

## Analysis of Similarity and Analysis of Variance

# Analysis of Similarity and Analysis of Variance

## Data

- Biomass of top 50 species
- average across depth strata using the NOAA IEA technical document (<https://noaa-edab.github.io/tech-doc/inshoresurvdatt.html#data-analysis-29>)
- calculate dissimilarity matrix with Bray-Curtis distances

Sea...	Reg...	Y...	alewife	bass.striped	butterfish	cod.atlantic	crab.atlantic
<chr>	<int>	<int>	<dbl>	<dbl>	<dbl>	<dbl>	
1 Fall	1	2000	5.380384	0	0.3518519	1.9828704	0.22
2 Fall	1	2001	11.422884	0	2.8428307	0.3520811	2.84
3 Fall	1	2002	4.145476	0	3.3043183	2.2230952	0.06
4 Fall	1	2003	4.924375	0	3.5231250	10.3700000	0.00
5 Fall	1	2004	6.528253	0	3.2305702	4.6161111	0.00
6 Fall	1	2005	3.781491	0	0.7742105	13.4031579	0.23

6 rows | 1-9 of 59 columns

## Analysis of similarity (Anosim)

- tests statistically whether there is a significant difference between two or more groups
- works by testing if distances between groups are greater than within groups
- significant values mean that there is a statistically significant difference in the communities between the groups
- R statistic closer to 1 is more dissimilar

## Region

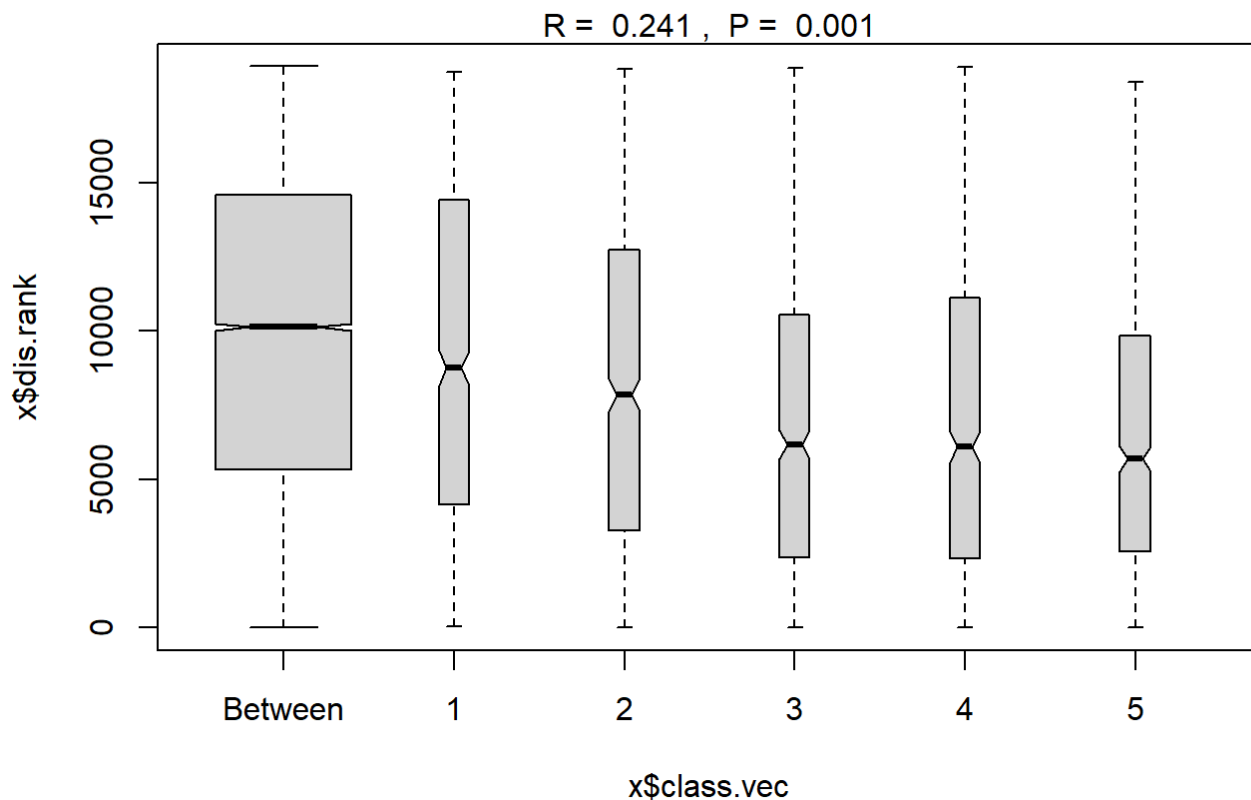
```
#region
ano_region<- anosim(trawl_dist, trawl_data_arrange$Region, permutations = 999)
ano_region #regions are statistically different communities
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$Region,      permutations = 999)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.2409
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
```

```
summary(ano_region)
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$Region,      permutations = 999)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.2409
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
##
## Upper quantiles of permutations (null model):
##      90%      95%      97.5%      99%
## 0.00992 0.01280 0.01757 0.02199
##
## Dissimilarity ranks between and within classes:
##           0%      25%      50%      75% 100%      N
## Between  4 5339.25 10126.5 14569.75 18915 15210
## 1         47 4152.00  8749.0 14402.00 18739   741
## 2          9 3263.00  7841.0 12723.00 18816   741
## 3          2 2364.00  6163.0 10546.00 18845   741
## 4          1 2319.00  6086.0 11106.00 18907   741
## 5         11 2575.00  5686.0  9835.00 18380   741
```

```
plot(ano_region) #regions don't look very different in plot though...confidence bands all overlap
```



## Region grouped

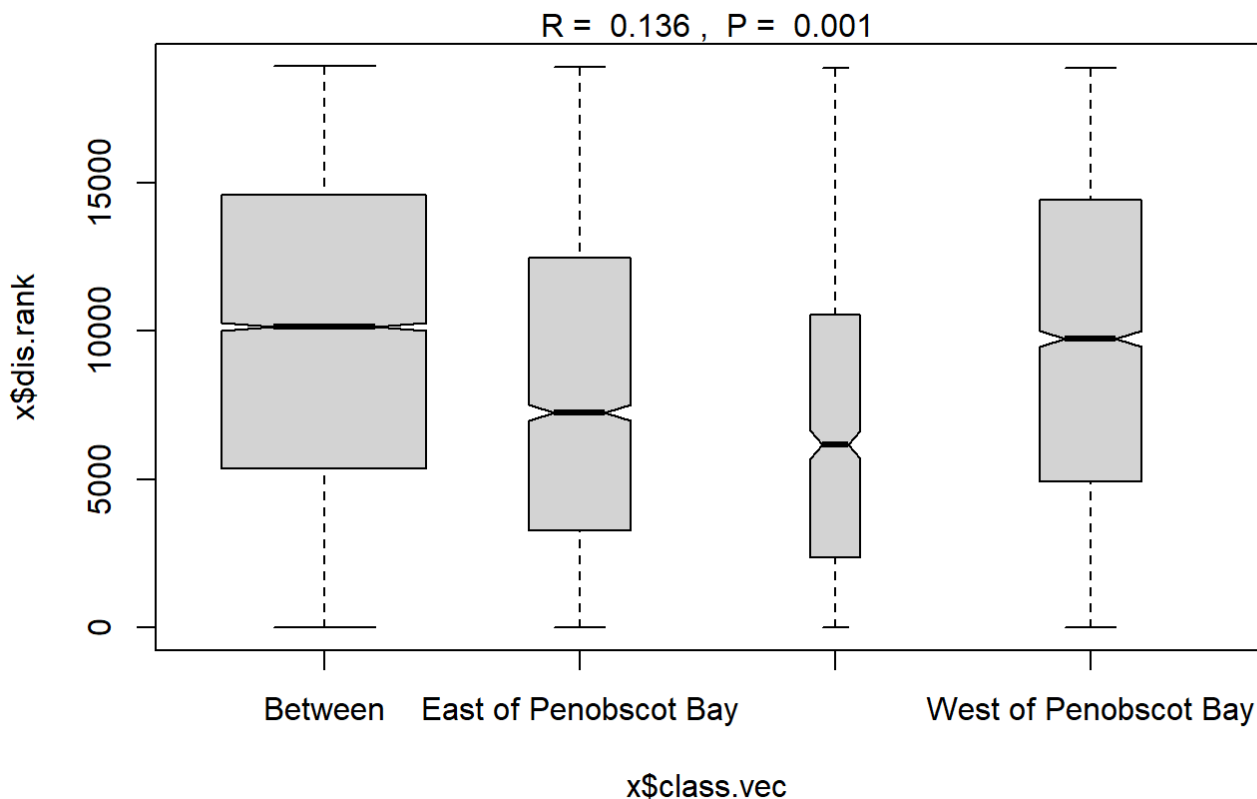
```
#region
ano_region_groups<- anosim(trawl_dist, trawl_data_arrange$REGION_NEW, permutations = 999)
ano_region_groups #regions are statistically different communities
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$REGION_NEW,      permutations = 99
9)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.1356
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
```

```
summary(ano_region_groups)
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$REGION_NEW,      permutations = 99
9)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.1356
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
##
## Upper quantiles of permutations (null model):
##      90%      95%      97.5%      99%
## 0.0206 0.0265 0.0324 0.0378
##
## Dissimilarity ranks between and within classes:
##              0%      25%      50%      75%      100%      N
## Between              4 5348.0 10153.5 14585.5 18915 12168
## East of Penobscot Bay 1 3285.5  7245.0 12459.5 18907  3003
## Penobscot Bay         2 2364.0  6163.0 10546.0 18845   741
## West of Penobscot Bay 9 4921.0  9748.0 14430.0 18860  3003
```

```
plot(ano_region_groups) #
```



## Year

```
#Time  
ano_year<- anosim(trawl_dist, trawl_data_arrange$Year, permutations = 999)  
ano_year #years are statistically different communities
```

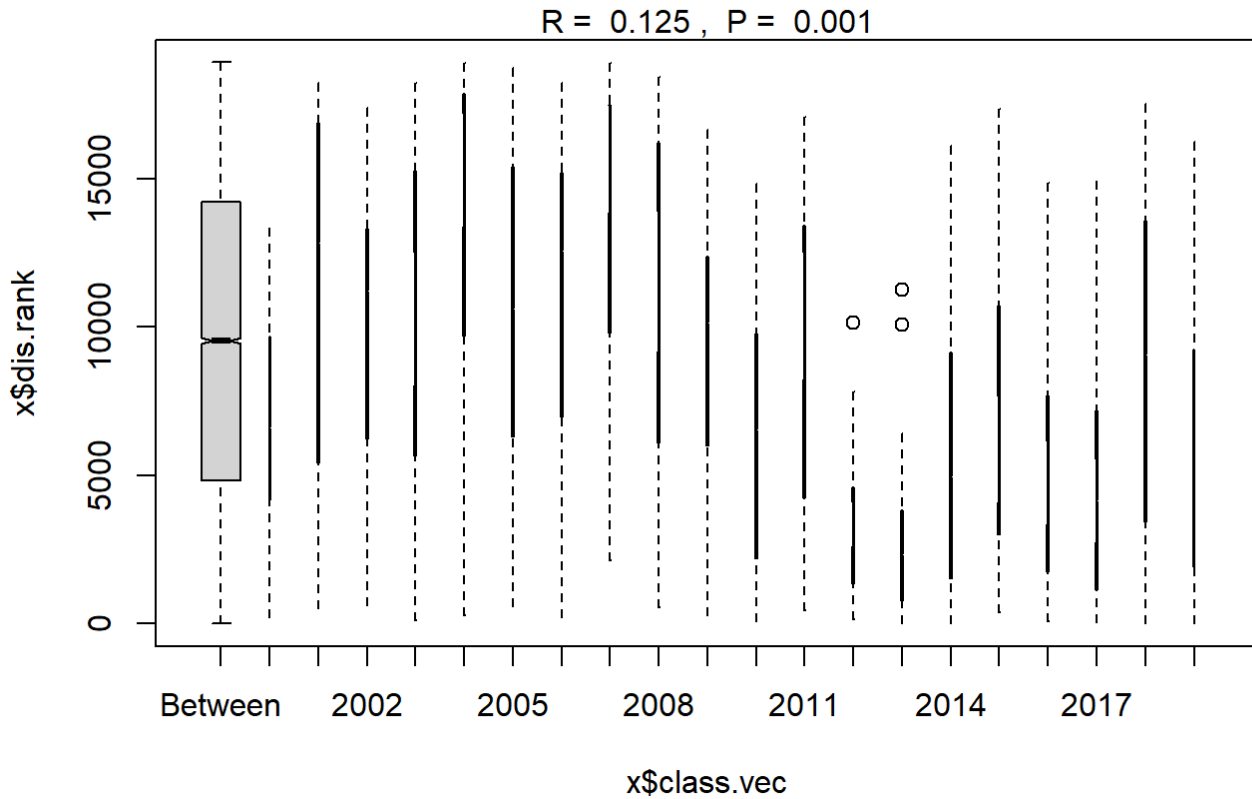
```
##  
## Call:  
## anosim(x = trawl_dist, grouping = trawl_data_arrange$Year, permutations = 999)  
## Dissimilarity: bray  
##  
## ANOSIM statistic R: 0.1252  
##      Significance: 0.001  
##  
## Permutation: free  
## Number of permutations: 999
```

```
summary(ano_year)
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$Year, permutations = 999)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.1252
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
##
## Upper quantiles of permutations (null model):
##      90%      95%      97.5%      99%
## 0.0191 0.0271 0.0307 0.0348
##
## Dissimilarity ranks between and within classes:
##           0%      25%      50%      75% 100%      N
## Between    1 4812.25  9534.5 14222.75 18915 18050
## 2000       217 4819.50  6612.5  9320.00 13344    10
## 2001       525 5418.00 12824.0 16868.00 18217    45
## 2002       619 6225.00 11209.0 13296.00 17389    45
## 2003        99 5655.00 10274.0 15244.00 18230    45
## 2004       260 9688.00 15280.0 17844.00 18887    45
## 2005       567 6315.00 10597.0 15396.00 18738    45
## 2006       198 6976.00 12562.0 15194.00 18221    45
## 2007      2131 9788.00 15651.0 17493.00 18900    45
## 2008       559 6095.00 11538.0 16202.00 18430    45
## 2009       266 5985.00 10139.0 12380.00 16642    45
## 2010        58 2203.00  6548.0  9759.00 14837    45
## 2011       457 4235.00 10369.0 13419.00 17082    45
## 2012       133 1364.00  3343.0  4590.00 10153    45
## 2013        18  795.00  2333.0  3796.00 11260    45
## 2014         6 1516.00  4963.0  9125.00 16084    45
## 2015       380 3017.00  5877.0 10700.00 17347    45
## 2016        70 1749.00  4757.0  7694.00 14871    45
## 2017        35 1168.00  4137.0  7191.00 14935    45
## 2018        12 3428.00  9051.0 13573.00 17500    45
## 2019        16 1930.00  4588.0  9241.00 16238    45
```

```
plot(ano_year)
```

```
## Warning in (function (z, notch = FALSE, width = NULL, varwidth = FALSE, : some
## notches went outside hinges ('box'): maybe set notch=FALSE
```



## Year blocks

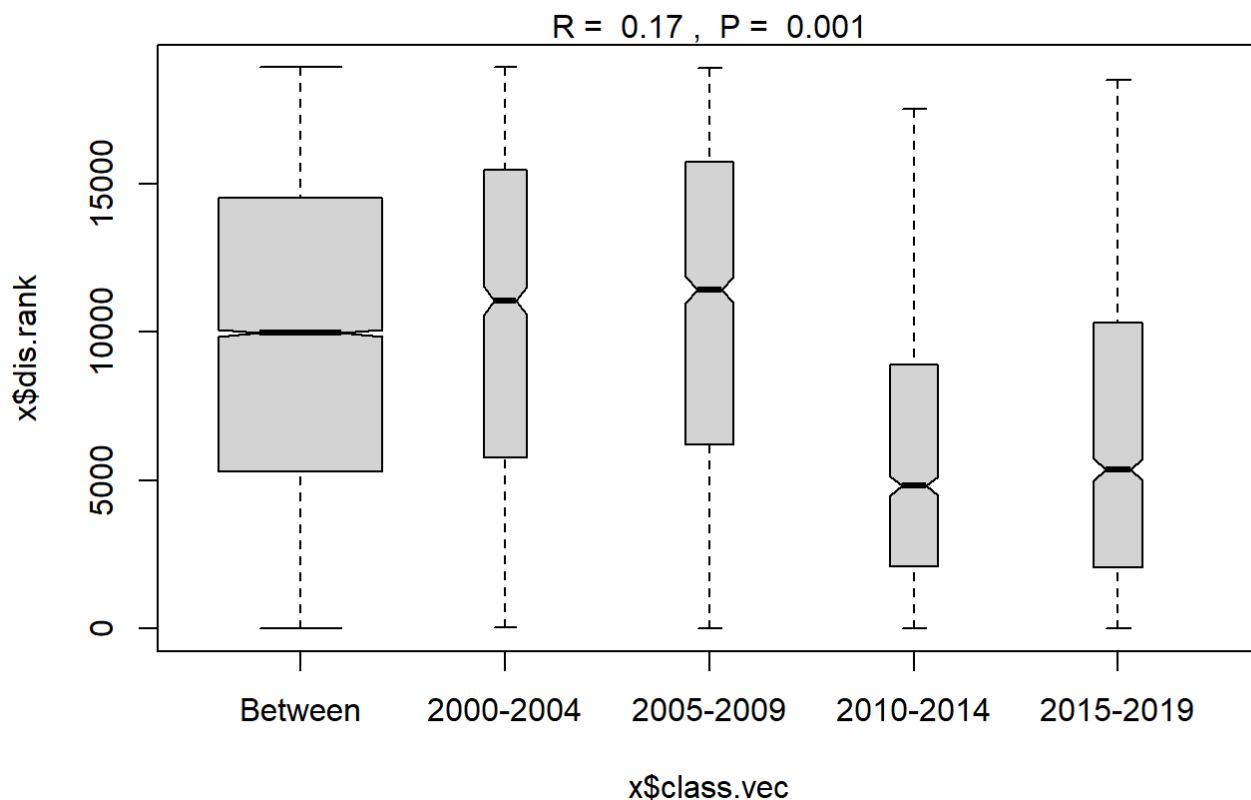
```
#Year blocks
ano_year_blocks<- anosim(trawl_dist, trawl_data_arrange$YEAR_GROUPS, permutations = 999)
ano_year_blocks #years are statistically different communities
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$YEAR_GROUPS,      permutations = 9
99)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.1698
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
```

```
summary(ano_year_blocks)
```

```
##
## Call:
## anosim(x = trawl_dist, grouping = trawl_data_arrange$YEAR_GROUPS,      permutations = 9
## 99)
## Dissimilarity: bray
##
## ANOSIM statistic R: 0.1698
##      Significance: 0.001
##
## Permutation: free
## Number of permutations: 999
##
## Upper quantiles of permutations (null model):
##      90%      95%      97.5%      99%
## 0.00942 0.01280 0.01632 0.01865
##
## Dissimilarity ranks between and within classes:
##           0%      25%      50%      75%      100%      N
## Between      1 5308.25  9966 14517.50 18915 14250
## 2000-2004    54 5768.50 11052 15452.75 18913   990
## 2005-2009    15 6208.00 11413 15720.00 18909  1225
## 2010-2014     6 2086.00  4807  8907.00 17501  1225
## 2015-2019     3 2053.00  5370 10302.00 18480  1225
```

```
plot(ano_year_blocks)
```





# Analysis of variance (Adonis)

- Permanova
- tests whether there is a difference between means of groups
- works by calculating the sum of squares from the centroid of the group

## Region and Year

```
adonis<-adonis2(trawl_dist~Region*Year, data=ME_group_data, by="terms", permutations = 999
9)
adonis
```

```
## Permutation test for adonis under reduced model
## Terms added sequentially (first to last)
## Permutation: free
## Number of permutations: 9999
##
## adonis2(formula = trawl_dist ~ Region * Year, data = ME_group_data, permutations = 999
9, by = "terms")
##           Df SumOfSqs      R2      F Pr(>F)
## Region      1   2.4733 0.08292 19.3464 1e-04 ***
## Year         1   2.3702 0.07947 18.5400 1e-04 ***
## Region:Year  1   0.5655 0.01896  4.4233 2e-04 ***
## Residual    191  24.4176 0.81865
## Total       194  29.8265 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(adonis)
```

```
##           Df      SumOfSqs      R2      F
## Min.      : 1.0   Min.      : 0.5655   Min.      :0.01896   Min.      : 4.423
## 1st Qu.:  1.0   1st Qu.: 2.3702   1st Qu.:0.07947   1st Qu.:11.482
## Median   :  1.0   Median   : 2.4733   Median :0.08292   Median :18.540
## Mean     : 77.6   Mean     :11.9306   Mean     :0.40000   Mean     :14.103
## 3rd Qu.:191.0   3rd Qu.:24.4176   3rd Qu.:0.81865   3rd Qu.:18.943
## Max.     :194.0   Max.     :29.8265   Max.     :1.00000   Max.     :19.346
##                                     NA's      :2
##           Pr(>F)
## Min.      :0.0001000
## 1st Qu.:0.0001000
## Median   :0.0001000
## Mean     :0.0001333
## 3rd Qu.:0.0001500
## Max.     :0.0002000
## NA's      :2
```

## Region and year block

```
#with year blocks
adonis<-adonis2(trawl_dist~Region*YEAR_GROUPS, data=ME_group_data, by="terms", permutation
s = 9999)
adonis
```

```
## Permutation test for adonis under reduced model
## Terms added sequentially (first to last)
## Permutation: free
## Number of permutations: 9999
##
## adonis2(formula = trawl_dist ~ Region * YEAR_GROUPS, data = ME_group_data, permutations
= 9999, by = "terms")
##              Df SumOfSqs      R2      F Pr(>F)
## Region          1   2.4733 0.08292 20.0943 1e-04 ***
## YEAR_GROUPS      3   3.3389 0.11194  9.0424 1e-04 ***
## Region:YEAR_GROUPS 3   0.9979 0.03346  2.7024 1e-04 ***
## Residual        187  23.0164 0.77168
## Total           194  29.8265 1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
summary(adonis)
```

```
##              Df      SumOfSqs      R2      F
## Min.      : 1.0   Min.      : 0.9979   Min.      :0.03346   Min.      : 2.702
## 1st Qu.:  3.0   1st Qu.:  2.4733   1st Qu.:0.08292   1st Qu.:  5.872
## Median :  3.0   Median :  3.3389   Median :0.11194   Median :  9.042
## Mean      : 77.6   Mean      :11.9306   Mean      :0.40000   Mean      :10.613
## 3rd Qu.:187.0   3rd Qu.:23.0164   3rd Qu.:0.77168   3rd Qu.:14.568
## Max.      :194.0   Max.      :29.8265   Max.      :1.00000   Max.      :20.094
##                                     NA's      :2
##      Pr(>F)
## Min.      :1e-04
## 1st Qu.:1e-04
## Median :1e-04
## Mean      :1e-04
## 3rd Qu.:1e-04
## Max.      :1e-04
## NA's      :2
```

## Region groups and year block

```
#with year blocks
```

```
adonis<-adonis2(trawl_dist~REGION_NEW*YEAR_GROUPS, data=ME_group_data, by="terms", permutations = 9999)
adonis
```

```
## Permutation test for adonis under reduced model
## Terms added sequentially (first to last)
## Permutation: free
## Number of permutations: 9999
##
## adonis2(formula = trawl_dist ~ REGION_NEW * YEAR_GROUPS, data = ME_group_data, permutations = 9999, by = "terms")
##
```

	Df	SumOfSqs	R2	F	Pr(>F)	
## REGION_NEW	2	2.8660	0.09609	11.7024	0.0001	***
## YEAR_GROUPS	3	3.3389	0.11194	9.0888	0.0001	***
## REGION_NEW:YEAR_GROUPS	6	1.2124	0.04065	1.6502	0.0044	**
## Residual	183	22.4091	0.75132			
## Total	194	29.8265	1.00000			

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

```
summary(adonis)
```

```
##
```

	Df	SumOfSqs	R2	F
## Min. :	2.0	Min. : 1.212	Min. :0.04065	Min. : 1.650
## 1st Qu.:	3.0	1st Qu.: 2.866	1st Qu.:0.09609	1st Qu.: 5.370
## Median :	6.0	Median : 3.339	Median :0.11194	Median : 9.089
## Mean :	77.6	Mean :11.931	Mean :0.40000	Mean : 7.480
## 3rd Qu.:183.0		3rd Qu.:22.409	3rd Qu.:0.75132	3rd Qu.:10.396
## Max. :194.0		Max. :29.826	Max. :1.00000	Max. :11.702

```
##
## NA's :2
## Pr(>F)
## Min. :0.000100
## 1st Qu.:0.000100
## Median :0.000100
## Mean :0.001533
## 3rd Qu.:0.002250
## Max. :0.004400
## NA's :2
```

## Pairwise

- Vegan does not have a function for this, but I found a wrapper that seems frequently used on github
- select groups to test, one pair at a time
- Adjust p-values for multiple tests

## Region

```
#pair-wise test to see what is different
pair<-pairwise.adonis2(trawl_dist~Region, data=ME_group_data, by="terms", permutations = 999)
summary(pair)
```

```
##           Length Class  Mode
## parent_call 1      -none- character
## 1_vs_2       6      anova  list
## 1_vs_3       6      anova  list
## 1_vs_4       6      anova  list
## 1_vs_5       6      anova  list
## 2_vs_3       6      anova  list
## 2_vs_4       6      anova  list
## 2_vs_5       6      anova  list
## 3_vs_4       6      anova  list
## 3_vs_5       6      anova  list
## 4_vs_5       6      anova  list
```

*pair #shows all the regions are significantly different except 3 and 4*

```
## $parent_call
## [1] "trawl_dist ~ Region , strata = Null"
##
## $`1_vs_2`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      1.1374 1.13737  7.9949 0.09518 1e-04 ***
## Residuals  76     10.8119 0.14226           0.90482
## Total      77     11.9492           1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`1_vs_3`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      1.8898 1.88977 14.078 0.15629 1e-04 ***
## Residuals  76     10.2019 0.13424           0.84371
## Total      77     12.0917           1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`1_vs_4`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      2.2077 2.20767 15.829 0.17237 1e-04 ***
## Residuals  76     10.5999 0.13947           0.82763
## Total      77     12.8076           1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`1_vs_5`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      2.1038 2.1037  15.89 0.17292 1e-04 ***
## Residuals  76     10.0621 0.1324           0.82708
## Total      77     12.1658           1.00000
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2_vs_3`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1    0.5465 0.54645  4.3301 0.0539 0.0016 **
## Residuals  76    9.5910 0.12620      0.9461
## Total      77   10.1374      1.0000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2_vs_4`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1    0.8377 0.83772  6.3737 0.07738 1e-04 ***
## Residuals  76    9.9890 0.13143      0.92262
## Total      77   10.8267      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2_vs_5`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1    1.7680 1.76803 14.217 0.15759 1e-04 ***
## Residuals  76    9.4512 0.12436      0.84241
## Total      77   11.2192      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`3_vs_4`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1    0.2281 0.22808  1.8482 0.02374 0.0794 .
## Residuals  76    9.3790 0.12341      0.97626
## Total      77    9.6071      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## $`3_vs_5`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      1.2119 1.21194  10.418 0.12055 1e-04 ***
## Residuals  76      8.8412 0.11633      0.87945
## Total      77     10.0531      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`4_vs_5`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## Region      1      1.2815 1.28154  10.542 0.12181 1e-04 ***
## Residuals  76      9.2392 0.12157      0.87819
## Total      77     10.5207      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## attr(,"class")
## [1] "pwadstrata" "list"
```

## Region groups

```
#pair-wise test to see what is different
pair<-pairwise.adonis2(trawl_dist~REGION_NEW, data=ME_group_data, by="terms", permutations
= 9999)
summary(pair)
```

```
##                               Length Class  Mode
## parent_call                   1      -none- character
## West of Penobscot Bay_vs_Penobscot Bay      6      anova  list
## West of Penobscot Bay_vs_East of Penobscot Bay 6      anova  list
## Penobscot Bay_vs_East of Penobscot Bay      6      anova  list
```

*pair #shows all the regions are significantly different except 3 and 4*

```
## $parent_call
## [1] "trawl_dist ~ REGION_NEW , strata = Null"
##
## $`West of Penobscot Bay_vs_Penobscot Bay`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## REGION_NEW  1      1.245 1.24503  8.7093 0.0704 1e-04 ***
## Residuals 115     16.440 0.14295      0.9296
## Total     116     17.685      1.0000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`West of Penobscot Bay_vs_East of Penobscot Bay`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## REGION_NEW  1      2.2491 2.24913 15.415 0.09099 1e-04 ***
## Residuals 154     22.4700 0.14591      0.90901
## Total     155     24.7191      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`Penobscot Bay_vs_East of Penobscot Bay`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## REGION_NEW  1      0.5328 0.53284  4.082 0.03428 6e-04 ***
## Residuals 115     15.0112 0.13053      0.96572
## Total     116     15.5440      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## attr("class")
## [1] "pwadstrata" "list"
```

## Year blocks

```
#pair-wise test to see what is different for year blocks
pair<-pairwise.adonis2(trawl_dist~YEAR_GROUPS, data=ME_group_data, by="terms", permutation
s = 9999)
summary(pair)
```



##		Length	Class	Mode
##	parent_call	1	-none-	character
##	2000-2004_vs_2005-2009	6	anova	list
##	2000-2004_vs_2010-2014	6	anova	list
##	2000-2004_vs_2015-2019	6	anova	list
##	2005-2009_vs_2010-2014	6	anova	list
##	2005-2009_vs_2015-2019	6	anova	list
##	2010-2014_vs_2015-2019	6	anova	list

pair

```
## $parent_call
## [1] "trawl_dist ~ YEAR_GROUPS , strata = Null"
##
## $`2000-2004_vs_2005-2009`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1    0.5499 0.54989  3.1888 0.03315 0.0026 **
## Residuals  93   16.0372 0.17244      0.96685
## Total      94   16.5871      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2000-2004_vs_2010-2014`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1    1.1475 1.14748  8.5301 0.08402 1e-04 ***
## Residuals  93   12.5104 0.13452      0.91598
## Total      94   13.6579      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2000-2004_vs_2015-2019`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1    1.7906 1.79056 12.878 0.12163 1e-04 ***
## Residuals  93   12.9309 0.13904      0.87837
## Total      94   14.7215      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2005-2009_vs_2010-2014`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1    1.2072 1.20723  8.727 0.08177 1e-04 ***
## Residuals  98   13.5566 0.13833      0.91823
## Total      99   14.7639      1.00000
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2005-2009_vs_2015-2019`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1      1.6775 1.67753  11.762 0.10716 1e-04 ***
## Residuals   98     13.9772 0.14262      0.89284
## Total       99     15.6547      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## $`2010-2014_vs_2015-2019`
## Permutation: free
## Number of permutations: 9999
##
## Terms added sequentially (first to last)
##
##           Df SumsOfSqs MeanSqs F.Model      R2 Pr(>F)
## YEAR_GROUPS 1      0.3126 0.31256   2.9311 0.02904 0.0052 **
## Residuals   98     10.4504 0.10664      0.97096
## Total       99     10.7629      1.00000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## attr("class")
## [1] "pwadstrata" "list"
```

## Dispersion

- anosim very sensitive to heterogeneity (Anderson and Walsh 2013)
- Could get false significant results from differences in variance instead of mean
- adonis is less affected by heterogeneity for *balanced designs*
- PRIMER can deal with dispersion issues, but vegan does not yet
- tests null hypothesis that there is no difference in dispersion between groups
- p-value <0.05 means difference is significant

## Region

```
#betadisper test homogeneity of dispersion among groups
#Region
bd<-betadisper(trawl_dist,ME_group_data$Region)
bd
```

```
##
## Homogeneity of multivariate dispersions
##
## Call: betadisper(d = trawl_dist, group = ME_group_data$Region)
##
## No. of Positive Eigenvalues: 83
## No. of Negative Eigenvalues: 111
##
## Average distance to median:
##      1      2      3      4      5
## 0.3754 0.3522 0.3255 0.3354 0.3214
##
## Eigenvalues for PCoA axes:
## (Showing 8 of 194 eigenvalues)
## PCoA1 PCoA2 PCoA3 PCoA4 PCoA5 PCoA6 PCoA7 PCoA8
## 7.177 4.988 3.828 2.354 1.707 1.515 1.353 1.176
```

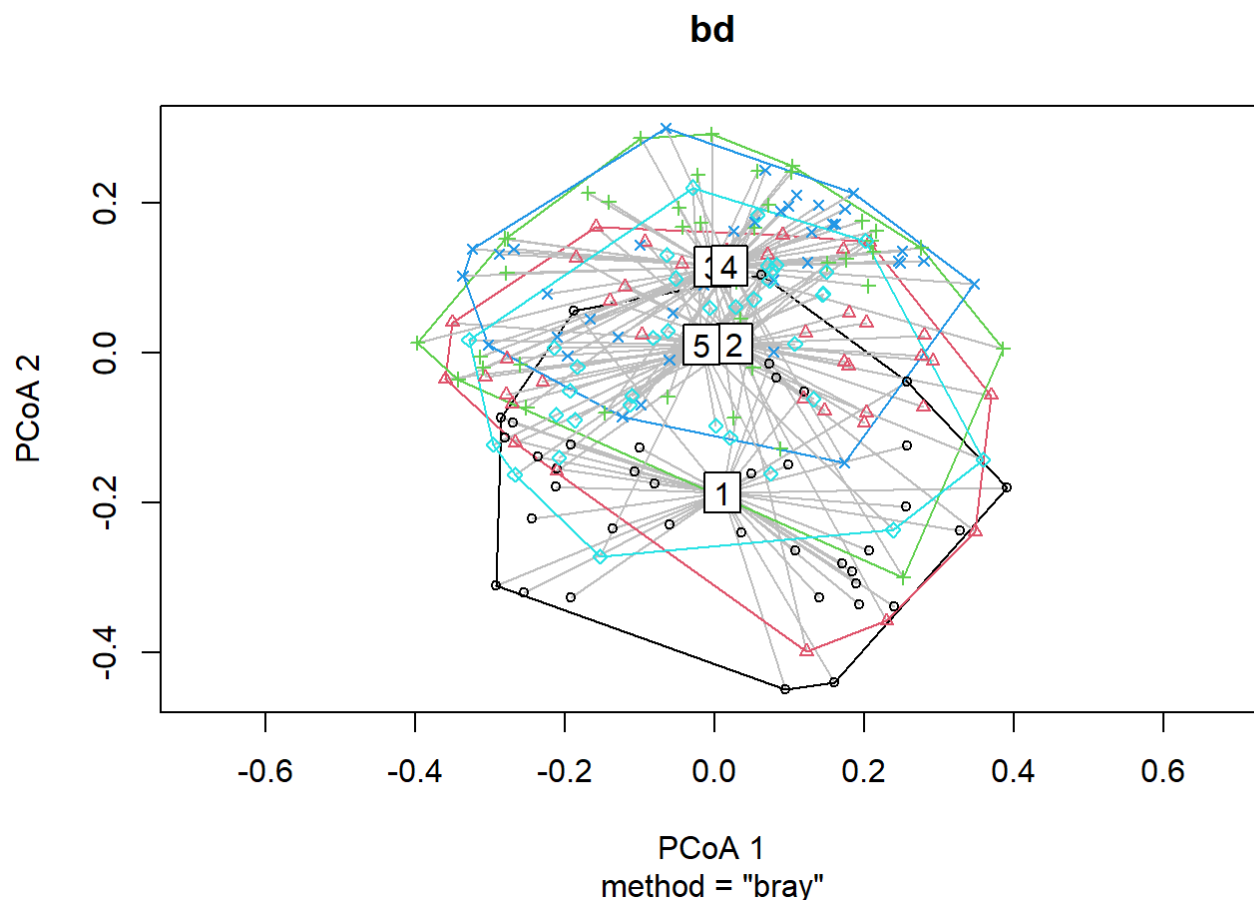
```
anova(bd)
```

```
## Analysis of Variance Table
##
## Response: Distances
##           Df Sum Sq Mean Sq F value Pr(>F)
## Groups      4 0.07648 0.0191204  2.0314 0.09165 .
## Residuals 190 1.78838 0.0094125
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#test based on permutations
permutest(bd)
```

```
##
## Permutation test for homogeneity of multivariate dispersions
## Permutation: free
## Number of permutations: 999
##
## Response: Distances
##           Df Sum Sq Mean Sq      F N.Perm Pr(>F)
## Groups      4 0.07648 0.0191204 2.0314   999 0.096 .
## Residuals 190 1.78838 0.0094125
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
plot(bd)
```



## Year

```
#Year
bd<-betadisper(trawl_dist,ME_group_data$Year)
bd
```

```
##
## Homogeneity of multivariate dispersions
##
## Call: betadisper(d = trawl_dist, group = ME_group_data$Year)
##
## No. of Positive Eigenvalues: 83
## No. of Negative Eigenvalues: 111
##
## Average distance to median:
##   2000   2001   2002   2003   2004   2005   2006   2007   2008   2009   2010
## 0.2937 0.3911 0.3688 0.3792 0.4275 0.3783 0.3880 0.4373 0.3760 0.3541 0.3072
##   2011   2012   2013   2014   2015   2016   2017   2018   2019
## 0.3562 0.2519 0.2343 0.2767 0.3180 0.2854 0.2742 0.3512 0.2904
##
## Eigenvalues for PCoA axes:
## (Showing 8 of 194 eigenvalues)
## PCoA1 PCoA2 PCoA3 PCoA4 PCoA5 PCoA6 PCoA7 PCoA8
## 7.177 4.988 3.828 2.354 1.707 1.515 1.353 1.176
```

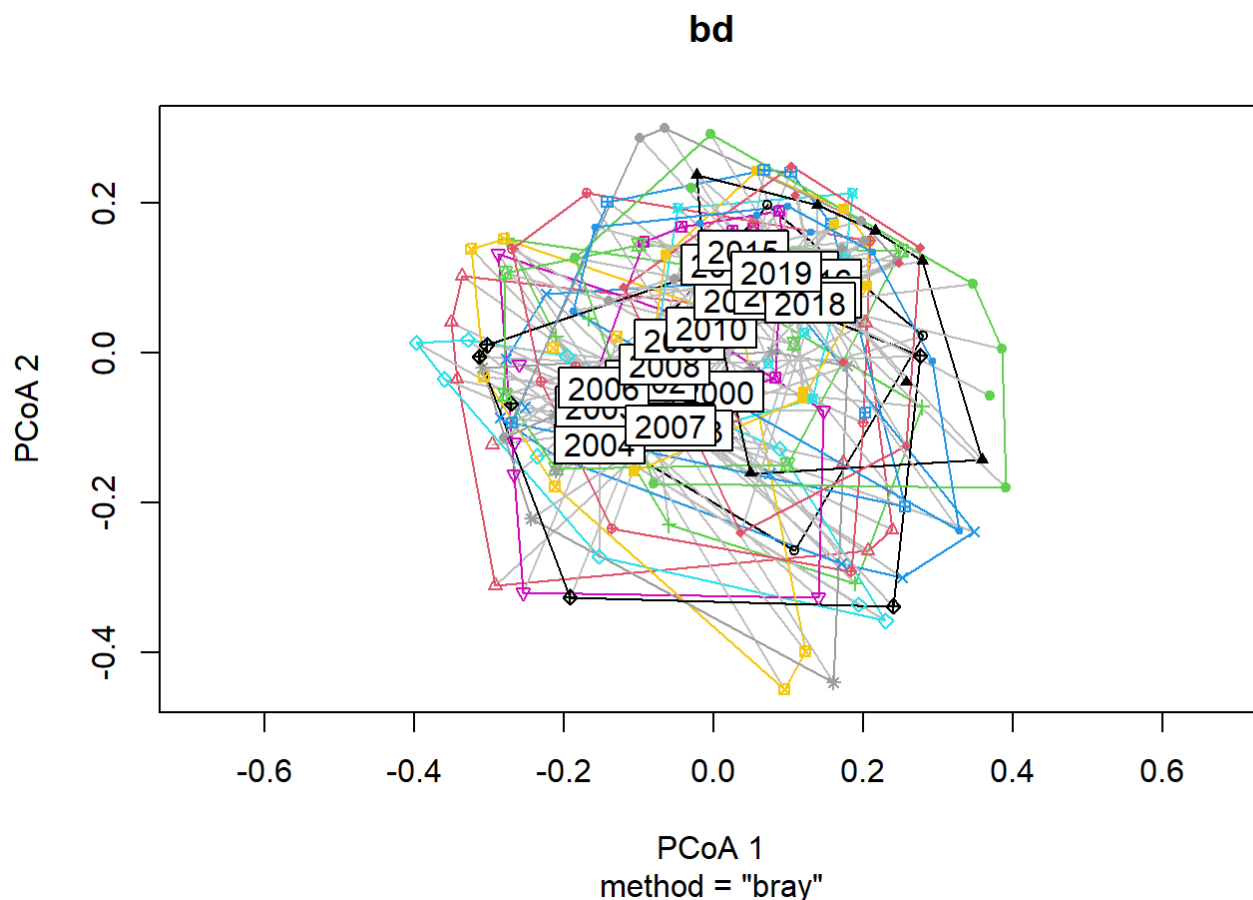
```
anova(bd)
```

```
## Analysis of Variance Table
##
## Response: Distances
##           Df Sum Sq Mean Sq F value    Pr(>F)
## Groups      19 0.63018  0.033167   3.6271 2.865e-06 ***
## Residuals  175 1.60025  0.009144
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#test based on permutations
permutest(bd)
```

```
##
## Permutation test for homogeneity of multivariate dispersions
## Permutation: free
## Number of permutations: 999
##
## Response: Distances
##           Df Sum Sq Mean Sq      F N.Perm Pr(>F)
## Groups      19 0.63018  0.033167 3.6271   999 0.001 ***
## Residuals  175 1.60025  0.009144
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
plot(bd)
```



## Year block

```
#Year blocks
bd<-betadisper(trawl_dist,ME_group_data$YEAR_GROUPS)
bd
```

```
##
## Homogeneity of multivariate dispersions
##
## Call: betadisper(d = trawl_dist, group = ME_group_data$YEAR_GROUPS)
##
## No. of Positive Eigenvalues: 83
## No. of Negative Eigenvalues: 111
##
## Average distance to median:
## 2000-2004 2005-2009 2010-2014 2015-2019
## 0.3991 0.4011 0.3045 0.3175
##
## Eigenvalues for PCoA axes:
## (Showing 8 of 194 eigenvalues)
## PCoA1 PCoA2 PCoA3 PCoA4 PCoA5 PCoA6 PCoA7 PCoA8
## 7.177 4.988 3.828 2.354 1.707 1.515 1.353 1.176
```

```
anova(bd)
```

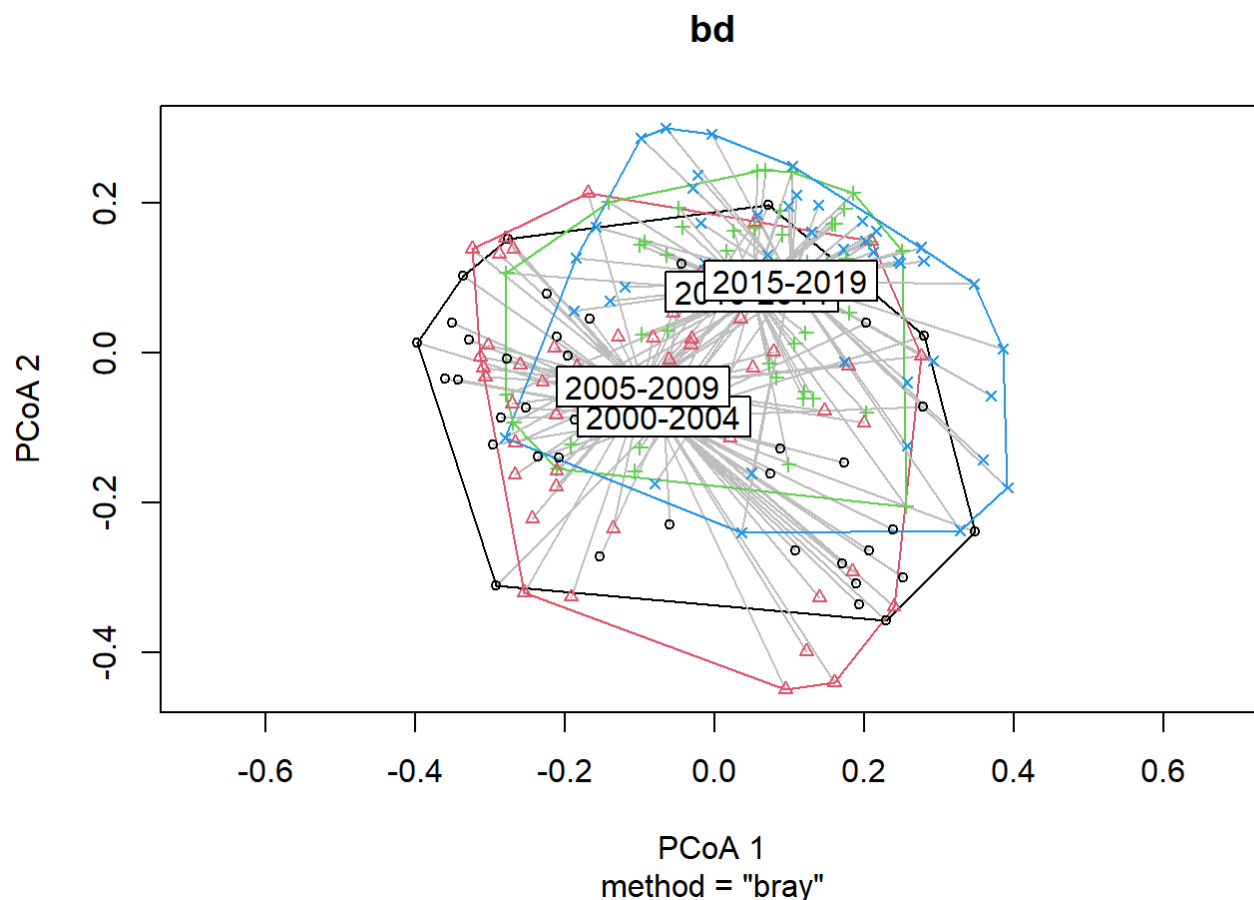
```
## Analysis of Variance Table
##
## Response: Distances
##           Df Sum Sq Mean Sq F value    Pr(>F)
## Groups      3  0.39156  0.130521   14.687 1.205e-08 ***
## Residuals 191  1.69735  0.008887
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#test based on permutations
permutest(bd)
```

```
##
## Permutation test for homogeneity of multivariate dispersions
## Permutation: free
## Number of permutations: 999
##
## Response: Distances
##           Df Sum Sq Mean Sq      F N.Perm Pr(>F)
## Groups      3  0.39156  0.130521  14.687    999  0.001 ***
## Residuals 191  1.69735  0.008887
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
plot(bd)
```





## Indicator species analysis

- test if a species is found significantly more in one group compared to another
- all combinations of groups

## Region

```
#see which species are found significantly more in each Region
inv_region<-multipatt(ME_NMDS_data, ME_group_data$Region, func = "r.g", control = how(nperm=999))
summary(inv_region)
```

```

##
## Multilevel pattern analysis
## -----
##
## Association function: r.g
## Significance level (alpha): 0.05
##
## Total number of species: 50
## Selected number of species: 37
## Number of species associated to 1 group: 17
## Number of species associated to 2 groups: 15
## Number of species associated to 3 groups: 3
## Number of species associated to 4 groups: 2
##
## List of species associated to each combination:
##
## Group 1 #sps. 9
##
##          stat p.value
## flounder.yellowtail 0.789 0.001 ***
## cod.atlantic         0.517 0.001 ***
## haddock              0.412 0.001 ***
## dogfish.spiny       0.379 0.001 ***
## hake.atlantic.red    0.280 0.003 **
## mackerel.atlantic    0.219 0.031 *
## squid.long.finned    0.211 0.042 *
## butterfish          0.210 0.046 *
## redfish.acadian.ocean.perch 0.205 0.001 ***
##
## Group 2 #sps. 4
##
##          stat p.value
## alewife              0.455 0.001 ***
## crab.northern.stone 0.354 0.001 ***
## smelt.rainbow        0.340 0.001 ***
## sturgeon.atlantic    0.256 0.004 **
##
## Group 4 #sps. 3
##
##          stat p.value
## cucumber.sea 0.224 0.002 **
## scallop.sea 0.205 0.048 *
## crab.green 0.172 0.008 **
##
## Group 5 #sps. 1
##
##          stat p.value
## flounder.winter 0.646 0.001 ***
##
## Group 1+2 #sps. 7
##
##          stat p.value
## plaice.american..dab. 0.676 0.001 ***
## shad.american         0.401 0.001 ***
## cunner                0.380 0.001 ***
## sculpin.longhorn      0.334 0.002 **
## herring.blueback      0.305 0.002 **
## monkfish              0.291 0.002 **

```

```
## crab.red          0.219   0.002 **
##
## Group 1+5 #sps. 6
##
##               stat p.value
## sea.raven      0.533   0.001 ***
## skate.little    0.477   0.001 ***
## pout.ocean      0.460   0.001 ***
## skate.smooth    0.299   0.003 **
## skate.winter    0.229   0.019 *
## flounder.atlantic.witch..gray.sole. 0.215   0.038 *
##
## Group 3+4 #sps. 1
##               stat p.value
## crab.atlantic.rock 0.347   0.001 ***
##
## Group 4+5 #sps. 1
##               stat p.value
## crab.jonah 0.339   0.001 ***
##
## Group 1+2+5 #sps. 1
##               stat p.value
## skate.thorny 0.297   0.001 ***
##
## Group 2+3+4 #sps. 1
##               stat p.value
## herring.atlantic 0.319   0.001 ***
##
## Group 3+4+5 #sps. 1
##               stat p.value
## halibut.atlantic 0.26   0.002 **
##
## Group 1+2+3+4 #sps. 1
##               stat p.value
## hake.silver..whiting. 0.209   0.034 *
##
## Group 2+3+4+5 #sps. 1
##               stat p.value
## lobster.american 0.329   0.001 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

## Year block

```
#see which species are found significantly more in each Region
inv_year<-multipatt(ME_NMDS_data, ME_group_data$YEAR_GROUPS, func = "r.g", control = how(n
perm=999))
summary(inv_year)
```

```

##
## Multilevel pattern analysis
## -----
##
## Association function: r.g
## Significance level (alpha): 0.05
##
## Total number of species: 50
## Selected number of species: 24
## Number of species associated to 1 group: 14
## Number of species associated to 2 groups: 8
## Number of species associated to 3 groups: 2
##
## List of species associated to each combination:
##
## Group 2000-2004 #sps. 6
##          stat p.value
## scallop.sea 0.374 0.001 ***
## skate.little 0.321 0.001 ***
## sea.raven 0.318 0.001 ***
## monkfish 0.281 0.001 ***
## skate.winter 0.236 0.005 **
## scup 0.202 0.001 ***
##
## Group 2005-2009 #sps. 4
##          stat p.value
## plaice.american..dab. 0.269 0.002 **
## wolffish.atlantic 0.207 0.022 *
## cod.atlantic 0.188 0.043 *
## squid.short.finned 0.184 0.021 *
##
## Group 2010-2014 #sps. 1
##          stat p.value
## crab.green 0.152 0.003 **
##
## Group 2015-2019 #sps. 3
##          stat p.value
## hake.atlantic.red 0.337 0.001 ***
## haddock 0.305 0.001 ***
## hake.white 0.303 0.001 ***
##
## Group 2000-2004+2005-2009 #sps. 5
##          stat p.value
## sculpin.longhorn 0.436 0.001 ***
## menhaden.atlantic 0.233 0.007 **
## smelt.rainbow 0.213 0.014 *
## skate.thorny 0.206 0.026 *
## lumpfish 0.171 0.025 *
##
## Group 2010-2014+2015-2019 #sps. 3
##          stat p.value
## lobster.american 0.499 0.001 ***
## skate.barndoor 0.231 0.011 *

```

```
## halibut.atlantic 0.230    0.010 **
##
## Group 2000-2004+2005-2009+2015-2019 #sps. 1
##          stat p.value
## crab.jonah 0.286    0.001 ***
##
## Group 2000-2004+2010-2014+2015-2019 #sps. 1
##          stat p.value
## hake.silver..whiting. 0.279    0.001 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```