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Integrating environmental isoscapes for spatiotemporal assignment

G. Bowen (1), C. Bataille (1), C. Kennedy (1), T. Zhang (1), and J. West (2)
(1) Purdue University, West Lafayette IN, USA, (2) Texas A&M University, College Station TX, USA

Numerous case studies in the ecological and forensic fields have illustrated the potential utility of light stable isotopes as tracers of the geographic origin of biological materials. However, a number of critical challenges continue to limit the application of these tools, among them (1) limitations to our knowledge of isotopic values expected for materials formed at particular locations and times, (2) uncertainty in our understanding of the interplay between temporal and spatial variation in the isotope 'signature' transferred to isotopic materials, and (3) lack of robust, widely used models for quantitative statistical assessment of spatiotemporal origin and associated uncertainty. In order to acknowledge and address each of these limitations, we present new models and analysis of spatiotemporal variation in the stable isotope ratios of hydrogen, oxygen, and strontium in the environment, representing three isotope systems with strong and complementary potential for provenancing applications. We demonstrate a statistical framework for the integration of these isoscapes in assignment problems and describe how this toolkit has been made broadly accessible through the IsoMAP web-GIS portal.