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Using multitable techniques for assessing copepods structure and succession in a temperate shallow estuary

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Abstract. *This study investigated copepod assemblages' distribution patterns and determined the main physical factors structuring it at different temporal scales. Copepods surveys were conducted seasonally from three years period, at five stations in Mondego estuary. Spatial variability of copepod community was analyzed using STATICO. Spatial variability of the environmental conditions was the main driver responsible for copepod community structure observed. The STATICO analysis, based on the 12 environmental variables and on the density of the 28 species, showed that the relationship between environmental variables and copepods appeared to be stronger in the north arm of the Mondego estuary followed, in decrease order of importance, by the mouth and the south arm of the estuary. STATICO also emphasized the effects of environment at spatial scales. The stable part of the species-environment relationships resulted from the combination of a salinity and temperature gradient linked to a fresh, brackish- and marine species gradient, which was dependent on site localization. The STATICO proved to be a valuable statistical tool to get a clear representation of spatial organization of the copepod assemblages.*

Keywords. *Multitable analysis; STATICO; Three-way data; Estuaries.*

1 Background and aims of the study

Environmental or species data sets can be multidimensional and have a complex structure. Usually, they are collected as a set of objects and variables (tables or matrices) obtained under different experimental circumstances or for various sampling periods, etc. Putting all tables together results in data with three-way structure. An example for such data is when in samples collected at different sampling sites, several environmental parameters (or species abundances) are measured during certain period of time (sites x parameters/abundances x time). There are many tools helping to explore and interpret three or higher way structure of the data. The aim of this work is (1) to use a method, called STATICO (Simier et al., 1999; Thioulouse et al., 2004), since it performs a simultaneous analysis of a sequence of paired ecological tables, evaluates the common structure between environmental and species abundances tables as well as the stability of this structure over a sampling period and can be applied for exploratory analysis of three-way data sets; (2) to demonstrate features of STATICO on real ecological data sets; and (3) to compare the advantages of STATICO over others multitable analysis.

2 The data

For this study, copepods assemblages were studied monthly, from March 2005 to November 2007, in a temperate shallow estuary (Mondego estuary, Portugal), across five stations. A total number of 28 species were found. Each of them represented more than 0.01% of the total abundance. These data were assembled inside two matrices comprising 152 rows, in which each column corresponded to a variable (species density or environmental parameters) and each sample occupied a row. These matrices were then subdivided into 5 sub-matrices, each corresponding to one station. Species density was changed to $log(x+1)$ prior to calculations (Legendre and Legendre, 1979), to minimize the dominant effect of exceptional catches and environmental data were normalized to homogenize the table.

3 The approach and models used: the STATICO method

STATICO analysis identifies the environmental factors that have a permanent effect on assemblages and sorting them out from those which act temporally or on specific sites. This method proceeds in three stages: (1) the first stage consists in analyzing each table by a one-table method (normed PCA of the environmental variables and centered PCA of the species data); (2) each pair of tables is linked by the Co-inertia analysis (Dolédec and Chessel, 1994) which provides an average image of the co-structure (species-variables); (3) Partial Triadic Analysis (Thioulouse and Chessel, 1987) is finally used to analyze this sequence. It is a three-step procedure, namely the interstructure, the compromise and the intrastructure analyses. STATICO also enables to plot the projection of the sampling seasons of each original table on the compromise axes (of the PCA factor map), in terms of species density and environmental factors structures. Hence, it is possible to discuss the correlation between species distribution and environmental factors. Due its properties STATICO could be presented as a very attractive three-way exploratory tool for the analysis of species-environmental relationship. Calculations and graphs were done using ADE-4 software (Thioulouse et al., 1997). This software is available free of charge at the following Internet address: http://pbil.univ-lyon1.fr/ADE-4.

4 Results

The application of this method proved to be well adapted in taking into account the spatio-temporal dynamics of both environmental factors and density of copepods, and the relationships between these two datasets. The interstructure factor map of the STATICO analysis, based on the 12 environmental variables and on the abundances of the 28 species, showed that the relationship between environmental variables and copepods appeared to be stronger in north arm of the estuary followed, in decrease order of importance in the compromise, by the sampling station at the mouth of the estuary (meaning that the compromise will be more influenced by these sampling stations). The remaining samples presented short relevance, which means that the corresponding tables are less structured and that their importance in the compromise will be lower. The first two axes represented, respectively, 69% and 11% of the total variability. The compromise revealed that the first axis was clearly dominant, and accounted for 89% of the explained variance in contrast with the second axis which accounted for 4% of the explained variance and was much less significant. The co-structure (divided according to sampling stations) clearly showed the dynamics of species-environment relationships and highlighted differences between seasons. This is possible through the visualization of the projection of each sample by two points: one is the projection of the row of the species table, and the other is the projection of the row of the environmental table. The length of the connecting line reveals the disagreement or the consensus between the two profiles (species-environment), i.e., the length of the line is proportional to the divergence between the datasets. When the datasets agree very strongly, the arrows will be short. Likewise, a long arrow demonstrates a locally weak relationship between the environment and species features for that case. So, this projection in terms of both environmental and copepods structure enables us not only to mark associations between species themselves but also to highlight the co-structures species-environment which are specific to some sampling station of the estuary. The result of the analysis provides an alternative solution by showing relevant associations and can improve the knowledge of the dynamics of species-environmental assemblages.

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