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Diversity of Species Communities

The Z12 indicator "Diversity of Species Communities" monitors the development of species compositions in various habitats and within Switzerland's individual regions. It is based on presence and absence data of individual species gathered in the two BDM sampling networks established for the "Species Diversity in Landscapes (Z7)" and "Species Diversity in Habitats (Z9)" indicators.

A wide variety of diverse species communities is a good thing, as homogenization of any kind will invariably result in a loss of biodiversity. Biotic communities grow to be more and more alike if land uses become increasingly similar or intensive, or if the same species are introduced nationwide, whether on purpose or by accident. In comparing species communities, however, even rather species-poor sites may contribute to biodiversity provided they harbor species that rarely occur anywhere else.

The latest results show that in the past 10 years, plant species communities in particular have been homogenizing at the landscape level. Mollusk communities have been doing the same, albeit at the smaller-scale habitat level. Depending on regions and land uses, though, individual species groups surveyed by BDM have been varying in their development. In some habitats, for example, moss species communities have even become more diverse.

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Contents

The Z12 indicator monitors the development of species community diversity in Switzerland as a whole, its individual regions, and its various habitats. Diverse species communities are found wherever species compositions differ strongly from one sampling area to the next. Such differences are not reflected by simply considering species numbers as established by other BDM indicators. Species compositions in landscapes are examined comparing separate species lists of vascular plants, breeding birds and butterflies compiled in 1-km^2 BDM sampling areas for the Z7 indicator “Species Diversity in Landscapes”.

The diversity of species communities in habitats or by types of land use is assessed using separate species lists of vascular plants, mosses and mollusks compiled in 10-m^2 BDM sampling areas for the Z9 indicator “Species Diversity in Habitats”.

In contrast to the Z7 and Z9 indicators, it is not the number of species found that matters most for the purposes of the Z12 indicator, but their identity. An indicator value of 100 equals maximum diversity of species communities – i.e. not a single species occurs in two sampling areas being compared –, while a low indicator value signifies that compared sampling areas have many species in common.

Species communities in landscapes: development in time

Table 1 below shows species community diversity trends nationwide and in individual biogeographical regions observed in the past 10 years. Downward arrows point to homogenization of species communities, whereas upward arrows are a sign of species communities having become more diverse.

Figure 1 below illustrates the complete development in time (14 years) recorded by the indicator since BDM surveys began in 2001.

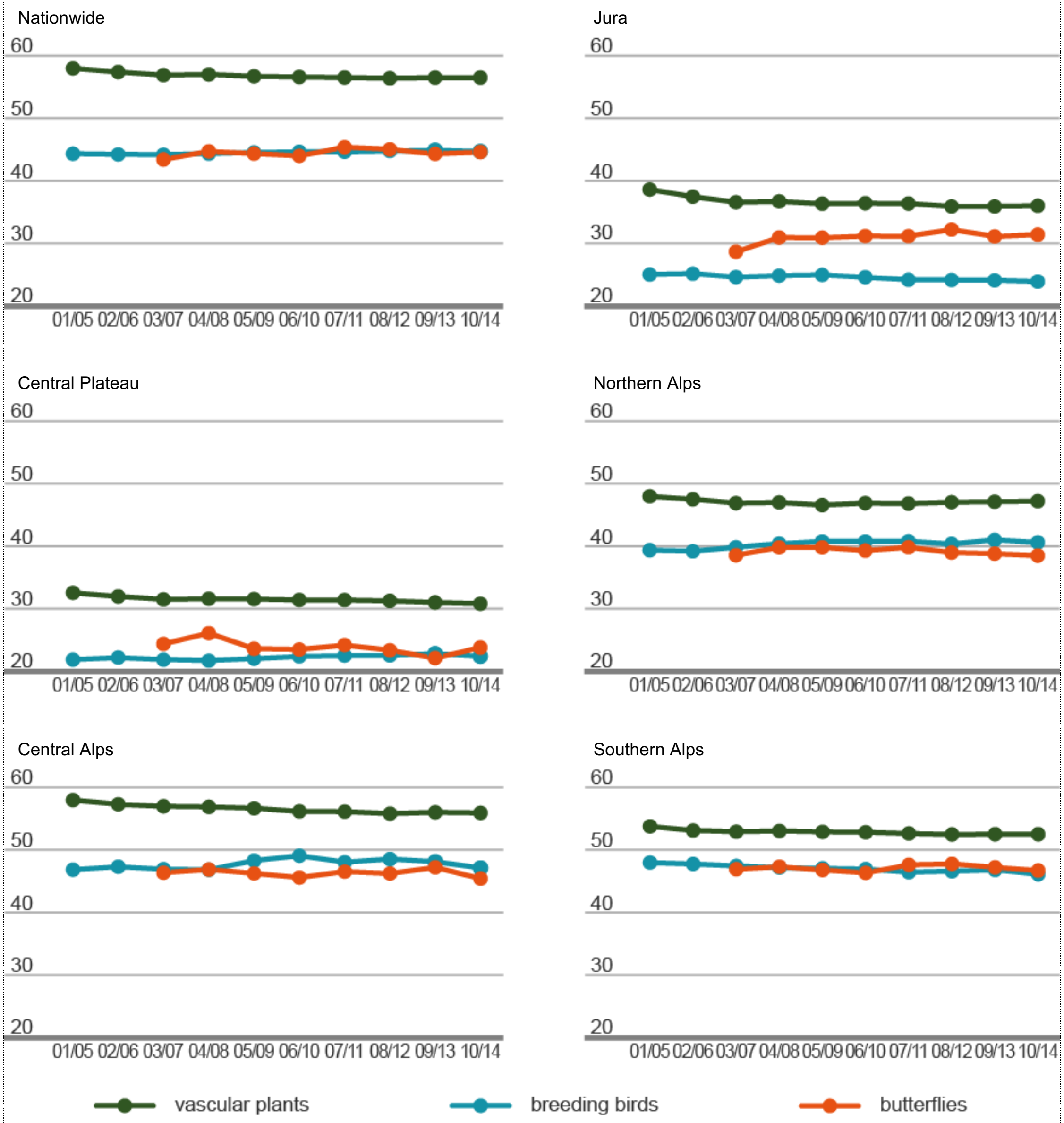
Analyses of data gathered in the past 10 years indicate that vascular plant communities in Switzerland’s landscapes are homogenizing, with their species compositions becoming increasingly similar. The diversity of butterfly and breeding bird species communities apparently remains the same nationwide, except for breeding bird species communities in the Jura, who are becoming more uniform as well.

Tab. 1: Species community diversity trends in landscapes 2005–2014

Biogeographical regions	Vascular plant trends	Breeding bird trends	Butterfly trends
Nationwide	➘	➙	➙
Jura	➘	➘	➙
Central Plateau	➘	➙	➙
Northern Alps	➙	➙	➙
Central Alps	➘	➙	➙
Southern Alps	➘	➙	➙

Fig. 1: Development of species community diversity in landscapes 2001–2014*

Mean Simpson's Index of all pairwise comparisons of 1-km² sampling areas since surveys began. As it takes a period of five years to survey every sampling area once, comprehensive comparisons of all sampling areas are based on data gathered during 5-year periods each.



*Butterfly species have not been surveyed until 2003.

Comments

- Indicator value differences among species groups are created by frequency distributions of individual species. The higher the number of rare species and the lower the number of common species within a group, the higher its indicator value. However, the indicator's main emphasis is on development in time, i.e. whether the diversity of species communities is increasing or decreasing through the years.
- Species community diversity in Switzerland's landscapes develops differently than species numbers in individual sampling areas: While species numbers of vascular plants, for example, have been rising nationwide for the past 10 years (cf. Z7 indicator "Species Diversity in Landscapes"), vascular plant

species communities have become more uniform in the same period of time, meaning that they are more alike now than ten years ago. As regards vascular plants, this trend can be observed almost throughout Switzerland's regions. For the past 10 years, only the Northern Alps have no longer been displaying a significant biotic homogenization trend anymore. Such large-scale depletion of plant communities usually equates a loss in biodiversity. Yet researchers assume ecosystem services to depend on a high degree of plant species diversity (Isbell et al., 2011).

- For the past 10 years, breeding bird species community diversity has hardly changed at all. The increase observed on the Central Plateau has been lessening in recent years.
- The reason for bird species community diversity in the Jura declining in the past 10 years is possibly intensified land use in that region (Horch et al., 2008).
- Looking not only at the past 10 years, but at the complete observation period beginning in 2001 reveals further and partially deviating developments in the diversity of species communities. Bird species communities, for example, have become more diverse both nationwide and on the Central Plateau as well as in the Northern Alps during the past 14 years, even though table 1 shows them to have been stable for the past 10 years.
- Butterflies are subject to particularly wide annual variations (cf. Z7 indicator "Species Diversity in Landscapes"). Hence, it will take a few more years to reveal whether trends recognized so far actually do reflect long-term changes in the diversity of butterfly species communities.

Species communities in landscapes: current situation

Figure 2 below illustrates the diversity of species communities of vascular plants, breeding birds and butterflies in the landscapes of Switzerland's various regions as recorded in the 2010–2014 surveying period. The greater the similarity between species communities in 1-km^2 sampling areas, the lower the indicator value, and vice versa. On a regional scale, species communities in landscapes of the Southern and Central Alps turn out to be the most diverse, while species communities in landscapes of the Central Plateau are generally the most uniform.

Fig. 2: Diversity of species communities in landscapes 2010–2014

Mean Simpson's Index of all pairwise comparisons of 1-km² sampling areas. The more darkly colored a biogeographical region, the more diverse its species communities.

Comments

- Except for butterfly species community diversity, which is slightly higher in the Jura, species communities in the Jura are almost as uniform as those found on the Central Plateau.
- The difference between the Central Plateau and the Jura on the one hand and the Alps on the other hand is due to both natural causes and human land use. Because of their wider ranges of altitudes and their more marked reliefs, it is only natural that alpine regions be home to more diverse species communities than low-land regions. However, the uniformity of species communities on the Central Plateau and in the Jura has most likely also been brought about by the intensive land use these two regions are subjected to, which made local particularities disappear (Chételat et al., 2013).
- The absolute indicator value computed for Switzerland overall (see Appendix 1) cannot be directly compared to the indicator values computed for its individual biogeographical regions. Since biogeographical regions are defined by standardized floral and faunal distribution patterns (Gonseth et al., 2001), the diversity of species communities is bound to increase when looking at the country as a whole.
- For exact indicator values and additional information please refer to Appendix 1.

Species communities in habitats: development in time

Table 2 below shows species community diversity trends in habitats or land-use types observed in the past 10 years. Downward arrows point to increasing homogenization of species communities, whereas upward arrows are a sign of species communities becoming more diverse.

Figure 3 below illustrates the complete development in time (14 years) recorded by the indicator since BDM surveys began in 2001.

Species community diversity of mollusks is declining in forests, in grassland, on alpine pastures, in the mountains and in settlements. In the meantime, the homogenization trend of vascular plants has eased off, so much so that in the past 10 years, it has only been discernible in forests anymore. As regards mosses, however, species communities tend to become more diverse, at least in forests, in settlements and on alpine pastures.

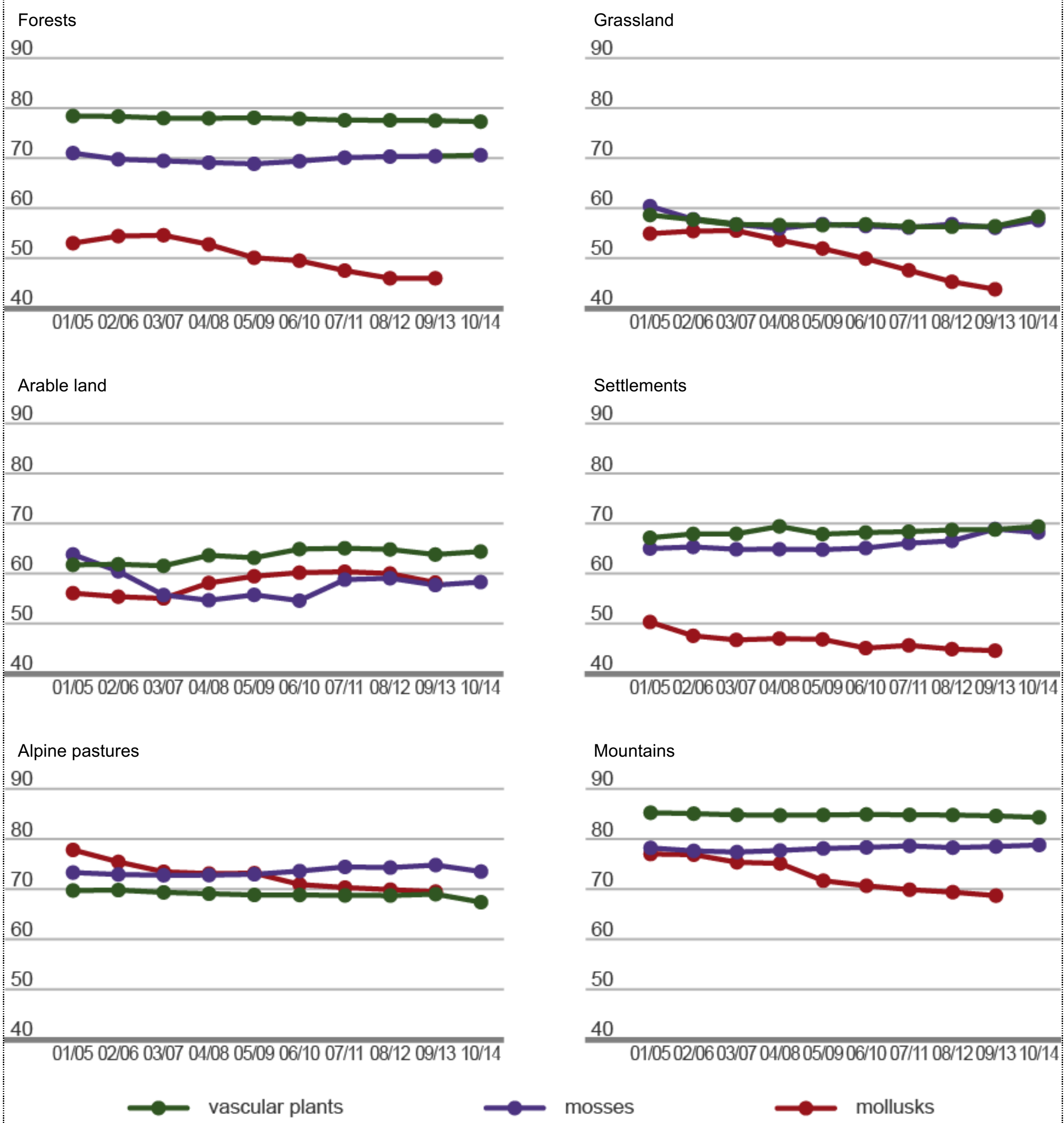
Tab. 2: Species community diversity trends in habitats 2005–2014*

Habitats/land-use types	Vascular plant trends	Moss trends	Mollusk trends
Forests	↘	↗	↘
Grassland	→	→	↘
Arable land	→	→	→
Settlements	↗	↗	↘
Alpine pastures	↗	↗	↘
Mountains	→	→	↘

*Mollusk data available at this time cover surveying periods through 2013.

Fig. 3: Development of species community diversity in habitats 2001–2014*

Mean Simpson's Index of all pairwise comparisons of 10-m² sampling areas since surveys began. As it takes a period of five years to survey every sampling area once, comprehensive comparisons of all sampling areas are based on data gathered during 5-year periods each.



*Mollusk data available at this time cover surveying periods through 2013.

Comments

- Indicator value differences among species groups are created by frequency distributions of individual species. The higher the number of rare species and the lower the number of common species within a group, the higher its indicator value. However, the indicator's main emphasis is on development in time.
- In the past 10 years, vascular plant species communities in forests have become more alike, possibly due to the entry of airborne nutrients (Kohli, 2011). Observed over the complete monitoring period of 14 years, species communities in grassland and on unused land in the mountains have been homogenizing as well. While these habitats and the diversity of their species communities could also

have been affected by the entry of airborne nutrients (Roth et al., 2013; see also results of the E6 indicator “Nutrient Supply in the Soil”), the trend has eased off during the past 10 years to the point of no longer being significant.

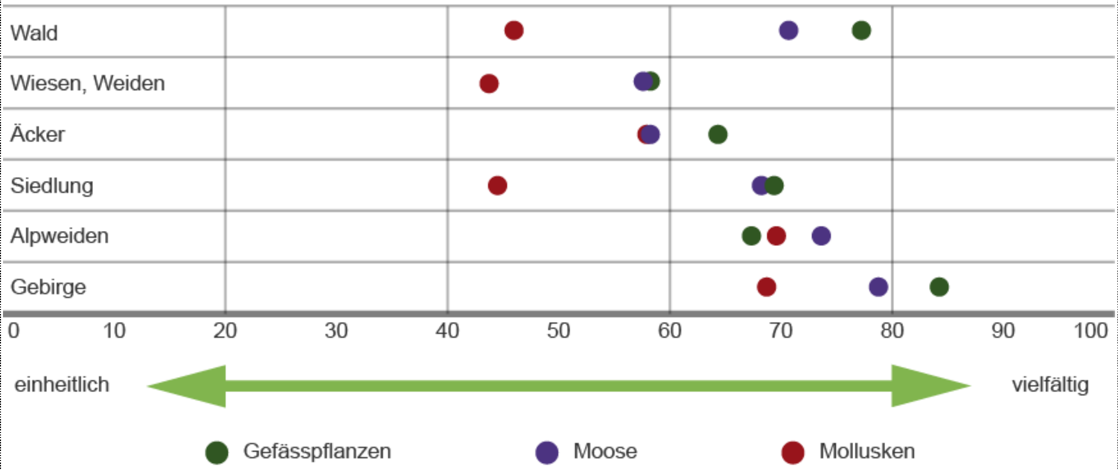
- As regards settlements, vascular plant species community diversity has even been recorded to increase. BDM special analyses have revealed that heat-loving ruderal plants are extending their ranges in the lowlands (Bühler, 2012). If this trend were also to apply to species rarely found in BDM sampling areas up until now, species community diversity would increase. Such plant species include e.g. the Yellow Woodsorrel (*Oxalis fontana*), the Green Bristlegrass (*Setaria viridis*) or the Thymeleaf Sandwort (*Arenaria serpyllifolia* agg.). Only occurring in 1-2% of all sampling areas so far, they have been colonizing 4 to 8 new sampling areas each in recent years.
- Apart from arable land, all types of land use exhibit a diminishing diversity of mollusk species communities. This decrease is caused by the widespread advance of already common mollusk species that make no particular demands on their habitat (ubiquists). For additional information, please refer to the Z9 indicator “Species Diversity in Habitats”.
- Moss species communities on alpine pastures are continuously increasing in diversity, conceivably because farming at the subalpine level is either extensified or abandoned outright. In contrast, moss species communities in grassland at lower elevations are becoming more and more alike. However, this development is only significant if observed for the complete surveying period of 14 years. It could be the result of intensified farming in the lowlands. As a matter of fact, a BDM special analysis of changes in land use in summer pasturing areas did find indications of remote high-altitude pasture extensification on the one hand and tendencies towards readily accessible lowland pasture intensification on the other hand.
- Moss species communities in forests tend to diversify in general, a development likely caused by increasing shares of hardwood forest and windthrow areas which have a positive impact on structural diversity and the supply of deadwood (Brändli, 2010).
- As evidenced for the first time in 2014 since BDM surveys began, moss species communities in settlements have become more diverse in the past 10 years. So far, we can only suspect what caused this trend, but the intense construction activity during that time might play a part: Contrary to vascular plants, specialized moss species are able to colonize even sealed surfaces, allowing them to form typical species communities on concrete or roofs. These habitat specialists include species commonly found in settlements, such as *Ceratodon purpureus* and *Syntrichia ruralis*. Based on BDM data, these two species have actually extended their ranges in settlement areas (see Z8 indicator “Population Size of Common Species”). Common and widely distributed moss species such as *Brachythecium rivulare* and *Hypnum cupressiforme*, however, are receding in settlements due to surface sealing. In combination, these opposite developments might contribute to increasing species community diversity.

Species communities in habitats: current situation

Figure 4 below illustrates species community diversity in the 2010–2014 surveying period. The greater the similarity between species communities in 10-m^2 sampling areas, the lower the indicator value, and vice versa. Species communities are typically found to be most diverse in the “mountains” habitat category, which mainly consists of high-mountain sampling areas.

Fig. 4: Diversity of species communities in habitats 2010–2014*

Mean Simpson's Index of all pairwise comparisons of 10-m² sampling areas. Indicator values range between 0 (uniform) and 100 (diverse).



*Mollusk data available at this time cover surveying periods through 2013.

Comments

- For the purposes of this indicator, the "mountains" habitat category encompasses alpine areas not subjected to alpine farming, such as scree plant communities, alpine turf, rock, and dwarf shrub heath, excluding glaciers and inaccessible rocks.
- Mountain areas offer a wider variety of sites than e.g. forests or grassland. Since site conditions such as temperature, humidity or substrate are often very heterogeneous, going from one extreme to the other within a few centimeters, such habitats harbor a particularly large number of specialized species, making species communities very diverse.
- Alpine pastures are characterized by high species community diversity as well, particularly as regards mosses and mollusks. In contrast, species communities of vascular plants are more diverse in forests.
- For exact indicator values and additional information please refer to Appendix 2.

Species communities by altitudinal zones

Figures 5a and 5b below illustrate the diversity of species communities in forests and grassland differentiated by three altitudinal zones in the surveying period covering the past 5 years, i.e. 2010 to 2014. The greater the similarity between species communities in 10-m² sampling areas, the lower the indicator value, and vice versa.

Fig. 5a: Diversity of species communities by altitudinal zones in forests 2010–2014

Mean Simpson's Index of all pairwise comparisons of 10-m^2 sampling areas. Indicator values range between 0 (uniform) and 100 (diverse).

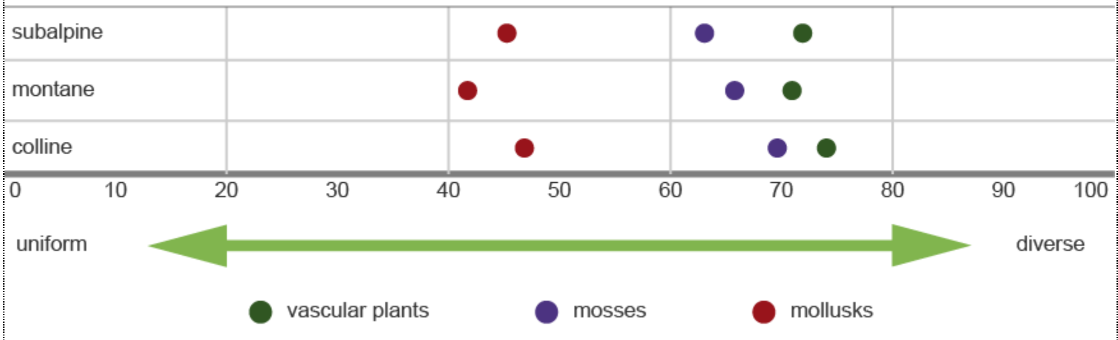
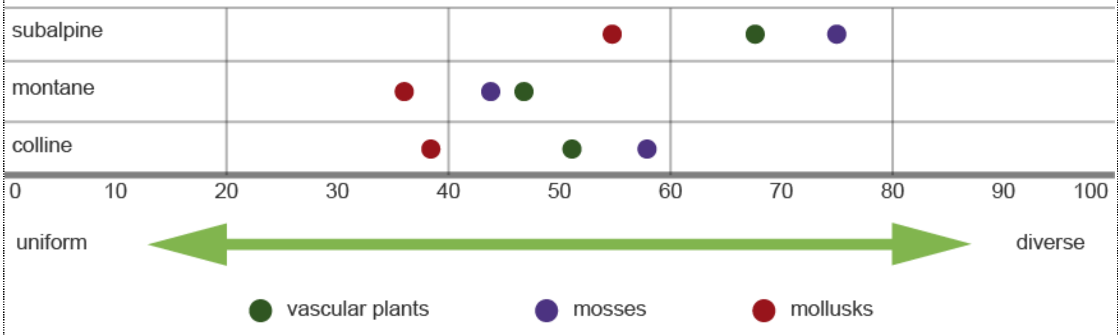


Fig. 5b: Diversity of species communities by altitudinal zones in grassland 2010–2014

Mean Simpson's Index of all pairwise comparisons of 10-m^2 sampling areas. Indicator values range between 0 (uniform) and 100 (diverse).



Comments

- Differentiating forests, grassland and pastures by altitudinal zones makes sense, since depending on altitude, different species communities will form due to many species occurring only up to a certain elevation. Moreover, land use differs with altitude as well. Altitudinal categorization is based on *"Wärmegliederung der Schweiz"* (Schreiber et al., 1997, only available in German). For the purposes of BDM evaluation, categories used in that publication have been condensed into three altitudinal zones: colline, montane, and subalpine.
- Lowland forests show greater diversity of vascular plant and moss species composition than highland forests. However, defining species diversity by species numbers only, the Z9 indicator "Species Diversity in Habitats" comes to the opposite conclusion: Mean species diversity of vascular plants and mosses is considerably lower in lowland forests than in subalpine forests. Both this and the following example show that diversity of species communities and species diversity need not necessarily correlate.
- Species numbers of mollusks in forest and grassland habitats decline with increasing altitude (cf. Z9 indicator "Species Diversity in Habitats"), whereas species community diversity is highest in subalpine grassland. Especially because of low-mobility species groups, high-mountain sites separated by

natural barriers result in more marked site-to-site differences between species communities and, hence, in a higher Z12 indicator value.

- Vascular plant and moss species compositions in grassland are more diverse at the subalpine level than at lower levels as well.
- For exact indicator values and additional information please refer to Appendix 3.

Significance for biodiversity

"Diversity of species communities" as defined by the Z12 indicator is often called "beta diversity" in literature. However, beta diversity is a contentious term, as it is being used to describe different biodiversity phenomena. For this reason, BDM uses the term "diversity of species communities" instead of "beta diversity", understanding it to mean a site-specific composition of species communities.

Any habitat is above all characterized by species that are either typical for a region or make specific ecological demands. It is such signature species that lend distinctiveness to a site. Species restricted to a very small range may also contribute to regionally exceptional species communities. For this reason, local diversity starts to dwindle as species communities as a whole take on similar compositions. This happens, for example, when habitats or landscapes become more alike due to human activities such as people accidentally introducing or intentionally planting/releasing alien species.

Rationalized methods of land use (e.g. fertilization and irrigation) or landscape design are bringing about similar habitat conditions everywhere. With such practices blurring site-related or even culturally caused habitat particularities, it is hardly surprising that species communities scarcely differ anymore from one region to the next. Dubbed "biotic homogenization", this phenomenon has been increasingly described and deplored in recent years. Homogenization of species communities equals a clear-cut loss of biodiversity, despite the fact that species numbers may remain the same or even grow. If this process were to continue, we are bound to end up with normalized meadows, forest skirts and hedges that look exactly the same all over Switzerland.

This scenario makes it obvious that the Z12 indicator offers essential additional information to insights provided by BDM core indicators Z7 and Z9. Increasing species numbers are positive only if such increases are not fuelled by alien or undemanding species that feel at home in many different habitats, since this kind of increase involves the risk of specialist species being crowded out by generalist species, uniforming and depleting the biodiversity of our landscapes and habitats. To name but one vivid example: We are already used to seeing richly green fertilized meadows everywhere, meadows that favor nutrient-loving generalists like the Dandelion, while vascular plant species typical of flower-rich rough pastures are being displaced.

Definition

Regarding data provided by the Z7 indicator “Species Diversity in Landscapes”: Changes in the mean Simpson’s Index (similarity value) calculated based on all pairwise comparisons of species lists compiled for 1-km^2 areas in the surveyed space, expressed in percent (between 0 and 100).

Regarding data provided by the Z9 indicator “Species Diversity in Habitats”: Changes in the mean Simpson’s Index (similarity value) calculated based on all pairwise comparisons of species lists compiled for 10-m^2 areas in the surveyed type of land use, expressed in percent (between 0 and 100).

Surveying methods

The Z12 indicator “Diversity of Species Communities” is based on the same data as the Z7 and Z9 indicators “Species Diversity in Landscapes” and “Species Diversity in Habitats”. Additional field surveys are not required. The Z12 indicator is calculated as follows:

1. The species list of the first sampling area is subjected to pairwise comparisons to the species lists of all other sampling areas of a stratum. Each comparison yields its own Simpson’s Index, calculated according to the following formula (Koleff et al., 2003),

$$\text{Simpson's Index} = \frac{\text{minimum}(b, c)}{\text{minimum}(b, c) + a}$$

   where *a* is the number of species occurring in both sampling areas, and *b* or *c* are the numbers of species occurring in only one sampling area.

2. The same process is applied to the second sampling area, comparing its species list to the species lists of the third and all remaining sampling areas of a stratum. The process is repeated until Simpson’s Index has been calculated for all possible pairs of sampling areas within a stratum.
3. The mean value of all Simpson’s Indexes calculated in this manner and expressed in percent (between 0 and 100) corresponds to the Z12 indicator value.

While these calculations are basically simple, they are also very time-consuming due to the large number of comparisons required. In order to assess the indicator value’s accuracy, a jackknife method is used to establish a confidence interval for the indicator.

Whenever indicator values are found to undergo a significant change over the survey years, the indicator will report a trend in time (increase or decrease).

Surveys conducted for the Z9 indicator quite often produce findings that cannot be clearly identified, for example if only mollusk fragments or plant seedlings are discovered. These findings are counted nevertheless, provided it is certain that they cannot be classified as belonging to a species that has already been identified in that particular sampling area. For Z12 calculation purposes, such additional species can be taken into consideration as well, using simulation calculations based on the assumption that additional species show the same frequency distribution as identified species found in that particular stratum.

For additional details on surveying methods, please refer to *Spread of common species results in local scale floristic homogenization in grassland of Switzerland* (Bühler & Roth, 2011).

Further Information

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Related indicators

> Z7: Species Diversity in Landscapes

> Z9: Species Diversity in Habitats

Additional sources of information

> www.vogelwarte.ch comprehensive information on the Common Breeding Bird Survey (MHB) and the Swiss Bird Index (SBI) of the Swiss Ornithological Institute Sempach

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