Using spatio-temporal models to infer ecological dynamics and estimate animal abundance from transect counts

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Abstract: Ecologists often estimate animal abundance by fitting models to transect survey count data. Such models often require that animal density remains constant across the landscape where sampling is being conducted. This assumption is problematic for animals inhabiting dynamic landscapes or otherwise exhibiting considerable spatio-temporal variation in density, and may be an impediment to inference about how changes in environmental conditions affect animals' spatial distribution. A variety of models have been developed for analyzing spatio-temporal variation in count data, but there has been little comparison of the efficacy of alternative modeling approaches for estimating animal abundance. We review several concepts from the burgeoning literature on spatio-temporal statistical models, including the nature of the temporal structure (i.e., descriptive or dynamical) and strategies for dimension reduction to promote computational tractability. We also review several features as they specifically relate to abundance estimation, including boundary conditions, population closure, choice of link function, and extrapolation of predicted relationships to unsampled areas. We compare a suite of novel and existing spatio-temporal hierarchical models for animal count data that permit animal density to vary over space and time. Models varied by the nature of the temporal structure (i.e., descriptive or dynamical), and whether total expected abundance was assumed constant over time (a pseudo-closure assumption). We gauge the relative performance (bias, precision, computational demands) of alternative spatio-temporal models when confronted with simulated and real datasets from dynamic animal populations. For the latter, we analyze spotted seal counts from an aerial survey of the Bering Sea where the quantity and quality of suitable habitat (sea ice) changed dramatically while surveys were being conducted.