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Inferring spatial structure from time-series data: using multivariate state-space models to detect metapopulation structure of California sea lions in the Gulf of California, Mexico

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1. Understanding spatial structure and identifying subpopulations are critical for estimating population growth rates and extinction risk, and as such essential for effective conservation planning. However, movement and spatiotemporal environmental data are often unavailable, limiting our ability to directly define subpopulations and their level of asynchrony. 2. This study applies a recently developed statistical technique using time-series analysis of abundance data to identify subpopulations. The approach uses multivariate state-space models and AIC-based model selection to quantify the data support for different subpopulation numbers and configurations. This technique is applied to the population of California sea lions *Zalophus californianus* in the Gulf of California, Mexico, distributed across 13 breeding sites. 3. The number of California sea lions have declined in the Gulf of California over the last decade, though not all areas have been equally affected. In light of this variation, it is important to understand the population structure to ensure accurate viability assessments and effective management.4. Our data support the hypothesis that the Gulf of California sea lion population has four subpopulations, each with two to five breeding sites. The dynamics between several adjacent subpopulations were correlated, suggesting that they experience similar environmental variation. For each subpopulation, we estimated long-term growth rates, as well as the environmental and observation variation. 5. For most of the subpopulations, our estimates of growth rates were considerably lower than those previously reported. In addition, we found considerable variability across subpopulations in their projected risk of severe decline over the next 50 years. 6. *Synthesis and applications.* We illustrate a new multivariate state-space modelling technique that uses timeseries ofabundance toquantify thedata support fordifferent subpopulationconfigurations. Our analysis of the California sea lion population in the Gulf of California indicates that the populationis spatially structuredinto four subpopulations, each exhibitingdistinct risks of extinction.Based on our results, we recommend that conservation and management efforts in the Gulf of California focus on the two subpopulations with high probabilities of extinction within the next 50 years (Northern Midriff, Southern Midriff).Multivariate state-space models provide a practical approach to determine the spatial structure of virtually any species; they may be particularly useful for species of conservation concern forwhich data on dispersal and environmental drivers are likely tobe scarce.

Palabras clave: zalophus californianus, MARSS, metapopulation, extinction risk, multivariate state-space model, spatial structure, stochastic growth rate