PRIMER-e
Empowering Research

PERMANOVA+ *Course in Multivariate Analysis*

Outline of Topics

*Each **lecture topic** is followed by a **computer practical** session where participants explore the topic using literature/published datasets.*

1	Introduction to permutational multivariate analysis of variance (**PERMANOVA**); partitioning for ANOVA designs; partitioning of sums of squares (SS) for multivariate data in the space of a chosen resemblance measure using a geometric approach.
2	Two-way analyses with **PERMANOVA**; testing and interpreting multivariate interactions; pair-wise comparisons; constructing specific *a priori* contrasts.
3	Permutational tests of homogeneity of multivariate dispersions (**PERMDISP**); permutation of residuals.
4	Dissimilarity measures and their properties (e.g., Jaccard, Sørensen, Euclidean, Bray-Curtis); multivariate dispersion as a measure of beta diversity (**PERMDISP**).
5	Principal coordinate analysis (**PCO**); comparison with **PCA**, **metric MDS**, **threshold-metric MDS**, and **non-metric MDS**; vector overlays; bubble plots.
6	Experimental design; fixed *vs* random factors; nested *vs* crossed relationships among factors; consequences for the expectations of mean squares (EMS), the construction of pseudo-*F* test-statistics, the hypothesis being tested and the extent of the inferences (**PERMANOVA**).
7	Estimating components of variation; degrees of freedom; hierarchical designs (**PERMANOVA**).
8	Simplifying **PERMANOVA** models; pooling or removing terms; how to tackle larger numbers of factors; multi-factorial designs and mixed models. Using **distances among centroids** to visualise salient factors and interactions in multi-factorial designs.
9	Unbalanced designs; Types of sums of squares; quantitative covariates; ANCOVA designs and their interpretation; interactions between covariates and ANOVA factors (**PERMANOVA**).
10	Experimental designs for detecting environmental impacts; BACI and beyond-BACI; designs that lack replication; asymmetrical designs (**PERMANOVA**).
11	Continuous predictor variables; regression; linear models; multiple regression; marginal and sequential permutation tests for linear models in **DISTLM**.
12	Multivariate multiple regression and redundancy analysis (RDA); explaining variation in community structure using continuous (e.g. environmental) variables (**DISTLM**); dissimilarity-based redundancy analysis (**dbRDA**).
13	Diagnostics on predictor (e.g., environmental) variables; model-selection procedures (forward, backward, step-wise or 'best') and criteria (R^2, adjusted R^2, AIC, AICc or BIC); analysing predictor variables in sets; coding for categorical predictors; visualising fitted values through constrained ordination (**dbRDA**).
14	Canonical analysis of principal coordinates (**CAP**); generalised discriminant analysis based on distances; diagnostics for CAP models; leave-one-out allocation success.
15	**CAP** as a predictive model; allocation of new (unknown or validation) samples to pre-existing groups.
16	Canonical analysis for continuous gradients (**CAP**); leave-one-out residual SS; models of community change along environmental/pollution gradients; models of 'ecosystem health' and monitoring; placement of new points onto gradients; canonical correlation and multiple X variables.
17	Wrap-up of the week with an overview of the **PERMANOVA+** tools. 'Own-data' analysis session, in consultation with the presenter.

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Provisional Time-Table

The time-table below is a rough guide only. Lectures and labs may flow over or under allotted time-slots, depending on the depth of coverage of specific topics, the number and length of participant-led questions and ensuing discussions, etc. The flow between lectures and computer practicals will be seamless.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Session 1 08:30 – 10:30	(**1**) ANOVA and PERMANOVA; one-way designs	(**5**) PCO, MDS (non-metric, metric and threshold metric)	(**9**) Unbalanced designs; covariates (PERMANOVA)	(**13**) Model selection (DISTLM)	(**17**) 'Own-data' session
Coffee/Tea Break 10:30 – 11:00					
Session 2 11:00 – 12:30	(**2**) PERMANOVA; two-way designs; interactions	(**6**) Fixed/random; crossed/nested (PERMANOVA)	(**10**) BACI and beyond (PERMANOVA)	(**14**) CAP; discriminant analysis	(**17**) 'Own-data' session (cont'd)
Lunch 12:30 – 13:30					
Session 3 13:30 – 15:30	(**3**) PERMDISP; permutation of residuals	(**7**) Components of variation; df; (PERMANOVA)	(**11**) DISTLM; simple and multiple regression	(**15**) CAP; predictive models	(**17**) 'Own-data' session (cont'd)
Coffee/Tea Break 15:30 – 16:00					
Session 4 16:00 – 17:30	(**4**) Resemblances; Beta diversity (PERMDISP)	(**8**) Complex designs; pooling; Distances among centroids	(**12**) DISTLM; dbRDA	(**16**) CAP; gradients; canonical correlation	(**17**) 'Own-data' session (cont'd)

Throughout, participants will be given real data sets to analyse, but they may also wish to bring their own data. These should be in numeric, rectangular arrays, with variables (e.g. species) as rows and samples as columns (or vice-versa), in an Excel spreadsheet, csv or text file. Non-numeric information (factors) on each sample are placed below (or to the side of) this table, separated by a blank row (or blank column). There is also a 3-column format (sample label, variable label, non-zero entry) suitable for entry from large record-type databases. Participants will have the opportunity to discuss their own dataset(s), sampling design(s), experiment(s), analyses and interpretation(s) in direct consultation with the presenter on Friday, during the 'own-data' sessions.