{rokbox title=| Predicted isoscape surfaces for δ15N (A, C) and δ13C (B, D) across the Mediterranean Sea :: Image: Authors|images/stories/ieo/imagenespublicaciones/centro-oceanografico-baleares-ieo-csic-spatial-models-cannot-compensate-2026-albo-thumb-et-al.jpg|}images/stories/ieo/imagenespublicaciones/centro-oceanografico-baleares-ieo-csic-spatial-models-cannot-compensate-2026-albo-et-al.jpg{/rokbox}

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Spatial models cannot compensate for sampling designs unstructured relative to isotopic variation: implications for baseline isoscape development in the Mediterranean Sea.

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Abstract:Isoscapes – spatial models of stable isotope ratios – are powerful tools for understanding biogeochemical cycles, food web structure, and ecological connectivity. In marine systems, however, broad-scale isoscapes are difficult to constrain because reference datasets are typically heterogeneous and opportunistic. Bayesian hierarchical models

implemented through Integrated Nested Laplace Approximation (INLA) provide an efficient framework for modeling spatial patterns while accounting for non-spatial variance. We tested whether broad-scale geographic baseline isoscapes could be constrained for the Mediterranean Sea using INLA models applied to an opportunistically compiled dataset from this semi-enclosed basin, where strong environmental gradients are expected but spatially explicit baselines remain lacking. We assembled the most comprehensive dataset of δ13C and δ15N values to date for low-trophic-level, primarily epipelagic food web compartments (> 6,000 samples from > 600 sites). Although discrete regions of relatively high and low δ values were identified, particularly for δ15N, semivariograms and model outputs indicated only short-range spatial autocorrelation (ca. 40 km for δ13C; 65 km for δ15N) within this large dataset. Environmental covariates improved model fit for δ15N values but did not enhance predictive performance or alter spatial predictions. Our results demonstrate that even advanced spatial models may not compensate where sampling design is structurally mismatched relative to unknown but structured spatial and non-spatial sources of isotopic variation. Coordinated sampling designed to capture spatial variability while accounting for major sources of non-spatial variance is required to develop robust marine isoscapes supporting ecological and management applications in the Mediterranean Sea and similar regions.

Keywords:Isoscapes,Stable isotopes,Spatial modeling,Bayesian inference,Opportunistic datasets,Sampling design,Mediterranean Sea.