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Statistical analysis of spatial distribution in populations of microspecies of Alchemilla L.

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Abstract: In this paper, we consider *Alchemilla vulgaris* L. (or common lady's mantle), which is an herbaceous perennial plant. It is known that within this species it is possible to distinguish microspecies, that is, fairly homogeneous groups having minor morphological differences. We study spatial distributions of the microspecies found in various localities as well as possible interaction between different microspecies.

Keywords: Spatial analysis; Join-count statistics; Plant populations; Microspecies; *Alchemilla vulgaris* L.

1 Introduction

Study of agamic complexes in such genera as *Alchemilla*, *Crepis*, *Citrus*, *Hieracium*, *Poa*, *Potentilla*, *Rubus*, *Taraxacum* etc. is of particular interest in plant biology; see Grant (1981). The complexes can be defined as groups of angiosperm (or flowering) plants that are characterised by apomictic reproduction (or apomixes), which is a form of seed reproduction without fertilization. In this paper, we study *Alchemilla* plants growing within Eastern Europe, which is considered as agamo-sexual complex *Alchemilla vulgaris* L.s.l. (Glazunova (1977)). A number of agamospecies are described within the agamo-sexual complex of *Alchemilla* plants. Such rather homogeneous groups with minor morphological differences are called microspecies. From a taxonomic point of view, it is quite difficult to classify microspecies of agamo-sexual complex *Alchemilla vulgaris*. The taxonomy is usually possible for plants in generative period, which are collected in June, during the first flowering. The microspecies may vary in nature and degree of fluffiness of radical leaves, flowers, generative stems as well as in size and form of

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lamina, lobes and their teeth. There are about a thousand of microspecies in the genus (e.g., see Fröhner, 1995), in Europe there are more than 300 microspecies, 38 are in Central Russia (Tikhomirov et al., 1995), and 31 are in the Republic of Mari El (the study region); see Abramov (2008).

2 Data and methodology

The data were collected from 28 localities (habitats), which are characterised by different environmental conditions: bottomland meadow, dry meadow, fallow land, edge of mixed and coniferous forest. The plants were considered on square sites with the area of 1 m^2. The surveyed area in the localities varies from 2 to 169 m^2. *Alchemilla* plants of generative period were excavated and put in a herbarium. The diagnostics of microspecies was carried out by a set of qualitative morphological traits of the plants preserved in the herbarium. The number of microspecies within the same locality varies from 1 to 14, while 28 different microspecies were identified. In this paper, we consider locality M1, which has the largest number of sites. Within this locality, we study spatial distribution of each microspecies and co-occurrence of different microspecies.

3 Results and discussion

In each of N sites (quadrants) we record whether the particular microspecies has or has not been observed. The i-th site can be coded as either $x_i = 1$ (B, black) or $x_i = 0$ (W, white). As a result, we have a mosaic map of black and white sites (see Figure 1). Following the chess terminology (e.g., see Upton and Fingleton, 1985), we consider two widely used definitions of contiguity on a lattice: rook's (touching edges) and queen's (either touching edges and touching corners). In order to determine whether neighbouring sites are more likely to be the same colour or different colours, we can count the numbers of BB, BW or WW joins (where, for example, BB denotes a join between two black sites) and compare these numbers with the corresponding expected numbers of joins under the null hypothesis of no spatial autocorrelation among the sites.

Let $\mathbf{W} = \{w_{ij}\}$ be a spatial proximity matrix of size $N \times N$ (where N is the total number of sites) in which $w_{ij} = 1$ if i-th and j-th sites are joined, and $w_{ij} = 0$ otherwise. Then the join-count statistics are given by

$$BB = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}x_i x_j, \qquad BW = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(x_i - x_j)^2,$$

$$WW = \text{the total number of joins} - (BB + BW).$$

The expected values and the variances of the join-count statistics under non-free sampling (or sampling without replacement) are given in Cliff and Ord (1981).

Using the `joincount.multi` function in R package `spdep` Bivand (2014), we can find the values of the join-count statistics. Table 1 shows the values of the join-count statistics and the z-values for a particular microspecies. In this example, the observed value of BB differs significantly from its expected value implying clustering of B sites in the locality (positive autocorrelation); see Figure 1. The analysis shows that all microspecies identified in locality M1 are spatially autocorrelated but the measures (based on the normalised join-count statistics) of the spatial autocorrelation considerably vary for different microspecies.

TABLE 1. The observed and expected values of the join-count statistics for microspecies *A. tubulosa* Juz. in locality M1.

	Rook			Queen		
	Observed	Expected	z-value	Observed	Expected	z-value
BB	8	2.9890	3.1982	10	5.7481	1.9325
BW	49	56.7912	−2.2225	107	109.2139	−0.3521
WW	255	252.2198	1.1653	483	485.0380	−0.3644

In order to test whether there exists an interaction between two microspecies, we use a modified chi-squared test of independence in 2×2 contingency tables; see Cerioli (1997). The results of the analysis suggest that there is significant interaction between several pairs of microspecies.

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101	102	103	104	105	106	107	108	109	110	201	211	221
111	112	113	114	115	116	117	118	119	120	202	212	222
121	122	123	124	125	126	127	128	129	130	203	213	223
131	132	133	134	135	136	137	138	139	140	204	214	224
141	142	143	144	145	146	147	148	149	150	205	215	225
151	152	153	154	155	156	157	158	159	160	206	216	226
161	162	163	164	165	166	167	168	169	170	207	217	227
171	172	173	174	175	176	177	178	179	180	208	218	228
181	182	183	184	185	186	187	188	189	190	209	219	229
191	192	193	194	195	196	197	198	199	200	210	220	230
231	232	233	234	235	236	237	238	239	240	261	262	263
241	242	243	244	245	246	247	248	249	250	264	265	266
251	252	253	254	255	256	257	258	259	260	267	268	269

FIGURE 1. Layout of sites in locality M1. The 169 sites are numbered from 101 to 269. If a site has microspecies *A. tubulosa* Juz. then it is colour coded black, otherwise it is white.