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One for all: can individual plant species indicate the overall number of plant species?

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ABSTRACT

Questions: Is the number of forest vascular plant species an indicator of the total number of plant species? Is there a forest species that might serve to indicate a high number of plant species?

Data: The flora of the sparsely populated Udomlya district (Tver region, central part of European Russia) mapped into 99 squares, each 5 km × 5 km.

Methods: Test for a correlation between the number of forest species and the total number of species in a grid-cell. For each species, test for a correlation between the range in the number of species within grid-cells it occupies versus the mean number of species within those same grid-cells.

Conclusion: The number of forest vascular plant species correlates positively but weakly with the total number of plant species. In general, a high number of species should be associated with species that are typical of rare habitat types (in the district). Thus indicators of a high number of species were not forest species, but species typical of open, mainly disturbed habitats (e.g. *Avena sativa*, *Crataegus sanguinea*, *Lycopsis arvensis*). Due to their unavoidable rarity, we cannot recommend using any of the species consistently found in speciose grid-cells as indicators of a high number of species in grid-cells within the central part of Eastern Europe. Floristic surveys remain an essential tool for studies of biodiversity and for evaluating human impact on ecosystems.

Keywords: anthropogenic disturbance, diversity of forest species, Eastern Europe, indicators, number of plant species, Russia.

INTRODUCTION

Diekmann *et al.* (2008) demonstrated by means of grid-mapping that the number of forest vascular plants in northwestern Germany is highly indicative of total species richness. They proposed that this covariation would likely exist in other forest-poor and agriculture-dominated regions because the presence of ancient forests indicates long established habitat continuity, associated with high plant species diversity. In addition, Diekmann *et al.* (2008) aimed to identify single forest species that serve as indicators of a high number of species.

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Such species would be consistently found in grid-cells with high diversity, i.e. they would be characterized by both a high mean number of other species in those grid-cells which they occupy and a low range in the number of species in those same grid-cells. Diekmann *et al.* (2008) did not identify forest species consistently found in speciose grid-cells, but there were several species that might serve as relatively good indicators of a high number of species.

Our aim was to determine whether the number of forest vascular plants is highly indicative of the total number of species in forest-rich regions, although Diekmann *et al.* (2008) supposed that not to be the case. We used the sparsely populated Udomlya district in the Tver region of European Russia as a model area. Furthermore, we hoped to identify single plant species that could be used as indicators of a high number of species in sparsely populated areas.

MATERIALS AND METHODS

The Udomlya district covers around 2500 km^2 and is characterized by well-preserved natural vegetation, of which about 60% is forest, and low human population density (*c*. 18 individuals per km^2). We divided the district into 105 grid-cells, each 5 km × 5 km. In 2007–2016, we surveyed 99 of them. We excluded four cells that were situated in the only town, Udomlya, as well as two cells that lay partly outside the district. For each grid-cell we compiled a list of the registered species (for further methodological detail, see Volkova *et al.*, 2016). Udomlya district comprises the $36VXK_2$ grid-cell of *Atlas Florae Europaeae* and parts of grid-cells $36VXK_1$, $36VXJ_1$, and $36VWK_4$.

Forest specialists were listed according to the *Flora of the Central Part of European Russia* (Majevsky, 2014), except those woody species that are usually planted (cf. Diekmann *et al.*, 2008). We also excluded rare species (i.e. those found in less than 5% of the cells surveyed).

For each species, we calculated the mean number of other species in the cells that it occupied, as well as the range in the number of species within those same cells (following Diekmann *et al.*, 2008). In addition, we calculated the abundance of each species as the percentage of grid-cells in Udomlya district in which that species was found.

We performed all computations and graphics creation in the R statistical environment (R Development Core Team, 2013).

RESULTS

We registered 787 species of vascular plants. Of these, we identified 75 as non-woody forest specialists (evolutionary-ecology.com/data/3104Appendix.pdf). The number of species in a grid-cell varied from 189 to 423, following approximately a Gaussian distribution. Thus, only a few cells had especially high or low species diversity (Fig. 1). We found a weak but significant relationship (Spearman correlation test: $R = 0.34$, $P = 0.0006$) between the number of forest species and the total number of species in a grid-cell.

The range in the number of species within the grid-cells occupied by a species was negatively correlated with the mean number of species in those same cells (Spearman correlation test: $R = -0.59$, $P < 2.2 \times 10^{-16}$) and positively correlated with species abundance (Spearman correlation test: $R = 0.85$, $P < 2.2 \times 10^{-16}$). Most species were characterized by an average number of other species in the grid-cells it occupies and a relatively high range in the number of species in those same cells. Several rare species had an unusually high (*Avena sativa* L., *Crataegus sanguinea* Pall., *Lycopus arvensis* L.) or low (*Cinna latifolia* (Trev.)

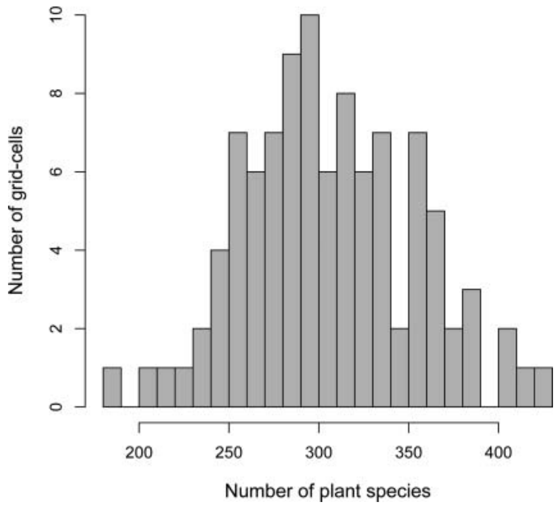

Fig. 1. Histogram of plant species diversity in the 99 grid-cells.

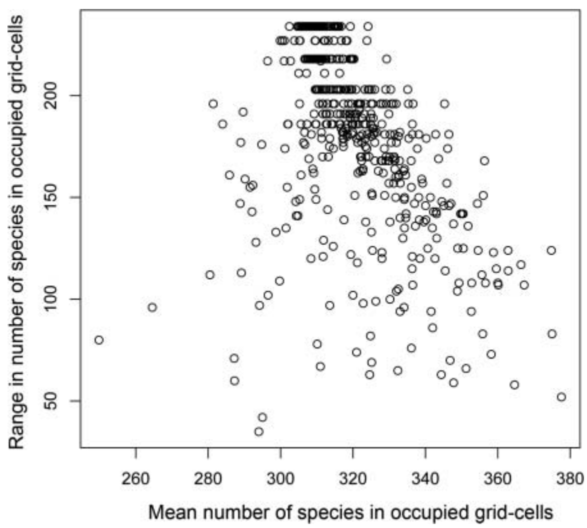

Fig. 2. Range in the number of species versus mean number of species per cell for all investigated species in all investigated grid-cells. Each circle represents one species. All the species that were found in more than 5% of the investigated grid-cells are included.

Griseb., *Stellaria longifolia* Fries.) average number of species, and a low range in the number of species in the grid-cells it occupies (Appendix; Fig. 2).

DISCUSSION

As in agriculture-dominated northwestern Germany (Diekmann *et al.*, 2008), we found a correlation between the number of forest vascular plants and the total number of vascular plant species in sparsely populated Udomlya district. However, this relationship is very weak (coefficient of determination = 0.12) and is likely mediated by the dependence of different species groups on the variability of environmental factors, as in Volkova *et al.* (2016). In general, a high number of species should be associated with species that are typical of rare habitat types for the district. In the case of forest-covered Udomlya district, non-forest habitats and species (including non-natives) account for a high number of plant species (Volkova *et al.*, 2016).

Indicators of a high number of species should appear exclusively in species-rich grid-cells (lower right corner of Fig. 2, see Introduction). We discovered three such species, namely *Avena sativa*, *Crataegus sanguinea*, and especially *Lycopsis arvensis*. According to our expectations, none of these non-native species are forest specialists, instead being typical of open, mainly disturbed habitats. As we stated above, in forest-rich Udomlya district, such habitats add to landscape heterogeneity, so increasing the number of plant species.

In addition, we found two indicators of a low number of species (lower left corner of Fig. 2) that were not observed in northwestern Germany (Diekmann *et al.*, 2008). These species (*Cinna latifolia*, *Stellaria longifolia*) are associated with waterlogged forests, a habitat typical of the sparsely inhabited parts of Udomlya district with low landscape heterogeneity.

Nevertheless, we would not recommend using any of the three species that are consistently found in speciose grid-cells as indicators of high species diversity in the central part of Eastern Europe, as these species are very rare (found in less than 10% of the studied grid-cells). Searching for rare indicator species would be more difficult than conducting a full floristic survey, given the likelihood of missing an individual species by chance (Rich and Woodruff, 1992). This problem would appear to be unavoidable since any indicator of a low or a high number of species ought to be rare, owing to the low number of especially depauperate and particularly diverse grid-cells, irrespective of the degree of anthropogenic transformation of the area (cf. Diekmann *et al.*, 2008). The relatively good indicators of a high number of species proposed by Diekmann *et al.* (2008) were also rare in northwestern Germany. We should also note that the range in the number of species in grid-cells occupied by the indicator species is in fact not very narrow (Fig. 2), making the use of indicators even less straightforward.

Volkova *et al.* (2016) found two floristic groups of grid-cells in Udomlya district, corresponding to the degree of their anthropogenic transformation. Even an incomplete floristic survey would let us classify a grid-cell correctly to one of these groups, thus determining the degree of anthropogenic pressure on it (L. Abramova *et al.*, unpublished). Thus, floristic surveys remain an essential tool for studies of biodiversity and evaluating human impact on ecosystems.

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