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## Understanding mechanism of spatial ecological phenomena: a preface to the special feature on “Spatial statistics”

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Understanding of the mechanism underlying the spatial distribution of animal and plant populations is one of the central themes in ecology. Ecological patterns tend to have scale dependency, which is problematic for a comparative approach, but could itself indicate the underlying ecology governed by biological and physical phenomena operating on characteristic spatial scales (O'Neill 1989; Powell 1989; Levin 1992; Tuda 1993). Theoretical studies such as host–parasitoid models by Hassell et al. (1991) and Comins et al. (1992) have explored population behavior in spatially explicit lattice space. Similar phenomena can also be found in other fields of science (e.g., Kaneko 1984). There has been a gap between the advanced theory and understanding of crude spatial data in spatial ecology.

Recent advances in spatial statistics, however, shed light on empirical spatial ecology (e.g., Dale et al. 2002; Perry et al. 2002). Direct observation of marked organisms (e.g., Tuda and Shima 2002) and bottle experiments (Huffaker 1958; recent reviews, Bonsall and Hassell 2005; Cadotte et al. 2005; Jessup et al. 2005; Holyoak and Lawler 2005; Sabelis et al. 2005; Tuda and Shimada 2005) may be the most basic and simple approach to capturing spatial mechanisms in ecology. Nevertheless, spatial statistics proposed or applied here can bring greater understanding of mechanisms when larger sets of data with a wider range of spatial scales are available.

In practice, information we obtain may be limited to a single snapshot of multiple transitional states or quantitative attributes of a single state on a map. On the contrary, richer information may be available as time-series data of spatial patterns more like an animation. Here, I have invited papers tackling ecological spatial

dynamics: Schlicht and Iwasa (2007) aim to handle both snapshots and animations of forest disturbance patterns. The other two papers (Yamanaka et al. 2007; Kim et al. 2007) elucidate spatial correlations from animations of quantitative spatio-temporal data for multiple transitional states, making full use of established spatial statistical methods.

Schlicht and Iwasa (2007) proposed two statistical methods and tested their relevancy by fitting them to three hypothetical spatial patterns, generated by simulating models that employed different numbers of states (two, three, and continuous states respectively). The first method that detects directionality of regeneration waves succeeded in distinguishing two-state and three-state hypothetical data, whereas the second method, which detects spatial-scale dependency in the variance of fractions of states, distinguished the three-state and continuous-state hypothetical data. The kind of data most suitable for the two methods is the temporal dynamics of spatial patterns for the first method and single snapshots of spatial patterns for the second method. The authors applied these methods to observed forest disturbance patterns and detected proper models. This study not only provides forest ecologists with the most parsimonious descriptive models that may narrow down possible ecological mechanisms underlying observed spatial patterns, but can also be extended to analyses of other spatial distributions of plants and animals.

Yamanaka et al. (2007) tested two hypotheses, resource concentration and reaction diffusion, on the mechanism inducing spatial distribution of the ragweed beetle. The nonparametric auto- and cross-correlation functions, developed by Bjørnstad and his colleagues, were applied to the 3-year seasonal spatial dynamics of a resource (the ragweed) and its herbivorous predator (the ragweed beetle). The resource concentration hypothesis was only weakly supported. The nonparametric cross-correlation with time lags between the weed and the beetle, on the other hand, supported trophic interaction between the two at a certain spatial lag, thereby leading

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the authors to conclude that the reaction diffusion hypothesis explains more readily the spatial dynamics of the beetle.

Kim et al. (2007), as well as Yamanaka et al. (2007), studied seasonal spatial dynamics of the stage-structured density of herbivorous insects, but with different species, census strategy and statistical approach. The insect is a pest of rice, the black rice bug, and three developmental stages (the egg, nymph, and adult) were monitored for two rice fields over 2 years. The statistical method employed was SADIE, which quantifies spatial aggregation and association. Positive spatial association was elucidated among different developmental stages between successive census dates, especially between the nymph and the new adult (Table 3, Kim et al. 2007). The authors concluded that the spatial distribution of the rice pest is determined by the initial establishment of immigrant, overwintered adults and disturbance by heavy rainfall.

Interestingly, both Yamanaka et al. (2007) and Kim et al. (2007) indicate the emergence of spatial structure on small spatial scales, in spite of the difference in the biology of the studied insects (the sedentary nature and univoltinism of the rice bug versus the high mobility and multivoltinism of the ragweed beetle) and the census strategy (the higher census frequency in the latter). It would be intriguing to test further the directionality in the spatial patterns analyzed by these studies.

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