Some aspects of the spatial dynamics of weeds

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ABSTRACT

This paper reviews briefly my recent work on the spatial dynamics of weeds, with particular reference to the measurement of spatial pattern by the new techniques termed SADIE (Spatial Analysis by Distance IndicEs). All the methods mentioned are usable through software that is available freely from the author.

Keywords: Spatial pattern, counts, maps, SADIE, clusters, association, simulation, sampling schemes, metapopulations.

The resolution of spatial data is greatest in maps, where the location of each individual is known precisely in two-dimensional space, and the sample area, usually a rectangle, is defined. For such data, there is already much methodology to study spatial pattern (e.g. Diggle, 1983). Information is less when the data are in the form of counts of individuals within spatially-defined areas or sample units; this paper focuses on such data.

Detailed spatio-temporal data when available allows metapopulation models of weed dynamics to be constructed. Perry & Gonzalez-Andujar (1993) and Gonzalez-Andujar & Perry (1995) gave examples for data in the form of counts of seeds. The models were built in explicit two-dimensional space; populations could go locally extinct and be revived only through colonization. The outcomes depended on dispersal, the scale of the environmental heterogeneity and other spatial effects.

Sampling schemes for weeds and pests (Perry, 1994) usually rely upon data based upon a count (or an incidence) in each sample unit. The information in field counts may be expressed in two mutually exclusive forms: number and location. The former relates to statistics such as the average weed population density, its variability (Clark & Perry, 1994; Clark *et al.*, 1996), incidence in sample units (Perry, 1987), the skewness of the frequency distribution of counts (Perry & Taylor, 1988), and the interrelationships between them. Sampling schemes may be derived that use some or all (Perry *et al.*, 1997) of these statistics and relationships. All relate to the properties of a list of the observed counts, without reference to where those counts were taken.

The latter information, on location, relates to features such as the spatial pattern of the counts and their degree of non-randomness (Perry, 1995*a*), patchiness in the field, the presence of clusters and gaps and their relative sizes (Perry, 1997*a*), and the presence of trends or edge effects (Perry & Klukowski, 1997).

SADIE (Spatial Analysis by Distance IndicEs) is a set of new techniques for analyzing spatial data (see Perry *et al.*, 1996; Perry, 1997*b* for a general introduction). These techniques compare the observed pattern with two extreme, baseline alternatives: crowding (Perry, 1997*a*), where all individuals in the sample are observed as close as the spatial resolution allows, and regularity (Perry, 1995*a*), where the individuals are observed spread as evenly as resolution allows. For mapped data (Perry, 1995*b;* Korie *et al., 1997a*) the techniques require that the sample area be a rectangle. For count data (Perry, 1995*a*), there are no restrictions on where the sample units may be located in two dimensions; irregular spacing of units, not on a grid, is perfectly acceptable. By conditioning on the counts observed, the SADIE measurement of spatial pattern remains independent of the properties of the list of numbers considered above, such as variance-heterogeneity. This is entirely reasonable, for, although the set of counts of weeds in six quadrats: {0, 1, 4, 56, 484, 4095} may be highly-skewed and obviously non-Poisson, their spatial arrangement may be completely random with respect to one another. The excess variance-heterogeneity arises because of spatial pattern, but it is pattern at a smaller scale than that to which the sample unit count relates; because there is no spatial information recorded at the scale on which it manifests itself such pattern cannot be studied. Conversely, a set of counts of weeds along a line transect: {0, 0, 1, 1, 2, 2, 2, 2, 3, 3, 5}, may conform closely to a Poisson distribution, but if sampled in that order shows an obvious linear trend departing strongly from spatial randomness. SADIE techniques provide indices of non-randomness, randomization tests of non-randomness and visual diagnostics.

The degree to which a set of observed counts occupies the edge or the centre of the area defined by the sample units is an important descriptor of basic spatial pattern. It corresponds to the role played by the arithmetic mean of a list of numbers. Perry (1996) noted that it could be represented by the distance δ, between the centroid of the counts and the centroid of the sample units. Furthermore, Perry (1996) provided an algorithm whereby a set of observed counts could be permuted amongst the sample units to provide a rearrangement that had the same value of both spatial pattern index and of δ. Thus, the rearrangement would resemble closely the original in a spatial sense, even though the counts in corresponding sample units were uncorrelated. He showed how this result could be very useful for simulation and could provide a relatively cheap method to test putative sampling schemes (Parker *et al.*, 1997). Perry & Klukowski (1997) attempt to provide definitions and methodology to cope with the difficult problem of edge effects.

Often, two populations of weed species may be studied, with a count from both being available simultaneously in each sample unit. The species may be spatially dissociated (for example, if they compete fiercely but equally), occur at random with respect to one another, or be positively associated (for example, if they utilize the same rare habitat) (Perry *et al.*, 1996; Perry, 1997*b*). Similar data occur when the same species is sampled at the same locations but on two separate occasions, yielding measures of within-species association through time; this relates to the stability and persistence of spatial patterns. SADIE methodology has been developed to provide indices of association and tests for such data also (Perry, 1997*c*,*d*; Korie *et al.*, 1997*b*).

All of the above methods are encoded within software that may be used to obtain analyses of spatial pattern for field data. This software is free and may be obtained from the author by contacting him via email: joe.perry@bbsrc.ac.uk; fax: +44 1582 760981; or telephone: +44 1582 763133.

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