

# **Energetic biomarkers and integrated biological indices reveal anthropogenic pressure in coastal mussels near the Oum Er-Rbia estuary (Moroccan Atlantic coast)**

**(ORAL)**

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## **Abstract**

Coastal ecosystems are increasingly exposed to multiple anthropogenic pressures, calling for assessment approaches that integrate environmental conditions with biological responses. In this study, physiochemical parameters, energetic biomarkers, and integrated biological indices were combined to evaluate spatial patterns of anthropogenic pressure along the Moroccan Atlantic coast. Two mussel species, *Perna perna* and *Mytilus galloprovincialis*, were used as bioindicators at coastal sites subjected to contrasting levels of human influence. The studied sites are located along the Moroccan Atlantic coast in the vicinity of the Oum Er-Rbia estuary, an area subjected to combined urban and estuarine influences.

Nutrient concentrations were used to derive an Organic Pollution Index. At the same time, energetic biomarkers (proteins, lipids, and carbohydrates) measured in the hepatopancreas were integrated into a biological index reflecting organism energetic status. Clear spatial differences were observed, with impacted sites showing higher nutrient levels and altered energetic reserves in both mussel species compared to the reference site. Negative values of the integrated biological index consistently reflected these changes.

The convergence of responses across species supports the robustness of the proposed framework and highlights the relevance of multi-species bioindication. By coupling chemical-based and biologically integrated indices, this approach provides a sensitive and operational tool for assessing coastal anthropogenic pressure and offers practical perspectives for environmental monitoring and management.

## **Key words**

Energetic biomarkers, Integrated biological indices, Mussels, Anthropogenic pressure, Coastal ecosystems.