

# 9.1 Why group covariables together?

There are situations where it may be useful or important to include one or more quantitative covariables in a PERMANOVA model. For example, in our study of invertebrates inhabiting holdfasts of the kelp, *Ecklonia radiata*, it was not possible to standardise the sizes of the individual holdfasts that were sampled, but roughly, because every individual kelp that we sampled was naturally unique in size. Thus, we measured the volume of each collected holdfast using water displacement. This continuous quantitative variable (*volume*) could then be used as a *covariable* in subsequent PERMANOVA analyses that compared the sizes of variance components at several hierarchical spatial scales ( [Anderson et al. \(2005\)](#) ).

PERMANOVA in PRIMER has, historically, always permitted the inclusion of more than one covariable at a time, *but* these were always treated as individual variables singly in PERMANOVA models. Specifically, each covariable is fitted linearly in the space of the resemblance measure and contributes 1 extra degree of freedom to the fitted model. An important limitation here, however, was that multiple covariables could not be 'kept together' and treated as a combined group in the analysis; so tests of their combined effect were not available. Of course, one could use the facility in DISTLM to fit a linear model on a combined set of quantitative (or other) variables, but in DISTLM, there is unfortunately no way to specify a complex ANOVA-style design with (say) random factors and/or nested/hierarchical terms.

In P8, it is now possible to *group multiple covariables together* using an indicator, so that a *set* of covariables are treated in a combined fashion in any PERMANOVA model. One or more sets of covariables can be specified in any given PERMANOVA model in the design file (along with one or more other factors that are identified in the usual way). Each *set* of covariables will then be included as a *single line* in the PERMANOVA output table, potentially contributing multiple degrees of freedom to the fitted model. In addition, one can choose either to include or exclude interactions of covariables (or sets of covariables) with either: (i) other factors, and/or (ii) other covariables (or sets of covariables).

This facility opens the door to a veritable plethora of new ways of formally analysing multivariate patterns and structures in the space of the chosen resemblance measure. It permits more complex conceptual spatio-temporal models to be examined formally with ease, such as spatial models with both latitude and longitude (that might also include multiple polynomials) or, notably, *periodic or cyclical models* (e.g., as would be used to capture seasonal patterns) and any other multi-dimensional model structures that might require multiple covariables (degrees of freedom) to model adequately within an ANOVA framework.

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