



## Original Articles

## Food web attributes to assess spatial–temporal dynamics in estuarine benthic ecosystem

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## ABSTRACT

Threatened benthic ecosystems need urgent tools for effective bioassessment and relevant management. EU Marine Strategy Framework Directive (MSFD) obligates member states to achieve GES (Good Environmental Status) for 11 descriptors of environmental state (MSFD; 2008/56/EC). From all of the descriptors, D4 that focuses on Food Webs is the most functional-oriented indicator, but also the most challenging to implement due to our limited knowledge on benthic interactions. Particularly, it is still unclear how spatially and temporally regulated abiotic variables determine the entire benthic food webs, and which benthic food web attributes best respond to these spatially and temporally derived environmental variations. To fill this gap, we measured the natural isotopic ratios ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) of macrobenthic organisms and their food sources and build twelve food web topologies across three distinct sites (Navigator, Gambia, Tróia) in summer and winter during two consecutive years. To assess these food web topologies, we applied isotopic metrics, further integrated with univariate and multivariate analysis to find food web-based indicators that best respond to these spatial and temporal variability.

We found clear spatial patterns associated to an increase in primary production and quantity and quality of organic matter (OM). Sites with higher organic load and less quality OM (Navigator and Gambia) had simpler food webs, likely associated to high abundance of opportunistic meiobenthic species. Site located inside protected area (Tróia) with high quality OM had the most complex food web characterized by high diversity of specialist consumers that used more efficiently available resources. Similarity metrics were valuable complementary tool that helped to further disentangle the causes of spatial variability, in this case distinguishing between two food webs (Navigator and Gambia) that had similar structures but different resource utilization.

The temporal patterns were not so evident than the spatial patterns, although significant differences were reported between sampling occasions for the same metrics (maximum trophic position and the percentage of carnivores and omnivores,  $p < 0.05$ ). The most complex Tróia's food web demonstrated greater responsiveness in capturing temporal differences in resource use, suggesting that more complex food webs are better equipped to reflect temporal variability. The integration of isotopic metrics complemented with multivariate and univariate analyses proved to be an important tool for the analysis of different aspects of the benthic food web complexity in a spatial–temporal context providing a promising approach to assess the functional integrity of the estuarine ecosystems, especially in the context of the descriptor 4 within MSFD.

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