eulachon_multivariate_analysis

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#==

#== # Data import and preparation #==

import data sets

```
taxa_data <- import("TaxaGroups.csv")

catch_data <- import("catch.csv")

temp_data <- import("temperature.csv")

# merge data sets

taxa_catch_data <- merge(catch_data, taxa_data, by = "Species_name")

taxa_catch_temp_data <- merge( taxa_catch_data, temp_data, by = c("TRIP_ID", "EVENT_ID"))

taxa_catch_temp_data <- taxa_catch_temp_data %>%
  dplyr::select(Species_name, TRIP_ID,EVENT_ID, SET_ID, YEAR, MONTH, DATE,
                MAJOR_STAT_AREA_CODE,START_LATITUDE, START_LONGITUDE,
                END_LATITUDE, END_LONGITUDE, DEPTH, MEAN_TEMPERATURE,
                CPUE, Taxonomic_group) %>%
  arrange(., Species_name)


# change species name, taxonomic group, and area code to factor

taxa_catch_temp_data$Species_name <- factor(taxa_catch_temp_data$Species_name)

taxa_catch_temp_data$Taxonomic_group <- factor(taxa_catch_temp_data$Taxonomic_group)

taxa_catch_temp_data$MAJOR_STAT_AREA_CODE <- factor(taxa_catch_temp_data$MAJOR_STAT_AREA_CODE)


# manipulate date variables with lubridate

taxa_catch_temp_data$DATE <- ymd(taxa_catch_temp_data$DATE)
```

```r
taxa_catch_temp_data$MONTH <- month(taxa_catch_temp_data$DATE, label = TRUE, abbr = TRUE)

taxa_catch_temp_data$YEAR <- year(taxa_catch_temp_data$DATE)


# remove irrelevant taxa groups and tows from Hecate Strait and sets with only Eulachon CPUE recorded

filtered_eulachon_data <- taxa_catch_temp_data %>%
  filter(., Taxonomic_group %nin% c("Marine mammal",
                                   "Other",
                                   "Euphausid",
                                   "Worm",
                                   "Isopod"),
         EVENT_ID %nin% c(4363856,
                         4363858,
                         4564096,
                         4564094,
                         4363883))

# factor species name, taxonomic group, and area code again
# with eulachon_data to get rid of extra levels that were filtered out

filtered_eulachon_data$Species_name <- factor(filtered_eulachon_data$Species_name)

filtered_eulachon_data$Taxonomic_group <- factor(filtered_eulachon_data$Taxonomic_group)

filtered_eulachon_data$MAJOR_STAT_AREA_CODE <- factor(filtered_eulachon_data$MAJOR_STAT_AREA_CODE)


# creating data table in wide format

eulachon_wide_all_species <- pivot_wider(filtered_eulachon_data,
                             names_from =Species_name,
                             values_from = CPUE,
                             #names_prefix = "CPUE for ",
                             id_cols = !Taxonomic_group)

# Remove species with mean CPUE < 40

eulachon_wide_1 <- eulachon_wide_all_species %>%
  dplyr::select(TRIP_ID:MEAN_TEMPERATURE)

eulachon_wide_2 <- eulachon_wide_all_species[14:217] %>%
  dplyr::select(where(~ is.numeric(.x) && mean(.x) > 40))

eulachon_wide <- cbind(eulachon_wide_1, eulachon_wide_2)

# use event ID as row names

row.names(eulachon_wide) <- eulachon_wide$EVENT_ID

#eulachon_wide4 <- data.frame(eulachon_wide3, row.names = 2)
```

```r
# log transform data

eulachon_wide_log <- eulachon_wide

for(i in 14:38){
 minfish_eulachon<-min(subset(eulachon_wide_log[,i],eulachon_wide_log[,i]>0))/2
 eulachon_wide_log[,i]<-log(eulachon_wide_log[,i]+minfish_eulachon)}

# log (CPUE + 1) transformed

eulachon_wide_log_2 <- eulachon_wide

for (i in 14:38) {
  eulachon_wide_log_2[,i]<-log1p(eulachon_wide_log_2[,i])
}

# adding season to data set

eulachon_wide_season <- eulachon_wide %>%
  mutate(., SEASON = recode(eulachon_wide$MONTH,
                            "Jan" = "Winter",
                            "Feb"="Winter",
                            "Mar"="Spring",
                            "Apr"="Spring",
                            "May"="Spring",
                            "Jun"="Summer",
                            "Jul"="Summer",
                            "Aug"="Summer",
                            "Sep"="Fall",
                            "Oct"="Fall",
                            "Nov"="Fall",
                            "Dec"="Winter"), .after=DATE)


season_colours <- c('Winter'="blue",
                    'Spring'="orange",
                    'Summer'="red",
                    'Fall'="green")
```

#===
following EBS.fish multivariate analysis outline #===

```r
####CORRELATIONS AMONG VARIABLES #########

species_cor <- cor(data.frame(eulachon_wide_log[,14:38]),use="complete.obs")
species_cor
```

```
##                            ACTINIARIA ANOPLOPOMA.FIMBRIA ATHERESTHES.STOMIAS
## ACTINIARIA                1.000000000        0.146235525         -0.06476067
## ANOPLOPOMA.FIMBRIA        0.146235525        1.000000000          0.32899150
## ATHERESTHES.STOMIAS      -0.064760669        0.328991498          1.00000000
## BATHYRAJA.INTERRUPTA      0.042604080       -0.003147683         -0.03504538
```

```
## BERINGRAJA.BINOCULATA     -0.074680445       -0.126457354         -0.20197485
## CLUPEA.PALLASII           -0.098778807       -0.164514874         -0.02813056
## GADUS.CHALCOGRAMMUS       -0.055631081       -0.065721651         -0.04258085
## GADUS.MACROCEPHALUS       -0.027919476       -0.078647520         -0.12823037
## GLYPTOCEPHALUS.ZACHIRUS    0.042135166        0.169938393          0.36837437
## HIPPOGLOSSOIDES.ELASSODON -0.023326138       -0.005430856          0.39466256
## HYDROLAGUS.COLLIEI         0.003426873        0.011652841         -0.01492716
## LYCODES.BREVIPES          -0.014969275        0.078146485          0.32063245
## LYCODES.PACIFICUS         -0.029232670        0.101122660          0.42567428
## LYOPSETTA.EXILIS           0.045036670        0.031783862          0.21486734
## MERLUCCIUS.PRODUCTUS      -0.034538792       -0.154751163         -0.29958306
## MICROSTOMUS.PACIFICUS      0.035702028        0.081018017          0.06832281
## PANDALOPSIS.DISPAR         0.144860118        0.150334975          0.30677195
## PANDALUS.BOREALIS          0.007363499        0.111484854          0.12226654
## PANDALUS.JORDANI          -0.014992995        0.201362464          0.42574806
## PANDALUS.PLATYCEROS        0.153814766        0.041695614          0.06876637
## PAROPHRYS.VETULUS         -0.012837649       -0.125507859         -0.23022141
## PECTINIDAE                -0.062294966        0.039885565          0.01528641
## RAJA.RHINA                -0.016796627       -0.085946538         -0.14436802
## SQUALUS.SUCKLEYI          -0.088235581       -0.102303925         -0.16439747
## THALEICHTHYS.PACIFICUS    -0.101881020        0.157370649          0.47278492
##                           BATHYRAJA.INTERRUPTA BERINGRAJA.BINOCULATA
## ACTINIARIA                         0.042604080           -0.07468044
## ANOPLOPOMA.FIMBRIA                -0.003147683           -0.12645735
## ATHERESTHES.STOMIAS               -0.035045384           -0.20197485
## BATHYRAJA.INTERRUPTA               1.000000000            0.17442187
## BERINGRAJA.BINOCULATA              0.174421868            1.00000000
## CLUPEA.PALLASII                   -0.018048676            0.16537213
## GADUS.CHALCOGRAMMUS                0.132422331            0.21606599
## GADUS.MACROCEPHALUS                0.110724405            0.04909444
## GLYPTOCEPHALUS.ZACHIRUS           -0.039425163            0.04763585
## HIPPOGLOSSOIDES.ELASSODON         -0.071385379           -0.13712667
## HYDROLAGUS.COLLIEI                 0.089883934            0.04946642
## LYCODES.BREVIPES                  -0.093720528           -0.22135940
## LYCODES.PACIFICUS                 -0.153725017           -0.25736778
## LYOPSETTA.EXILIS                  -0.255238374           -0.24870264
## MERLUCCIUS.PRODUCTUS              -0.024792842            0.13350691
## MICROSTOMUS.PACIFICUS              0.127242894            0.05316238
## PANDALOPSIS.DISPAR                -0.149945558           -0.25398637
## PANDALUS.BOREALIS                 -0.067217801           -0.04389106
## PANDALUS.JORDANI                  -0.103012258           -0.24546262
## PANDALUS.PLATYCEROS               -0.061258440           -0.06931995
## PAROPHRYS.VETULUS                  0.004170696            0.30492530
## PECTINIDAE                         0.004825412           -0.03017212
## RAJA.RHINA                         0.190305432            0.14621106
## SQUALUS.SUCKLEYI                   0.175895866            0.17043065
## THALEICHTHYS.PACIFICUS            -0.051032446           -0.08363564
##                           CLUPEA.PALLASII GADUS.CHALCOGRAMMUS
## ACTINIARIA                   -0.098778807      -0.05563108078
## ANOPLOPOMA.FIMBRIA           -0.164514874      -0.06572165125
## ATHERESTHES.STOMIAS          -0.028130565      -0.04258084950
## BATHYRAJA.INTERRUPTA         -0.018048676       0.13242233054
## BERINGRAJA.BINOCULATA         0.165372128       0.21606599437
## CLUPEA.PALLASII               1.000000000       0.23770652327
```

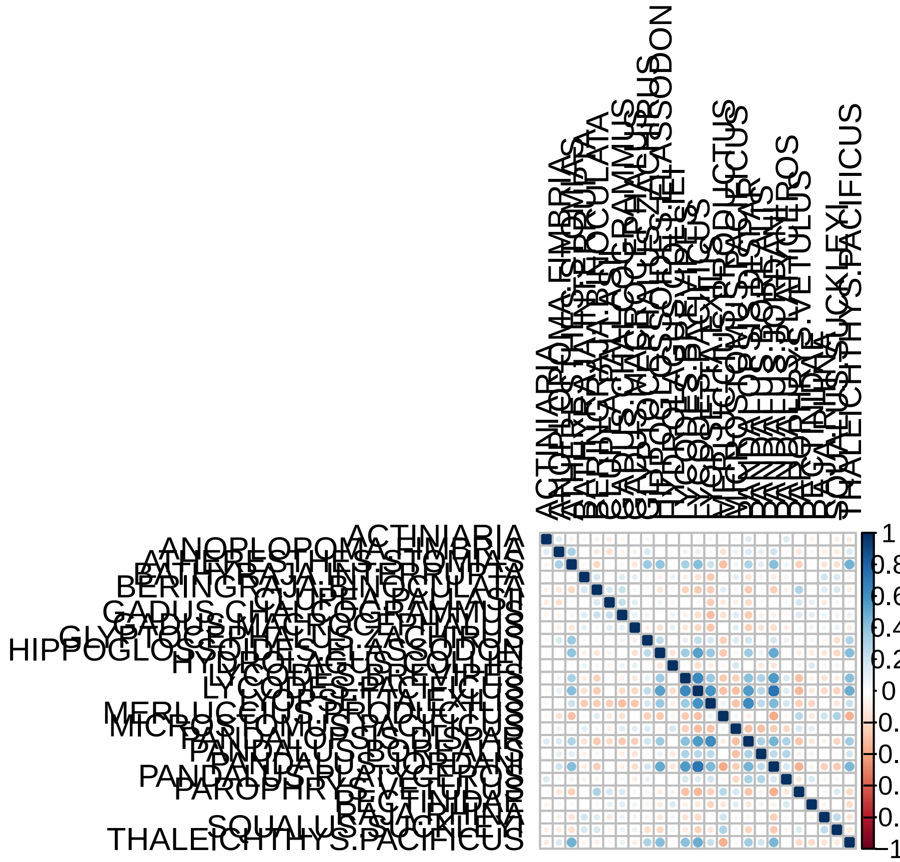
```
## GADUS.CHALCOGRAMMUS          0.237706523       1.00000000000
## GADUS.MACROCEPHALUS          0.128089224       0.10300850778
## GLYPTOCEPHALUS.ZACHIRUS     -0.026447132       0.07470324849
## HIPPOGLOSSOIDES.ELASSODON    0.063698897       0.00008346637
## HYDROLAGUS.COLLIEI          -0.054982313       0.08309795515
## LYCODES.BREVIPES             0.003524293      -0.07093540009
## LYCODES.PACIFICUS           -0.021401906      -0.18236930531
## LYOPSETTA.EXILIS            -0.244074529      -0.30236576313
## MERLUCCIUS.PRODUCTUS        -0.110384131      -0.16027661015
## MICROSTOMUS.PACIFICUS       -0.082894472       0.13942542269
## PANDALOPSIS.DISPAR          -0.187452543      -0.25532750892
## PANDALUS.BOREALIS           -0.034782288      -0.08234805405
## PANDALUS.JORDANI            -0.007204396      -0.08191403497
## PANDALUS.PLATYCEROS          0.040031707      -0.03244394821
## PAROPHRYS.VETULUS            0.178975535       0.15546462453
## PECTINIDAE                   0.100926410       0.12399588128
## RAJA.RHINA                  -0.119399708       0.08468141291
## SQUALUS.SUCKLEYI            -0.052437933       0.07129653377
## THALEICHTHYS.PACIFICUS       0.030822745       0.09696184985
##                           GADUS.MACROCEPHALUS GLYPTOCEPHALUS.ZACHIRUS
## ACTINIARIA                       -0.027919476              0.04213517
## ANOPLOPOMA.FIMBRIA               -0.078647520              0.16993839
## ATHERESTHES.STOMIAS              -0.128230367              0.36837437
## BATHYRAJA.INTERRUPTA              0.110724405             -0.03942516
## BERINGRAJA.BINOCULATA             0.049094443              0.04763585
## CLUPEA.PALLASII                   0.128089224             -0.02644713
## GADUS.CHALCOGRAMMUS               0.103008508              0.07470325
## GADUS.MACROCEPHALUS               1.000000000             -0.08197024
## GLYPTOCEPHALUS.ZACHIRUS          -0.081970237              1.00000000
## HIPPOGLOSSOIDES.ELASSODON        -0.151101633              0.25860247
## HYDROLAGUS.COLLIEI                0.103470839             -0.02306954
## LYCODES.BREVIPES                 -0.125442457              0.10761664
## LYCODES.PACIFICUS                -0.204379035              0.24799568
## LYOPSETTA.EXILIS                 -0.273457299              0.17918993
## MERLUCCIUS.PRODUCTUS             -0.007482525             -0.23923577
## MICROSTOMUS.PACIFICUS             0.129174510              0.14930597
## PANDALOPSIS.DISPAR               -0.234276096              0.19718251
## PANDALUS.BOREALIS                -0.142919086              0.02679318
## PANDALUS.JORDANI                 -0.174100224              0.18123729
## PANDALUS.PLATYCEROS              -0.094215839              0.09416668
## PAROPHRYS.VETULUS                 0.042764433              0.04452228
## PECTINIDAE                        0.065544118             -0.05476428
## RAJA.RHINA                        0.065506516             -0.06582137
## SQUALUS.SUCKLEYI                  0.094873658             -0.17641984
## THALEICHTHYS.PACIFICUS           -0.090986240              0.30211757
##                           HIPPOGLOSSOIDES.ELASSODON HYDROLAGUS.COLLIEI
## ACTINIARIA                            -0.02332613761        0.003426873
## ANOPLOPOMA.FIMBRIA                    -0.00543085608        0.011652841
## ATHERESTHES.STOMIAS                    0.39466255612       -0.014927162
## BATHYRAJA.INTERRUPTA                  -0.07138537909        0.089883934
## BERINGRAJA.BINOCULATA                 -0.13712666855        0.049466419
## CLUPEA.PALLASII                        0.06369889732       -0.054982313
## GADUS.CHALCOGRAMMUS                    0.00008346637        0.083097955
## GADUS.MACROCEPHALUS                   -0.15110163265        0.103470839
```

```
## GLYPTOCEPHALUS.ZACHIRUS              0.25860247219       -0.023069543
## HIPPOGLOSSOIDES.ELASSODON            1.00000000000       -0.142387415
## HYDROLAGUS.COLLIEI                  -0.14238741484        1.000000000
## LYCODES.BREVIPES                     0.35885978612       -0.017647526
## LYCODES.PACIFICUS                    0.54433576494       -0.181307958
## LYOPSETTA.EXILIS                     0.37149461544       -0.094668272
## MERLUCCIUS.PRODUCTUS                -0.26574097326       -0.040517068
## MICROSTOMUS.PACIFICUS               -0.04985849852        0.173761962
## PANDALOPSIS.DISPAR                   0.35016537775       -0.004057897
## PANDALUS.BOREALIS                    0.09298727370       -0.118971934
## PANDALUS.JORDANI                     0.50483124038       -0.137332816
## PANDALUS.PLATYCEROS                  0.00104933001       -0.013014322
## PAROPHRYS.VETULUS                   -0.09334137386        0.062918378
## PECTINIDAE                          -0.10763835397        0.157661955
## RAJA.RHINA                          -0.12899618240        0.059057202
## SQUALUS.SUCKLEYI                    -0.20156105656        0.066417389
## THALEICHTHYS.PACIFICUS               0.42964461349       -0.025814714
##                           LYCODES.BREVIPES LYCODES.PACIFICUS LYOPSETTA.EXILIS
## ACTINIARIA                    -0.014969275       -0.02923267       0.04503667
## ANOPLOPOMA.FIMBRIA             0.078146485        0.10112266       0.03178386
## ATHERESTHES.STOMIAS            0.320632454        0.42567428       0.21486734
## BATHYRAJA.INTERRUPTA          -0.093720528       -0.15372502      -0.25523837
## BERINGRAJA.BINOCULATA         -0.221359404       -0.25736778      -0.24870264
## CLUPEA.PALLASII                0.003524293       -0.02140191      -0.24407453
## GADUS.CHALCOGRAMMUS           -0.070935400       -0.18236931      -0.30236576
## GADUS.MACROCEPHALUS           -0.125442457       -0.20437904      -0.27345730
## GLYPTOCEPHALUS.ZACHIRUS        0.107616640        0.24799568       0.17918993
## HIPPOGLOSSOIDES.ELASSODON      0.358859786        0.54433576       0.37149462
## HYDROLAGUS.COLLIEI            -0.017647526       -0.18130796      -0.09466827
## LYCODES.BREVIPES               1.000000000        0.64471480       0.36943767
## LYCODES.PACIFICUS              0.644714804        1.00000000       0.59735589
## LYOPSETTA.EXILIS               0.369437668        0.59735589       1.00000000
## MERLUCCIUS.PRODUCTUS          -0.252192634       -0.29644746       0.08662163
## MICROSTOMUS.PACIFICUS         -0.231999947       -0.30152632      -0.28941015
## PANDALOPSIS.DISPAR             0.416367950        0.56601210       0.63523956
## PANDALUS.BOREALIS              0.306930742        0.27636827       0.26791332
## PANDALUS.JORDANI               0.560379751        0.73297229       0.44795808
## PANDALUS.PLATYCEROS            0.167610137        0.14280138       0.18339531
## PAROPHRYS.VETULUS             -0.299378561       -0.32707749      -0.23183857
## PECTINIDAE                    -0.078992951       -0.12234353      -0.21101876
## RAJA.RHINA                    -0.149687193       -0.19309005       0.01616981
## SQUALUS.SUCKLEYI              -0.101129646       -0.22440250      -0.13655501
## THALEICHTHYS.PACIFICUS         0.412424593        0.49515093       0.22119245
##                           MERLUCCIUS.PRODUCTUS MICROSTOMUS.PACIFICUS
## ACTINIARIA                       -0.0345387923            0.03570203
## ANOPLOPOMA.FIMBRIA               -0.1547511633            0.08101802
## ATHERESTHES.STOMIAS              -0.2995830605            0.06832281
## BATHYRAJA.INTERRUPTA             -0.0247928419            0.12724289
## BERINGRAJA.BINOCULATA             0.1335069056            0.05316238
## CLUPEA.PALLASII                  -0.1103841312           -0.08289447
## GADUS.CHALCOGRAMMUS              -0.1602766102            0.13942542
## GADUS.MACROCEPHALUS              -0.0074825250            0.12917451
## GLYPTOCEPHALUS.ZACHIRUS          -0.2392357698            0.14930597
## HIPPOGLOSSOIDES.ELASSODON        -0.2657409733           -0.04985850
```

```
## HYDROLAGUS.COLLIEI              -0.0405170680        0.17376196
## LYCODES.BREVIPES                -0.2521926337       -0.23199995
## LYCODES.PACIFICUS               -0.2964474595       -0.30152632
## LYOPSETTA.EXILIS                 0.0866216336       -0.28941015
## MERLUCCIUS.PRODUCTUS             1.0000000000        0.05823751
## MICROSTOMUS.PACIFICUS            0.0582375067        1.00000000
## PANDALOPSIS.DISPAR              -0.0935446732       -0.29397139
## PANDALUS.BOREALIS                0.0003385881       -0.29479067
## PANDALUS.JORDANI                -0.3709470053       -0.24179287
## PANDALUS.PLATYCEROS             -0.0402555578       -0.20055097
## PAROPHRYS.VETULUS                0.2733030780        0.17562172
## PECTINIDAE                      -0.1253324318        0.12493129
## RAJA.RHINA                       0.2084519930        0.03635768
## SQUALUS.SUCKLEYI                 0.3064607149        0.04968602
## THALEICHTHYS.PACIFICUS          -0.3555123485       -0.03516164
##                            PANDALOPSIS.DISPAR PANDALUS.BOREALIS PANDALUS.JORDANI
## ACTINIARIA                        0.144860118      0.0073634991     -0.014992995
## ANOPLOPOMA.FIMBRIA                0.150334975      0.1114848540      0.201362464
## ATHERESTHES.STOMIAS               0.306771953      0.1222665385      0.425748057
## BATHYRAJA.INTERRUPTA             -0.149945558     -0.0672178008     -0.103012258
## BERINGRAJA.BINOCULATA            -0.253986365     -0.0438910579     -0.245462623
## CLUPEA.PALLASII                  -0.187452543     -0.0347822884     -0.007204396
## GADUS.CHALCOGRAMMUS              -0.255327509     -0.0823480541     -0.081914035
## GADUS.MACROCEPHALUS              -0.234276096     -0.1429190861     -0.174100224
## GLYPTOCEPHALUS.ZACHIRUS           0.197182512      0.0267931808      0.181237294
## HIPPOGLOSSOIDES.ELASSODON         0.350165378      0.0929872737      0.504831240
## HYDROLAGUS.COLLIEI               -0.004057897     -0.1189719342     -0.137332816
## LYCODES.BREVIPES                  0.416367950      0.3069307416      0.560379751
## LYCODES.PACIFICUS                 0.566012103      0.2763682696      0.732972290
## LYOPSETTA.EXILIS                  0.635239559      0.2679133245      0.447958084
## MERLUCCIUS.PRODUCTUS             -0.093544673      0.0003385881     -0.370947005
## MICROSTOMUS.PACIFICUS            -0.293971390     -0.2947906653     -0.241792867
## PANDALOPSIS.DISPAR                1.000000000      0.3124191681      0.461645250
## PANDALUS.BOREALIS                 0.312419168      1.0000000000      0.252701619
## PANDALUS.JORDANI                  0.461645250      0.2527016192      1.000000000
## PANDALUS.PLATYCEROS               0.314100391      0.2935136418      0.172768813
## PAROPHRYS.VETULUS                -0.270689692     -0.0737401194     -0.355979706
## PECTINIDAE                       -0.121924679      0.0762413806     -0.067065043
## RAJA.RHINA                       -0.068340547     -0.0256365713     -0.237481012
## SQUALUS.SUCKLEYI                 -0.210290785      0.0157313801     -0.254649434
## THALEICHTHYS.PACIFICUS            0.341869640      0.1917337914      0.458148265
##                            PANDALUS.PLATYCEROS PAROPHRYS.VETULUS   PECTINIDAE
## ACTINIARIA                         0.153814766      -0.012837649 -0.062294966
## ANOPLOPOMA.FIMBRIA                 0.041695614      -0.125507859  0.039885565
## ATHERESTHES.STOMIAS                0.068766372      -0.230221406  0.015286410
## BATHYRAJA.INTERRUPTA              -0.061258440       0.004170696  0.004825412
## BERINGRAJA.BINOCULATA             -0.069319954       0.304925297 -0.030172121
## CLUPEA.PALLASII                    0.040031707       0.178975535  0.100926410
## GADUS.CHALCOGRAMMUS               -0.032443948       0.155464625  0.123995881
## GADUS.MACROCEPHALUS               -0.094215839       0.042764433  0.065544118
## GLYPTOCEPHALUS.ZACHIRUS            0.094166676       0.044522278 -0.054764278
## HIPPOGLOSSOIDES.ELASSODON          0.001049330      -0.093341374 -0.107638354
## HYDROLAGUS.COLLIEI                -0.013014322       0.062918378  0.157661955
## LYCODES.BREVIPES                   0.167610137      -0.299378561 -0.078992951
```

```
## LYCODES.PACIFICUS                0.142801381      -0.327077491 -0.122343527
## LYOPSETTA.EXILIS                 0.183395310      -0.231838574 -0.211018759
## MERLUCCIUS.PRODUCTUS            -0.040255558       0.273303078 -0.125332432
## MICROSTOMUS.PACIFICUS           -0.200550971       0.175621725  0.124931293
## PANDALOPSIS.DISPAR               0.314100391      -0.270689692 -0.121924679
## PANDALUS.BOREALIS                0.293513642      -0.073740119  0.076241381
## PANDALUS.JORDANI                 0.172768813      -0.355979706 -0.067065043
## PANDALUS.PLATYCEROS              1.000000000      -0.125646600  0.160593007
## PAROPHRYS.VETULUS               -0.125646600       1.000000000 -0.014616967
## PECTINIDAE                       0.160593007      -0.014616967  1.000000000
## RAJA.RHINA                      -0.052815856       0.045392537 -0.060616619
## SQUALUS.SUCKLEYI                -0.050489244       0.157009932  0.007819690
## THALEICHTHYS.PACIFICUS           0.000419443      -0.195806137 -0.189033277
##                             RAJA.RHINA SQUALUS.SUCKLEYI THALEICHTHYS.PACIFICUS
## ACTINIARIA                 -0.01679663      -0.08823558           -0.101881020
## ANOPLOPOMA.FIMBRIA         -0.08594654      -0.10230392            0.157370649
## ATHERESTHES.STOMIAS        -0.14436802      -0.16439747            0.472784923
## BATHYRAJA.INTERRUPTA        0.19030543       0.17589587           -0.051032446
## BERINGRAJA.BINOCULATA       0.14621106       0.17043065           -0.083635641
## CLUPEA.PALLASII            -0.11939971      -0.05243793            0.030822745
## GADUS.CHALCOGRAMMUS         0.08468141       0.07129653            0.096961850
## GADUS.MACROCEPHALUS         0.06550652       0.09487366           -0.090986240
## GLYPTOCEPHALUS.ZACHIRUS    -0.06582137      -0.17641984            0.302117568
## HIPPOGLOSSOIDES.ELASSODON -0.12899618      -0.20156106            0.429644613
## HYDROLAGUS.COLLIEI          0.05905720       0.06641739           -0.025814714
## LYCODES.BREVIPES           -0.14968719      -0.10112965            0.412424593
## LYCODES.PACIFICUS          -0.19309005      -0.22440250            0.495150929
## LYOPSETTA.EXILIS            0.01616981      -0.13655501            0.221192449
## MERLUCCIUS.PRODUCTUS        0.20845199       0.30646071           -0.355512348
## MICROSTOMUS.PACIFICUS       0.03635768       0.04968602           -0.035161635
## PANDALOPSIS.DISPAR         -0.06834055      -0.21029079            0.341869640
## PANDALUS.BOREALIS          -0.02563657       0.01573138            0.191733791
## PANDALUS.JORDANI           -0.23748101      -0.25464943            0.458148265
## PANDALUS.PLATYCEROS        -0.05281586      -0.05048924            0.000419443
## PAROPHRYS.VETULUS           0.04539254       0.15700993           -0.195806137
## PECTINIDAE                 -0.06061662       0.00781969           -0.189033277
## RAJA.RHINA                  1.00000000       0.25635004           -0.141353598
## SQUALUS.SUCKLEYI            0.25635004       1.00000000           -0.117652775
## THALEICHTHYS.PACIFICUS     -0.14135360      -0.11765277            1.000000000
```

```r
corrplot(species_cor, tl.col = "black")
```

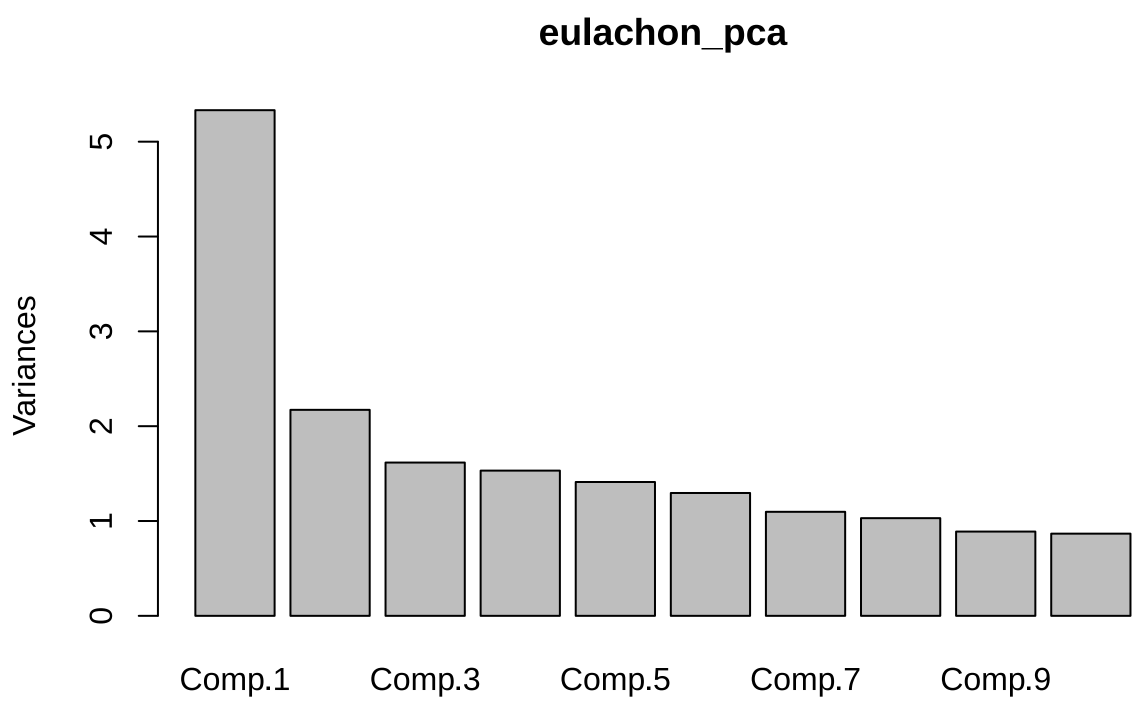



```r
####PRINCIPAL COMPONENTS ANALYSIS OF BIOLOGICAL DATA#######

eulachon_pca <- princomp(eulachon_wide_log[,(14:38)],cor=TRUE)

summary(eulachon_pca)
```

```
## Importance of components:
##                           Comp.1     Comp.2     Comp.3     Comp.4     Comp.5
## Standard deviation     2.3091551 1.47386070 1.27134118 1.23745510 1.18793825
## Proportion of Variance 0.2132879 0.08689061 0.06465234 0.06125181 0.05644789
## Cumulative Proportion  0.2132879 0.30017851 0.36483085 0.42608265 0.48253055
##                            Comp.6     Comp.7     Comp.8     Comp.9    Comp.10
## Standard deviation     1.13822139 1.04729323 1.01490081 0.94270044 0.93100153
## Proportion of Variance 0.05182192 0.04387292 0.04120095 0.03554736 0.03467055
## Cumulative Proportion  0.53435246 0.57822539 0.61942633 0.65497370 0.68964425
##                           Comp.11    Comp.12    Comp.13   Comp.14   Comp.15
## Standard deviation     0.90820632 0.88248620 0.83445729 0.8226832 0.7884669
## Proportion of Variance 0.03299355 0.03115128 0.02785276 0.0270723 0.0248672
## Cumulative Proportion  0.72263780 0.75378908 0.78164184 0.8087141 0.8335813
##                           Comp.16    Comp.17    Comp.18   Comp.19    Comp.20
## Standard deviation     0.76698523 0.75449202 0.73211941 0.6972464 0.65535220
## Proportion of Variance 0.02353065 0.02277033 0.02143995 0.0194461 0.01717946
## Cumulative Proportion  0.85711199 0.87988232 0.90132228 0.9207684 0.93794784
##                           Comp.21   Comp.22    Comp.23    Comp.24     Comp.25
## Standard deviation     0.63917369 0.5965170 0.57102045 0.51674806 0.440267602
## Proportion of Variance 0.01634172 0.0142333 0.01304257 0.01068114 0.007753422
```

```
## Cumulative Proportion  0.95428956 0.9685229 0.98156544 0.99224658 1.000000000
```

```r
plot(eulachon_pca)
```




```r
loadings(eulachon_pca)
```

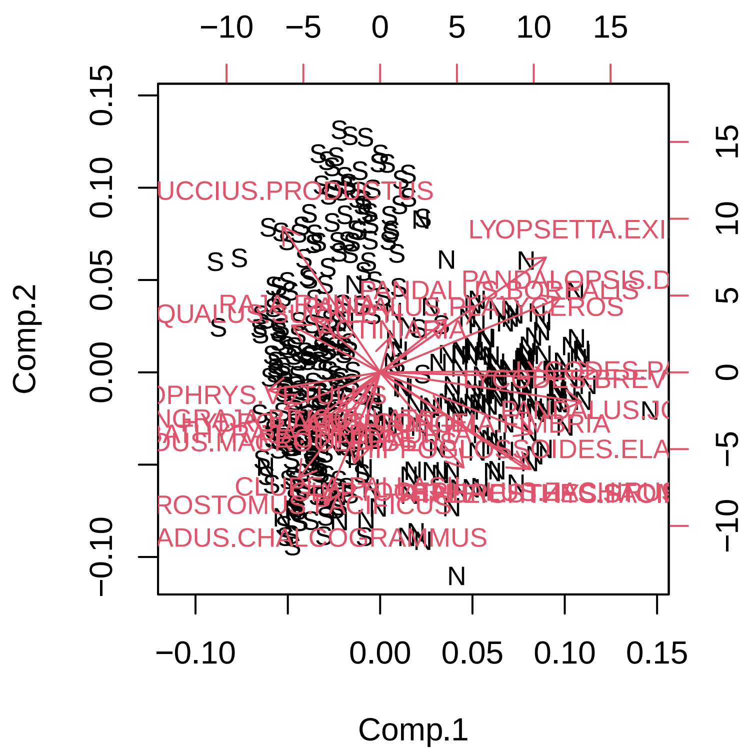
```
##
## Loadings:
##                           Comp.1 Comp.2 Comp.3 Comp.4 Comp.5 Comp.6 Comp.7
## ACTINIARIA                               0.304                0.281  0.597
## ANOPLOPOMA.FIMBRIA         0.108 -0.110  0.428         0.148  0.105
## ATHERESTHES.STOMIAS        0.252 -0.261  0.171 -0.119               -0.198
## BATHYRAJA.INTERRUPTA             -0.133        -0.135  0.360 -0.279  0.392
## BERINGRAJA.BINOCULATA     -0.165        -0.286 -0.200  0.232  0.236  0.109
## CLUPEA.PALLASII                  -0.247 -0.457  0.233         0.141
## GADUS.CHALCOGRAMMUS              -0.358 -0.220         0.233
## GADUS.MACROCEPHALUS       -0.132 -0.150                      -0.291  0.101
## GLYPTOCEPHALUS.ZACHIRUS    0.144 -0.258  0.121 -0.250  0.101  0.406
## HIPPOGLOSSOIDES.ELASSODON  0.264 -0.165 -0.156 -0.216 -0.100
## HYDROLAGUS.COLLIEI               -0.108  0.217         0.261 -0.118 -0.274
## LYCODES.BREVIPES           0.298        -0.142         0.122 -0.198
## LYCODES.PACIFICUS          0.374        -0.133
## LYOPSETTA.EXILIS           0.287  0.312        -0.189
## MERLUCCIUS.PRODUCTUS      -0.169  0.395        -0.232         0.120 -0.220
## MICROSTOMUS.PACIFICUS     -0.141 -0.287  0.346 -0.216               -0.198
```

```
## PANDALOPSIS.DISPAR         0.312  0.202                0.141
## PANDALUS.BOREALIS          0.165  0.180 -0.169  0.156  0.379  0.125 -0.117
## PANDALUS.JORDANI           0.348                             -0.109
## PANDALUS.PLATYCEROS        0.115  0.143         0.360  0.376  0.282
## PAROPHRYS.VETULUS         -0.193        -0.184 -0.199         0.460 -0.149
## PECTINIDAE                       -0.142         0.472  0.224        -0.392
## RAJA.RHINA                -0.115  0.149        -0.305  0.354 -0.184
## SQUALUS.SUCKLEYI          -0.152  0.127 -0.126 -0.206  0.360 -0.222 -0.186
## THALEICHTHYS.PACIFICUS     0.261 -0.263        -0.215
##                           Comp.8 Comp.9 Comp.10 Comp.11 Comp.12 Comp.13 Comp.14
## ACTINIARIA                 0.180  0.211          0.309   0.260
## ANOPLOPOMA.FIMBRIA        -0.479  0.236 -0.156  -0.149   0.112   0.314  -0.250
## ATHERESTHES.STOMIAS       -0.171         0.131                          -0.323
## BATHYRAJA.INTERRUPTA             -0.135          0.338  -0.501
## BERINGRAJA.BINOCULATA                   -0.280  -0.189  -0.330           0.151
## CLUPEA.PALLASII                   0.167                          0.193  -0.574
## GADUS.CHALCOGRAMMUS              -0.187                  0.588           0.112
## GADUS.MACROCEPHALUS        0.212  0.607  0.453  -0.326  -0.132   0.112   0.217
## GLYPTOCEPHALUS.ZACHIRUS                  0.216  -0.289  -0.180  -0.224   0.108
## HIPPOGLOSSOIDES.ELASSODON  0.158         0.202   0.328           0.224
## HYDROLAGUS.COLLIEI         0.591  0.137 -0.517                          -0.120
## LYCODES.BREVIPES                  0.185 -0.115   0.164   0.101
## LYCODES.PACIFICUS
## LYOPSETTA.EXILIS           0.215
## MERLUCCIUS.PRODUCTUS              0.181  0.134   0.150                  -0.149
## MICROSTOMUS.PACIFICUS                    0.239   0.294          -0.121   0.123
## PANDALOPSIS.DISPAR         0.226
## PANDALUS.BOREALIS         -0.296  0.171                          0.198   0.438
## PANDALUS.JORDANI                                 0.112
## PANDALUS.PLATYCEROS        0.125         0.217          -0.107  -0.435  -0.232
## PAROPHRYS.VETULUS                 0.252          0.219           0.271
## PECTINIDAE                       -0.267  0.231   0.204           0.260   0.163
## RAJA.RHINA                 0.110 -0.306  0.287  -0.294   0.234   0.405  -0.203
## SQUALUS.SUCKLEYI          -0.158  0.238          0.273   0.179  -0.349  -0.158
## THALEICHTHYS.PACIFICUS            0.164 -0.139  -0.109   0.146  -0.171
##                           Comp.15 Comp.16 Comp.17 Comp.18 Comp.19 Comp.20
## ACTINIARIA                 0.204   0.121   0.243           0.171   0.119
## ANOPLOPOMA.FIMBRIA         0.146  -0.194  -0.260          -0.103  -0.185
## ATHERESTHES.STOMIAS                        0.142   0.197   0.129   0.653
## BATHYRAJA.INTERRUPTA      -0.302          -0.230           0.139
## BERINGRAJA.BINOCULATA      0.491  -0.337   0.242   0.163           0.100
## CLUPEA.PALLASII                            0.227  -0.124   0.244  -0.258
## GADUS.CHALCOGRAMMUS       -0.120  -0.306  -0.359           0.254   0.132
## GADUS.MACROCEPHALUS               -0.105  -0.146   0.106
## GLYPTOCEPHALUS.ZACHIRUS            0.332  -0.117  -0.322   0.283
## HIPPOGLOSSOIDES.ELASSODON                          0.364  -0.241   0.107
## HYDROLAGUS.COLLIEI
## LYCODES.BREVIPES           0.111           0.157  -0.601           0.218
## LYCODES.PACIFICUS          0.189                  -0.168
## LYOPSETTA.EXILIS                  -0.119  -0.156           0.220  -0.114
## MERLUCCIUS.PRODUCTUS      -0.125  -0.443                   0.341   0.125
## MICROSTOMUS.PACIFICUS             -0.359   0.358  -0.170  -0.135  -0.276
## PANDALOPSIS.DISPAR        -0.101                   0.238   0.147  -0.268
## PANDALUS.BOREALIS         -0.353   0.115   0.271
```

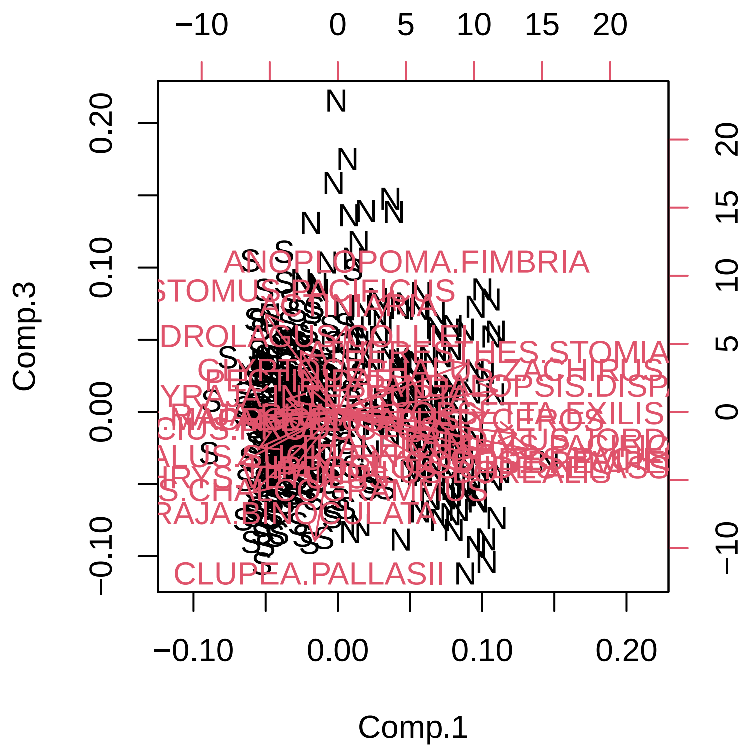
```
## PANDALUS.JORDANI           0.188  -0.210  -0.171          -0.155
## PANDALUS.PLATYCEROS       -0.125  -0.191                  -0.447
## PAROPHRYS.VETULUS         -0.150   0.222  -0.313  -0.116  -0.354
## PECTINIDAE                 0.283                           0.179  -0.118
## RAJA.RHINA                                 0.234  -0.158  -0.235
## SQUALUS.SUCKLEYI           0.386   0.325  -0.111   0.149          -0.132
## THALEICHTHYS.PACIFICUS    -0.215           0.248   0.306          -0.360
##                           Comp.21 Comp.22 Comp.23 Comp.24 Comp.25
## ACTINIARIA                         0.106   0.135
## ANOPLOPOMA.FIMBRIA        -0.100  -0.233           0.108
## ATHERESTHES.STOMIAS        0.155   0.211  -0.171
## BATHYRAJA.INTERRUPTA                               0.116
## BERINGRAJA.BINOCULATA                     -0.100
## CLUPEA.PALLASII           -0.159
## GADUS.CHALCOGRAMMUS                       -0.115
## GADUS.MACROCEPHALUS
## GLYPTOCEPHALUS.ZACHIRUS   -0.161  -0.118   0.170  -0.182
## HIPPOGLOSSOIDES.ELASSODON -0.345  -0.493   0.123
## HYDROLAGUS.COLLIEI        -0.269           0.132
## LYCODES.BREVIPES           0.253  -0.390                  -0.237
## LYCODES.PACIFICUS                  0.198           0.131   0.818
## LYOPSETTA.EXILIS          -0.135   0.183  -0.106   0.646  -0.337
## MERLUCCIUS.PRODUCTUS                       0.428  -0.226
## MICROSTOMUS.PACIFICUS     -0.114   0.123  -0.292
## PANDALOPSIS.DISPAR         0.340  -0.171  -0.510  -0.422
## PANDALUS.BOREALIS         -0.355          -0.101
## PANDALUS.JORDANI          -0.192   0.552   0.158  -0.467  -0.320
## PANDALUS.PLATYCEROS                        0.104   0.119
## PAROPHRYS.VETULUS          0.316   0.196
## PECTINIDAE                 0.300           0.195
## RAJA.RHINA
## SQUALUS.SUCKLEYI          -0.128          -0.147
## THALEICHTHYS.PACIFICUS     0.343           0.447   0.132  -0.106
##
##                Comp.1 Comp.2 Comp.3 Comp.4 Comp.5 Comp.6 Comp.7 Comp.8 Comp.9
## SS loadings      1.00   1.00   1.00   1.00   1.00   1.00   1.00   1.00   1.00
## Proportion Var   0.04   0.04   0.04   0.04   0.04   0.04   0.04   0.04   0.04
## Cumulative Var   0.04   0.08   0.12   0.16   0.20   0.24   0.28   0.32   0.36
##                Comp.10 Comp.11 Comp.12 Comp.13 Comp.14 Comp.15 Comp.16 Comp.17
## SS loadings       1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
## Proportion Var    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
## Cumulative Var    0.40    0.44    0.48    0.52    0.56    0.60    0.64    0.68
##                Comp.18 Comp.19 Comp.20 Comp.21 Comp.22 Comp.23 Comp.24 Comp.25
## SS loadings       1.00    1.00    1.00    1.00    1.00    1.00    1.00    1.00
## Proportion Var    0.04    0.04    0.04    0.04    0.04    0.04    0.04    0.04
## Cumulative Var    0.72    0.76    0.80    0.84    0.88    0.92    0.96    1.00
```

```
####MAKE BIPLOTS ######

eulachon_wide_log$MAJOR_STAT_AREA_CODE <- as.numeric(as.character(eulachon_wide_log$MAJOR_STAT_AREA_CODE


area_name<-eulachon_wide_log$MAJOR_STAT_AREA_CODE
```

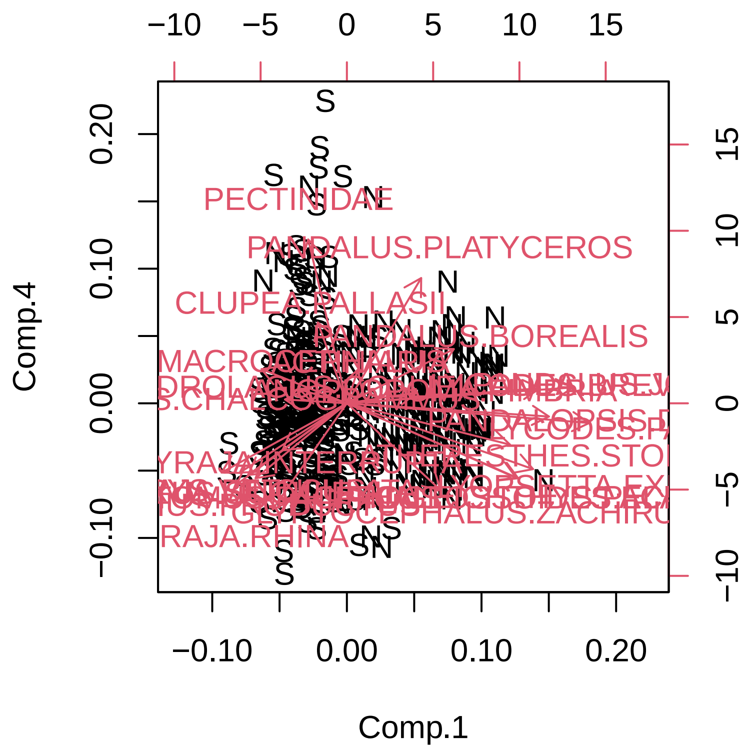
```
area_name[area_name==1]<-"S"
area_name[area_name==8]<-"N"


biplot(eulachon_pca,xlabs=as.character(area_name),cex=0.8)#,xlim=c(-.05,.07))
```



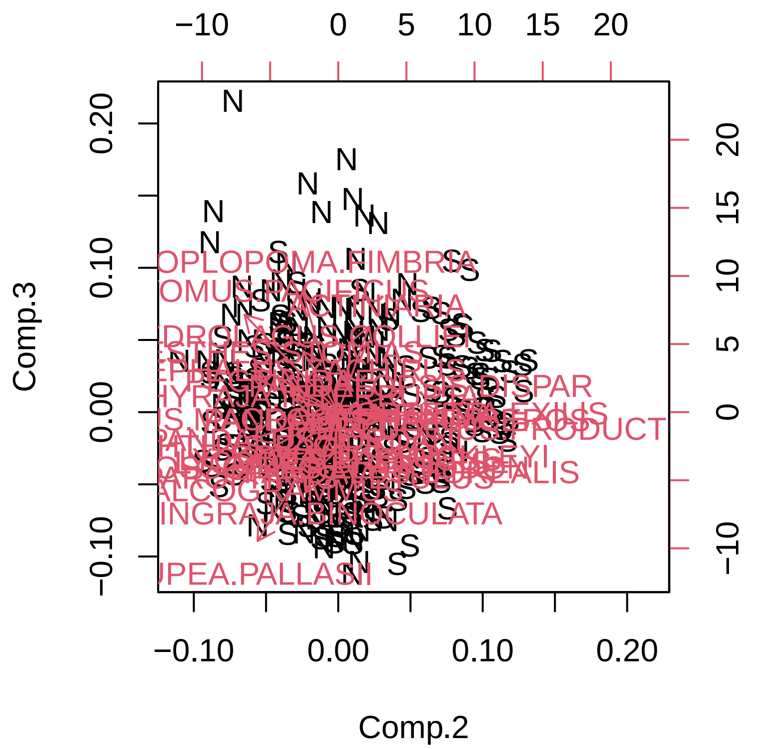

```
biplot(eulachon_pca,choices=c(1,3),xlabs=as.character(area_name))#,cex=0.8,xlim=c(-.15,.05))
```



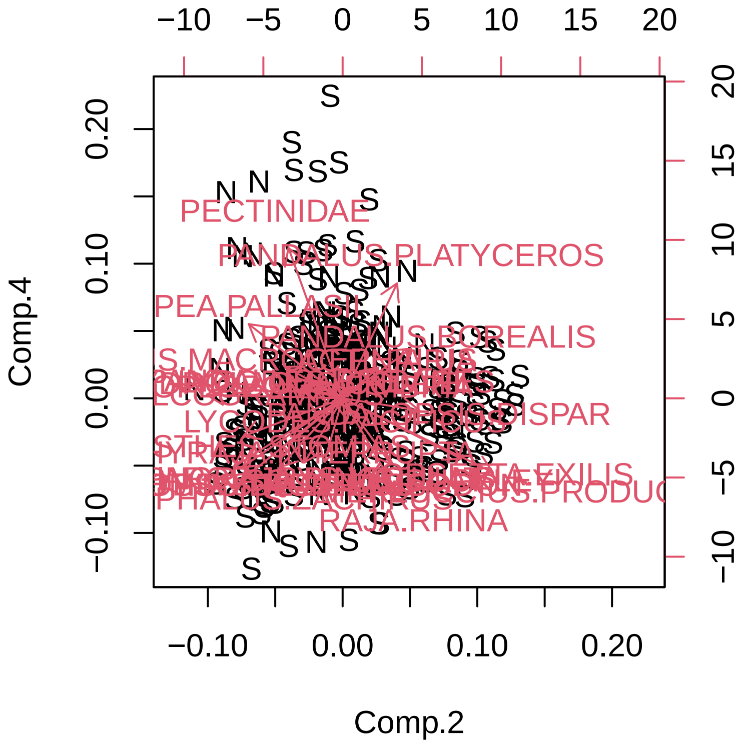

```r
biplot(eulachon_pca,choices=c(1,4),xlabs=as.character(area_name))#,cex=0.8,xlim=c(-.05,.07))
```



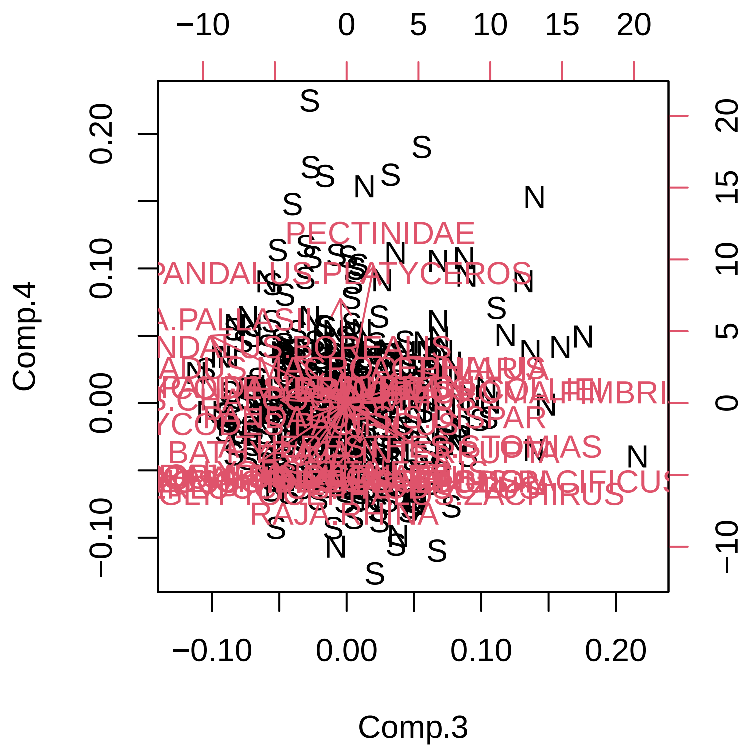

```r
biplot(eulachon_pca,choices=c(2,3),xlabs=as.character(area_name))#,cex=0.8,xlim=c(-.05,.07))
```




```
biplot(eulachon_pca,choices=c(2,4),xlabs=as.character(area_name))#,cex=0.8,xlim=c(-.05,.07))
```




```r
biplot(eulachon_pca,choices=c(3,4),xlabs=as.character(area_name))#,cex=0.8,xlim=c(-.05,.07))
```



```
##Heirarchical clustering on the normalized data just for the slope data
#normalize the data

#cluster_data<-cbind(eulachon_wide[,14:38],eulachon_wide["MAJOR_STAT_AREA_CODE"])

#mean_cluster<-colMeans(cluster_data[,1:25])

#sd_cluster<-apply(cluster_data[,1:25],2, sd)

#for(i in 1:25){
#  cluster_data[,i]<-(cluster_data[,i]-mean_cluster[i])/sd_cluster[i]}


####### Hierarchical clustering ########

apply(eulachon_wide[,14:38], 1, sum)
```

```
##     4363805     4363806     4363807     4363808     4363809     4363810
##  11704.3651   1170.0680    928.2775   9451.3585  20816.3265  12776.8441
##     4363811     4363812     4363813     4363814     4363815     4363817
##   5953.7898   2915.9476  18125.8969   1568.6988  34366.4021  13596.7159
##     4363818     4363819     4363820     4363822     4363824     4363825
##  22408.7548   3519.6687  12476.8384  12317.4603  12418.5464  26519.5402
##     4363846     4363847     4363848     4363849     4363851     4363852
##  29175.0411  22737.8336  17311.5942  37430.8571  56059.3768  24674.1855
##     4363854     4363855     4363857     4363859     4363882     4363884
```

```
##   33618.4971  17598.5832   1632.8904  11097.0018  38213.5274   4824.6225
##      4363885     4363886     4363887     4363888     4363889     4363890
##   15449.1962  55405.2111  11973.3091  13633.8751  15449.8747  25628.1513
##      4363891     4363892     4363893     4363894     4363895     4363896
##   34998.0695   8800.6457   6865.5286  75540.7210  44163.9861  10138.8411
##      4363897     4363898     4363899     4363900     4363901     4363903
##    2462.2384   8727.5672  10862.0408  21774.5218  12579.7619  13061.3060
##      4452485     4452486     4452487     4452488     4452489     4452490
##    6236.4066   6339.8001   7419.0476  22654.0330  14731.7867  84273.6419
##      4452492     4452493     4452494     4452495     4452496     4452497
##   43472.1444  10876.4172   7504.2017  30273.3894   9109.7308  11909.4650
##      4452498     4452499     4452500     4452501     4452503     4452504
##    9066.5484  75200.2609  10184.8408  24319.0779  10239.3008  18247.9099
##      4452571     4452572     4452573     4452574     4452575     4452576
##   20236.8897  12561.2053   9283.9286  15783.1933  20761.9048  19966.4502
##      4452577     4452578     4452579     4452580     4452581     4452582
##   10891.4729   7841.0786  13501.4006  11678.4819  14959.5882  27091.0973
##      4452583     4452584     4452585     4452586     4452587     4452588
##   11112.9568  17345.2381   8598.7261   2765.7143   3748.0981   5716.5806
##      4452589     4452590     4452591     4452605     4452607     4452608
##    8594.5804   4574.7316   4374.6313  12247.6190    726.4368   6443.7467
##      4452610     4452611     4452612     4452614     4452615     4452616
##   45464.8994  23416.0126  25165.2035   8684.0618   8585.1913  42596.4912
##      4452617     4452618     4452619     4452620     4452621     4452622
##   17763.0662  11713.1910   3540.3959  11011.2647  18885.2669   5628.2430
##      4536245     4536246     4536247     4536248     4536249     4536250
##   23341.0553  16415.6315  28703.2482  53272.3005  12117.7100  11267.1756
##      4536251     4536252     4536253     4536254     4536255     4536256
##   32429.0835  25799.3411  21166.5258  24599.4398  32412.6984  16205.6675
##      4536257     4536258     4536259     4536260     4536261     4536262
##   22564.6741  21011.9048  10952.3810  17222.3273  16556.1905   3616.3070
##      4536263     4536264     4536265     4536266     4536267     4536268
##   14589.9970   8268.1018  21411.3597  21005.6689   6160.0221   7515.1515
##      4536269     4536270     4536271     4536272     4536273     4536274
##    8218.5374  25091.7958  16144.7839  32804.9155  54272.7004  15380.9524
##      4536275     4536276     4536305     4536306     4536307     4536308
##   17231.3328  12318.8940   8839.1096  44042.6587   8341.8054   1963.3205
##      4536309     4536310     4536311     4536312     4536313     4536314
##   11897.8606  13440.5475   7450.8493  61473.6242  28798.8095  14435.5475
##      4536315     4536316     4536317     4536318     4536319     4536320
##   12705.1168  21486.0737  19138.2114  17890.5649  12599.6473  12502.5457
##      4536321     4536322     4536323     4536324     4536325     4536326
##   10796.4206  18141.1360  11035.6354   4341.5873  18615.7532   3808.3900
##      4536327     4536328     4536329     4536330     4536331     4536332
##    2801.9412  12667.4473   6131.5193  35306.7916  11966.4189  45773.2983
##      4538364     4538365     4538366     4538367     4538368     4538369
##   14533.7763  35533.9010   7447.0505  22288.5657  29120.9633   5432.7643
##      4538370     4538371     4538372     4538373     4538374     4538375
##    5364.4003  11360.8865  24796.5368  10364.1115   9976.4089  33046.8632
##      4538376     4538377     4538379     4538380     4538381     4538382
##    4834.4671   9352.7834   9868.5714  12151.4042  21289.9048   8143.9776
##      4538383     4538384     4538385     4538386     4538387     4538388
##   12597.0696   8011.4058   9830.8802  15822.6100  16193.6508  24122.7863
##      4538389     4538390     4538391     4538392     4538393     4538394
```

```
##  34748.9524   3934.1564   9899.4286   3580.9524  11463.3409   7539.3298
##     4538395     4538396     4538397     4538398     4538399     4538400
##   1034.6667  13406.9628  18472.6368  11724.1119  14077.6311  22145.3634
##     4538865     4538866     4538867     4538868     4538869     4538870
##  34885.5981  34941.6588   6493.9920  76330.7974  14453.5714  18662.0690
##     4538871     4538872     4538873     4538874     4538875     4538876
##   8942.8008   6699.9155  12644.2177  19874.5875   8996.7384  15364.8732
##     4538877     4538878     4538879     4538880     4538881     4538882
##  11692.2619  19029.9539  17587.8220  11350.7038  10094.4444  10145.9900
##     4538883     4538884     4538885     4538887     4538888     4538889
##   6948.2402  13481.0059  16537.4932   6712.5645  18153.9313  16843.9799
##     4538890     4538891     4546089     4546090     4546091     4546092
##  16300.4155   9660.3641  25321.0884  17137.8774  11908.9947  11485.9307
##     4546093     4546094     4546095     4546096     4546097     4546098
##  18867.2746  17202.6578  10106.3123  11080.4598  20411.9850   9303.9389
##     4546099     4546100     4546101     4546102     4546103     4546104
##  11843.1373  28996.8254  23883.3819  54000.0000  30305.4187  22750.0000
##     4546105     4546106     4546107     4546108     4546109     4546110
##  16506.4935  33079.3651  12449.6124  19382.7160   4754.9361  19759.7403
##     4546111     4546112     4546113     4546114     4546115     4546116
##  18443.0642 108938.7755  24524.9169  21025.6410  47714.2857  19868.2877
##     4546118     4546119     4546120     4563845     4563846     4563847
##  23820.1058 136698.4127  14512.4717  53483.5979  23826.0073  12113.4752
##     4563848     4563849     4563850     4563851     4563852     4563853
##  26326.8983  11935.1570  15600.0000  11760.9329  19153.9313  18155.0388
##     4563854     4563855     4563856     4563857     4563858     4563859
##  16596.8992   6665.6315   6782.3129  17516.7173  12126.9841  63930.7359
##     4563860     4563861     4563862     4563863     4563864     4563865
##  12772.4868  44662.4339  15024.3902  31103.8961  10179.1383  19292.5170
##     4563866     4563867     4563868     4563869     4563870     4563871
##  27653.8908  40931.6770  19699.7930  10959.1837  54709.7506  12144.7619
##     4563872     4563873     4563874     4563875     4563876     4563877
##  13132.0755  22708.0745  29351.1905  28308.9701  19099.9066  30498.3389
##     4564071     4564072     4564073     4564074     4564075     4564076
##  22862.0269   8975.6614  28651.7857  20348.4848  41894.1799  19673.4694
##     4564077     4564078     4564079     4564080     4564081     4564082
##  25235.8804  36780.9524  14507.1429  14988.3199  14962.7329  25335.6009
##     4564083     4564084     4564085     4564086     4564087     4564088
##   7306.8783  39842.0441  38461.6977  23684.6561  14702.6455   7053.9683
##     4564089     4564091     4564092     4564093     4564095     4590165
##  30782.8107  32340.7407  21005.8072  49328.7982  17858.6790  10303.4330
##     4590166     4590167     4590168     4590169     4590170     4590171
##  22604.3956  17290.3828  13000.8354  11837.6623  17400.5602  64071.9145
##     4590172     4590173     4590174     4590175     4590176     4590177
## 157468.7831  37936.5079  15477.2487   7195.9707 100814.5897  36066.2526
##     4590178     4590179     4590180     4590181     4590182     4590183
##  18362.9829  18937.0200  34828.3499  11531.1355  29240.0389  23288.5154
##     4590184     4590185     4590186     4590187     4590188     4590189
##  37622.8571  20329.2517  13034.9206  36252.2046  35451.9317  57845.2381
##     4590190     4590191     4590192     4590234     4590235     4590236
##  25216.7733  40553.8847  57086.9565  31268.1097  14795.3668  12429.1521
##     4590237     4590238     4590239     4590240     4590241     4590242
##  12855.9373  18871.5729   4034.0976  14661.3095  13296.1310  13610.2757
##     4590243     4590244     4590245     4590246     4590247     4590248
```

```
##  32411.6037  20072.1680  20520.5479   9351.2678  28647.4868  12117.9994
##     4590249     4590250     4590251     4590252     4590253     4590254
##  13827.8616  15415.2260   7836.7347   3792.8262  27114.3505  31825.5814
##     4590256     4590257     4590258     4590259     4590260     4590261
##  10148.2821   7683.9551  41524.9300  23808.9501  21331.6427  14249.8662
##     4590262     4590265     4590266     4590267     4590268     4590269
##   9904.1629  12930.5795  10380.9524 712190.4762  10401.3605  34444.0877
##     4590270     4590271     4590272     4590273     4590274     4590275
##  39181.8703   9560.0414   3689.1078  14941.6667  22301.5873  22565.6214
##     4590276     4590277     4590278     4590279     4590280     4590281
##  10294.4718   7504.9971  27590.8289  15619.0476  36691.7989  68746.2492
##     4590282     4590283     4590284     4590285     4590286     4590287
##  47093.1677   7078.7172  17611.5780  12264.2857   5114.4883  10639.1534
##     4590288     4590289     4590290     4590291     4590292     4590293
##  35706.0041  13275.2613   9472.1550  39976.6082  25708.8123  18778.1649
##     4590294     4590295     4590296     4590297     4590298     4590299
##  13620.2845  15317.4603  34483.3333  40236.8742   7288.5154   9095.2381
##     4590300     4590301     4590302     4590303     4590304     4590305
##  17320.9110  17761.9048  46908.4249  15920.9726   5586.5801  31224.1580
##     4590306     4590307     4590308     4590309     4590310     4590311
##  44076.6551  15106.3830 102699.1342  19773.2426  21701.2987  50387.4459
```

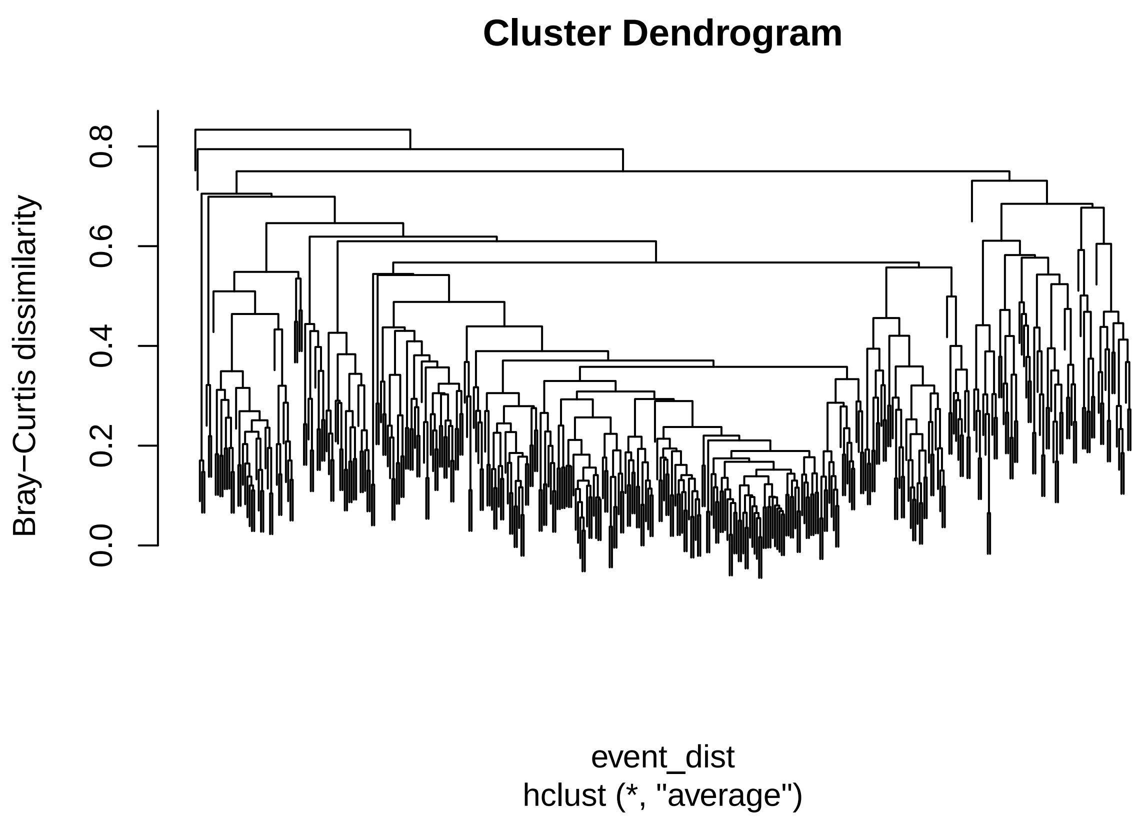
```r
# Turn CPUE to relative abundance by dividing each value by sample total abundance

cluster_data <- decostand(eulachon_wide[,14:38], method = "total")

# check total abundance in each sample

apply(cluster_data, 1, sum)
```

```
## 4363805 4363806 4363807 4363808 4363809 4363810 4363811 4363812 4363813 4363814
##       1       1       1       1       1       1       1       1       1       1
## 4363815 4363817 4363818 4363819 4363820 4363822 4363824 4363825 4363846 4363847
##       1       1       1       1       1       1       1       1       1       1
## 4363848 4363849 4363851 4363852 4363854 4363855 4363857 4363859 4363882 4363884
##       1       1       1       1       1       1       1       1       1       1
## 4363885 4363886 4363887 4363888 4363889 4363890 4363891 4363892 4363893 4363894
##       1       1       1       1       1       1       1       1       1       1
## 4363895 4363896 4363897 4363898 4363899 4363900 4363901 4363903 4452485 4452486
##       1       1       1       1       1       1       1       1       1       1
## 4452487 4452488 4452489 4452490 4452492 4452493 4452494 4452495 4452496 4452497
##       1       1       1       1       1       1       1       1       1       1
## 4452498 4452499 4452500 4452501 4452503 4452504 4452571 4452572 4452573 4452574
##       1       1       1       1       1       1       1       1       1       1
## 4452575 4452576 4452577 4452578 4452579 4452580 4452581 4452582 4452583 4452584
##       1       1       1       1       1       1       1       1       1       1
## 4452585 4452586 4452587 4452588 4452589 4452590 4452591 4452605 4452607 4452608
##       1       1       1       1       1       1       1       1       1       1
## 4452610 4452611 4452612 4452614 4452615 4452616 4452617 4452618 4452619 4452620
##       1       1       1       1       1       1       1       1       1       1
## 4452621 4452622 4536245 4536246 4536247 4536248 4536249 4536250 4536251 4536252
##       1       1       1       1       1       1       1       1       1       1
## 4536253 4536254 4536255 4536256 4536257 4536258 4536259 4536260 4536261 4536262
##       1       1       1       1       1       1       1       1       1       1
```

```
## 4536263 4536264 4536265 4536266 4536267 4536268 4536269 4536270 4536271 4536272
##       1       1       1       1       1       1       1       1       1       1
## 4536273 4536274 4536275 4536276 4536305 4536306 4536307 4536308 4536309 4536310
##       1       1       1       1       1       1       1       1       1       1
## 4536311 4536312 4536313 4536314 4536315 4536316 4536317 4536318 4536319 4536320
##       1       1       1       1       1       1       1       1       1       1
## 4536321 4536322 4536323 4536324 4536325 4536326 4536327 4536328 4536329 4536330
##       1       1       1       1       1       1       1       1       1       1
## 4536331 4536332 4538364 4538365 4538366 4538367 4538368 4538369 4538370 4538371
##       1       1       1       1       1       1       1       1       1       1
## 4538372 4538373 4538374 4538375 4538376 4538377 4538379 4538380 4538381 4538382
##       1       1       1       1       1       1       1       1       1       1
## 4538383 4538384 4538385 4538386 4538387 4538388 4538389 4538390 4538391 4538392
##       1       1       1       1       1       1       1       1       1       1
## 4538393 4538394 4538395 4538396 4538397 4538398 4538399 4538400 4538865 4538866
##       1       1       1       1       1       1       1       1       1       1
## 4538867 4538868 4538869 4538870 4538871 4538872 4538873 4538874 4538875 4538876
##       1       1       1       1       1       1       1       1       1       1
## 4538877 4538878 4538879 4538880 4538881 4538882 4538883 4538884 4538885 4538887
##       1       1       1       1       1       1       1       1       1       1
## 4538888 4538889 4538890 4538891 4546089 4546090 4546091 4546092 4546093 4546094
##       1       1       1       1       1       1       1       1       1       1
## 4546095 4546096 4546097 4546098 4546099 4546100 4546101 4546102 4546103 4546104
##       1       1       1       1       1       1       1       1       1       1
## 4546105 4546106 4546107 4546108 4546109 4546110 4546111 4546112 4546113 4546114
##       1       1       1       1       1       1       1       1       1       1
## 4546115 4546116 4546118 4546119 4546120 4563845 4563846 4563847 4563848 4563849
##       1       1       1       1       1       1       1       1       1       1
## 4563850 4563851 4563852 4563853 4563854 4563855 4563856 4563857 4563858 4563859
##       1       1       1       1       1       1       1       1       1       1
## 4563860 4563861 4563862 4563863 4563864 4563865 4563866 4563867 4563868 4563869
##       1       1       1       1       1       1       1       1       1       1
## 4563870 4563871 4563872 4563873 4563874 4563875 4563876 4563877 4564071 4564072
##       1       1       1       1       1       1       1       1       1       1
## 4564073 4564074 4564075 4564076 4564077 4564078 4564079 4564080 4564081 4564082
##       1       1       1       1       1       1       1       1       1       1
## 4564083 4564084 4564085 4564086 4564087 4564088 4564089 4564091 4564092 4564093
##       1       1       1       1       1       1       1       1       1       1
## 4564095 4590165 4590166 4590167 4590168 4590169 4590170 4590171 4590172 4590173
##       1       1       1       1       1       1       1       1       1       1
## 4590174 4590175 4590176 4590177 4590178 4590179 4590180 4590181 4590182 4590183
##       1       1       1       1       1       1       1       1       1       1
## 4590184 4590185 4590186 4590187 4590188 4590189 4590190 4590191 4590192 4590234
##       1       1       1       1       1       1       1       1       1       1
## 4590235 4590236 4590237 4590238 4590239 4590240 4590241 4590242 4590243 4590244
##       1       1       1       1       1       1       1       1       1       1
## 4590245 4590246 4590247 4590248 4590249 4590250 4590251 4590252 4590253 4590254
##       1       1       1       1       1       1       1       1       1       1
## 4590256 4590257 4590258 4590259 4590260 4590261 4590262 4590265 4590266 4590267
##       1       1       1       1       1       1       1       1       1       1
## 4590268 4590269 4590270 4590271 4590272 4590273 4590274 4590275 4590276 4590277
##       1       1       1       1       1       1       1       1       1       1
## 4590278 4590279 4590280 4590281 4590282 4590283 4590284 4590285 4590286 4590287
##       1       1       1       1       1       1       1       1       1       1
```

```
## 4590288 4590289 4590290 4590291 4590292 4590293 4590294 4590295 4590296 4590297
##       1       1       1       1       1       1       1       1       1       1
## 4590298 4590299 4590300 4590301 4590302 4590303 4590304 4590305 4590306 4590307
##       1       1       1       1       1       1       1       1       1       1
## 4590308 4590309 4590310 4590311
##       1       1       1       1
```

```r
# calculate Bray-Curtis distance among samples

event_dist <- vegdist(cluster_data, method = "bray")

# cluster communities using average-linkage algorithm
event_cluster <- hclust(event_dist, method = "average")

# plot cluster diagram
plot(event_cluster, ylab = "Bray-Curtis dissimilarity", labels = FALSE)
```

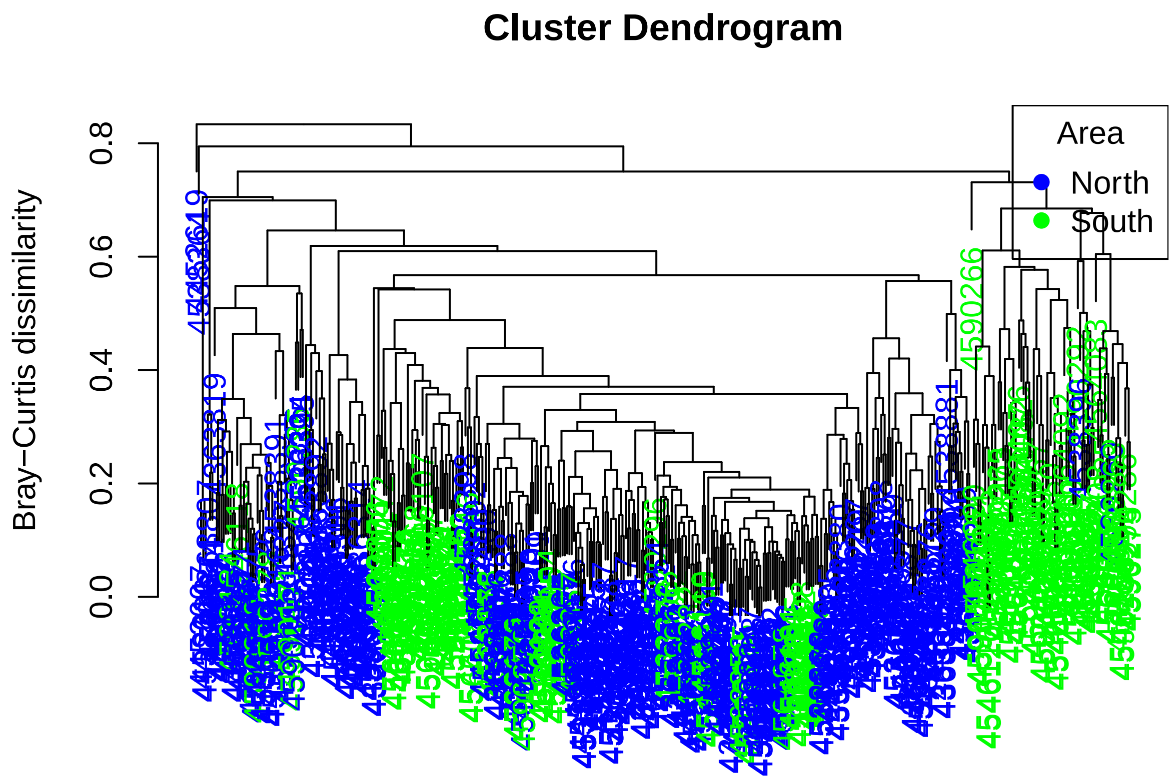



```r
# cluster diagram coloured by area

area_colours <- c('8'="blue", '1'="green")

bc_dend <- as.dendrogram(hclust(event_dist, method = "average"))

order.dendrogram(bc_dend)
```

```
##   [1]  99 163  89  92 165   3 173 347  14  24 101  97 102  48 123 331  23  93
```

```
##  [19] 253  95 152 132 201 203 133  37 413 209  58 121 124 134 381  98 130 189
##  [37]  96 359 360 157 351 318 337 349 156 388 154 193  87 362 182  46 361  38
##  [55]  50  51  39 357  68 164  69 168 136 141 202 340 110 111  61 170  22 200
##  [73] 144  26 140 139 109 367  30 129 267 321 375 247 282 299 374 273 325 281
##  [91] 384 272 324 379 382 246 306 279 258 261 243 332 311 412 288 234 241 242
## [109] 280 407 250 410 333 380 393 259 260 238 249 196 257 248 307 190 108 115
## [127]  90 366 198 269 322 338  11  19 146  57 137 221 208 191 365 323 372  56
## [145] 153 373  88 127  15 159  64 364 245 394 397 414 240 398 278 283 335 336
## [163] 135 145 206 219 268  72 214 350 207 212 213  49  80 356  71  84 160 174
## [181]  73  34 205 112 151  32 181 106 150 175  12  33 143 104 341  59 342  31
## [199] 343 166  28  60 344 399  25 185 199 216 284 409   2  43 339  29  66  94
## [217]  13 128 385  62 155 186  54 158 254 312 239 297 179 107  70 346  52 176
## [235]  55  40  41  91 105 147 113 270 251 287 383 353 138 142 149 148 363 103
## [253] 187  67 100 162 131 184 188 161 296 180 354 237 308 256 320 396 244 319
## [271] 310 400 286 304 285 408 167 171  85 217 183   6  75  36 172 178   1  35
## [289] 352 169  78 345 125 355  63 122 220  86 218   8  42  44  76   4  77  79
## [307]  27  47 117 120 126  81  65 358 211 195   5  45  82 348 116 119  83 177
## [325] 210  74 224  53 204 114  20  21 215 192 223 197  17  16   9  18 222   7
## [343]  10 369 226 313 314 326 289 225 252 255 263 291 315 368 376 328 327 330
## [361] 329 334 298 302 294 300 293 262 295 317 386 387 370 402 371 406 264 390
## [379] 271 232 227 235 231 290 309 276 403 316 392 405 395 194 230 265 228 277
## [397] 233 292 301 411 229 275 303 266 305 118 274 401 404 236 391 389 377 378
```

```r
labels_colors(bc_dend)<-area_colours[eulachon_wide$MAJOR_STAT_AREA_CODE][order.dendrogram(bc_dend)]

plot(hang.dendrogram(bc_dend, hang = 0.1), ylab = "Bray-Curtis dissimilarity", main = "Cluster Dendrogra
legend("topright", legend=c("North", "South"), title= "Area", pch=19,
       col=c("blue", "green"))
```

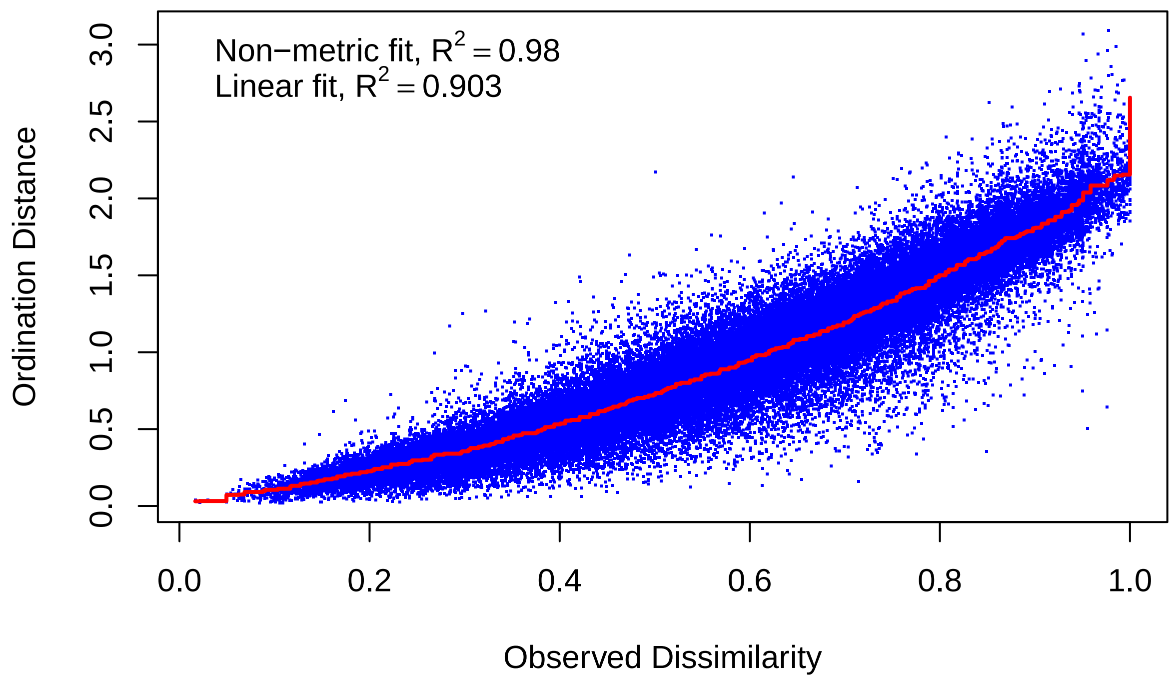



```
####### ordination ########

# The metaMDS function automatically transforms data and checks solution
# robustness

event_mds <- metaMDS(cluster_data, dist = "bray", trymax = 150, k=3,
                     maxit = 300)
```

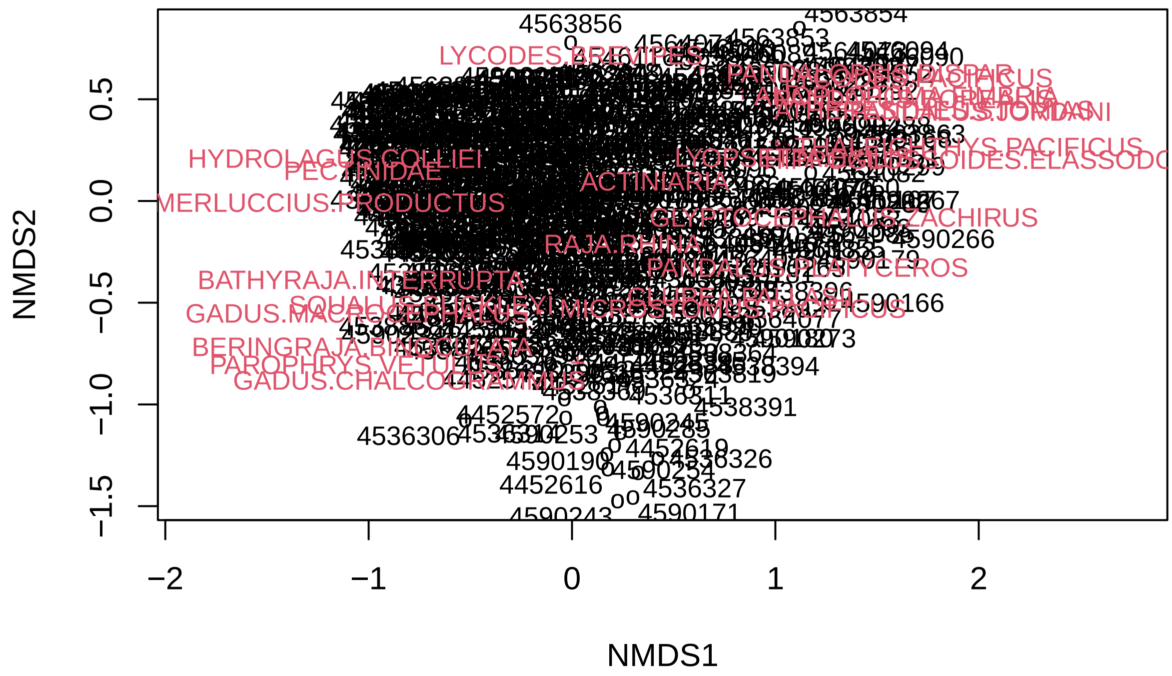
```
## Run 0 stress 0.1403672
## Run 1 stress 0.140367
## ... New best solution
## ... Procrustes: rmse 0.00004114101  max resid 0.0007267103
## ... Similar to previous best
## Run 2 stress 0.140367
## ... Procrustes: rmse 0.0005696715  max resid 0.01018602
## Run 3 stress 0.1426113
## Run 4 stress 0.1446369
## Run 5 stress 0.1403658
## ... New best solution
## ... Procrustes: rmse 0.0002533923  max resid 0.004078596
## ... Similar to previous best
## Run 6 stress 0.1403658
## ... Procrustes: rmse 0.00002703534  max resid 0.0003172821
## ... Similar to previous best
## Run 7 stress 0.1457401
## Run 8 stress 0.1451643
```

```
## Run 9 stress 0.1403671
## ... Procrustes: rmse 0.0002784529  max resid 0.004595975
## ... Similar to previous best
## Run 10 stress 0.1426115
## Run 11 stress 0.1425689
## Run 12 stress 0.1461144
## Run 13 stress 0.1413883
## Run 14 stress 0.1442233
## Run 15 stress 0.1403657
## ... New best solution
## ... Procrustes: rmse 0.00005610878  max resid 0.0006093678
## ... Similar to previous best
## Run 16 stress 0.1403678
## ... Procrustes: rmse 0.0003728389  max resid 0.006263873
## ... Similar to previous best
## Run 17 stress 0.1404452
## ... Procrustes: rmse 0.002318294  max resid 0.03551521
## Run 18 stress 0.1403985
## ... Procrustes: rmse 0.0014998  max resid 0.03001545
## Run 19 stress 0.1438871
## Run 20 stress 0.1456346
## *** Solution reached
```

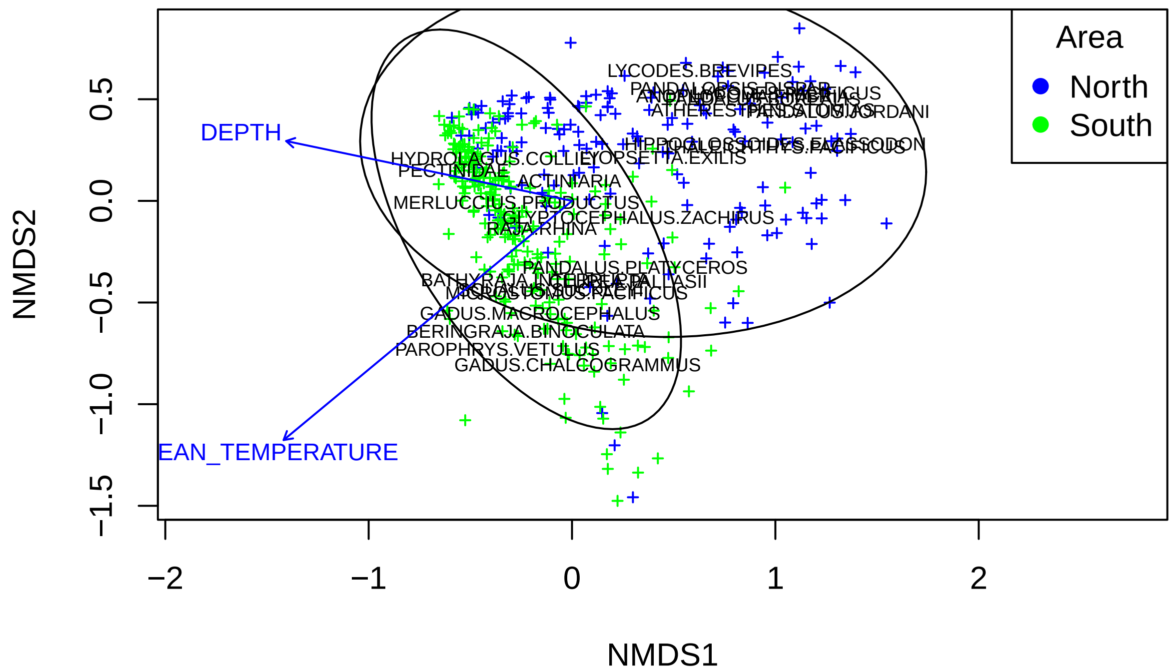
```
# Assess goodness of ordination fit (stress plot)
stressplot(event_mds)
```



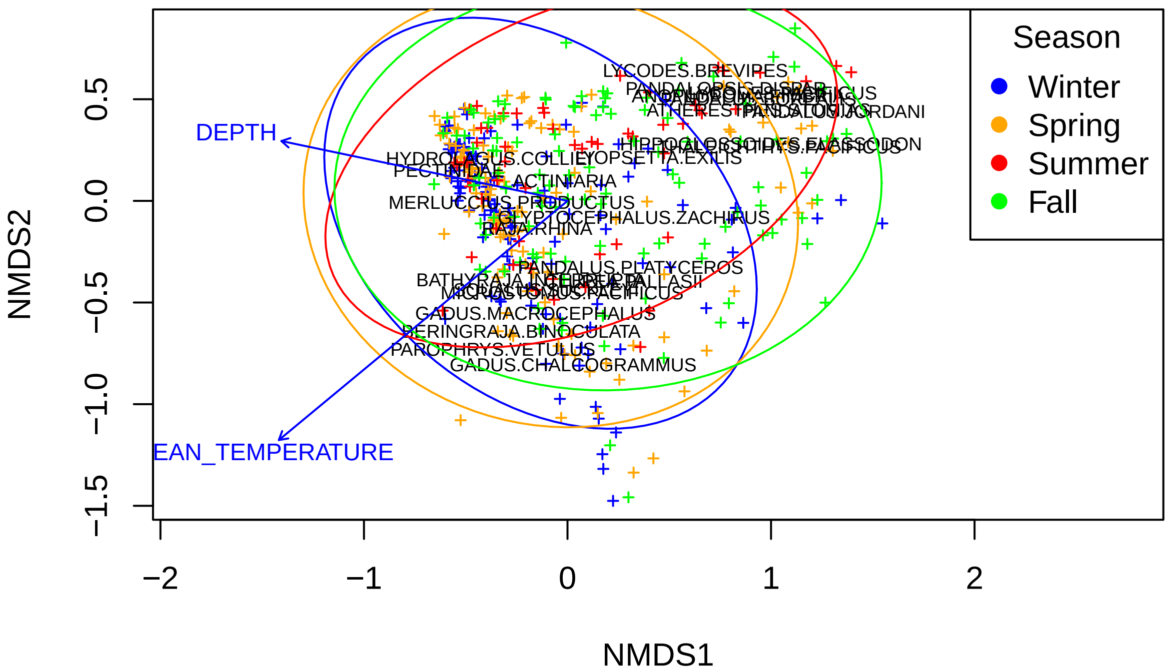
```r
# automated plotting of results
ordipointlabel(event_mds)
```



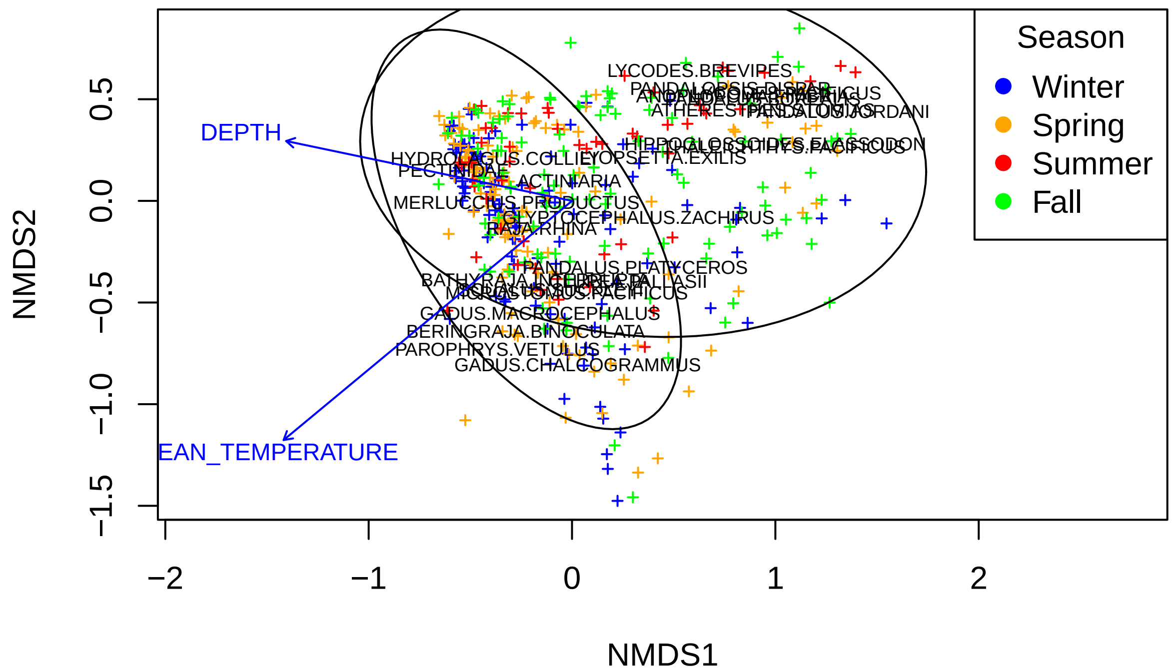

```r
# colour plot by area

blank_mds<- ordiplot(event_mds, type = "n")
points(blank_mds, "sites", col = "blue",
       select=eulachon_wide$MAJOR_STAT_AREA_CODE=="8", pch=3, cex=0.5)
points(blank_mds, "sites", col = "green",
       select=eulachon_wide$MAJOR_STAT_AREA_CODE=="1", pch=3, cex=0.5)
text(blank_mds, "species", col = "black", cex=0.6)

ordiellipse(blank_mds, eulachon_wide$MAJOR_STAT_AREA_CODE, conf = 0.95, label = FALSE)

legend("topright", legend=c("North", "South"), title= "Area", pch=19,
       col=c("blue", "green"))

# add temp and depth axes to the plot

plot(envfit(blank_mds, eulachon_wide[, 12:13]), cex = 0.75)
```



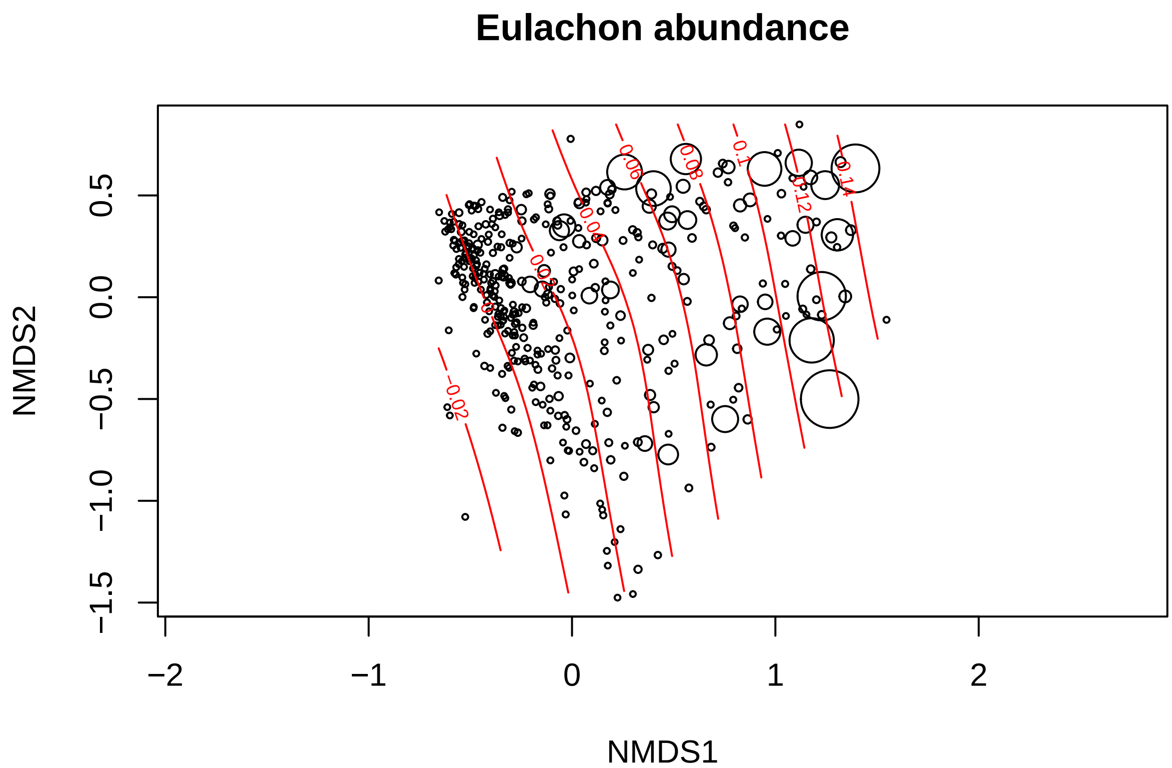

```r
# colour plot by season with season ellipse

blank_mds<- ordiplot(event_mds, type = "n")
points(blank_mds, "sites", col = "blue",
       select=eulachon_wide_season$SEASON=="Winter", pch=3, cex=0.5)
points(blank_mds, "sites", col = "orange",
       select=eulachon_wide_season$SEASON=="Spring", pch=3, cex=0.5)
points(blank_mds, "sites", col = "red",
       select=eulachon_wide_season$SEASON=="Summer", pch=3, cex=0.5)
points(blank_mds, "sites", col = "green",
       select=eulachon_wide_season$SEASON=="Fall", pch=3, cex=0.5)
text(blank_mds, "species", col = "black", cex=0.6)

ordiellipse(blank_mds, eulachon_wide_season$SEASON, conf = 0.95,
            label = FALSE, col = season_colours)
legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)
# add temp and depth axes to the plot

plot(envfit(blank_mds, eulachon_wide[, 12:13]), cex = 0.75)
```




```r
# colour plot by season with area ellipse

blank_mds<- ordiplot(event_mds, type = "n")
points(blank_mds, "sites", col = "blue",
       select=eulachon_wide_season$SEASON=="Winter", pch=3, cex=0.5)
points(blank_mds, "sites", col = "orange",
       select=eulachon_wide_season$SEASON=="Spring", pch=3, cex=0.5)
points(blank_mds, "sites", col = "red",
       select=eulachon_wide_season$SEASON=="Summer", pch=3, cex=0.5)
points(blank_mds, "sites", col = "green",
       select=eulachon_wide_season$SEASON=="Fall", pch=3, cex=0.5)
text(blank_mds, "species", col = "black", cex=0.6)

ordiellipse(blank_mds, eulachon_wide_season$MAJOR_STAT_AREA_CODE, conf = 0.95,
            label = FALSE)
legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)

# add temp and depth axes to the plot

plot(envfit(blank_mds, eulachon_wide[, 12:13]), cex = 0.75)
```




```
# plot eulachon abundance

ordisurf(event_mds, cluster_data[, "THALEICHTHYS.PACIFICUS"], bubble = TRUE, main = "Eulachon abundance
         cex = 4)
```



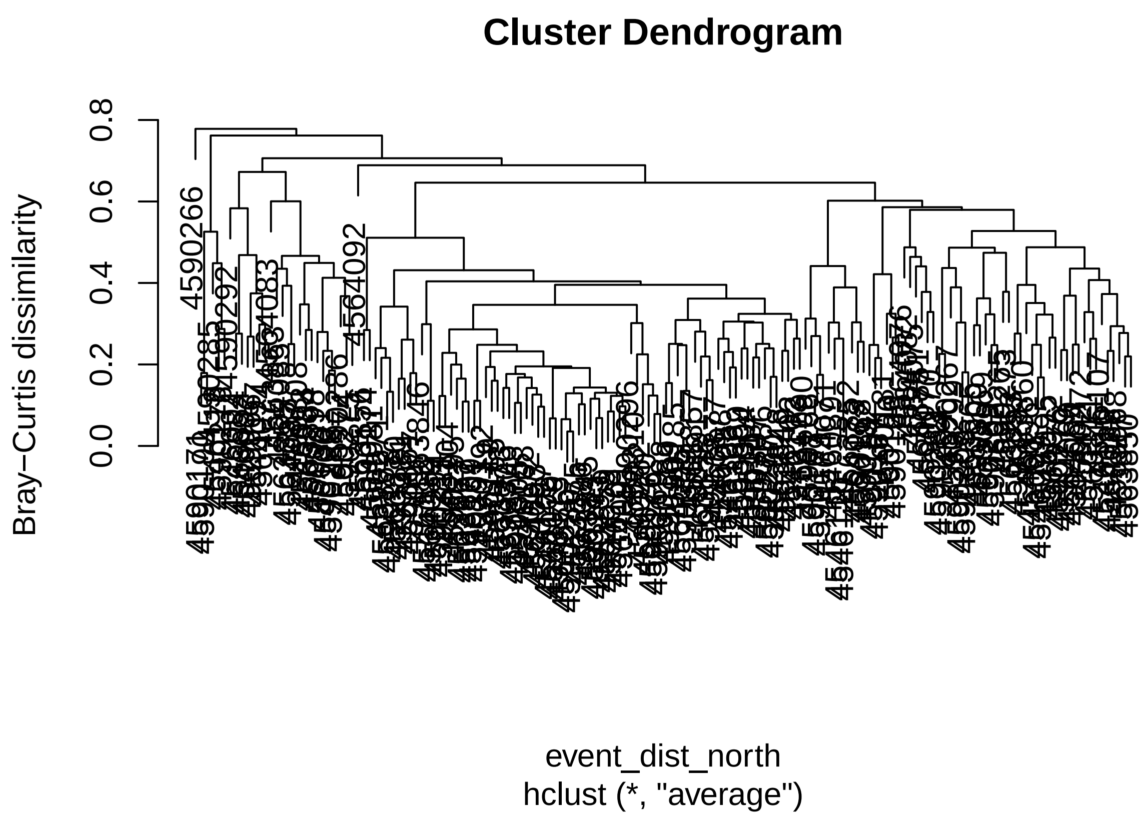

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## y ~ s(x1, x2, k = 10, bs = "tp", fx = FALSE)
##
## Estimated degrees of freedom:
## 3.51  total = 4.51
##
## REML score: -511.7365
```

```
############# Hierarchical clustering by area and season ############


##### filter by area - north #####

eulachon_wide_north <- eulachon_wide_season %>%
  filter(., MAJOR_STAT_AREA_CODE==8)

row.names(eulachon_wide_north) <- eulachon_wide_north$EVENT_ID

# Turn CPUE to relative abundance by dividing each value by sample total abundance

cluster_data_north <- decostand(eulachon_wide_north[,15:39], method = "total")
```

```r
# check total abundance in each sample

apply(cluster_data_north, 1, sum)
```

```
## 4546089 4546090 4546091 4546092 4546093 4546094 4546095 4546096 4546097 4546098
##       1       1       1       1       1       1       1       1       1       1
## 4546099 4546100 4546101 4546102 4546103 4546104 4546105 4546106 4546107 4546108
##       1       1       1       1       1       1       1       1       1       1
## 4546109 4546110 4546111 4546112 4546113 4546114 4546115 4546116 4546118 4546119
##       1       1       1       1       1       1       1       1       1       1
## 4546120 4563845 4563846 4563847 4563848 4563849 4563850 4563851 4563852 4563853
##       1       1       1       1       1       1       1       1       1       1
## 4563854 4563855 4563856 4563857 4563858 4563859 4563860 4563861 4563862 4563863
##       1       1       1       1       1       1       1       1       1       1
## 4563864 4563865 4563866 4563867 4563868 4563869 4563870 4563871 4563872 4563873
##       1       1       1       1       1       1       1       1       1       1
## 4563874 4563875 4563876 4563877 4564071 4564072 4564073 4564074 4564075 4564076
##       1       1       1       1       1       1       1       1       1       1
## 4564077 4564078 4564079 4564080 4564081 4564082 4564083 4564084 4564085 4564086
##       1       1       1       1       1       1       1       1       1       1
## 4564087 4564088 4564089 4564091 4564092 4564093 4564095 4590165 4590166 4590167
##       1       1       1       1       1       1       1       1       1       1
## 4590168 4590169 4590170 4590171 4590172 4590173 4590174 4590175 4590176 4590177
##       1       1       1       1       1       1       1       1       1       1
## 4590178 4590179 4590180 4590181 4590182 4590183 4590184 4590185 4590186 4590187
##       1       1       1       1       1       1       1       1       1       1
## 4590188 4590189 4590190 4590191 4590192 4590265 4590266 4590267 4590268 4590269
##       1       1       1       1       1       1       1       1       1       1
## 4590270 4590271 4590272 4590273 4590274 4590275 4590276 4590277 4590278 4590279
##       1       1       1       1       1       1       1       1       1       1
## 4590280 4590281 4590282 4590283 4590284 4590285 4590286 4590287 4590288 4590289
##       1       1       1       1       1       1       1       1       1       1
## 4590290 4590291 4590292 4590293 4590294 4590295 4590296 4590297 4590298 4590299
##       1       1       1       1       1       1       1       1       1       1
## 4590300 4590301 4590302 4590303 4590304 4590305 4590306 4590307 4590308 4590309
##       1       1       1       1       1       1       1       1       1       1
## 4590310 4590311
##       1       1
```

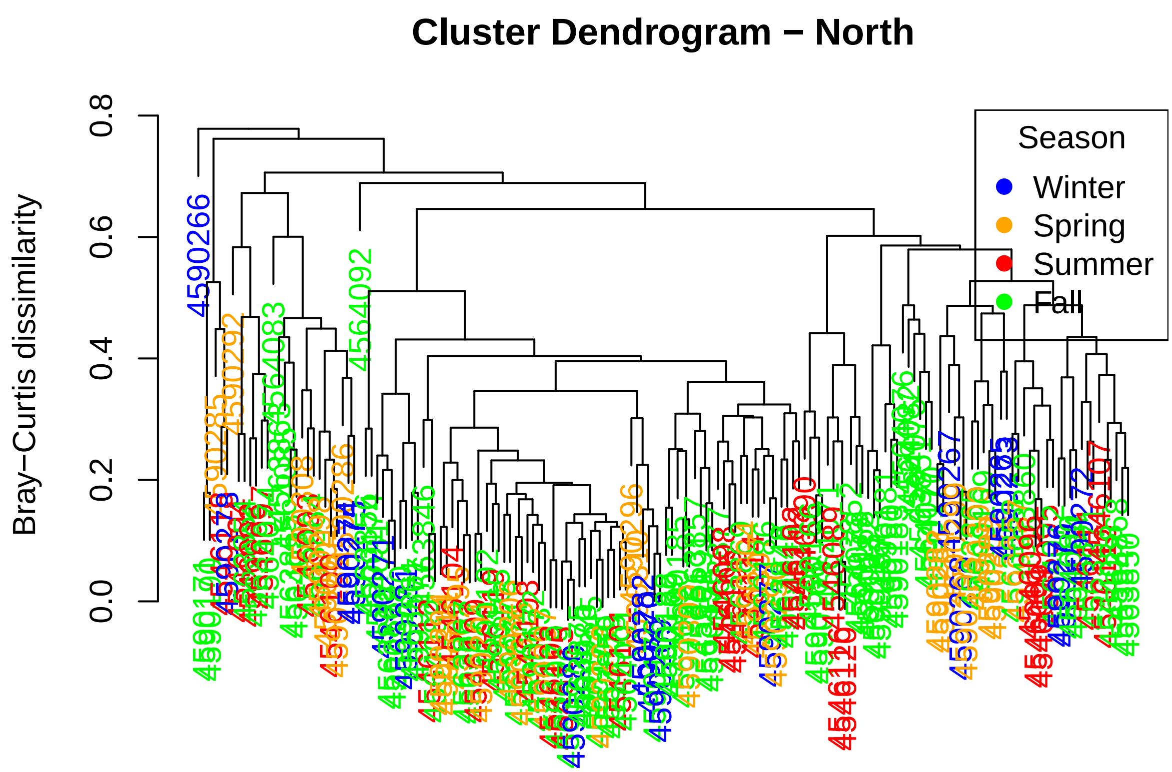
```r
# calculate Bray-Curtis distance among samples

event_dist_north <- vegdist(cluster_data_north, method = "bray")

# cluster communities using average-linkage algorithm
event_cluster_north <- hclust(event_dist_north, method = "average")

# plot cluster diagram
plot(event_cluster_north, ylab = "Bray-Curtis dissimilarity")
```




```
# colouring labels by season

north_dend <- as.dendrogram(hclust(event_dist_north, method = "average"))

order.dendrogram(north_dend)
```

```
##   [1] 117  94 113 136  29 129 143   6  41   4  53   9  68  77  50  79  42  81
##  [19] 159   5  51 149 152  12 139 137 125 126  85  43  97  75 122  49 101  57
##  [37] 132  48 100  33  24  83 145 162  16 146  54  59  21 142 115  30  88  60
##  [55] 157  61 156  20  95  86 148  15  73  27  63 131  62  80  32  96 144  46
##  [73]  72  13  84 147 161 133 121  99 120 111 112 108  87 160  44 114  45  98
##  [91]  64  10  17  18  56 155  26 158 109 128 141  35  36  14  25   2  89  90
## [109] 102  65   1  28  31  39  67  91 105 107 110 104 103 106  70  76  69  38
## [127]  71  93 134 135 118 150 119 154  52 151  92 140 153 116 124  40 138  47
## [145]   8   3  11   7  66 127 130  74  78 123  23  58  19  22  82  55  34  37
```

```
labels_colors(north_dend)<-season_colours[eulachon_wide_north$SEASON][order.dendrogram(north_dend)]

plot(hang.dendrogram(north_dend, hang = 0.1), ylab = "Bray-Curtis dissimilarity", main = "Cluster Dendro
legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)
```

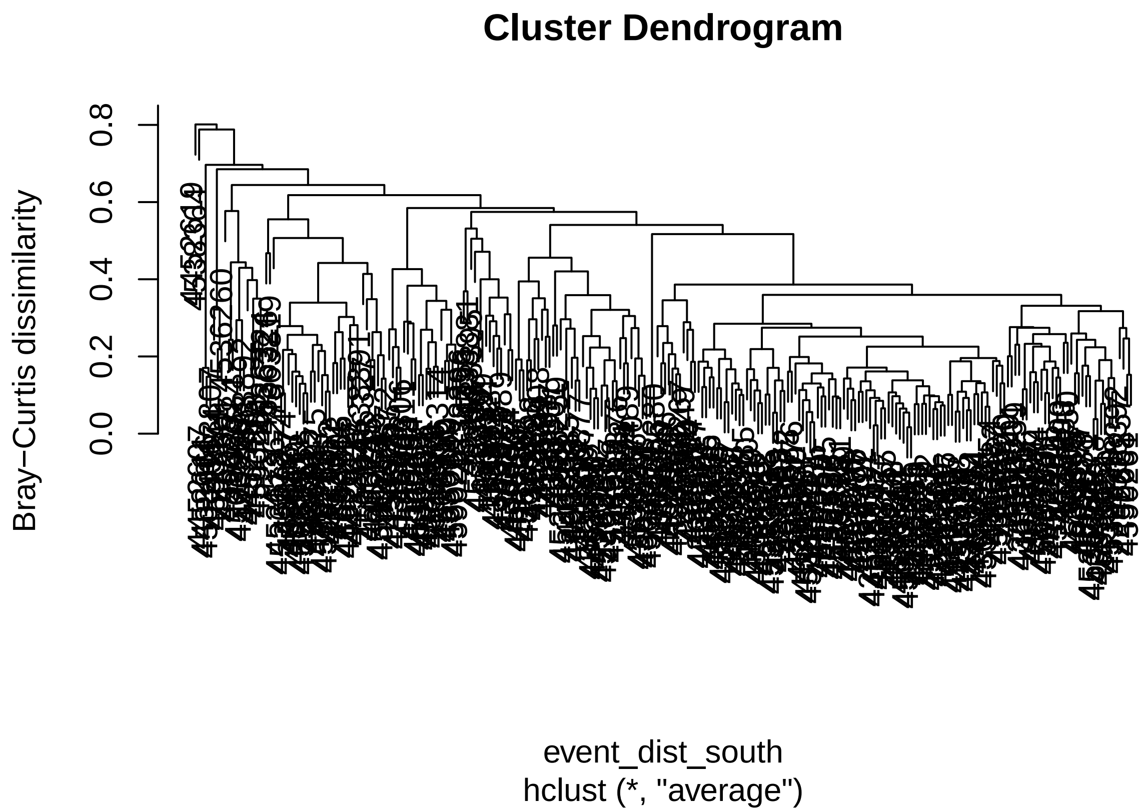



```
##### filter by area - south #####

eulachon_wide_south <- eulachon_wide_season %>%
  filter(., MAJOR_STAT_AREA_CODE==1)

row.names(eulachon_wide_south) <- eulachon_wide_south$EVENT_ID

# Turn CPUE to relative abundance by dividing each value by sample total abundance

cluster_data_south <- decostand(eulachon_wide_south[,15:39], method = "total")

# check total abundance in each sample

apply(cluster_data_south, 1, sum)
```

```
## 4363805 4363806 4363807 4363808 4363809 4363810 4363811 4363812 4363813 4363814
##       1       1       1       1       1       1       1       1       1       1
## 4363815 4363817 4363818 4363819 4363820 4363822 4363824 4363825 4363846 4363847
##       1       1       1       1       1       1       1       1       1       1
## 4363848 4363849 4363851 4363852 4363854 4363855 4363857 4363859 4363882 4363884
##       1       1       1       1       1       1       1       1       1       1
## 4363885 4363886 4363887 4363888 4363889 4363890 4363891 4363892 4363893 4363894
##       1       1       1       1       1       1       1       1       1       1
## 4363895 4363896 4363897 4363898 4363899 4363900 4363901 4363903 4452485 4452486
##       1       1       1       1       1       1       1       1       1       1
## 4452487 4452488 4452489 4452490 4452492 4452493 4452494 4452495 4452496 4452497
```

```
##       1       1       1       1       1       1       1       1       1       1
## 4452498 4452499 4452500 4452501 4452503 4452504 4452571 4452572 4452573 4452574
##       1       1       1       1       1       1       1       1       1       1
## 4452575 4452576 4452577 4452578 4452579 4452580 4452581 4452582 4452583 4452584
##       1       1       1       1       1       1       1       1       1       1
## 4452585 4452586 4452587 4452588 4452589 4452590 4452591 4452605 4452607 4452608
##       1       1       1       1       1       1       1       1       1       1
## 4452610 4452611 4452612 4452614 4452615 4452616 4452617 4452618 4452619 4452620
##       1       1       1       1       1       1       1       1       1       1
## 4452621 4452622 4536245 4536246 4536247 4536248 4536249 4536250 4536251 4536252
##       1       1       1       1       1       1       1       1       1       1
## 4536253 4536254 4536255 4536256 4536257 4536258 4536259 4536260 4536261 4536262
##       1       1       1       1       1       1       1       1       1       1
## 4536263 4536264 4536265 4536266 4536267 4536268 4536269 4536270 4536271 4536272
##       1       1       1       1       1       1       1       1       1       1
## 4536273 4536274 4536275 4536276 4536305 4536306 4536307 4536308 4536309 4536310
##       1       1       1       1       1       1       1       1       1       1
## 4536311 4536312 4536313 4536314 4536315 4536316 4536317 4536318 4536319 4536320
##       1       1       1       1       1       1       1       1       1       1
## 4536321 4536322 4536323 4536324 4536325 4536326 4536327 4536328 4536329 4536330
##       1       1       1       1       1       1       1       1       1       1
## 4536331 4536332 4538364 4538365 4538366 4538367 4538368 4538369 4538370 4538371
##       1       1       1       1       1       1       1       1       1       1
## 4538372 4538373 4538374 4538375 4538376 4538377 4538379 4538380 4538381 4538382
##       1       1       1       1       1       1       1       1       1       1
## 4538383 4538384 4538385 4538386 4538387 4538388 4538389 4538390 4538391 4538392
##       1       1       1       1       1       1       1       1       1       1
## 4538393 4538394 4538395 4538396 4538397 4538398 4538399 4538400 4538865 4538866
##       1       1       1       1       1       1       1       1       1       1
## 4538867 4538868 4538869 4538870 4538871 4538872 4538873 4538874 4538875 4538876
##       1       1       1       1       1       1       1       1       1       1
## 4538877 4538878 4538879 4538880 4538881 4538882 4538883 4538884 4538885 4538887
##       1       1       1       1       1       1       1       1       1       1
## 4538888 4538889 4538890 4538891 4590234 4590235 4590236 4590237 4590238 4590239
##       1       1       1       1       1       1       1       1       1       1
## 4590240 4590241 4590242 4590243 4590244 4590245 4590246 4590247 4590248 4590249
##       1       1       1       1       1       1       1       1       1       1
## 4590250 4590251 4590252 4590253 4590254 4590256 4590257 4590258 4590259 4590260
##       1       1       1       1       1       1       1       1       1       1
## 4590261 4590262
##       1       1
```

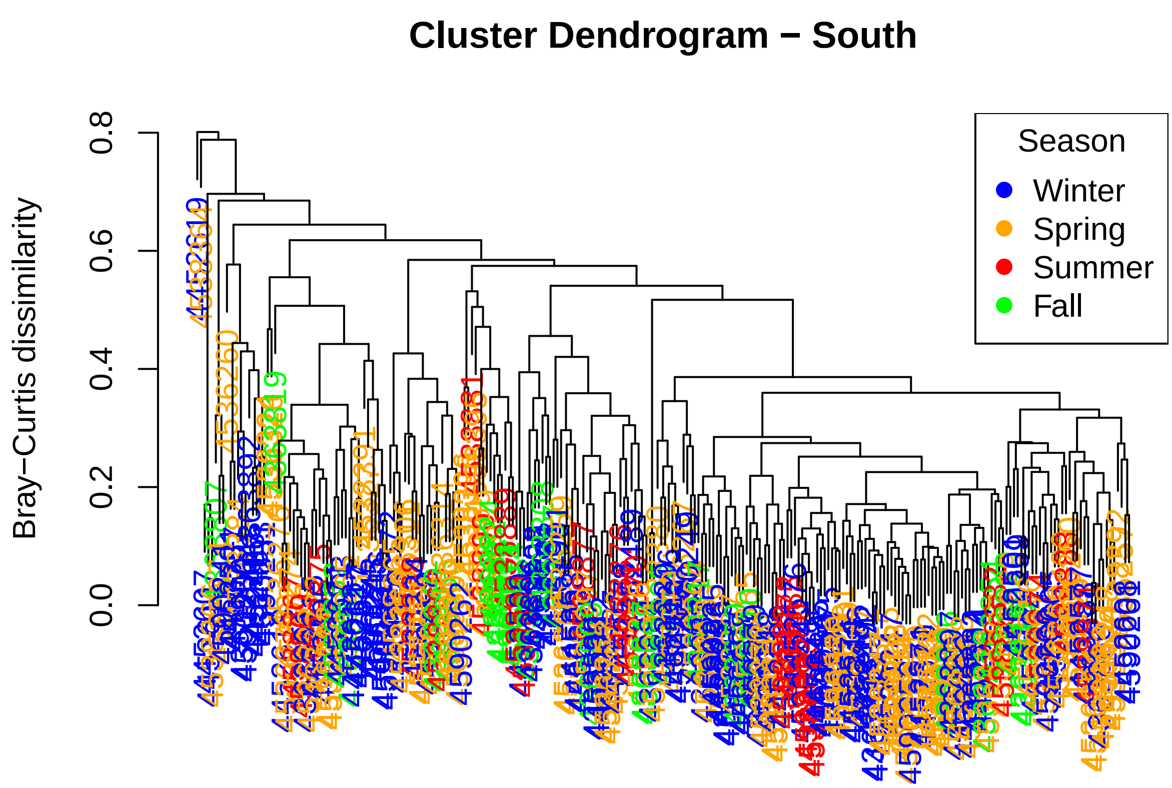
```r
# calculate Bray-Curtis distance among samples

event_dist_south <- vegdist(cluster_data_south, method = "bray")

# cluster communities using average-linkage algorithm
event_cluster_south <- hclust(event_dist_south, method = "average")

# plot cluster diagram
plot(event_cluster_south, ylab = "Bray-Curtis dissimilarity")
```




```r
# colouring labels by season

south_dend <- as.dendrogram(hclust(event_dist_south, method = "average"))

order.dendrogram(south_dend)
```

```
##   [1]  99 163  89  92 165   3 173 232 118  87 247 182  46 246  38  50  51  39
##  [19] 242 154 156  14 134  98 130 132 201 133 203  37 153  95 152 209  58 121
##  [37] 124  24 101  48 123  23  93  97 102 189 157 234 236  96 244 245  68 164
##  [55]  69 168 136 141 202 225 110 111  61 170  22 200 144  26 140 139 109 252
##  [73] 194 196 215 193 192 223 197  17  16   9  18 222   7  10 220  86 218   8
##  [91]  42  44  76   4  77  79  27  47 117 120 126  81  65 243 211 195   5  45
## [109]  82 233 116 119  83 177 210  74 224  53 204 114  20  21  30 129 178   1
## [127]  35 237 169  78 230 125 240  63 122  12  33 143 104 226  59 227  31 228
## [145] 166  28  60 229 183   6  75  36 172 180 239 167 171  85 217 206 219  72
## [163] 214 235 207 212 213  49  80 241  71  84 160 174 179 107  70 231  52 176
## [181]  55  40  41  91 105 147 113 238 138 142 149 148 248 103 187  67 100 162
## [199] 131 161 184 188   2  43  62 155 186  54 158  29  66  94  13 128  25 216
## [217] 185 199  15 159  64 249  11  19 146  57 137 208 191 250  88  56 127 198
## [235] 221 108 135 145  73  34 205 112 151  32 181 106 150 175 190 115  90 251
```

```r
labels_colors(south_dend)<-season_colours[eulachon_wide_south$SEASON][order.dendrogram(south_dend)]

plot(hang.dendrogram(south_dend, hang = 0.1), ylab = "Bray-Curtis dissimilarity", main = "Cluster Dendr
legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)
```

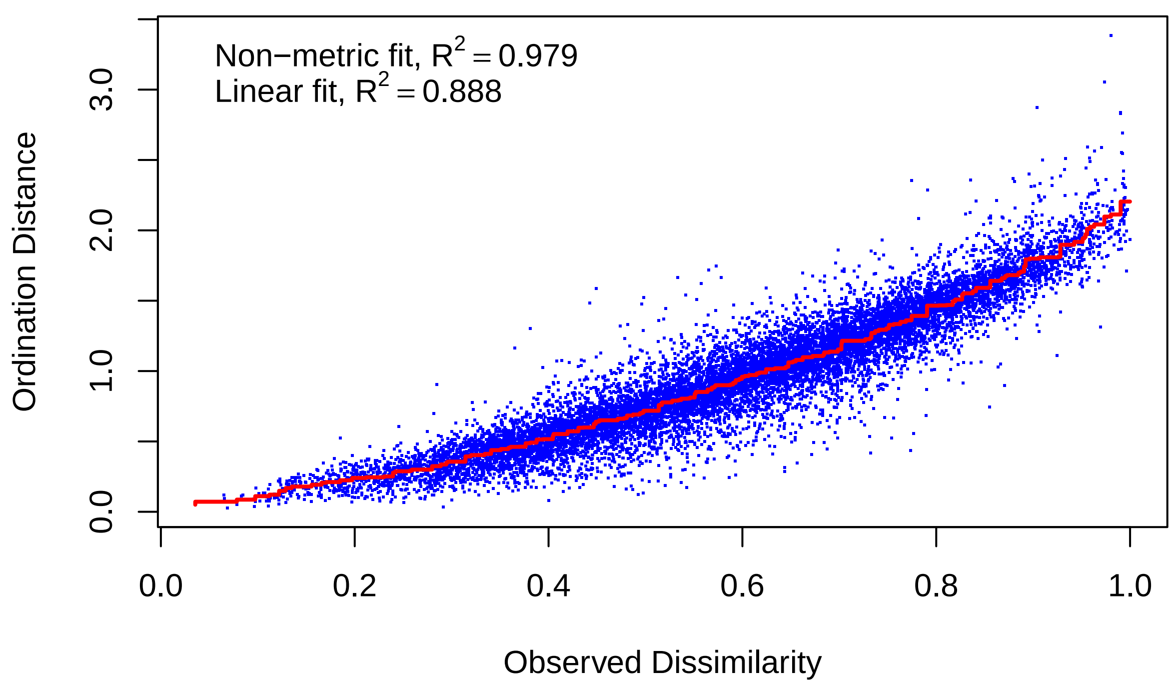



```
####### ordination  by area and season ########

#### North ####

# The metaMDS function automatically transforms data and checks solution
# robustness

event_mds_north <- metaMDS(cluster_data_north, dist = "bray", trymax = 150, k=3,
                           maxit = 300)
```

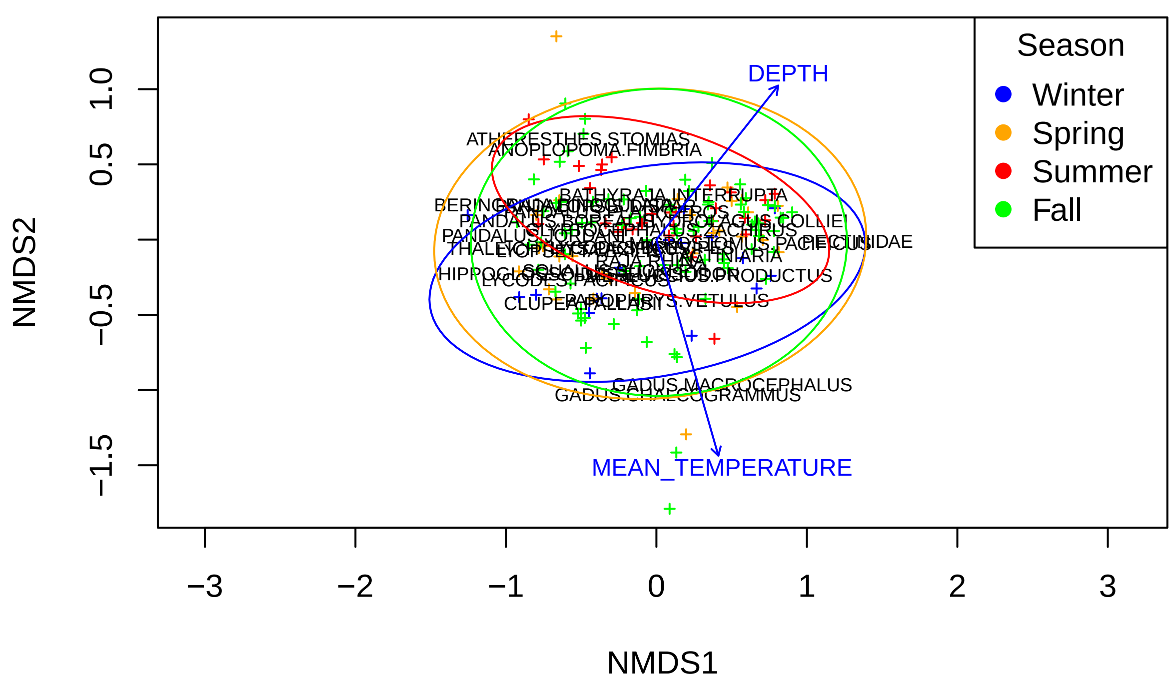
```
## Run 0 stress 0.147438
## Run 1 stress 0.1445421
## ... New best solution
## ... Procrustes: rmse 0.02384894  max resid 0.1527581
## Run 2 stress 0.1445459
## ... Procrustes: rmse 0.003853056  max resid 0.02965439
## Run 3 stress 0.1458267
## Run 4 stress 0.1445261
## ... New best solution
## ... Procrustes: rmse 0.002392182  max resid 0.01911947
## Run 5 stress 0.1510129
## Run 6 stress 0.1434125
## ... New best solution
## ... Procrustes: rmse 0.04505469  max resid 0.2694222
```

```
## Run 7 stress 0.1444104
## Run 8 stress 0.1442558
## Run 9 stress 0.1441816
## Run 10 stress 0.1434315
## ... Procrustes: rmse 0.00157069  max resid 0.01824022
## Run 11 stress 0.1446039
## Run 12 stress 0.1445836
## Run 13 stress 0.1436259
## ... Procrustes: rmse 0.0105661  max resid 0.1183286
## Run 14 stress 0.1467245
## Run 15 stress 0.1458274
## Run 16 stress 0.1438223
## ... Procrustes: rmse 0.008930229  max resid 0.09553756
## Run 17 stress 0.1434135
## ... Procrustes: rmse 0.0003877973  max resid 0.002765667
## ... Similar to previous best
## Run 18 stress 0.1445267
## Run 19 stress 0.1445419
## Run 20 stress 0.1438242
## ... Procrustes: rmse 0.009423314  max resid 0.09987496
## *** Solution reached
```

```r
# Assess goodness of ordination fit (stress plot)

stressplot(event_mds_north)
```



```
# layering the plot

blank_mds_north<- ordiplot(event_mds_north, type = "n")
points(blank_mds_north, "sites", col = "blue",
       select=eulachon_wide_north$SEASON=="Winter", pch=3, cex=0.5)
points(blank_mds_north, "sites", col = "orange",
       select=eulachon_wide_north$SEASON=="Spring", pch=3, cex=0.5)
points(blank_mds_north, "sites", col = "red",
       select=eulachon_wide_north$SEASON=="Summer", pch=3, cex=0.5)
points(blank_mds_north, "sites", col = "green",
       select=eulachon_wide_north$SEASON=="Fall", pch=3, cex=0.5)
text(blank_mds_north, "species", col = "black", cex=0.6)


ordiellipse(blank_mds_north, eulachon_wide_north$SEASON,
            conf = 0.95, label = FALSE, col = season_colours)

legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)

# add temp and depth axis

plot(envfit(blank_mds_north, eulachon_wide_north[, 13:14]), cex = 0.75)
```



```r
#### South ####

# The metaMDS function automatically transforms data and checks solution
# robustness

##increased max # of iterations from 200 to 300
event_mds_south <- metaMDS(cluster_data_south, dist = "bray", trymax = 150, k=3,
                           maxit = 300, previous.best = TRUE)
```

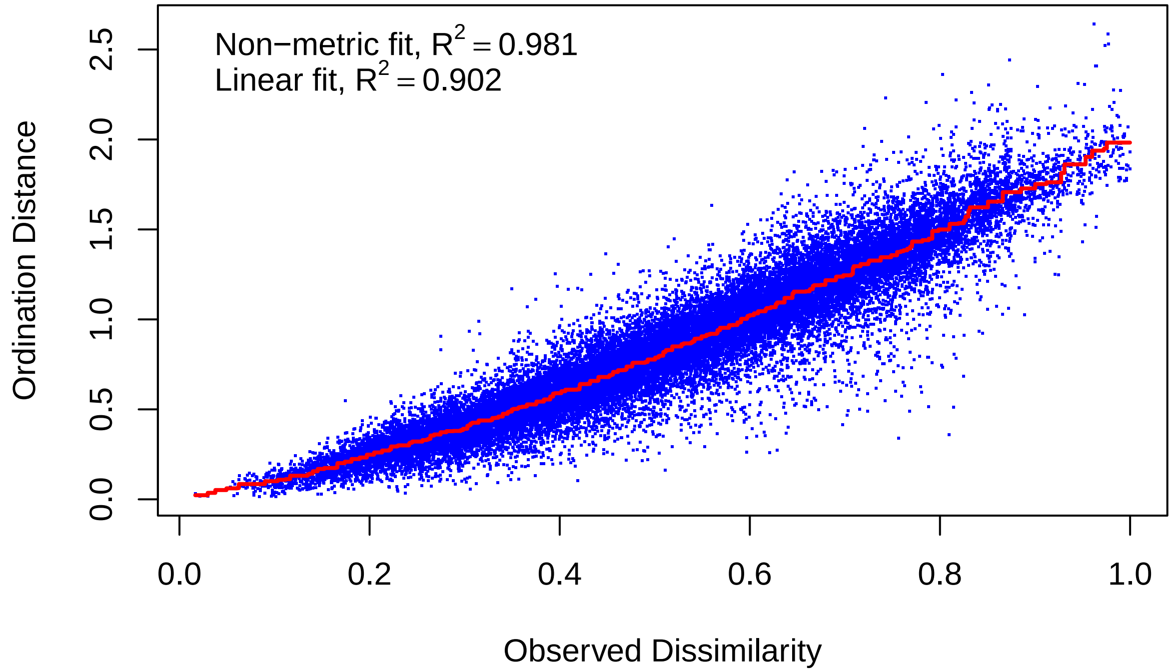
```
## Run 0 stress 0.9919479
## Run 1 stress 0.1402513
## ... New best solution
## ... Procrustes: rmse 0.06270893  max resid 0.9838569
## Run 2 stress 0.1452966
## Run 3 stress 0.1434271
## Run 4 stress 0.1450477
## Run 5 stress 0.1437738
## Run 6 stress 0.1443806
## Run 7 stress 0.1449238
## Run 8 stress 0.1421462
## Run 9 stress 0.1441308
## Run 10 stress 0.1422118
## Run 11 stress 0.1416194
## Run 12 stress 0.1403463
## ... Procrustes: rmse 0.0379252  max resid 0.1983517
## Run 13 stress 0.1417318
## Run 14 stress 0.1418984
## Run 15 stress 0.1405168
## ... Procrustes: rmse 0.02920834  max resid 0.1655668
## Run 16 stress 0.1388215
## ... New best solution
## ... Procrustes: rmse 0.0157532  max resid 0.1756671
## Run 17 stress 0.1410493
## Run 18 stress 0.1392329
## ... Procrustes: rmse 0.00923224  max resid 0.1423742
## Run 19 stress 0.1392502
## ... Procrustes: rmse 0.01025783  max resid 0.1422956
## Run 20 stress 0.1440845
## Run 21 stress 0.1399518
## Run 22 stress 0.1434939
## Run 23 stress 0.1430803
## Run 24 stress 0.1478294
## Run 25 stress 0.1448119
## Run 26 stress 0.1392504
## ... Procrustes: rmse 0.01026961  max resid 0.1424278
## Run 27 stress 0.1400354
## Run 28 stress 0.1449184
## Run 29 stress 0.142269
## Run 30 stress 0.1424568
## Run 31 stress 0.1401358
## Run 32 stress 0.1402295
## Run 33 stress 0.143058
## Run 34 stress 0.1417159
```

```
## Run 35 stress 0.1413583
## Run 36 stress 0.1430045
## Run 37 stress 0.1406586
## Run 38 stress 0.1412495
## Run 39 stress 0.1410843
## Run 40 stress 0.1467727
## Run 41 stress 0.1443279
## Run 42 stress 0.1401756
## Run 43 stress 0.1399574
## Run 44 stress 0.1428487
## Run 45 stress 0.1408802
## Run 46 stress 0.1470132
## Run 47 stress 0.1463806
## Run 48 stress 0.1422686
## Run 49 stress 0.1409284
## Run 50 stress 0.1415824
## Run 51 stress 0.1403121
## Run 52 stress 0.1424627
## Run 53 stress 0.1418351
## Run 54 stress 0.1415827
## Run 55 stress 0.1409902
## Run 56 stress 0.1402836
## Run 57 stress 0.1410919
## Run 58 stress 0.1393409
## Run 59 stress 0.1461136
## Run 60 stress 0.1461166
## Run 61 stress 0.1392304
## ... Procrustes: rmse 0.007459876  max resid 0.09394911
## Run 62 stress 0.1424342
## Run 63 stress 0.1463113
## Run 64 stress 0.1410222
## Run 65 stress 0.1417744
## Run 66 stress 0.1485945
## Run 67 stress 0.1402462
## Run 68 stress 0.1412958
## Run 69 stress 0.1478789
## Run 70 stress 0.1443525
## Run 71 stress 0.1403892
## Run 72 stress 0.1441391
## Run 73 stress 0.1422416
## Run 74 stress 0.146492
## Run 75 stress 0.1429215
## Run 76 stress 0.1443018
## Run 77 stress 0.1420596
## Run 78 stress 0.1414572
## Run 79 stress 0.1405373
## Run 80 stress 0.1391191
## ... Procrustes: rmse 0.006094681  max resid 0.06862657
## Run 81 stress 0.1416439
## Run 82 stress 0.1421701
## Run 83 stress 0.1416224
## Run 84 stress 0.141787
## Run 85 stress 0.1405492
## Run 86 stress 0.1400157
```

```
## Run 87 stress 0.1459289
## Run 88 stress 0.1454952
## Run 89 stress 0.1423178
## Run 90 stress 0.1432612
## Run 91 stress 0.1406346
## Run 92 stress 0.1430609
## Run 93 stress 0.1418606
## Run 94 stress 0.144077
## Run 95 stress 0.1420599
## Run 96 stress 0.1442281
## Run 97 stress 0.1484627
## Run 98 stress 0.1471564
## Run 99 stress 0.143504
## Run 100 stress 0.1435683
## Run 101 stress 0.1421275
## Run 102 stress 0.1430438
## Run 103 stress 0.1427919
## Run 104 stress 0.146723
## Run 105 stress 0.1428927
## Run 106 stress 0.1426259
## Run 107 stress 0.1444321
## Run 108 stress 0.1414624
## Run 109 stress 0.1405397
## Run 110 stress 0.1428574
## Run 111 stress 0.1432755
## Run 112 stress 0.1409864
## Run 113 stress 0.1404386
## Run 114 stress 0.1449594
## Run 115 stress 0.1415094
## Run 116 stress 0.1441024
## Run 117 stress 0.1421255
## Run 118 stress 0.1410284
## Run 119 stress 0.1399906
## Run 120 stress 0.1428794
## Run 121 stress 0.1402171
## Run 122 stress 0.1466319
## Run 123 stress 0.1424317
## Run 124 stress 0.143066
## Run 125 stress 0.1431722
## Run 126 stress 0.1425415
## Run 127 stress 0.1433193
## Run 128 stress 0.1390547
## ... Procrustes: rmse 0.005555763  max resid 0.06787468
## Run 129 stress 0.1436025
## Run 130 stress 0.1406462
## Run 131 stress 0.1403418
## Run 132 stress 0.1436619
## Run 133 stress 0.1410451
## Run 134 stress 0.1410857
## Run 135 stress 0.143502
## Run 136 stress 0.1422356
## Run 137 stress 0.1388227
## ... Procrustes: rmse 0.0007750253  max resid 0.008771351
## ... Similar to previous best
```

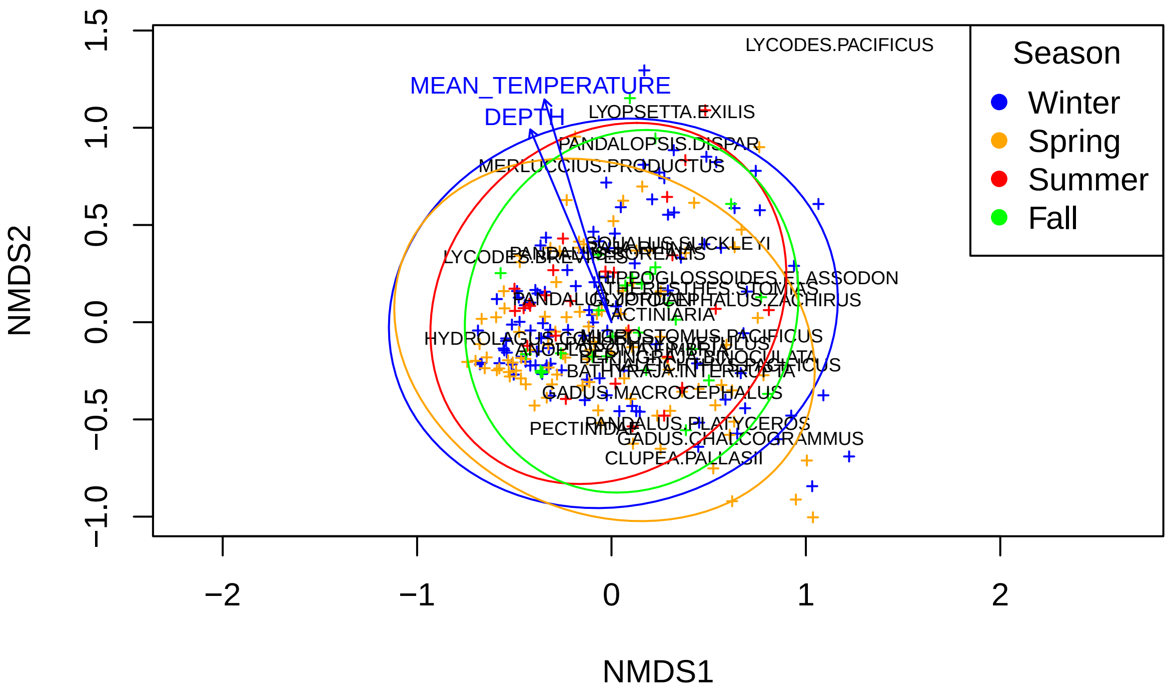
```
## *** Solution reached
```

```r
# Assess goodness of ordination fit (stress plot)

stressplot(event_mds_south)
```




```r
# layering the plot

blank_mds_south<- ordiplot(event_mds_south, type = "n")
points(blank_mds_south, "sites", col = "blue",
       select=eulachon_wide_south$SEASON=="Winter", pch=3, cex=0.5)
points(blank_mds_south, "sites", col = "orange",
       select=eulachon_wide_south$SEASON=="Spring", pch=3, cex=0.5)
points(blank_mds_south, "sites", col = "red",
       select=eulachon_wide_south$SEASON=="Summer", pch=3, cex=0.5)
points(blank_mds_south, "sites", col = "green",
       select=eulachon_wide_south$SEASON=="Fall", pch=3, cex=0.5)
text(blank_mds_south, "species", col = "black", cex=0.6)


ordiellipse(blank_mds_south, eulachon_wide_south$SEASON, conf = 0.95,
            label = FALSE, col = season_colours)
legend("topright", legend=c("Winter", "Spring", "Summer", "Fall"), title= "Season", pch=19,
       col=season_colours)
```

```r
# add temp and depth axis

plot(envfit(blank_mds_south, eulachon_wide_south[, 13:14]), cex = 0.75)
```




```r
###### k means clustering ######
library(factoextra)
```

```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```r
library(cluster)

scaled_cluster <- scale(eulachon_wide[,14:38])

# check data

apply(scaled_cluster, 2, sd)
```

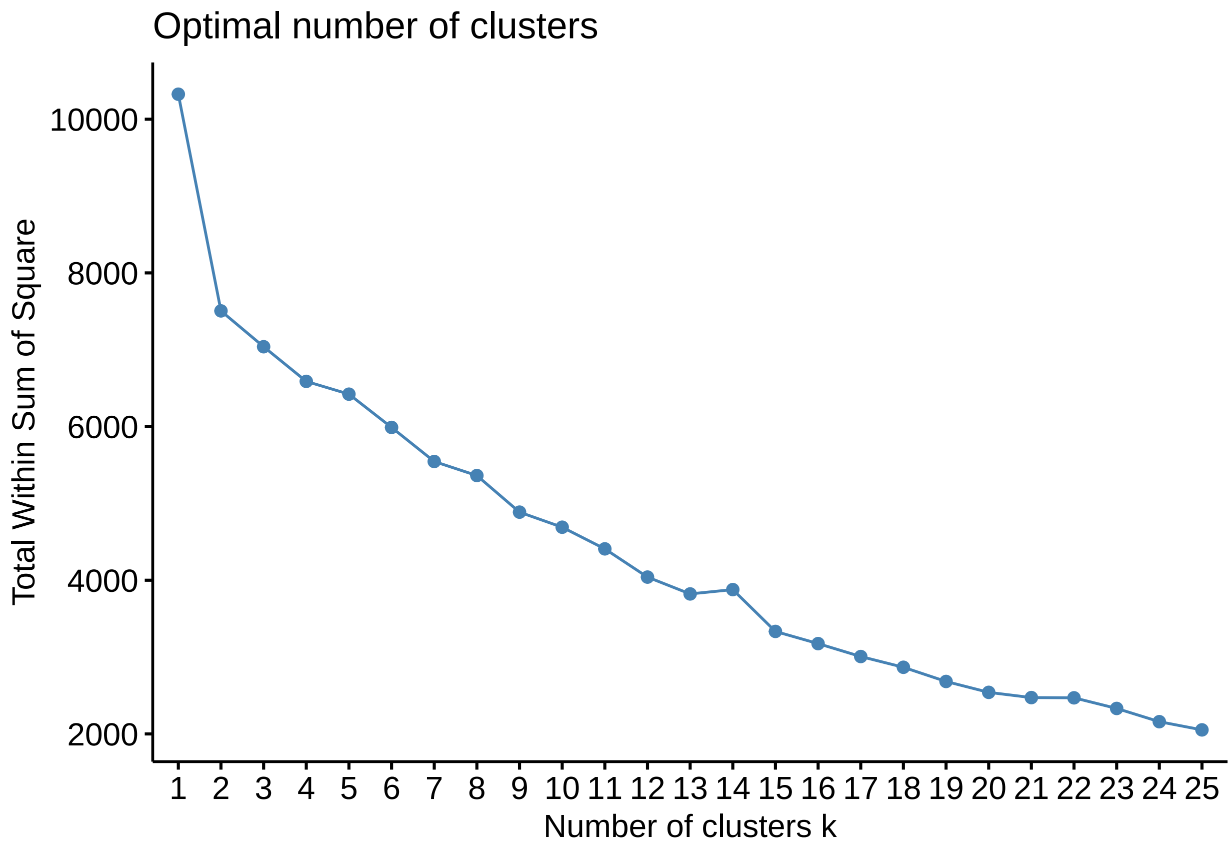
```
##              ACTINIARIA        ANOPLOPOMA.FIMBRIA       ATHERESTHES.STOMIAS
##                       1                         1                         1
##     BATHYRAJA.INTERRUPTA    BERINGRAJA.BINOCULATA           CLUPEA.PALLASII
##                       1                         1                         1
##      GADUS.CHALCOGRAMMUS       GADUS.MACROCEPHALUS   GLYPTOCEPHALUS.ZACHIRUS
##                       1                         1                         1
## HIPPOGLOSSOIDES.ELASSODON       HYDROLAGUS.COLLIEI           LYCODES.BREVIPES
```

```
##                         1                       1                       1
##         LYCODES.PACIFICUS         LYOPSETTA.EXILIS     MERLUCCIUS.PRODUCTUS
##                         1                       1                       1
##     MICROSTOMUS.PACIFICUS       PANDALOPSIS.DISPAR        PANDALUS.BOREALIS
##                         1                       1                       1
##          PANDALUS.JORDANI      PANDALUS.PLATYCEROS        PAROPHRYS.VETULUS
##                         1                       1                       1
##                PECTINIDAE               RAJA.RHINA        SQUALUS.SUCKLEYI
##                         1                       1                       1
##    THALEICHTHYS.PACIFICUS
##                         1
```

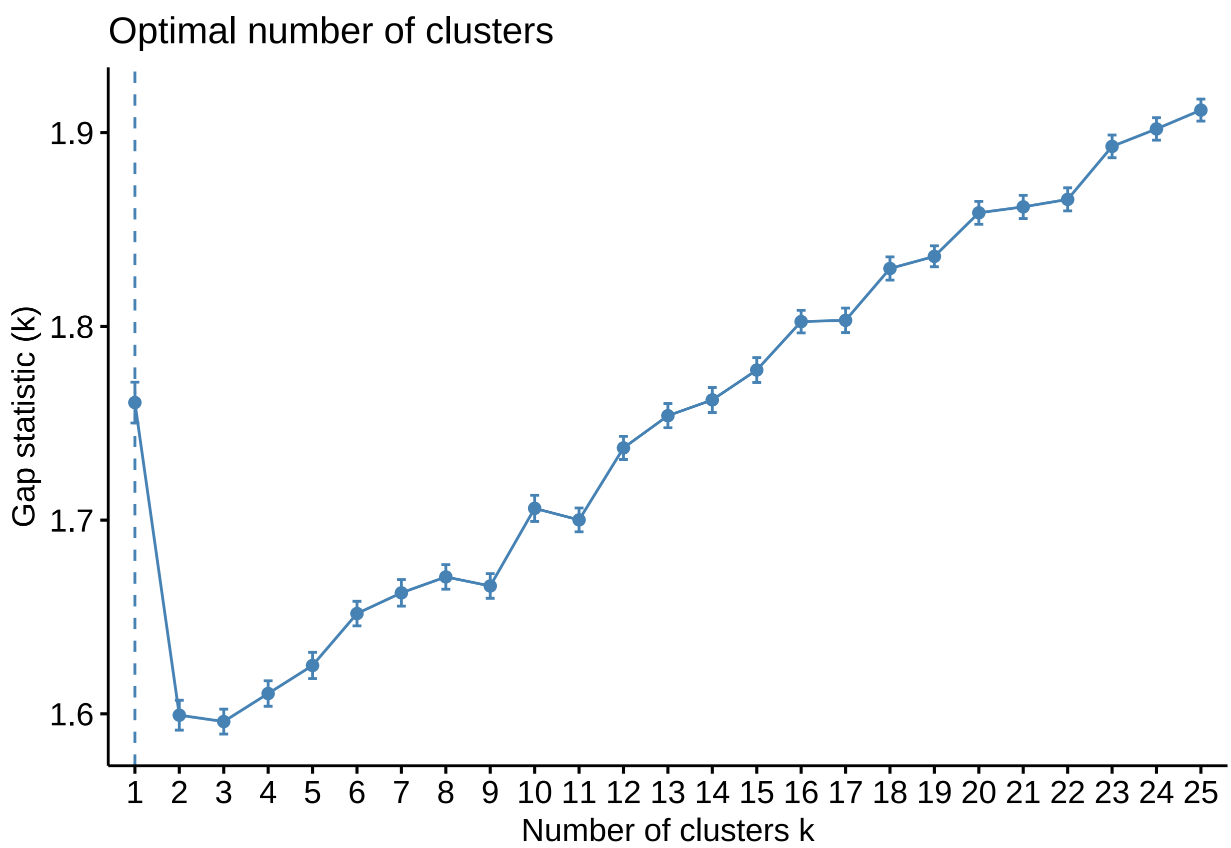
```r
colMeans(scaled_cluster)
```

```
##                   ACTINIARIA            ANOPLOPOMA.FIMBRIA
##  0.0000000000000000008430588  0.0000000000000000012263007
##          ATHERESTHES.STOMIAS          BATHYRAJA.INTERRUPTA
## -0.0000000000000000014020253  0.0000000000000000004433182
##        BERINGRAJA.BINOCULATA                CLUPEA.PALLASII
##  0.0000000000000000035867712 -0.0000000000000000020535941
##          GADUS.CHALCOGRAMMUS           GADUS.MACROCEPHALUS
##  0.0000000000000000027939942  0.0000000000000000007961291
##      GLYPTOCEPHALUS.ZACHIRUS    HIPPOGLOSSOIDES.ELASSODON
## -0.0000000000000000020217490  0.0000000000000000001215144
##           HYDROLAGUS.COLLIEI               LYCODES.BREVIPES
##  0.0000000000000000034495437 -0.0000000000000000005778221
##            LYCODES.PACIFICUS               LYOPSETTA.EXILIS
##  0.0000000000000000009511648  0.0000000000000000002333915
##         MERLUCCIUS.PRODUCTUS          MICROSTOMUS.PACIFICUS
##  0.0000000000000000018093082 -0.0000000000000000009649923
##           PANDALOPSIS.DISPAR              PANDALUS.BOREALIS
## -0.0000000000000000012974286  0.0000000000000000006163716
##             PANDALUS.JORDANI            PANDALUS.PLATYCEROS
##  0.0000000000000000010978202  0.0000000000000000003529157
##            PAROPHRYS.VETULUS                     PECTINIDAE
##  0.0000000000000000002773882 -0.0000000000000000005216741
##                   RAJA.RHINA               SQUALUS.SUCKLEYI
##  0.0000000000000000015428145 -0.0000000000000000013752083
##       THALEICHTHYS.PACIFICUS
## -0.0000000000000000016706141
```

```r
# number of clusters vs. the total within sum of squares

fviz_nbclust(scaled_cluster, kmeans, method = "wss", k.max = 25)
```




```
#calculate gap statistic based on number of clusters
gap_stat <- clusGap(scaled_cluster,
                    FUN = kmeans,
                    K.max = 25)

#plot number of clusters vs. gap statistic
fviz_gap_stat(gap_stat)
```




```r
#perform k-means clustering with k = 4 clusters
km <- kmeans(scaled_cluster, centers = 18, nstart = 100, iter.max = 100)

#view results
km
```

```
## K-means clustering with 18 clusters of sizes 15, 2, 4, 13, 23, 14, 7, 6, 2, 39, 1, 27, 1, 1, 1, 19,
##
## Cluster means:
##     ACTINIARIA ANOPLOPOMA.FIMBRIA ATHERESTHES.STOMIAS BATHYRAJA.INTERRUPTA
## 1   0.04600218        0.005307568         0.336872297          -0.21054050
## 2  -0.10723866       -0.256611628        -0.326842665          12.37594330
## 3  -0.10723866        0.021055853         0.133332049           0.16210035
## 4  -0.05739436        0.305630417        -0.122623208           0.45478959
## 5  -0.02599870       -0.104135914         0.001429673           0.23972876
## 6  -0.04465744        0.039623834         0.434918312          -0.21054050
## 7  -0.10723866       -0.207494035         0.532847765          -0.21054050
## 8   0.09168652        6.704895479         1.505851418           0.39147791
## 9  -0.10723866        0.508533557        10.461966264          -0.21054050
## 10 -0.10188357       -0.051036339        -0.128843504          -0.10573924
## 11 -0.10723866       -0.256611628        -0.246683372          -0.21054050
## 12 -0.10703826       -0.212957459        -0.201135295          -0.12039019
## 13 18.84020263       -0.256611628        -0.326842665          -0.21054050
## 14 -0.10723866        1.929346548         3.043410242          -0.21054050
## 15 -0.10723866       -0.256611628         3.809376811          -0.21054050
## 16  0.18700989       -0.256611628        -0.291708103          -0.06033111
```

```
## 17 -0.05340074       -0.124927415       -0.138299207          -0.09025630
## 18 -0.10723866       -0.256611628       -0.326842665          -0.21054050
##    BERINGRAJA.BINOCULATA CLUPEA.PALLASII GADUS.CHALCOGRAMMUS
## 1           -0.310363645     -0.03305815         -0.23931243
## 2           -0.310363645     -0.34765289         -0.10394983
## 3           -0.197819203      0.26421248          0.14676357
## 4           -0.239443987     -0.27891691         -0.10690419
## 5            0.009350628     -0.29625118          0.22159265
## 6           -0.254817021      0.30676245         -0.19319299
## 7           -0.255775168      6.13748014         -0.17100249
## 8           -0.310363645     -0.33939718         -0.05371591
## 9           -0.310363645      0.13429699         -0.06862237
## 10          -0.129731263     -0.11166921          0.96630004
## 11          -0.310363645      0.06603855         -0.06944844
## 12          -0.167046469     -0.32438830         -0.28495783
## 13          -0.310363645     -0.34866910          0.08174878
## 14          -0.310363645      0.08626820         -0.40312979
## 15          -0.310363645     -0.34866910         12.63944359
## 16           3.574602246      0.22663662          0.50015737
## 17          -0.175295032     -0.10491715         -0.19962246
## 18           0.622324091     -0.34866910         -0.28400383
##    GADUS.MACROCEPHALUS GLYPTOCEPHALUS.ZACHIRUS HIPPOGLOSSOIDES.ELASSODON
## 1           -0.2337730              0.01845515                0.12610476
## 2           -0.2337730             -0.27970501                0.25893217
## 3            8.3662375             -0.25351117               -0.18081951
## 4           -0.1577072              1.30442976               -0.16705309
## 5           -0.1046477             -0.12853513                0.14945920
## 6           -0.2337730             -0.10374742                0.07241266
## 7            0.2381810             -0.32957447                0.31502822
## 8           -0.2337730              1.52130501               -0.13829518
## 9           -0.2337730              0.90960967                0.33382913
## 10           0.2683394              0.33143734                0.10180669
## 11          -0.2337730              0.47216772               -0.19153505
## 12          -0.1761831             -0.26013258               -0.18428050
## 13          -0.2337730              0.56129247               -0.12419291
## 14          -0.2337730             -0.42852349               -0.19153505
## 15          -0.2337730             13.58117935               17.02130605
## 16          -0.0760101              0.15476729               -0.18563928
## 17          -0.1090766             -0.17748667               -0.07429369
## 18           0.4820870             -0.42852349               -0.19153505
##    HYDROLAGUS.COLLIEI LYCODES.BREVIPES LYCODES.PACIFICUS LYOPSETTA.EXILIS
## 1         -0.02255213      4.148359247        1.65595364      0.004089751
## 2          2.86450115     -0.270451540       -0.22930376     -0.084600847
## 3         -0.32212817     -0.006727206       -0.17987668     -0.092423454
## 4          0.21218396     -0.270451540       -0.22986180     -0.099616529
## 5          0.10105121     -0.148531029       -0.09419321     -0.058516481
## 6         -0.06460602      0.882255834        0.58360916     -0.003982503
## 7         -0.45334530      0.161554036        0.26741200     -0.078343631
## 8          1.13878429     -0.268051509       -0.18540430     -0.026450209
## 9          1.48092568     -0.270451540       -0.22986180     -0.101790236
## 10         1.49865077     -0.232789516       -0.20365068     -0.066325371
## 11        -0.66257511     -0.270451540       -0.22986180     -0.101790236
## 12        -0.17215126     -0.265581912       -0.22471484     -0.011873014
## 13         0.94959894     -0.270451540       -0.22986180     -0.101790236
```

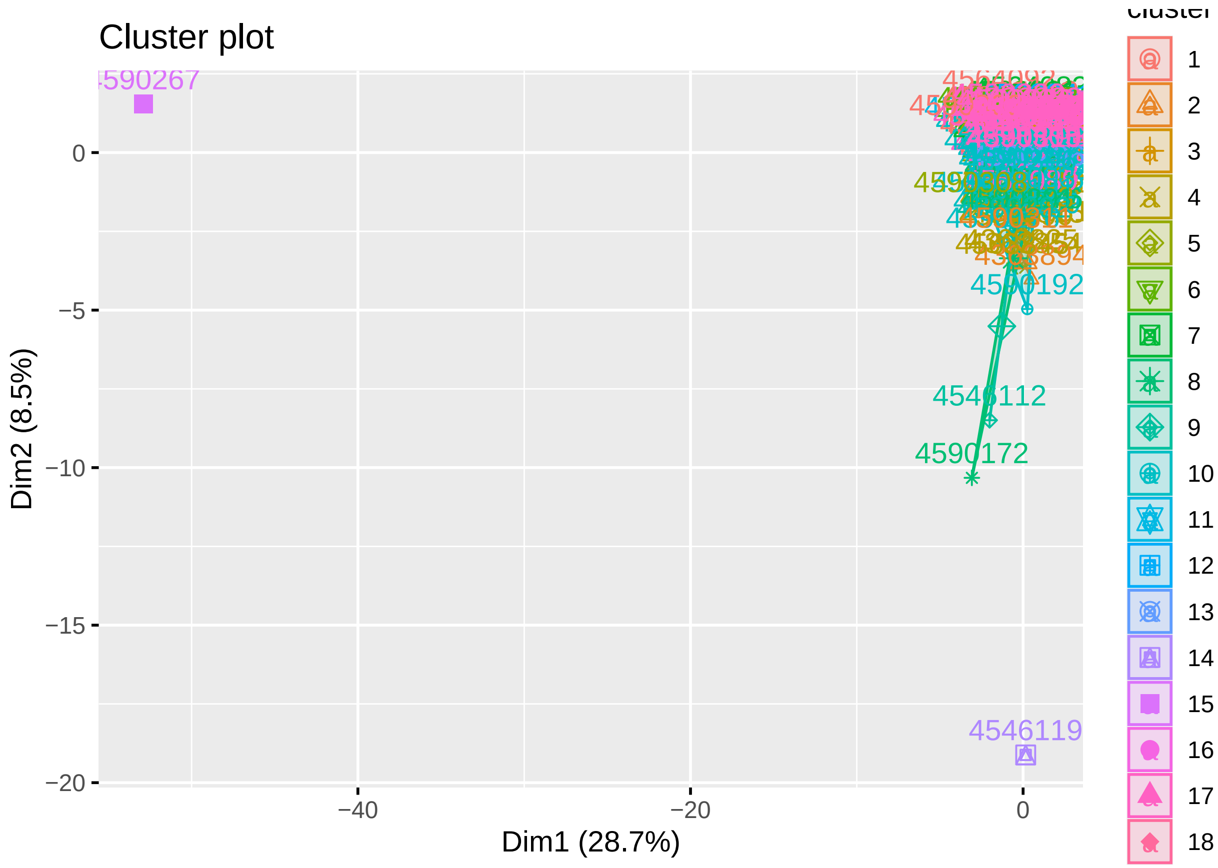
```
## 14          7.02223718     -0.270451540       -0.21349274     -0.101790236
## 15         -0.46670801      0.334356267       15.14068725     20.202844684
## 16         -0.10052641     -0.270451540       -0.22984347     -0.101487704
## 17         -0.31449854     -0.184188850       -0.09548027     -0.045457725
## 18          0.45143686     -0.270451540       -0.21937537     -0.101790236
##    MERLUCCIUS.PRODUCTUS MICROSTOMUS.PACIFICUS PANDALOPSIS.DISPAR
## 1           -0.40231596          -0.282483764        0.122401350
## 2           -0.40724899          -0.047769798        0.186740288
## 3           -0.36721153          -0.154535820       -0.085600451
## 4            0.12793697           3.584044719       -0.108953290
## 5            0.05674101          -0.124858755       -0.076399659
## 6           -0.39828836          -0.307142281        0.202505698
## 7           -0.32255840          -0.315723567       -0.113201954
## 8           -0.40724899          -0.168540555        0.117284311
## 9           -0.40724899           2.807516452       -0.085490155
## 10          -0.28606559          -0.005794077       -0.074905203
## 11          -0.40724899          -0.314922644       -0.105606325
## 12           3.10227555          -0.105114770       -0.108534422
## 13          -0.40724899          -0.238234234       -0.124808123
## 14          -0.40724899          11.565974182        0.003630574
## 15          -0.40724899          -0.315723567       20.085938267
## 16          -0.17312406          -0.064534709       -0.123890033
## 17          -0.21546046          -0.184454231       -0.053472137
## 18          -0.09030080           0.222581482       -0.124760341
##    PANDALUS.BOREALIS PANDALUS.JORDANI PANDALUS.PLATYCEROS PAROPHRYS.VETULUS
## 1        -0.02185487       0.25993736         0.056305062      -0.217631992
## 2        -0.24961775      -0.12884641        -0.127962616      -0.257740427
## 3        -0.12699485      -0.11759793         0.006395014      -0.123186008
## 4        -0.23398307      -0.12874958        -0.095072882      -0.144673466
## 5        -0.11971303      -0.09562364        -0.084962435       0.308728690
## 6         4.69790166       0.11501759         0.167180951      -0.257740427
## 7        -0.24864124       0.06425786        -0.035247750       0.642586914
## 8        -0.14568768       0.02645978        -0.090138125      -0.224362587
## 9        -0.01079043      -0.06862498        -0.042179700      -0.180889530
## 10       -0.14958629      -0.09418857         0.011157617      -0.140401981
## 11        0.11259616      -0.12884641        18.208018087      -0.205323114
## 12       -0.20793322      -0.12879302        -0.106002973       0.045446113
## 13       -0.24961775      -0.12884641        -0.128908254       0.006820093
## 14       -0.24961775      -0.08200752        -0.128908254      -0.257740427
## 15       -0.24961775      19.78939046         7.561023556      -0.257740427
## 16       -0.23874233      -0.12879249        -0.118616491       0.188411685
## 17       -0.16406984      -0.04630220        -0.082132997      -0.095417568
## 18       -0.24961775      -0.12884641        -0.128908254      11.933834895
##      PECTINIDAE  RAJA.RHINA SQUALUS.SUCKLEYI THALEICHTHYS.PACIFICUS
## 1  -0.088059639 -0.13019384      -0.16009323             0.21247725
## 2  -0.088354332  0.46158932       0.42905075            -0.21160075
## 3  -0.058197902 -0.16799046      -0.18148449            -0.17747440
## 4  -0.082077452 -0.02300645      -0.08015913            -0.11329963
## 5  -0.008737405  0.15408640       3.09734639             0.01523326
## 6  -0.073407425  0.09855196      -0.19035283             0.41763922
## 7  -0.064673656 -0.12986527      -0.52947076            -0.18871922
## 8  -0.088354332  0.12198071       0.07890404            -0.15097462
## 9  -0.088354332 -0.17396890      -0.57830714             0.11721728
## 10  0.182725020 -0.01731392      -0.12699873            -0.10349384
```

```
## 11  0.744324294 -0.12263797      -0.57830714            -0.21457738
## 12 -0.088354332 -0.04472985      -0.05295347            -0.20405316
## 13 -0.088354332 -0.17396890      -0.57830714            -0.20979026
## 14 18.344683245 -0.17396890      -0.57830714            -0.16624580
## 15 -0.088354332 19.20797315      -0.57830714            17.44946503
## 16 -0.086331843 -0.02177353       0.44135963            -0.18964562
## 17 -0.070254759 -0.07801959      -0.26280820            -0.03409774
## 18 -0.088354332 -0.17396890       0.86119740            -0.20737799
##
## Clustering vector:
## 4363805 4363806 4363807 4363808 4363809 4363810 4363811 4363812 4363813 4363814
##      12      17      17      12       5      12      17      17       4      17
## 4363815 4363817 4363818 4363819 4363820 4363822 4363824 4363825 4363846 4363847
##       4      17      17      17      17       4      17       4       4       5
## 4363848 4363849 4363851 4363852 4363854 4363855 4363857 4363859 4363882 4363884
##       5       5       5      16       4      17      17      17      10      17
## 4363885 4363886 4363887 4363888 4363889 4363890 4363891 4363892 4363893 4363894
##      17       5      17      17      12      12      10      17      17       2
## 4363895 4363896 4363897 4363898 4363899 4363900 4363901 4363903 4452485 4452486
##      10      17      17      12      17      17       5      16      17      17
## 4452487 4452488 4452489 4452490 4452492 4452493 4452494 4452495 4452496 4452497
##      17      17      16      10       6      17      17      10      17      17
## 4452498 4452499 4452500 4452501 4452503 4452504 4452571 4452572 4452573 4452574
##      17      10      17      16      17      17      17      17      17      17
## 4452575 4452576 4452577 4452578 4452579 4452580 4452581 4452582 4452583 4452584
##      17      16      17      17      12      12      12      12      12      17
## 4452585 4452586 4452587 4452588 4452589 4452590 4452591 4452605 4452607 4452608
##      17      17      17      17      17      17      17      17      17      17
## 4452610 4452611 4452612 4452614 4452615 4452616 4452617 4452618 4452619 4452620
##      10      17       5      17      17      16       3      17      17      17
## 4452621 4452622 4536245 4536246 4536247 4536248 4536249 4536250 4536251 4536252
##      16      17      16      17      10       5      17      17      17      16
## 4536253 4536254 4536255 4536256 4536257 4536258 4536259 4536260 4536261 4536262
##      17      17      10       5      16       5      17      17      17      17
## 4536263 4536264 4536265 4536266 4536267 4536268 4536269 4536270 4536271 4536272
##      17      17      16      17      17      17      17      17      16      10
## 4536273 4536274 4536275 4536276 4536305 4536306 4536307 4536308 4536309 4536310
##      10       7      17      17      17      18      17      17      17      17
## 4536311 4536312 4536313 4536314 4536315 4536316 4536317 4536318 4536319 4536320
##      17      10      12      12      17      16      17      17      17      17
## 4536321 4536322 4536323 4536324 4536325 4536326 4536327 4536328 4536329 4536330
##      17      17      17       7      17      17      17      17      17       5
## 4536331 4536332 4538364 4538365 4538366 4538367 4538368 4538369 4538370 4538371
##      17      10      11      16      17      17      12      17      17      17
## 4538372 4538373 4538374 4538375 4538376 4538377 4538379 4538380 4538381 4538382
##      12      12      12       5      17      17      17      12      17      17
## 4538383 4538384 4538385 4538386 4538387 4538388 4538389 4538390 4538391 4538392
##      17      17      12      17      17      17      16      17      17      17
## 4538393 4538394 4538395 4538396 4538397 4538398 4538399 4538400 4538865 4538866
##      17       4      17      12       5      12       4      10      10      12
## 4538867 4538868 4538869 4538870 4538871 4538872 4538873 4538874 4538875 4538876
##      17      18      17       5      17      17      17      17      17       5
## 4538877 4538878 4538879 4538880 4538881 4538882 4538883 4538884 4538885 4538887
##      12      17      17      17       4      17      17       5      17      17
```

```
## 4538888 4538889 4538890 4538891 4546089 4546090 4546091 4546092 4546093 4546094
##      17       4       4      17       6      17      17      17      17       8
## 4546095 4546096 4546097 4546098 4546099 4546100 4546101 4546102 4546103 4546104
##      17      17      17      17      17      17      17       6      17       1
## 4546105 4546106 4546107 4546108 4546109 4546110 4546111 4546112 4546113 4546114
##      17       1       3       1      17      17       7       9       6      17
## 4546115 4546116 4546118 4546119 4546120 4563845 4563846 4563847 4563848 4563849
##      10      17      17      14      17       4       3      17       6       6
## 4563850 4563851 4563852 4563853 4563854 4563855 4563856 4563857 4563858 4563859
##      17      17      17      17       8      17      17      17      17      10
## 4563860 4563861 4563862 4563863 4563864 4563865 4563866 4563867 4563868 4563869
##       6      10       1       6      17       1       1       1       1       1
## 4563870 4563871 4563872 4563873 4563874 4563875 4563876 4563877 4564071 4564072
##      10      17      17      12      17      17      17       6      17      17
## 4564073 4564074 4564075 4564076 4564077 4564078 4564079 4564080 4564081 4564082
##       6      17       5       8       8      10      17       1       7       6
## 4564083 4564084 4564085 4564086 4564087 4564088 4564089 4564091 4564092 4564093
##       7       6       7      17      17      17      17      10       1      10
## 4564095 4590165 4590166 4590167 4590168 4590169 4590170 4590171 4590172 4590173
##      17      17      17      17      17      17      17      10       8       4
## 4590174 4590175 4590176 4590177 4590178 4590179 4590180 4590181 4590182 4590183
##      17      17      10      10       1      17       5      17       5       1
## 4590184 4590185 4590186 4590187 4590188 4590189 4590190 4590191 4590192 4590234
##       5      17      17       5      17       1      10      10      10       7
## 4590235 4590236 4590237 4590238 4590239 4590240 4590241 4590242 4590243 4590244
##      17      17      17      17      17      17      12      17      10      17
## 4590245 4590246 4590247 4590248 4590249 4590250 4590251 4590252 4590253 4590254
##      17      12      10      17      12      17      17      17      16      16
## 4590256 4590257 4590258 4590259 4590260 4590261 4590262 4590265 4590266 4590267
##      17      17      10      16      17      16      17      17      17      15
## 4590268 4590269 4590270 4590271 4590272 4590273 4590274 4590275 4590276 4590277
##       6      10      10      17      17      17      17      17      17      17
## 4590278 4590279 4590280 4590281 4590282 4590283 4590284 4590285 4590286 4590287
##      10      17      10      10      10      17       6       3      17      17
## 4590288 4590289 4590290 4590291 4590292 4590293 4590294 4590295 4590296 4590297
##      17      17      17       8       9      17      17      17      13      10
## 4590298 4590299 4590300 4590301 4590302 4590303 4590304 4590305 4590306 4590307
##      17      17      17      17       1      17      17      17      10      17
## 4590308 4590309 4590310 4590311
##       5      17      17       2
##
## Within cluster sum of squares by cluster:
##  [1] 200.26470  10.65243  25.76534 103.60356 227.79270 167.32327 124.34543
##  [8] 180.93935  35.77086 452.79410   0.00000 112.01409   0.00000   0.00000
## [15]   0.00000 232.78921 769.98735  11.33924
##  (between_SS / total_SS =  74.3 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
#plot results of final k-means model
```

```r
fviz_cluster(km, data = scaled_cluster)
```

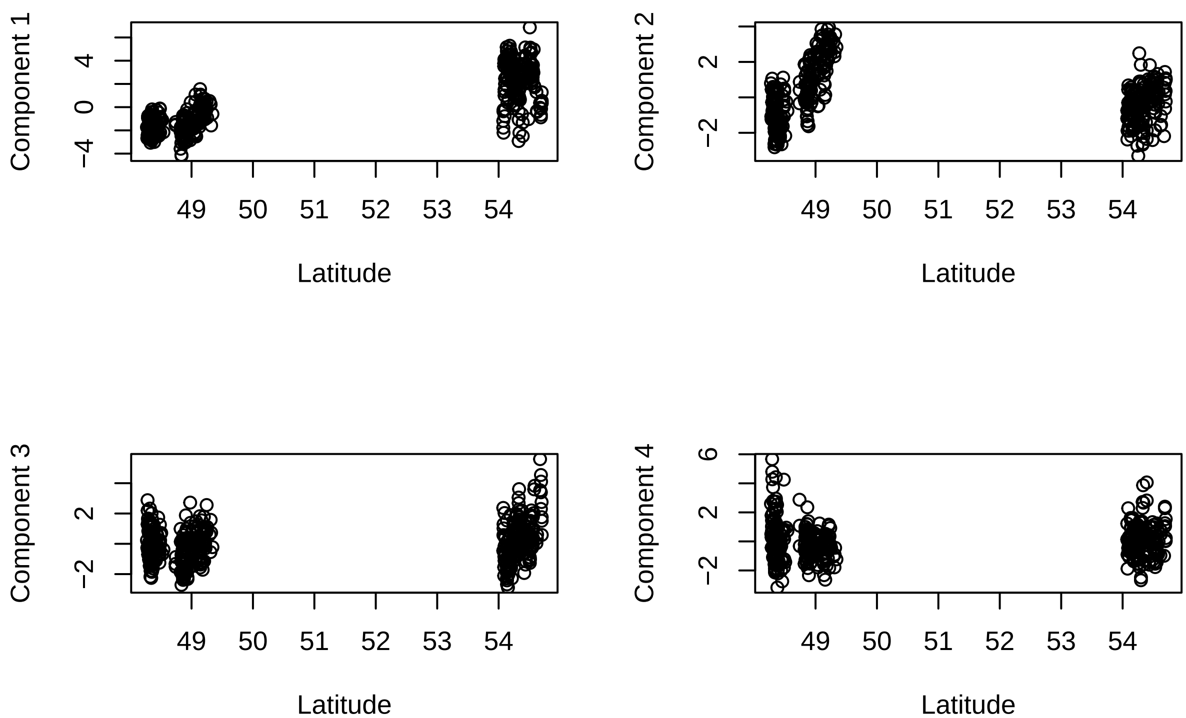



```r
#######PLOT OF PC's AGAINST LATITUDE, DEPTH and PHYSICAL VARIABLE PCA SCORES#####

fish_scores <- eulachon_pca$scores

par(mfrow=c(2,2))

plot(eulachon_wide_log[,8],fish_scores[,1],xlab="Latitude",ylab="Component 1")
summary(lm(fish_scores[,1]~eulachon_wide_log[,8]))
```

```
##
## Call:
## lm(formula = fish_scores[, 1] ~ eulachon_wide_log[, 8])
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.2415 -0.7034  0.0890  0.7788  4.4158
##
## Coefficients:
##                         Estimate Std. Error t value            Pr(>|t|)
## (Intercept)            -34.51702    1.22279  -28.23 <0.0000000000000002 ***
## eulachon_wide_log[, 8]   0.67815    0.02399   28.27 <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 1.35 on 412 degrees of freedom
## Multiple R-squared:  0.6598, Adjusted R-squared:  0.659
## F-statistic: 799.2 on 1 and 412 DF,  p-value: < 0.00000000000000022
```

```
plot(eulachon_wide_log[,8],fish_scores[,2],xlab="Latitude",ylab="Component 2")
plot(eulachon_wide_log[,8],fish_scores[,3],xlab="Latitude",ylab="Component 3")
plot(eulachon_wide_log[,8],fish_scores[,4],xlab="Latitude",ylab="Component 4")
```

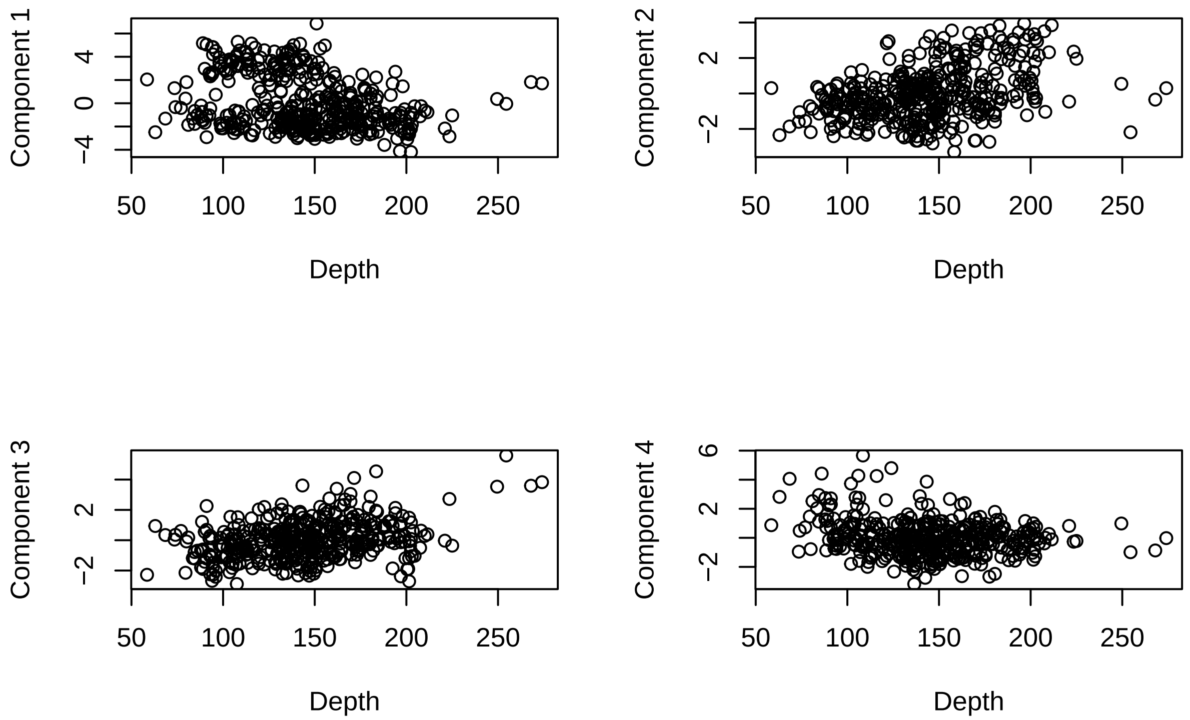



```
plot(eulachon_wide_log[,12],fish_scores[,1],xlab="Depth",ylab="Component 1")
summary(lm(fish_scores[,1]~eulachon_wide_log[,12]))
```

```
##
## Call:
## lm(formula = fish_scores[, 1] ~ eulachon_wide_log[, 12])
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.0751 -1.7984 -0.5661  1.8497  6.9879
##
## Coefficients:
##                          Estimate Std. Error t value      Pr(>|t|)
## (Intercept)              2.806423   0.468364   5.992 0.00000000453 ***
## eulachon_wide_log[, 12] -0.019410   0.003151  -6.161 0.00000000172 ***
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.215 on 412 degrees of freedom
## Multiple R-squared:  0.08435,    Adjusted R-squared:  0.08213
## F-statistic: 37.95 on 1 and 412 DF,  p-value: 0.000000001724
```

```r
plot(eulachon_wide_log[,12],fish_scores[,2],xlab="Depth",ylab="Component 2")
plot(eulachon_wide_log[,12],fish_scores[,3],xlab="Depth",ylab="Component 3")
plot(eulachon_wide_log[,12],fish_scores[,4],xlab="Depth",ylab="Component 4")
```




```r
library(mgcv)
```

```
## This is mgcv 1.8-35. For overview type 'help("mgcv-package")'.
```

```r
pc_gam<-gam(fish_scores[,1]~s(eulachon_wide_log[,8])+s(eulachon_wide_log[,12]))
summary(pc_gam)
```

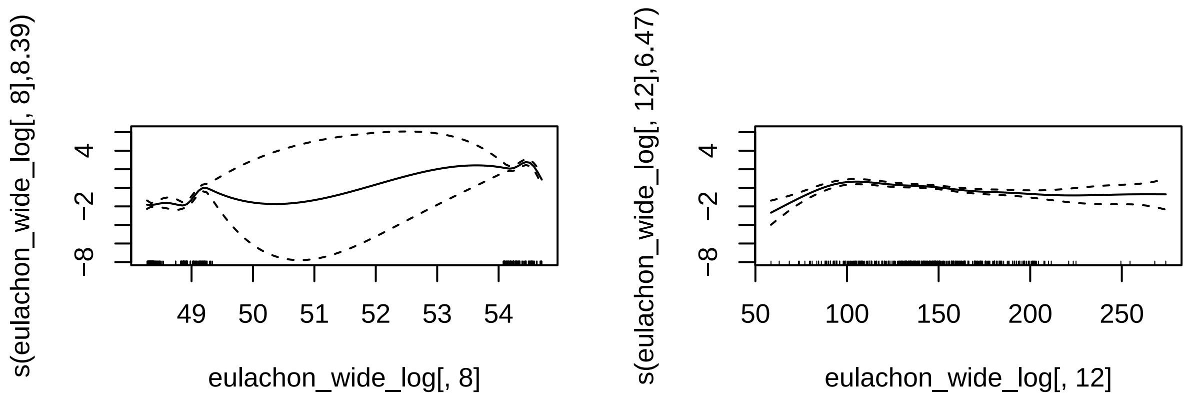
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## fish_scores[, 1] ~ s(eulachon_wide_log[, 8]) + s(eulachon_wide_log[,
##     12])
```

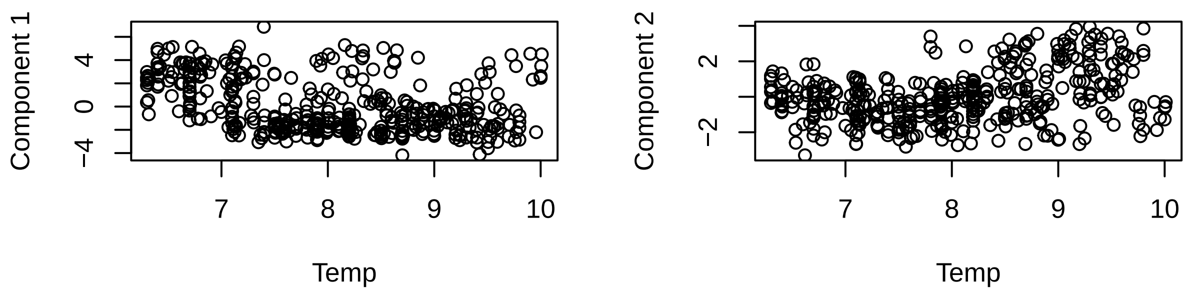
```
##
## Parametric coefficients:
##                         Estimate           Std. Error t value Pr(>|t|)
## (Intercept) -0.00000000000001989  0.05800748919221083       0        1
##
## Approximate significance of smooth terms:
##                                edf Ref.df       F              p-value
## s(eulachon_wide_log[, 8])  8.390  8.868 109.169 <0.0000000000000002 ***
## s(eulachon_wide_log[, 12]) 6.473  7.633   6.764 <0.0000000000000002 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.739   Deviance explained = 74.9%
## GCV = 1.4486  Scale est. = 1.3931    n = 414
```

```
plot(pc_gam)

plot(eulachon_wide_log[,13],fish_scores[,1],xlab="Temp",ylab="Component 1")
summary(lm(fish_scores[,1]~eulachon_wide_log[,13]))
```

```
##
## Call:
## lm(formula = fish_scores[, 1] ~ eulachon_wide_log[, 13])
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.6781 -1.6972 -0.4152  1.3130  6.2972
##
## Coefficients:
##                         Estimate Std. Error t value            Pr(>|t|)
## (Intercept)               7.1145     0.8671   8.205 0.00000000000000297 ***
## eulachon_wide_log[, 13]  -0.8851     0.1071  -8.267 0.00000000000000191 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.144 on 412 degrees of freedom
## Multiple R-squared:  0.1423, Adjusted R-squared:  0.1402
## F-statistic: 68.34 on 1 and 412 DF,  p-value: 0.000000000000001914
```

```
plot(eulachon_wide_log[,13],fish_scores[,2],xlab="Temp",ylab="Component 2")
```






```r
plot(eulachon_wide_log[,13],fish_scores[,3],xlab="Temp",ylab="Component 3")
plot(eulachon_wide_log[,13],fish_scores[,4],xlab="Temp",ylab="Component 4")

###########Testing for multivariate differences among groups#############

# quantify the relationship between dissimilarity measures and different
# explanatory variables using the permutational MANOVA

# Taxonomic (Bray-Curtis) dissimilarity explained - north vs south

adonis(event_dist ~ MAJOR_STAT_AREA_CODE, data = eulachon_wide)
```

```
##
## Call:
## adonis(formula = event_dist ~ MAJOR_STAT_AREA_CODE, data = eulachon_wide)
##
## Permutation: free
## Number of permutations: 999
##
## Terms added sequentially (first to last)
##
##                       Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## MAJOR_STAT_AREA_CODE   1     9.727  9.7274  58.025 0.12345  0.001 ***
## Residuals            412    69.068  0.1676         0.87655
## Total                413    78.795                 1.00000
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Taxonomic (Bray-Curtis) dissimilarity explained - temperature

adonis(event_dist ~ MEAN_TEMPERATURE, data = eulachon_wide)
```

```
##
## Call:
## adonis(formula = event_dist ~ MEAN_TEMPERATURE, data = eulachon_wide)
##
## Permutation: free
## Number of permutations: 999
##
## Terms added sequentially (first to last)
##
##                   Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## MEAN_TEMPERATURE   1     4.595  4.5952  25.515 0.05832  0.001 ***
## Residuals        412    74.200  0.1801         0.94168
## Total            413    78.795                 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Taxonomic (Bray-Curtis) dissimilarity explained - depth

adonis(event_dist ~ DEPTH, data = eulachon_wide)
```

```
##
## Call:
## adonis(formula = event_dist ~ DEPTH, data = eulachon_wide)
##
## Permutation: free
## Number of permutations: 999
##
## Terms added sequentially (first to last)
##
##            Df SumsOfSqs MeanSqs F.Model     R2 Pr(>F)
## DEPTH       1     3.798  3.7981  20.865 0.0482  0.001 ***
## Residuals 412    74.997  0.1820         0.9518
## Total     413    78.795                 1.0000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

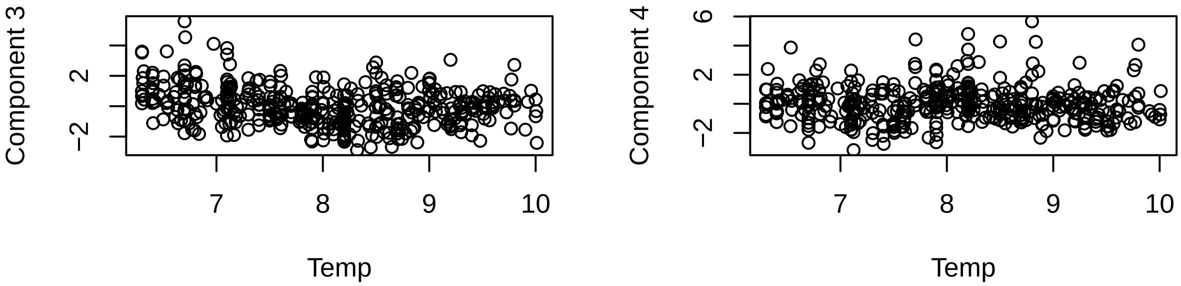
```r
# Taxonomic (Bray-Curtis) dissimilarity explained - north by season

adonis(event_dist_north ~ SEASON, data = eulachon_wide_north)
```

```
##
## Call:
## adonis(formula = event_dist_north ~ SEASON, data = eulachon_wide_north)
##
## Permutation: free
```

```
## Number of permutations: 999
##
## Terms added sequentially (first to last)
##
##            Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## SEASON      3    1.3642 0.45473  2.4141 0.04383  0.002 **
## Residuals 158   29.7622 0.18837         0.95617
## Total     161   31.1264                 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Taxonomic (Bray-Curtis) dissimilarity explained - south by season

adonis(event_dist_south ~ SEASON, data = eulachon_wide_south)
```

```
##
## Call:
## adonis(formula = event_dist_south ~ SEASON, data = eulachon_wide_south)
##
## Permutation: free
## Number of permutations: 999
##
## Terms added sequentially (first to last)
##
##            Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## SEASON      3     1.181 0.39373  2.6563 0.03113  0.002 **
## Residuals 248    36.760 0.14823         0.96887
## Total     251    37.942                 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```



Component 3
2
−2
7
8
9
10
Temp
Component 4
6
2
−2
7
8
9
10
Temp