PRIMER-e
empowering research

PERMANOVA+ WORKSHOP
Multivariate Analysis in Ecology (& other Sciences)

OUTLINE of TOPICS – PERMANOVA+ WORKSHOP

*Each **lecture topic** below 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 one-way ANOVA designs; motivation and comparison with MANOVA and ANOSIM; distance-based partitioning of sums of squares (SS) for multivariate data 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., simple matching, Jaccard, Sørensen, Euclidean, chi-squared, Bray-Curtis, modified Gower); effects of different dissimilarity measures on relative dispersions; multivariate dispersion as a measure of beta diversity (**PERMDISP**).
5	Principal coordinate analysis (**PCO**); comparison with **PCA**, **metric MDS** and **non-metric MDS**; negative eigenvalues; vector overlays (pros and cons); 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; exchangeable units for permutation dictated by denominator mean squares; hierarchical designs (**PERMANOVA**);
8	Simplifying **PERMANOVA** models; pooling or removing terms; how to tackle higher-way multi-factorial designs and mixed models. Using **distances among centroids** (**PCO** axes) to visualise salient factors and interactions in multi-factorial designs; Monte Carlo P-values.
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. A plethora of ways to model community responses in 'time' or 'space'.
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; visualizing fitted values through constrained ordination (**dbRDA**).
14	Canonical analysis of principal coordinates (**CAP**); generalized discriminant analysis based on distances; finding axes through the cloud of points that best discriminate among groups; diagnostics for CAP models; leave-one-out allocation success.
15	**CAP** as a predictive model; allocation of new (unknown or validation) samples to existing groups
16	Canonical analysis of 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.

PROVISIONAL TIMETABLE – PERMANOVA+ WORKSHOP

The timetable 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 labs will be seamless. All times below are given in Pacific Standard Time, USA (UTC – 8 hrs).

	Monday	Tuesday	Wednesday	Thursday	Friday
Session 1 08:30 – 10:30	(**1**) PERMANOVA; rationale; one-way designs	(**5**) PCO; negative eigenvalues; vector overlays	(**9**) Unbalanced designs; covariates (PERMANOVA)	(**13**) Model selection (DISTLM)	(**17**) 'Own-data' session
Coffee 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 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 are also encouraged to bring their own data. These should be in numeric, rectangular arrays, with variables (e.g. species) as rows, samples as columns (**or** *vice-versa*), in an Excel spreadsheet 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 (during the 'own-data' sessions scheduled for Friday) to discuss their own data, projects, sampling/experimental designs and analyses by booking an individual (or small-group) online consultation session with the presenter.