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Enough is enough: searching for the optimal sample size to characterize and monitoring sand dune Natura 2000 habitats

Enrico Tordoni[1]*, _Claudia Angiolini[2]_, _Giovanni Bacaro[1]_, _Andrea Bertacchi[3]_,
Daniela Ciccarelli[4], _Bruno Foggi[5]_, _Matilde Gennai[5]_, _Simona Sarmati[2]_, _Daniele Viciani[5]_,
Simona Maccherini[2]

[1]Department of Life Sciences, University of Trieste, via L. Giorgieri 10, 34127 Trieste, Italy
[2]Department of Life Sciences, University of Siena, via P.A. Mattioli 4, 53100 Siena, Italy
[3]Department of Agriculture, Food and Environment, University of Pisa, via del Borghetto 80, 56124 Pisa, Italy
[4]Department of Biology, University of Pisa, via Luca Ghini 13, 56126 Pisa, Italy
[5]Department of Biology, University of Florence, via G. La Pira 4, 50121 Firenze, Italy
*E-mail: etordoni@units.it

Coastal dune systems are among the most threatened and investigated environment worldwide. Sand dune are characterized by a marked vegetation zonation which often host rare or exclusive species. Due to their particular characteristics, most of the habitats occurring in these environments are considered of community interest (Directive 92/43/EEC) and protected within the Natura 2000 Network; therefore, continuous monitoring actions are needed in order to assess habitat changes or biodiversity loss. However, multifaced monitoring of community composition is usually considered a problematic task for three main reasons: inadequacy of a single monitoring design for all species occurring in a community (e.g., rare vs. common species), unpredictable and often unquantifiable variability of the multivariate dataset, high costs. Recently, Anderson and Santana-Garcon (2015) proposed a measure of variability defined "pseudomultivariate dissimilarity-based standard error" (_MultSE_) for assessing the sample-size adequacy in studies of ecological communities. This measure can be interpreted as a multivariate precision estimate for multivariate assemblage data in the space of the chosen dissimilarity measure. In this study, we aimed at: 1) using the _MultSE_ to determine the adequate number of replicates needed to characterize the species composition of sand dune habitat within a given precision level; 2) understanding how the observed compositional variation is partitioned among the spatial levels of the sampling design adopted. Combining these two types of information could be vital to design efficient and optimized future sampling campaign for monitoring purposes. Accordingly, we sampled psammophilous vegetation by using a simple random sampling in three EUNIS habitat types (shifting coastal dunes - B1.3; coastal stable dune grassland - B1.4, and coastal dune scrub - B1.6) belonging to three Special Areas of Conservation (SACs) in Tuscany ("Parco dell'Uccellina", "Dune Litoranee di Torre del Lago", "Selva Pisana"). Plant species composition and abundance were sampled in a total of 206 squared plots (size 4 m^2) during spring-summer 2018. Analyses were performed both on abundance and incidence matrices using Bray-Curtis and Jaccard distances, respectively. The study of the _MultiSE_ profiles revealed that an approximated number of 10 plots was able to grasp the overall variation in plant composition for B1.3 and B1.6

habitats, while a sampling effort of about 25 plots was needed for habitat B1.4. A two-way PERMANOVA confirmed that plant community composition is significantly explained by the interaction between habitat type and SAC. The analysis of diversity components for the studied communities (namely α and β diversity) pointed further out that the three sampling sites actually protect different dune vegetation and plant communities, especially among habitats. To the best of our knowledge, this is one of the first attempt made to characterize sampling adequacy in plant communities using *MultSE*. Our results, that evaluated different aspects of the multivariate variability in plant communities, will be useful for plant ecologists and nature managers to plan optimal sampling design for habitat monitoring activities.

References
1. Anderson, M.J., Santana-Garcon, J., 2015. Measures of precision for dissimilarity-based multivariate analysis of ecological communities. Ecol. Lett. 18: 66–73.