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Epigeic bryophytes do not improve bioindication by Ellenberg values in mountain forests

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Abstract

Based on a stratified random sample of 93 vegetation plots and coincident measurements of ecological conditions in mountain forests of the Bavarian Alps, the degree to which species composition and Ellenberg indicator values derived thereof were related to measured environmental variables was assessed for vascular understorey plants and epigeic bryophytes. According to Mantel tests vascular composition contained ca. 30% more ecological information than bryophyte composition. When expressed as average Ellenberg or Düll values, vascular plant-based values reflected 60% more of measured variables than bryophyte-based values. The differences remained after rarefaction of the vascular matrix to the gamma diversity of bryophytes, showing that indication is not a function of indicator richness. Analysing vascular plants and bryophytes combined yielded very similar, or even slightly less stringent relationships with the environment than using vascular plants only.

Bivariate relationships of indicator values with corresponding ecological measurements confirmed the specific potential of the values to estimate ecological factors from both plant groups, but vascular plants performed better for all factors. Bryophyte indication was particularly poor for light, temperature and base saturation. Bryophyte-based indicator values did not significantly predict the residuals of measured ecological variables against vascular plant-based Ellenberg values.

For the study region, it is concluded that indicator values of vascular forest understorey should be used without consideration of Düll's indicator values for epigeic bryopyhtes. There appears to be potential to improve bioindication by recalibrating indicator values of epigeic bryophytes based on ecological measurements and vascular plant indicator values.

Zusammenfassung

Auf Grundlage einer stratifizierten Zufallsstichprobe von 93 Vegetationsaufnahmen und zugehörigen ökologischen Messungen in Bergwäldern der Bayerischen Alpen wurde die Übereinstimmung zwischen Artenzusammensetzung bzw. mittleren Ellenberg-Zeigerwerten und gemessenen Umweltvariablen getrennt für Gefäßpflanzen der Feldschicht und bodenbewohnende Moose untersucht. Mantel-Tests zufolge spiegelt die Artenzusammensetzung der Gefäßpflanzen ca. 30% mehr Varianz in den Umweltbedingungen wider als die der Moose. In der Zusammenfassung als Ellenberg- (bzw. Düll-) Zeigerwerte entsprechen die Gefäßpflanzen-basierten Werte den Messwerten sogar zu 60% genauer als die auf Moosen beruhenden. Diese Unterschiede bleiben nach einer zufälligen Ausdünnung der Gefäßpflanzenmatrix auf die

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Gesamtartenzahl der Moose im Datensatz bestehen, was zeigt, dass es sich nicht um eine Funktion der Zeigerartenvielfalt handelt. Die gemeinsame Analyse von Gefäßpflanzen und Moosen erbrachte sehr ähnliche oder sogar etwas schwächere Beziehungen zu gemessenen Größen als bei Verwendung der Gefäßpflanzen allein.

Bivariate Beziehungen der Zeigerwerte mit den entsprechenden Messwerten bestätigten das Potential, bestimmte ökogologische Faktoren gezielt aus dem Artenbestand beider Gruppen zu schätzen, jedoch schnitten dabei die Gefäßpflanzen stets besser ab als die Moose. Die Indikation durch Moose war vergleichsweise gut für Bodenreaktion und Feuchte, vergleichsweise schlecht für Licht, Temperatur und Basensättigung. Die Moos-basierten Zeigerwerte waren nicht signifikant geeignet, um die Residuen der gemessenen Umweltvariablen gegen die Gefäßpflanzen-basierten Zeigerwerte vorherzusagen.

Im betrachteten Naturraum ist eine Ergänzung der Ellenberg-Zahlen der Gefäßpflanzen durch zusätzliche Berücksichtigung der Düll'schen Moos-Zeigerwerte nicht zu empfehlen. Die Analysen weisen gleichwohl darauf hin, dass die Bioindikation durch eine Neueichung von Zeigerwerten für epigäische Moose auf Basis von ökologischen Messungen oder Gefäßpflanzen-basierten Zeigerwerten durchaus verbessert werden könnte.

Keywords: Calibration; Ecological indicator values; Environmental gradients; Forest site ecology

Introduction

Vascular plants and soil-dwelling bryophytes are major components of temperate and boreal forest understorey vegetation. Both functional plant groups often grow in an intermingled fashion, with vascular understorey forming part of the canopy shading the bryophyte layer and rooting in bryophyte mats and swards. Although differences in life form and niche dimensions are obvious, both groups are often thought of as equally important members of plant communities, which are sampled in the same plots, used as diagnostic species of the same community types (Berg & Dengler, 2005) and interpreted as bioindicators of ecological conditions that are expensive to measure and map directly (Diekmann, 1995, 2003).

Against this background, it is not surprising that Ellenberg's list of vascular indicator plants has been supplemented by a comparable list of bryophytes (Düll, 2001; Ellenberg, 2001). While it has been shown that Ellenberg indicator values of vascular plants and bryophytes are highly significantly correlated (Ewald, 2008), it is unknown whether bryophytes really contribute to the power and precision of bioindication, which warrants additional effort involved in recording, sampling, identifying and analysing bryophytes in vegetation plots. A model data set of mountain forest vegetation and concomitant ecological measurements in the Bavarian Alps allows to test the following hypotheses:

1. Composition of bryophytes contains ecological information that can be used in bioindication.
2. Bryophytes and vascular plants respond to the same ecological gradients.
3. Bryophyte records in plots increase the fit between average indicator values and measured ecological variables.

Material and methods

Forest vegetation was sampled in the "Werdenfelser Land" region (Bavaria, Germany), which extends from the Flysch prealps in the north across the central part of the Bavarian Limestone Alps to the Wetterstein Mts. in the South, where, on the border to Austria, Germany's highest mountains are found (Zugspitze 2.978 m). Covering a high proportion of the geological units occurring in the Bavarian Alps (Anonymous, 2003), the study area is quite representative of the larger region. Climate is cool humid with annual precipitation rising from 1200 mm at lower elevations (700 m) to ca. 1700 mm at timberline (1600 m). In the same interval, mean temperature drops from 7 to 3 °C (Anonymous, 2003). The climate gradient is mirrored in altitudinal belts with montane mixed deciduous–coniferous forests (*Fagus sylvatica*, *Picea abies*, *Abies alba* and *Acer pseudoplatanus*, Ewald, 1997) and subalpine *Picea abies* forest above 1400 m (Ewald, 1999).

Ninety-three plot locations were chosen in a stratified random design based on existing forest inventories (3449 raster points) to ensure that stands older than 60 yr were evenly represented in terms of dominant tree species (classes: *Picea* [43 plots], *Picea–Fagus* [35], *Fagus* [15]), elevation (classes: <1000 m [34], 1000–1400 m [51], >1400 m [8]), geological zone (classes: Flysch [26], northern synclinal [18], southern synclinal [15], dolomite [25], limestone [13]), soil depth and moisture (classes: shallow [25], intermediate [43], deep [8], waterlogged [9], wet [5], blocky [3]) and slope exposition (classes: WNW to SE [39], ESE to NW [54]). To obtain a representative, multivariately balanced sample with minimised intercorrelations among stratification criteria, plot positions were chosen randomly from the 93 most common (out of 540 possible) combinations of the above-mentioned stratification criteria (see Ewald, 2000 for details). Selected inventory points were located in the field and