S18813_mini_project_2

S/18/813

2024-05-30

importing the packages

```
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.2     v readr     2.1.4
## v forcats   1.0.0     v stringr   1.5.0
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.2     v tidyr     1.3.0
## v purrr     1.0.1
## -- Conflicts ---------------------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
require(ggplot2)
require(GGally)
```

```
## Loading required package: GGally
## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2
```

```
require(CCA)
```

```
## Loading required package: CCA
## Loading required package: fda
## Loading required package: splines
## Loading required package: fds
## Loading required package: rainbow
## Loading required package: MASS
##
## Attaching package: 'MASS'
##
## The following object is masked from 'package:dplyr':
##
##     select
##
```

```
## Loading required package: pcaPP
## Loading required package: RCurl
##
## Attaching package: 'RCurl'
##
## The following object is masked from 'package:tidyr':
##
##     complete
##
## Loading required package: deSolve
##
## Attaching package: 'fda'
##
## The following object is masked from 'package:graphics':
##
##     matplot
##
## Loading required package: fields
## Loading required package: spam
## Spam version 2.10-0 (2023-10-23) is loaded.
## Type 'help( Spam)' or 'demo( spam)' for a short introduction
## and overview of this package.
## Help for individual functions is also obtained by adding the
## suffix '.spam' to the function name, e.g. 'help( chol.spam)'.
##
## Attaching package: 'spam'
##
## The following objects are masked from 'package:base':
##
##     backsolve, forwardsolve
##
## Loading required package: viridisLite
##
## Try help(fields) to get started.
```

```
require(CCP)
```

```
## Loading required package: CCP
```

Loading the datasets

```
bioData <- read_csv("../Data/bioData.csv")
```

```
## Rows: 65 Columns: 18
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr  (1): Kod_Canoco
## dbl (17): SaprInd, Lital, RETI, EPTAbu, Marg, Metaritr, JepAbu, Epiritral, H...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
chemData <- read_csv("../Data/chemData.csv")
```

```
## Rows: 64 Columns: 8
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (1): Kod_Canoco
## dbl (7): Tepl_max, %O2, BSK5, Kond, N-NH4, N-NO3, Pcelk
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Viewing Two

```
head(bioData)
```

```
## # A tibble: 6 x 18
##   Kod_Canoco SaprInd Lital  RETI EPTAbu  Marg Metaritr JepAbu Epiritral
##   <chr>        <dbl> <dbl> <dbl>  <dbl> <dbl>    <dbl>  <dbl>     <dbl>
## 1 BecvChor      2.58  32.0 0.375  26.9   7.11    16.3   14.9       7.69
## 2 BecvOsek      2.44  28.1 0.278  23.3   5.80    14.1   11.1       6.97
## 3 BecvTrou      2.10  21.3 0.314  36.5   6.15    11.2   30.2       5.92
## 4 BelaBosk      1.53  37.1 0.482  38.5   9.37    25.3   10.1      20.4
## 5 BilyPoto      1.79  27.2 0.371  23.3   8.62    17.9    5.96     12.1
## 6 BlatTova      2.90  16.0 0.304   8.64  5.52     7.98   4.71      5.24
## # i 9 more variables: Hyporitral <dbl>, Ntaxon <dbl>, Nceled <dbl>,
## #   Bindex <dbl>, EPTTax <dbl>, PosAbu <dbl>, Spasaci <dbl>, MDS_1 <dbl>,
## #   MDS_2 <dbl>
```

```
head(chemData)
```

```
## # A tibble: 6 x 8
##   Kod_Canoco Tepl_max `%O2`  BSK5  Kond `N-NH4` `N-NO3` Pcelk
##   <chr>         <dbl> <dbl> <dbl> <dbl>   <dbl>   <dbl> <dbl>
## 1 BecvChor       20.9   107   1.3  33.7    0.09    1.55 0.077
## 2 BecvOsek       21.8   105   1.2  37      0.06    2.32 0.063
## 3 BecvTrou       22.1   106   1.4  43.9    0.07    2.49 0.08
## 4 BelaBosk       16.4   104   1.1  22.1    0.02    2.05 0.029
## 5 BilyPoto       18.9   104   1.9  30.4    0.1     4.48 0.131
## 6 BrezJaro       18.4    84   2.5  83.8    0.3     3.63 0.237
```

Combining two data set

```
mergedData <- merge(bioData, chemData, by = "Kod_Canoco")
```

```
head(mergedData)
```

```
##   Kod_Canoco SaprInd    Lital    RETI   EPTAbu    Marg Metaritr   JepAbu
```

```
## 1   BecvChor 2.57620 31.96916 0.37453 26.90136 7.10911 16.25647 14.89330
## 2   BecvOsek 2.43686 28.12037 0.27790 23.32888 5.80443 14.14831 11.06343
## 3   BecvTrou 2.10235 21.30691 0.31422 36.49575 6.14622 11.21903 30.23011
## 4   BelaBosk 1.53297 37.12914 0.48181 38.49802 9.36742 25.32146 10.11182
## 5   BilyPoto 1.79499 27.21495 0.37100 23.26918 8.62000 17.88813  5.95577
## 6   BrezJaro 2.70210 18.20885 0.27896  9.95374 5.52100 10.60614  3.02442
##   Epiritral Hyporitral Ntaxon Nceled  Bindex EPTTax  PosAbu  Spasaci
## 1   7.68869   22.52242     18     40 0.64865     23 0.33939 28.29352
## 2   6.96659   19.74992     12     25 0.37838     16 0.00000 20.84029
## 3   5.92213   18.63735      9     25 0.16216     12 1.47017 20.88415
## 4  20.37168   18.17237     16     40 0.72000     30 8.07504 28.62651
## 5  12.08359   19.09771     21     36 0.54167     21 0.54567 22.02324
## 6   6.68063   15.56050     18     25 0.08000      8 0.00000 21.02811
##         MDS_1       MDS_2 Tepl_max %O2 BSK5 Kond N-NH4 N-NO3 Pcelk
## 1 -0.69831500 -0.70405170     20.9 107  1.3 33.7  0.09  1.55 0.077
## 2 -0.61323430 -0.37968870     21.8 105  1.2 37.0  0.06  2.32 0.063
## 3 -0.08536265  1.60514400     22.1 106  1.4 43.9  0.07  2.49 0.080
## 4  0.55758620 -0.44240910     16.4 104  1.1 22.1  0.02  2.05 0.029
## 5  0.40888510 -0.21729880     18.9 104  1.9 30.4  0.10  4.48 0.131
## 6 -0.63877130  0.07480576     18.4  84  2.5 83.8  0.30  3.63 0.237
```

Renaming Dataset

```
old_names <- c("Kod_Canoco", "SaprInd", "Lital", "RETI", "EPTAbu", "Marg", "Metaritr",
               "JepAbu", "Epiritral", "Hyporitral", "Ntaxon", "Nceled", "Bindex", "EPTTax",
               "PosAbu", "Spasaci", "MDS_1", "MDS_2", "Tepl_max", "%O2", "BSK5", "Kond",
               "N-NH4", "N-NO3", "Pcelk")
new_names <- c("Site_Code", "Saprobic_Index", "Littoral_Abundance", "Retention_Index",
               "EPT_Abundance", "Margalef_Index", "Metarhithral_Abundance", "Jep_Abundance",
               "Epiritral_Abundance", "Hyporitral_Abundance", "Number_of_Taxa", "Number_of_Cephalopods"
               "Biotic_Index", "EPT_Taxa", "Positive_Abundance", "Spasaci_Index", "MDS_1", "MDS_2",
               "Max_Temperature", "Oxygen_Percentage", "Biochemical_Oxygen_Demand", "Conductivity",
               "Ammonium_Nitrogen", "Nitrate_Nitrogen", "Total_Phosphorus")

colnames(mergedData) <- new_names[match(colnames(mergedData), old_names)]
```

```
head(mergedData)
```

```
##   Site_Code Saprobic_Index Littoral_Abundance Retention_Index EPT_Abundance
## 1  BecvChor        2.57620           31.96916         0.37453      26.90136
## 2  BecvOsek        2.43686           28.12037         0.27790      23.32888
## 3  BecvTrou        2.10235           21.30691         0.31422      36.49575
## 4  BelaBosk        1.53297           37.12914         0.48181      38.49802
## 5  BilyPoto        1.79499           27.21495         0.37100      23.26918
## 6  BrezJaro        2.70210           18.20885         0.27896       9.95374
##   Margalef_Index Metarhithral_Abundance Jep_Abundance Epiritral_Abundance
## 1        7.10911               16.25647      14.89330             7.68869
## 2        5.80443               14.14831      11.06343             6.96659
## 3        6.14622               11.21903      30.23011             5.92213
## 4        9.36742               25.32146      10.11182            20.37168
## 5        8.62000               17.88813       5.95577            12.08359
```

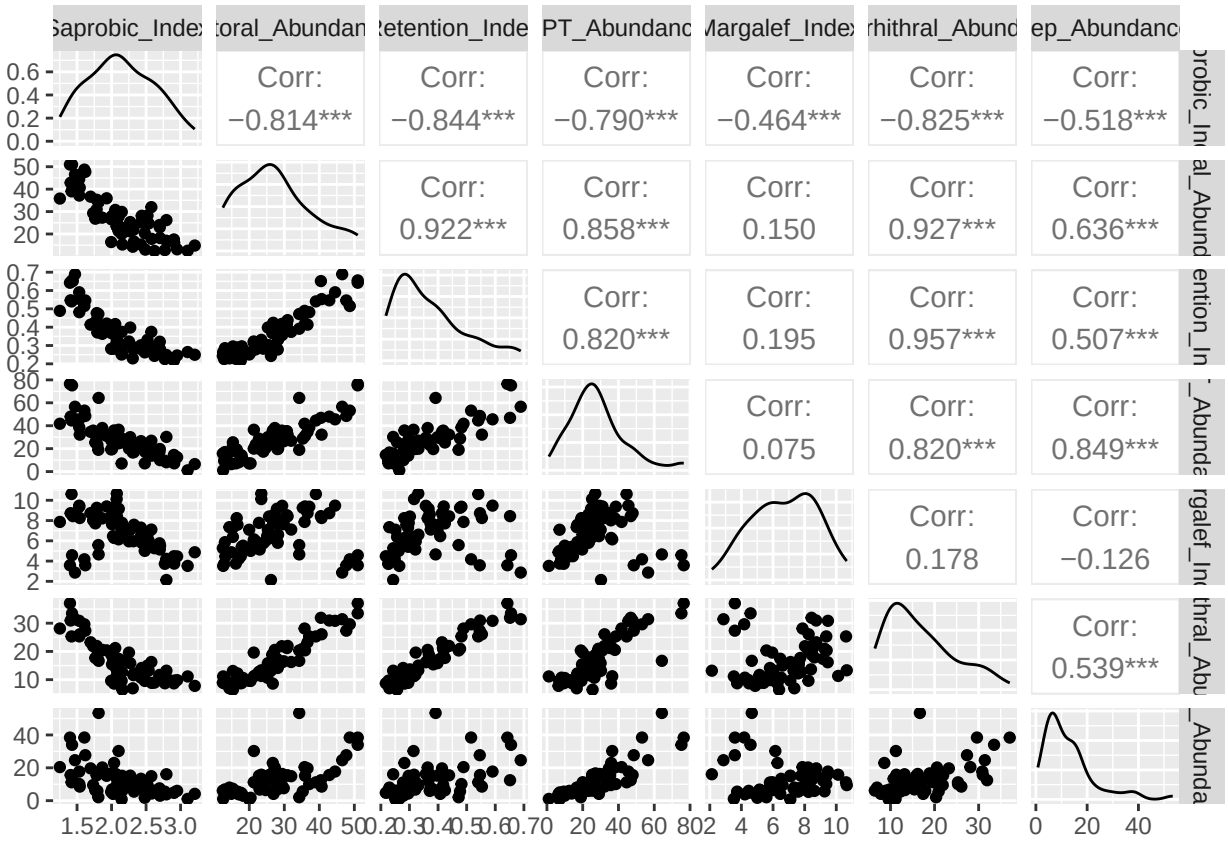
```
## 6        5.52100               10.60614       3.02442             6.68063
##   Hyporitral_Abundance Number_of_Taxa Number_of_Cephalopods Biotic_Index
## 1             22.52242             18                    40      0.64865
## 2             19.74992             12                    25      0.37838
## 3             18.63735              9                    25      0.16216
## 4             18.17237             16                    40      0.72000
## 5             19.09771             21                    36      0.54167
## 6             15.56050             18                    25      0.08000
##   EPT_Taxa Positive_Abundance Spasaci_Index       MDS_1       MDS_2
## 1       23            0.33939      28.29352 -0.69831500 -0.70405170
## 2       16            0.00000      20.84029 -0.61323430 -0.37968870
## 3       12            1.47017      20.88415 -0.08536265  1.60514400
## 4       30            8.07504      28.62651  0.55758620 -0.44240910
## 5       21            0.54567      22.02324  0.40888510 -0.21729880
## 6        8            0.00000      21.02811 -0.63877130  0.07480576
##   Max_Temperature Oxygen_Percentage Biochemical_Oxygen_Demand Conductivity
## 1            20.9               107                       1.3         33.7
## 2            21.8               105                       1.2         37.0
## 3            22.1               106                       1.4         43.9
## 4            16.4               104                       1.1         22.1
## 5            18.9               104                       1.9         30.4
## 6            18.4                84                       2.5         83.8
##   Ammonium_Nitrogen Nitrate_Nitrogen Total_Phosphorus
## 1              0.09             1.55            0.077
## 2              0.06             2.32            0.063
## 3              0.07             2.49            0.080
## 4              0.02             2.05            0.029
## 5              0.10             4.48            0.131
## 6              0.30             3.63            0.237
```

Selecting subset

```
bio <- mergedData[,2:8]
chem <- mergedData[,19:23]
```

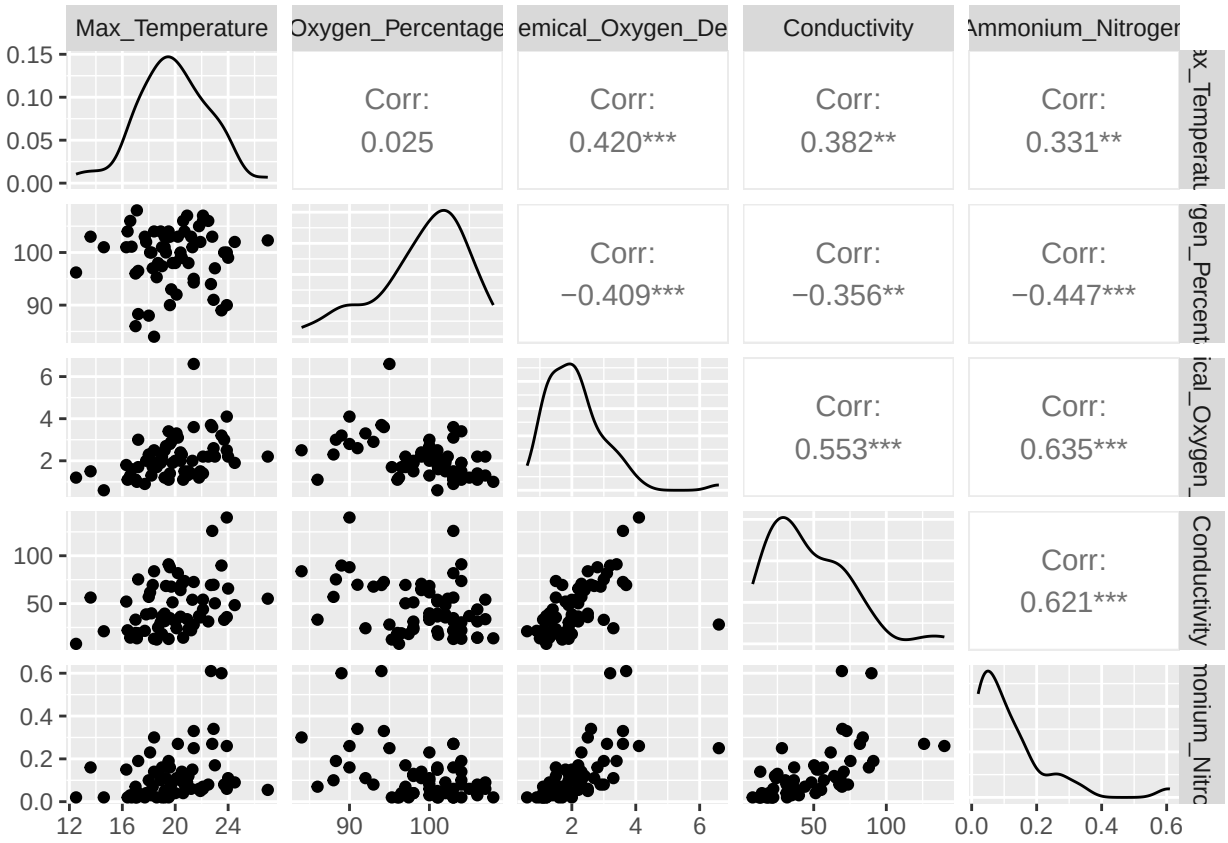
Correlation plot for bio data

```
ggpairs(bio)
```



Correlation plot for chem data

```
ggpairs(chem)
```




```
matcor(bio, chem)
```

```
## $Xcor
##                         Saprobic_Index Littoral_Abundance Retention_Index
## Saprobic_Index               1.0000000         -0.8135058      -0.8440417
## Littoral_Abundance          -0.8135058          1.0000000       0.9224602
## Retention_Index             -0.8440417          0.9224602       1.0000000
## EPT_Abundance               -0.7895581          0.8583838       0.8197055
## Margalef_Index              -0.4644557          0.1502805       0.1949925
## Metarhithral_Abundance      -0.8250756          0.9272982       0.9566919
## Jep_Abundance               -0.5176319          0.6358656       0.5073462
##                         EPT_Abundance Margalef_Index Metarhithral_Abundance
## Saprobic_Index             -0.7895581     -0.4644557              -0.8250756
## Littoral_Abundance          0.8583838      0.1502805               0.9272982
## Retention_Index             0.8197055      0.1949925               0.9566919
## EPT_Abundance               1.0000000      0.0749044               0.8201122
## Margalef_Index              0.0749044      1.0000000               0.1776293
## Metarhithral_Abundance      0.8201122      0.1776293               1.0000000
## Jep_Abundance               0.8490667     -0.1264523               0.5394190
##                         Jep_Abundance
## Saprobic_Index             -0.5176319
## Littoral_Abundance          0.6358656
## Retention_Index             0.5073462
## EPT_Abundance               0.8490667
## Margalef_Index             -0.1264523
```

```
## Metarhithral_Abundance     0.5394190
## Jep_Abundance              1.0000000
##
## $Ycor
##                           Max_Temperature Oxygen_Percentage
## Max_Temperature                1.00000000        0.02517222
## Oxygen_Percentage              0.02517222        1.00000000
## Biochemical_Oxygen_Demand      0.41990416       -0.40861067
## Conductivity                   0.38177606       -0.35637944
## Ammonium_Nitrogen              0.33070433       -0.44658766
##                           Biochemical_Oxygen_Demand Conductivity
## Max_Temperature                           0.4199042    0.3817761
## Oxygen_Percentage                        -0.4086107   -0.3563794
## Biochemical_Oxygen_Demand                 1.0000000    0.5525383
## Conductivity                              0.5525383    1.0000000
## Ammonium_Nitrogen                         0.6348814    0.6208863
##                           Ammonium_Nitrogen
## Max_Temperature                   0.3307043
## Oxygen_Percentage                -0.4465877
## Biochemical_Oxygen_Demand         0.6348814
## Conductivity                      0.6208863
## Ammonium_Nitrogen                 1.0000000
##
## $XYcor
##                           Saprobic_Index Littoral_Abundance Retention_Index
## Saprobic_Index                 1.0000000         -0.8135058      -0.8440417
## Littoral_Abundance            -0.8135058          1.0000000       0.9224602
## Retention_Index               -0.8440417          0.9224602       1.0000000
## EPT_Abundance                 -0.7895581          0.8583838       0.8197055
## Margalef_Index                -0.4644557          0.1502805       0.1949925
## Metarhithral_Abundance        -0.8250756          0.9272982       0.9566919
## Jep_Abundance                 -0.5176319          0.6358656       0.5073462
## Max_Temperature                0.3957630         -0.5077584      -0.5429186
## Oxygen_Percentage             -0.2927284          0.2012199       0.2060571
## Biochemical_Oxygen_Demand      0.6051785         -0.5514128      -0.5583261
## Conductivity                   0.7637746         -0.6799530      -0.7079914
## Ammonium_Nitrogen              0.6776461         -0.6069721      -0.5354850
##                           EPT_Abundance Margalef_Index Metarhithral_Abundance
## Saprobic_Index               -0.7895581    -0.46445572              -0.8250756
## Littoral_Abundance            0.8583838     0.15028052               0.9272982
## Retention_Index               0.8197055     0.19499249               0.9566919
## EPT_Abundance                 1.0000000     0.07490440               0.8201122
## Margalef_Index                0.0749044     1.00000000               0.1776293
## Metarhithral_Abundance        0.8201122     0.17762925               1.0000000
## Jep_Abundance                 0.8490667    -0.12645225               0.5394190
## Max_Temperature              -0.3670946     0.01390825              -0.5967410
## Oxygen_Percentage             0.1713302     0.44667336               0.1978019
## Biochemical_Oxygen_Demand    -0.4452583    -0.43772094              -0.5531977
## Conductivity                 -0.5867470    -0.42953424              -0.7130402
## Ammonium_Nitrogen            -0.5161975    -0.52073955              -0.5249274
##                           Jep_Abundance Max_Temperature Oxygen_Percentage
## Saprobic_Index              -0.51763187      0.39576302       -0.29272844
## Littoral_Abundance           0.63586565     -0.50775843        0.20121990
## Retention_Index              0.50734618     -0.54291860        0.20605713
```

```
## EPT_Abundance                0.84906675     -0.36709458        0.17133019
## Margalef_Index              -0.12645225      0.01390825        0.44667336
## Metarhithral_Abundance       0.53941903     -0.59674105        0.19780191
## Jep_Abundance                1.00000000     -0.17523647        0.08445738
## Max_Temperature             -0.17523647      1.00000000        0.02517222
## Oxygen_Percentage            0.08445738      0.02517222        1.00000000
## Biochemical_Oxygen_Demand   -0.21431644      0.41990416       -0.40861067
## Conductivity                -0.34124946      0.38177606       -0.35637944
## Ammonium_Nitrogen           -0.28491116      0.33070433       -0.44658766
##                           Biochemical_Oxygen_Demand Conductivity
## Saprobic_Index                            0.6051785    0.7637746
## Littoral_Abundance                       -0.5514128   -0.6799530
## Retention_Index                          -0.5583261   -0.7079914
## EPT_Abundance                            -0.4452583   -0.5867470
## Margalef_Index                           -0.4377209   -0.4295342
## Metarhithral_Abundance                   -0.5531977   -0.7130402
## Jep_Abundance                            -0.2143164   -0.3412495
## Max_Temperature                           0.4199042    0.3817761
## Oxygen_Percentage                        -0.4086107   -0.3563794
## Biochemical_Oxygen_Demand                 1.0000000    0.5525383
## Conductivity                              0.5525383    1.0000000
## Ammonium_Nitrogen                         0.6348814    0.6208863
##                           Ammonium_Nitrogen
## Saprobic_Index                    0.6776461
## Littoral_Abundance               -0.6069721
## Retention_Index                  -0.5354850
## EPT_Abundance                    -0.5161975
## Margalef_Index                   -0.5207396
## Metarhithral_Abundance           -0.5249274
## Jep_Abundance                    -0.2849112
## Max_Temperature                   0.3307043
## Oxygen_Percentage                -0.4465877
## Biochemical_Oxygen_Demand         0.6348814
## Conductivity                      0.6208863
## Ammonium_Nitrogen                 1.0000000
```

##Canonical Correlation Analysis

Canonical Correlations

```
cc1 <- cc(bio, chem)
cc1$cor
```

```
## [1] 0.8649396 0.6706442 0.3559172 0.2152026 0.0777321
```

Canonical Coefficients

```
cc1[3:4]
```

```
## $xcoef
##                              [,1]        [,2]         [,3]        [,4]
## Saprobic_Index         -0.93517362 -0.42415063  -1.36559985  3.96528283
## Littoral_Abundance      0.05577233  0.12489973   0.19167664  0.13078478
## Retention_Index        -2.29862084 -4.28176444 -16.47652035 -9.32239116
## EPT_Abundance           0.00805593  0.06791587   0.08599306  0.04777590
## Margalef_Index          0.13090771  0.25378408  -0.47213596  0.37523390
## Metarhithral_Abundance  0.02561489 -0.26959660  -0.06941195  0.13966065
## Jep_Abundance          -0.02316241 -0.04192396  -0.14503932 -0.07555441
##                              [,5]
## Saprobic_Index          0.074098734
## Littoral_Abundance      0.002148512
## Retention_Index        19.781483978
## EPT_Abundance           0.025634247
## Margalef_Index         -0.075255020
## Metarhithral_Abundance -0.278072417
## Jep_Abundance          -0.102397362
##
## $ycoef
##                                    [,1]         [,2]        [,3]        [,4]
## Max_Temperature           -0.030861966  0.318074283 -0.10056511 -0.24900935
## Oxygen_Percentage         -0.007712911 -0.005084202 -0.15323497  0.12193853
## Biochemical_Oxygen_Demand -0.215470234 -0.039341337  0.30540195 -0.08663165
## Conductivity              -0.019397486  0.014443821  0.01505867  0.03812515
## Ammonium_Nitrogen         -3.193631053 -7.471468779 -7.76266287 -2.66241844
##                                   [,5]
## Max_Temperature            0.12023353
## Oxygen_Percentage         -0.09044003
## Biochemical_Oxygen_Demand -1.41523408
## Conductivity               0.01222378
## Ammonium_Nitrogen          3.65755745
```

Canonical Loadings

```
cc2 <- comput(bio, chem, cc1)
cc2[3:6]
```

```
## $corr.X.xscores
##                              [,1]        [,2]         [,3]         [,4]
## Saprobic_Index         -0.9438165  0.02576695 -0.002012332  0.324073610
## Littoral_Abundance      0.8628506 -0.21410255  0.260737185  0.022770282
## Retention_Index         0.8530773 -0.37191461  0.049225297 -0.093114825
## EPT_Abundance           0.7270823 -0.10545357  0.181589188 -0.233136248
## Margalef_Index          0.5799074  0.47060875 -0.561665723  0.205672515
## Metarhithral_Abundance  0.8558455 -0.45810224  0.080481566  0.007085438
## Jep_Abundance           0.4023294 -0.03477190  0.109128918 -0.343041781
##                              [,5]
## Saprobic_Index          0.03444685
## Littoral_Abundance     -0.09804219
## Retention_Index         0.13087707
## EPT_Abundance          -0.26798687
## Margalef_Index          0.08163651
```

```
## Metarhithral_Abundance -0.09344004
## Jep_Abundance          -0.59775777
##
## $corr.Y.xscores
##                                 [,1]        [,2]        [,3]        [,4]
## Max_Temperature           -0.4356444  0.46714867 -0.11430686 -0.08549092
## Oxygen_Percentage          0.3488675  0.18161166 -0.24952180  0.09880998
## Biochemical_Oxygen_Demand -0.6628901 -0.01282728  0.05688265 -0.05713922
## Conductivity              -0.7834295  0.10345479  0.06852342  0.06607872
## Ammonium_Nitrogen         -0.7427202 -0.25718468 -0.07332907 -0.05296982
##                                  [,5]
## Max_Temperature            0.0009586581
## Oxygen_Percentage         -0.0193032738
## Biochemical_Oxygen_Demand -0.0437117608
## Conductivity               0.0121545893
## Ammonium_Nitrogen          0.0087063333
##
## $corr.X.yscores
##                                [,1]        [,2]          [,3]         [,4]
## Saprobic_Index           -0.8163443  0.01728045 -0.0007162236  0.069741473
## Littoral_Abundance        0.7463137 -0.14358663  0.0928008483  0.004900223
## Retention_Index           0.7378604 -0.24942237  0.0175201297 -0.020038549
## EPT_Abundance             0.6288823 -0.07072182  0.0646307149 -0.050171519
## Margalef_Index            0.5015849  0.31561102 -0.1999064905  0.044261253
## Metarhithral_Abundance    0.7402547 -0.30722360  0.0286447735  0.001524804
## Jep_Abundance             0.3479907 -0.02331957  0.0388408586 -0.073823472
##                                 [,5]
## Saprobic_Index           0.002677626
## Littoral_Abundance      -0.007621025
## Retention_Index          0.010173349
## EPT_Abundance           -0.020831182
## Margalef_Index           0.006345778
## Metarhithral_Abundance -0.007263290
## Jep_Abundance          -0.046464967
##
## $corr.Y.yscores
##                                 [,1]       [,2]       [,3]       [,4]
## Max_Temperature           -0.5036702  0.6965671 -0.3211614 -0.3972579
## Oxygen_Percentage          0.4033432  0.2708018 -0.7010670  0.4591487
## Biochemical_Oxygen_Demand -0.7664004 -0.0191268  0.1598199 -0.2655137
## Conductivity              -0.9057621  0.1542618  0.1925263  0.3070536
## Ammonium_Nitrogen         -0.8586960 -0.3834890 -0.2060285 -0.2461393
##                                  [,5]
## Max_Temperature            0.01233285
## Oxygen_Percentage         -0.24833079
## Biochemical_Oxygen_Demand -0.56233861
## Conductivity               0.15636512
## Ammonium_Nitrogen          0.11200435
```

Tests Of Canonical Dimension

```
rho <- cc1$cor

n <- dim(bio)[1] # number of observations
p <- length(bio) # number of variables in first set
q <- length(chem)  # number of variables in the second set
```

```
p.asym(rho, n, p, q, tstat = "Wilks")
```

Wilks Test

```
## Wilks' Lambda, using F-approximation (Rao's F):
##               stat    approx df1      df2      p.value
## 1 to 5:  0.1147337 4.2537084  35 221.1740 1.547873e-11
## 2 to 5:  0.4555104 1.9605174  24 186.1050 6.937958e-03
## 3 to 5:  0.8278450 0.7058554  15 149.4716 7.757596e-01
## 4 to 5:  0.9479254 0.3726311   8 110.0000 9.330442e-01
## 5 to 5:  0.9939577 0.1134749   3  56.0000 9.518664e-01
```

```
p.asym(rho, n, p, q, tstat = "Hotelling")
```

Hotelling Test

```
##  Hotelling-Lawley Trace, using F-approximation:
##                stat    approx df1 df2     p.value
## 1 to 5:  3.98724644 5.7416349  35 252 0.000000000
## 2 to 5:  1.01709266 2.2206523  24 262 0.001221481
## 3 to 5:  0.19969191 0.7242160  15 272 0.759345476
## 4 to 5:  0.05464012 0.3852129   8 282 0.928092732
## 5 to 5:  0.00607901 0.1183381   3 292 0.949292538
```

```
p.asym(rho, n, p, q, tstat = "Pillai")
```

Pillai Test

```
##  Pillai-Bartlett Trace, using F-approximation:
##                 stat    approx df1 df2      p.value
## 1 to 5:  1.376915689 3.0403172  35 280 1.729530e-07
## 2 to 5:  0.628795101 1.7381800  24 290 1.923471e-02
## 3 to 5:  0.179031476 0.7427200  15 300 7.401569e-01
## 4 to 5:  0.052354424 0.4100403   8 310 9.145366e-01
## 5 to 5:  0.006042279 0.1290579   3 320 9.428035e-01
```

```
p.asym(rho, n, p, q, tstat = "Roy")
```

Roy Test

```
##  Roy's Largest Root, using F-approximation:
##               stat   approx df1 df2      p.value
## 1 to 1:  0.7481206 34.45378   5  58 3.330669e-16
##
##  F statistic for Roy's Greatest Root is an upper bound.
```

standardized bio canonical coefficients

```
s1 <- diag(sqrt(diag(cov(bio))))
s1 %*% cc1$xcoef
```

```
##            [,1]       [,2]       [,3]       [,4]        [,5]
## [1,] -0.4475953 -0.2030081 -0.6536071  1.8978744  0.03546534
## [2,]  0.5726257  1.2823706  1.9679825  1.3427936  0.02205920
## [3,] -0.2774900 -0.5168955 -1.9890489 -1.1254010  2.38802481
## [4,]  0.1255077  1.0580983  1.3397328  0.7443268  0.39936991
## [5,]  0.2668115  0.5172539 -0.9622910  0.7647886 -0.15338216
## [6,]  0.1952035 -2.0545155 -0.5289678  1.0643122 -2.11910718
## [7,] -0.2308117 -0.4177692 -1.4453062 -0.7528941 -1.02038223
```

standardized chem canonical coefficients

```
s2 <- diag(sqrt(diag(cov(chem))))
s2 %*% cc1$ycoef
```

```
##             [,1]        [,2]       [,3]        [,4]       [,5]
## [1,] -0.08345454  0.86011187 -0.2719404 -0.67335181  0.3251262
## [2,] -0.04252181 -0.02802956 -0.8447949  0.67225550 -0.4986021
## [3,] -0.20847770 -0.03806462  0.2954909 -0.08382025 -1.3693063
## [4,] -0.53415020  0.39774072  0.4146720  1.04985541  0.3366073
## [5,] -0.38608181 -0.90323464 -0.9384374 -0.32186290  0.4421664
```