars.accndvi$state_name %in% c("Minnesota","Wisconsin","Michigan

#short timescales
gls.coh.accndvi.st<-gls(accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r2,
```

```
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.st)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r2
##        AIC      BIC   logLik
##   8.735372 31.91025 5.632314
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.03129037
##
## Coefficients:
##                             Value  Std.Error    t-value p-value
## (Intercept)            0.28607581 0.21299322  1.3431217  0.1833
## log10_maxdepth        -0.01689086 0.09430048 -0.1791174  0.8583
## log10_lake_area_ha     0.06013256 0.04140631  1.4522560  0.1506
## log10_pct.ag           0.02030745 0.04630595  0.4385494  0.6622
## log10_chla            -0.01032580 0.14007796 -0.0737147  0.9414
## tsi.cathypereutrophic -0.00039694 0.18263045 -0.0021734  0.9983
## tsi.catmesotrophic    -0.01328850 0.09828536 -0.1352033  0.8928
## tsi.catoligotrophic    0.02026451 0.14423173  0.1404997  0.8886
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.333
## log10_lake_area_ha    -0.261 -0.455
## log10_pct.ag          -0.036 -0.228 -0.014
## log10_chla            -0.897  0.191  0.062 -0.025
## tsi.cathypereutrophic  0.400  0.083 -0.137 -0.270 -0.484
## tsi.catmesotrophic    -0.786 -0.003  0.097  0.008  0.827 -0.327
## tsi.catoligotrophic   -0.794 -0.019  0.076 -0.002  0.887 -0.381  0.902
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -1.9480579 -0.6731269  0.1071575  0.7101748  2.1282868
##
## Residual standard error: 0.2018212
## Degrees of freedom: 83 total; 75 residual
```

```
suppressWarnings(dredge.coh.accndvi.st<-dredge(gls.coh.accndvi.st, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.st))
```

```
## Global model call: gls(model = accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r2,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##    (Int)  l10_chl l10_lak_are_ha  l10_mxd l10_pct.ag df logLik  AICc delta
```

```
## 1 0.4071                                          3 15.926 -25.5  0.00
## 3 0.2663                 0.06561                  4 15.247 -22.0  3.57
## 5 0.3337                         0.068010         4 14.656 -20.8  4.75
## 2 0.4299 -0.03222                                 4 14.042 -19.6  5.98
## 9 0.3804                                 0.03362  4 13.986 -19.5  6.09
## 7 0.2641                 0.06413 0.004766         5 13.599 -16.4  9.13
##   weight
## 1  0.730
## 3  0.123
## 5  0.068
## 2  0.037
## 9  0.035
## 7  0.008
## Models ranked by AICc(x)
```

```
#long timescales
gls.coh.accndvi.lt<-gls(accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r2,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.lt)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r2
##        AIC      BIC    logLik
##   39.57158 62.74646 -9.785788
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.01094399
##
## Coefficients:
##                            Value  Std.Error    t-value p-value
## (Intercept)            0.4022266 0.26538113  1.5156565  0.1338
## log10_maxdepth         0.0448547 0.11078985  0.4048633  0.6867
## log10_lake_area_ha    -0.0025275 0.05026837 -0.0502804  0.9600
## log10_pct.ag          -0.0083418 0.05285305 -0.1578303  0.8750
## log10_chla             0.0801777 0.17277591  0.4640562  0.6440
## tsi.cathypereutrophic -0.0686111 0.22077203 -0.3107779  0.7568
## tsi.catmesotrophic     0.0978619 0.12262431  0.7980632  0.4274
## tsi.catoligotrophic    0.1745667 0.17842440  0.9783794  0.3310
##
##  Correlation:
##                       (Intr) lg10_m l10___ lg10_. lg10_c ts.cth ts.ctm
## log10_maxdepth        -0.324
## log10_lake_area_ha    -0.287 -0.458
## log10_pct.ag          -0.048 -0.221  0.000
## log10_chla            -0.906  0.201  0.088 -0.002
## tsi.cathypereutrophic  0.416  0.068 -0.149 -0.274 -0.495
## tsi.catmesotrophic    -0.801  0.006  0.131  0.031  0.824 -0.331
## tsi.catoligotrophic   -0.813  0.000  0.099  0.018  0.892 -0.392  0.896
##
## Standardized residuals:
```

```
##        Min         Q1        Med         Q3        Max
## -2.0877939 -0.7435957  0.1885692  0.6979656  1.8033777
##
## Residual standard error: 0.2429035
## Degrees of freedom: 83 total; 75 residual
```

```
suppressWarnings(dredge.coh.accndvi.lt<-dredge(gls.coh.accndvi.lt, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.lt))
```

```
## Global model call: gls(model = accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r2,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##    (Int)  l10_chl l10_lak_are_ha l10_mxd l10_pct.ag df logLik AICc delta
## 1 0.5859                                           3 -0.205  6.7  0.00
## 2 0.6417 -0.08064                                  4 -1.198 10.9  4.19
## 5 0.4983                 0.08116                   4 -1.298 11.1  4.39
## 9 0.5908                                -0.006597  4 -2.297 13.1  6.39
## 3 0.5584                 0.01266                   4 -2.421 13.4  6.64
## 6 0.5954 -0.06707        0.03417                   5 -2.585 15.9  9.23
##   weight
## 1  0.757
## 2  0.093
## 5  0.084
## 9  0.031
## 3  0.027
## 6  0.007
## Models ranked by AICc(x)
```

```
#Region 2: Minnesota, Wisconsin, Michigan

modvars.accndvi.r3<-modvars.accndvi[modvars.accndvi$state_name %in% c("Pennsylvania","New York","Rhode

#short timescales
gls.coh.accndvi.st<-gls(accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r3,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
summary(gls.coh.accndvi.st)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r3
##        AIC      BIC   logLik
##   9.164191 22.07008 4.417904
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##       range
## 0.003779199
##
## Coefficients:
```

```
##                          Value  Std.Error    t-value p-value
## (Intercept)          0.21241634 0.26294047  0.8078496  0.4253
## log10_maxdepth       0.03208964 0.09960645  0.3221643  0.7495
## log10_lake_area_ha  -0.00426500 0.04508113 -0.0946071  0.9252
## log10_pct.ag         0.10384655 0.09153875  1.1344545  0.2653
## log10_chla           0.09041243 0.23645366  0.3823685  0.7048
## tsi.catmesotrophic   0.01669973 0.11205213  0.1490354  0.8825
## tsi.catoligotrophic  0.00182967 0.20486674  0.0089310  0.9929
##
##  Correlation:
##                     (Intr) lg10_m l10___ lg10_. lg10_c ts.ctm
## log10_maxdepth      -0.322
## log10_lake_area_ha   0.065 -0.720
## log10_pct.ag         0.229 -0.181  0.217
## log10_chla          -0.924  0.248 -0.229 -0.404
## tsi.catmesotrophic  -0.812  0.052 -0.088 -0.264  0.829
## tsi.catoligotrophic -0.891  0.144 -0.081 -0.251  0.891  0.827
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -1.66726060 -0.68761196  0.01185272  0.64105237  1.85204595
##
## Residual standard error: 0.1713488
## Degrees of freedom: 38 total; 31 residual
```

```
suppressWarnings(dredge.coh.accndvi.st<-dredge(gls.coh.accndvi.st, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.st))
```

```
## Global model call: gls(model = accndvicoh.ts1 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r3,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##     (Int) l10_chl l10_lak_are_ha l10_mxd l10_pct.ag df logLik  AICc delta
## 1  0.3585                                           3 12.262 -17.8  0.00
## 9  0.3097                                  0.1318   4 12.069 -14.9  2.89
## 2  0.2662  0.1125                                   4 11.579 -13.9  3.87
## 5  0.3384                        0.0173             4 10.493 -11.8  6.04
## 3  0.3411              0.007171                     4  9.690 -10.2  7.65
## 10 0.2586  0.0720                          0.1096   5 10.880  -9.9  7.93
##    weight
## 1   0.681
## 9   0.160
## 2   0.098
## 5   0.033
## 3   0.015
## 10  0.013
## Models ranked by AICc(x)
```

```
#long timescales
gls.coh.accndvi.lt<-gls(accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag + log10_chla
                        data=modvars.accndvi.r3,
                        correlation=corExp(form = ~ nhd_lat + nhd_long))
```

```
summary(gls.coh.accndvi.lt)
```

```
## Generalized least squares fit by REML
##   Model: accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha + log10_pct.ag +      log10_chla + tsi
##   Data: modvars.accndvi.r3
##        AIC      BIC    logLik
##   35.08597 47.99186 -8.542985
##
## Correlation Structure: Exponential spatial correlation
##  Formula: ~nhd_lat + nhd_long
##  Parameter estimate(s):
##      range
## 0.03300913
##
## Coefficients:
##                           Value Std.Error    t-value p-value
## (Intercept)           0.8880316 0.4131097  2.1496266  0.0395
## log10_maxdepth       -0.1846762 0.1587917 -1.1630088  0.2537
## log10_lake_area_ha    0.0204226 0.0692501  0.2949115  0.7700
## log10_pct.ag          0.0055346 0.1420425  0.0389647  0.9692
## log10_chla           -0.1337809 0.3610361 -0.3705470  0.7135
## tsi.catmesotrophic   -0.1366497 0.1713489 -0.7974937  0.4312
## tsi.catoligotrophic -0.0227148 0.3098206 -0.0733160  0.9420
##
##  Correlation:
##                      (Intr) lg10_m l10___ lg10_. lg10_c ts.ctm
## log10_maxdepth       -0.373
## log10_lake_area_ha    0.080 -0.699
## log10_pct.ag          0.195 -0.153  0.217
## log10_chla           -0.917  0.275 -0.246 -0.386
## tsi.catmesotrophic   -0.813  0.067 -0.091 -0.272  0.851
## tsi.catoligotrophic -0.884  0.178 -0.107 -0.240  0.897  0.837
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -1.65144556 -0.74932722  0.06598187  0.72630229  1.51875534
##
## Residual standard error: 0.2651477
## Degrees of freedom: 38 total; 31 residual
```

```
suppressWarnings(dredge.coh.accndvi.lt<-dredge(gls.coh.accndvi.lt, beta="sd")) #intercept only is best
```

```
## Fixed term is "(Intercept)"
```

```
print(head(dredge.coh.accndvi.lt))
```

```
## Global model call: gls(model = accndvicoh.ts2 ~ log10_maxdepth + log10_lake_area_ha +
##     log10_pct.ag + log10_chla + tsi.cat, data = modvars.accndvi.r3,
##     correlation = corExp(form = ~nhd_lat + nhd_long))
## ---
## Model selection table
##     (Int) l10_chl l10_lak_are_ha l10_mxd l10_pct.ag df logLik AICc delta
## 1  0.5536                                           3 -3.900 14.5  0.00
## 5  0.7727                        -0.1840            4 -3.728 16.7  2.16
## 9  0.5605                                  -0.01839  4 -5.046 19.3  4.80
```

```
## 2  0.5330 0.02538                                    4 -5.060 19.3  4.83
## 3  0.6596              -0.04289                      4 -5.629 20.5  5.96
## 13 0.7877                       -0.1863   -0.03200  5 -4.874 21.6  7.12
##    weight
## 1   0.626
## 5   0.212
## 9   0.057
## 2   0.056
## 3   0.032
## 13  0.018
## Models ranked by AICc(x)
```