Assessing mire-specific biodiversity with an indicator based approach

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SUMMARY

The biodiversity of mires is characterised by a small number of highly specialised species, mostly high spatial heterogeneity and a strong influence of abiotic factors such as high water table and soil substrate (peat). To assess mire-specific biodiversity, indicators that represent and value all of these characteristics are needed. In this study, we present a system of such indicators for the example of north-east Germany. Our indicators encompass different levels of mire-specific biodiversity and enable an overall assessment. We place special emphasis on high user-friendliness. The attributes considered have been well researched in the study area. Based on data from 30 study sites, we developed scales for rating mire-specific biodiversity in six categories. To evaluate the indicator system, we compared the assessment of selected peatlands via the indicator system with the assessments of experts and practitioners in peatland research and management. This evaluation showed high correspondence. We also demonstrate the use of the indicator system as a practical tool for assessing the effects of peatland restoration, and provide suggestions for its application in other geographical regions.

KEY WORDS: biocoenosis, ecosystem, monitoring, peatland, species, value, vegetation

INTRODUCTION

Biodiversity is the complex of diversity within species, between species, and of biocoenosis within their habitats, i.e. ecosystems (UN 1992, Küchler-Krischung & Walter 2007, Wittig & Niekisch 2014). It has gained global importance owing to its drastic decline. In recent decades, the effort to maintain existing biodiversity and restore lost biodiversity has been driven by various international treaties (e.g. Convention on Biological Diversity, Ramsar Convention, Bonn Convention, etc.) and their national implementations as well as by an increasing number of biodiversity conservation projects. This creates an immediate need for assessment methods to quantify biodiversity loss or gain in general, and to judge the success of privately or publicly funded restoration projects in particular. However, because biodiversity is complex, methods which are not only validated but also cost effective and practitioner friendly are scarce (Brunbjerg *et al.* 2018).

Peatlands (areas with a naturally accumulated layer of peat) and in particular mires (peatlands with a vegetation that forms peat) (Joosten *et al.* 2017a) are of great and often unrecognised biodiversity value (Parish *et al.* 2008, Prentice 2011, Minayeva *et al.* 2017). The biodiversity of mires is the key element for a wide range of ecosystem services, such as landscape-scale water regulation as well as nutrient and carbon storage (Bonn *et al.* 2016, Luthardt & Wichmann 2016). Nonetheless, around 10 % of the former total peatland area in Europe has been lost due to a long history of drainage for agriculture and other land uses. Forty-eight percent of the remaining European peatland area is degraded, in Germany only 4 % of all peatlands are unused and/or nature conservation areas (Joosten & Tanneberger 2017, Trepel *et al*. 2017). Of the 163,150 ha of peatlands remaining in the federal state of Brandenburg in north-east Germany, only around 3,000 ha are still mires and another 4,000 ha are under restoration (Luthardt 2014a, LfU 2016). A primary focus for rewetting projects is the re-establishment of mire biodiversity. Therefore, its assessment is of great importance for gauging the success of restoration (cf. Luthardt & Wichmann 2016).

Typical biodiversity assessments based upon species richness - such as the concept of alpha, beta and gamma biodiversity (Whittaker 1972) - are not suitable for mires (Littlewood *et al.* 2010). A broader approach is needed, encompassing heterogeneity at different levels and a variety of functional elements

(Minayeva *et al.* 2017). In order to evaluate the biodiversity of mires, their naturalness as well as their natural ecosystem functions and processes must be considered (Bragg & Lindsay 2003, Prentice 2011). This is shown in recent multifunctional restoration assessments focussing not on single taxa but on plant diversity, water table, peat decomposition, water holding capacity, and nutrient level (Strobel *et al*. 2019). The unique characteristics of each mire biodiversity component should be key elements for its assessment and all components of mire biodiversity including specialist species, habitat conditions and morphological heterogeneity must be examined (Bragg & Lindsay 2003, Prentice 2011, Minayeva *et al.* 2017).

Genetic diversity is regarded as the basis of biodiversity because it enables the adaptation of species to selective pressures (Laikre *et al.* 2016). It determines important factors such as extinction risk, resilience to environmental change and the fitness of populations or individuals, but is influenced by habitat size and quality and can, therefore, be threatened by the fragmentation and isolation of habitats (Struebig *et al.* 2011, Crawford & Keyghobadi 2018). In the context of peatlands, there have been some investigations on the genetic variation of e.g. *Sphagnum* species (Stenøien & Flatberg 2000, Shaw *et al.* 2008, Yousefi *et al.* 2019), species interactions in bog-plant communities (Schwarzer *et al.* 2013), and the implications of conservation and management strategies for genetic diversity (Crawford & Keyghobadi 2018, Eschenbrenner *et al.* 2019). It is estimated that in future, the role of genetics will gain more importance and recognition in conservation practice due to the currently intensive research effort and the increasing number of available genome sequences for species (Allendorf *et al.* 2013).

Plant species play an important role in the function, characterisation and assessment of habitats (Kaiser *et al.* 2002). They are used in (biodiversity) monitoring programmes because they are sessile, provide an indication of their abiotic environment (e.g. Ellenberg *et al.* 2010), occur in a wide variety of ecosystems, exhibit fairly low seasonality and dependency on weather conditions, and the availability of field botanists with expertise in vascular plants is generally good (cf. Brunbjerg *et al.* 2018). More than other ecosystems, mires are characterised by highly specialised plant species that are adapted to water-saturated, often extreme pH and nutrient conditions; and are mostly very rare, endangered and declining (Minayeva *et al.* 2008, Littlewood *et al.* 2010, Prentice 2011, Aapala *et al.* 2014). Following drainage, the specialised species disappear in favour of more numerous but ubiquitous species (Luthardt & Wichmann 2016). Various publications (inter alia Landgraf 2007, Penttinen *et al.* 2014, Joosten *et al.* 2015) advise that vascular plants and mosses should be considered in any assessment or monitoring of the biodiversity of peatlands.

In general, animal taxa are more demanding of habitat properties than plants, and indicate environmental changes more promptly (Görn & Fischer 2011, Lehmitz *et al.* 2020). Because it is generally impossible to record all taxa within one biocoenosis, surrogate taxa that allow broad assumptions about the peatland’s status are commonly chosen. A surrogate taxon should include a broad range of typical peatland species with well-known ecology, that express sensitivity to habitat changes as changes in abundance (Görn 2016). Multi-taxon approaches for ecological assessment of peatlands which have been researched and/or applied have considered birds, butterflies, orthoptera, ground beetles, dragonflies, ants, oribatid mites and spiders in different combinations (e.g. Görn & Fischer 2011, Penttinen *et al.* 2014, Joosten *et al.* 2015, Tiemeyer *et al.* 2015, Lehmitz *et al.* 2020).

Spatial heterogeneity and morphological variation positively affect biodiversity by influencing the occurrence and distribution of species (Dauber *et al.* 2003, Walz 2011). They can enhance connectivity, the potential for niche formation and the availability of habitats (Ludwig 1991, Wulf 2001, Fontaine *et al.* 2007, Walz 2011). Mires show a wide range of physiognomy (morphological forms), and structural heterogeneity at different scales (biogeographic zone, mire massif, complex of phytocoenoses/microtope, phytocoenosis/microform, micrococoenosis) is an essential part of mire biodiversity (Bragg & Lindsay 2003, Minayeva *et al.* 2017). The juxtaposition of typical microhabitats such as hollows, lawns and hummocks, offering conditions ranging from wet to dry, favours the development of vegetation patterns and plant species diversity at small scale (Luthardt 2014b, Korpela *et al.* 2020). Habitat heterogeneity has also been identified as a key determinant of faunistic diversity in bogs (Krieger *et al.* 2019).

Connectivity between habitats can positively influence genetic exchange and, therefore, the potential of a population for adaptation; whereas isolation can increase the extinction risk (e.g. Herrmann *et al.* 2013, De Vriendt *et al.* 2016). Mires maintain relatively stable conditions of, for example, microclimate and water availability, and thus play an important role in the connectivity between ecosystems by offering refuge to species (Minayeva & Sirin 2012). It has been shown that the sizes and connectivity of peatland ecosystems are important for the long-term abundance of butterflies, due to possible genetic exchange as well as the effectiveness of protection from natural enemies and/or local weather extremes (Settele & Reinhardt 1999).

Ecosystem ecology links the biota to their physical surroundings, describing the integrated system of interactions between organisms and their environment. The essential biota of a terrestrial ecosystem are its animals, plants and decomposers; whereas the abiotic components are soil, water and atmosphere (Chapin *et al.* 2011). Although numerous regional types of mire ecosystems can be distinguished on the basis of differences in hydrology, ecology, geomorphology or genesis (Joosten *et al.* 2017b), all mires share many ecological functions and features due to similar ecohydrological processes which are based on permanent water saturation and the accumulation of organic matter as peat (Parish *et al.* 2008). In mires, the water table is maintained at a level close to the ground surface by groundwater, surface water inflow or an excess of precipitation over evapotranspiration resulting in a positive climatic water balance (Edom 2001, Parish *et al.* 2008). Peat accumulates naturally under water-saturated conditions. When a mire is drained, peat formation is replaced by secondary pedogenetic processes (mineralisation, humification, shrinkage, consolidation, compaction, dislocation, leaching and accumulation of soil substances), leading to a hydrophobic topsoil with reduced water regulation and storage functions (Stegmann & Zeitz 2001, Zeitz 2016). Therefore, water table depth (below ground surface) and topsoil condition are used in peatland biodiversity assessments as indicators of the overall state of the ecosystem (Landgraf 2007, Klingenfuß *et al.* 2015).

As the assessment and monitoring of peatlands is often focussed only on parts of biodiversity components (mainly vegetation) and is often based on case studies (inter alia Duinen *et al.* 2002, Mälson *et al.* 2008, González *et al.* 2014, Renou-Wilson *et al.* 2019), tools that allow comparison and specifically address mire-specific biodiversity, are missing. In this article, we describe the development of a method for assessment of mire-specific biodiversity, aiming to provide a system that is practitioner friendly and transferable between geographical regions. Assuming that the complex composition of biodiversity cannot be assessed effectively on the basis of a single indicator (Hill *et al.* 2016), we adopted a multi-indicator approach that allows mire-specific biodiversity to be rated in terms of its heterogeneity at different levels. To calibrate the system we sampled 30 peatlands in the federal state of Brandenburg in north-east Germany, and carried out a validation exercise in collaboration with peatland experts and practitioners.

METHODS

Basic criteria

We set the following five basic criteria for the eventual assessment method:

1. Different levels of mire-specific biodiversity shall be considered in the assessment. A single surrogate (e.g. vegetation) cannot be used successfully to assess the different levels of mire biodiversity, due to the different time delays in reactions to change of individual mire-specific factors and the spatial and morphological heterogeneity of mire-specific biodiversity at different levels and scales.
2. The focus will be on mire-specific characteristics. Thus, for example, the number of mire-specific species will be evaluated, rather than the total number of species.
3. All states of peatlands shall be represented, ranging from natural/unused to highly degraded/used as well as restored.
4. To ensure usefulness of the assessment method in practice, only features whose mire-specific attributes or components have been well researched and are accessible for the focus region shall be considered.
5. The final indicator system shall be practitioner friendly and cost effective.

Literature screening

We identified the relevant components of mire-specific biodiversity according to literature (Bragg & Lindsay 2003, Landgraf 2007, Parish *et al.* 2008, Littlewood *et al.* 2010, Görn & Fischer 2011, Prentice 2011, Minayeva & Sirin 2012, Aapala *et al*. 2014, Penttinen *et al*. 2014, Joosten *et al*. 2015, Klingenfuß *et al.* 2015, Tiemeyer *et al*. 2015, Minayeva *et al*. 2017, see also Introduction). We defined ‘mire-specific biodiversity’ as all biodiversity components that are exclusively adapted to functioning mires; and ‘mire-typical biodiversity’ as all biodiversity components that are highly adapted to mires but also occur in degraded mires and other peat and non-peat-forming wetlands. For each component, we identified suitable measurable indicators. The integrated system of indicators was developed for our study area in north-east Germany, but we place special emphasis on describing the methods we applied in order to demonstrate and enable transferability to other regions.

Field data and scaling

During the period 2002 to 2020, members of Eberswalde University for Sustainable Development collected biodiversity data from peatlands in the German federal state of Brandenburg, which encompass a wide range of different hydro-ecological mire types arising from the effects of different glacial influences (cf. Succow & Jeschke 1986, Kühn 2014). Although peatlands in the state have been drained intensively, about 3000 ha of mires are present (Luthardt 2014a). These peatlands were classified from natural to non-natural following the method for defining hemeroby as the level of human influence of peatlands developed by Wagner & Wagner (2005) (Table 1). For each of the hemeroby classes the data for six peatlands belonging to diverse ecological mire types (acidic to calcareous and nutrient poor to nutrient rich) were analysed (see Figure 3 for locations of the 30 sites selected and Table 7 for mire types). Due to degradation processes resulting from drainage (particularly mineralisation and the release of nutrients), eutrophic peatlands were represented more frequently in the three ‘anthropogenic’ categories.

Based on the analysed data, ordinal scales defining ‘low’ to ‘high’ mire-specific biodiversity for each attribute of the indicator system were defined. The scale values range from 0 (not mire-specific) to 5 (highly mire-specific) in each case. This aligns with the five stages of peatland naturalness described by Wagner & Wagner (2005), with addition of a ‘stage 0’ for no mire-specific biodiversity as described by Tiemeyer *et al*. (2015). To reach an overall assessment, the values for all indicators were summed and again classified from ‘no mire-specific biodiversity’ to ‘high mire-specific biodiversity’.

Expert validation and final calibration

Eleven experts in peatland restoration and 42 practitioners with experience in peatland restoration were interviewed, either individually (experts) or in a group workshop (practitioners). During these meetings, data on vegetation (complete list of vascular plants and mosses, highlighting mire-specific ones), physiognomy (plant formations and mire-typical special habitats), dominant water table and soil conditions as well as aerial pictures and representative photos for four (practitioners) or five (experts) peatlands was presented for assessment of the individual indicators and overall mire-specific biodiversity. To be able to compare these assessments with the assessment of our indicator system, the practitioners and experts were asked to assess each peatland subjectively. Therefore, they estimated the value for each indicator and overall mire-specific biodiversity based on their knowledge and expertise with peatlands using the scale from 0 to 5. The assessments by experts and practitioners were

Table 1. Stages of naturalness and hemeroby (human modification) of peatlands (translated and slightly modified from Wagner & Wagner 2005).

	Stage of naturalness/ hemeroby	Level of human influence	Nutrient balance (input/output)	Hydrology (drainage)	Vegetation (indicator species)
Natural	Natural (ahemerob to oligohemerob)	None to very low	Undisturbed	Undisturbed	Undisturbed
	Near-natural (oligohemerob to mesohemerob)	Low	Slightly disturbed	Slightly disturbed	Slightly disturbed
Athropogenic	Culturally-accentuated (mesohemerob)	Moderate	Moderately disturbed	Moderately disturbed	Moderately disturbed
	Culturally-characterised (euhemerob)	High	Highly disturbed	Highly disturbed	Highly disturbed; species indicating wet conditions still present
	Non-natural (polyhemerob)	Very high	Very highly disturbed	Very highly disturbed	Very highly disturbed; species indicating wet conditions missing

then compared with the assessment of our indicator system, and the outcome was used to optimise the calibration of our scales for assessment of biodiversity value.

Practical example

The ‘Großes Brennbruch’ (Brandenburg, Germany) is a complex of mesotrophic-acidic terrestrialisation mire and eutrophic paludification mire, which has been drained for forestry for over 130 years although the most intense interventions were applied in the late 1970s. In 2005 and 2006, the drainage systems within the ‘Großes Brennbruch’ and its catchment were dismantled in order to rewet the peatland (Koch 2007). To demonstrate the potential usage of our indicator system as a monitoring tool, we applied it to data collected before and after restoration of this peatland.

RESULTS

The indicator system

The indicator system for measuring mire-specific biodiversity consists of three indicators representing (a) species level, (b) biocoenosis level and (c) ecosystem level. Genetic diversity is not included due to insufficient genetic research in our study area to support a genetic component for the assessment tool.

Each indicator consists of two sub-indicators, each with defined mire attributes and metrics representing the essential components of the biodiversity level. The attributes and values to be measured have been well researched within the study area and are highly mire-specific or, at minimum, mire-typical (Figure 1). The indicators are based upon the cited literature and explained in detail below.

Species

The indicator for the species level is ‘mire-specific species’. It consists of two sub-indicators: ‘mire-specific flora’ and ‘mire-specific fauna’. For both sub-indicators, the value measured is the number of mire-specific species.

‘Mire-specific flora’ is described by the attribute ‘vascular plants and mosses’. For our study area there is a complete revision of mire-typical and mire-specific vascular plants and mosses which lists 69 mire-specific vascular plants and 58 mire-specific mosses (Table 2; Klawitter 2014, Klawitter & Luthardt 2014, Luthardt 2014c). The species lists

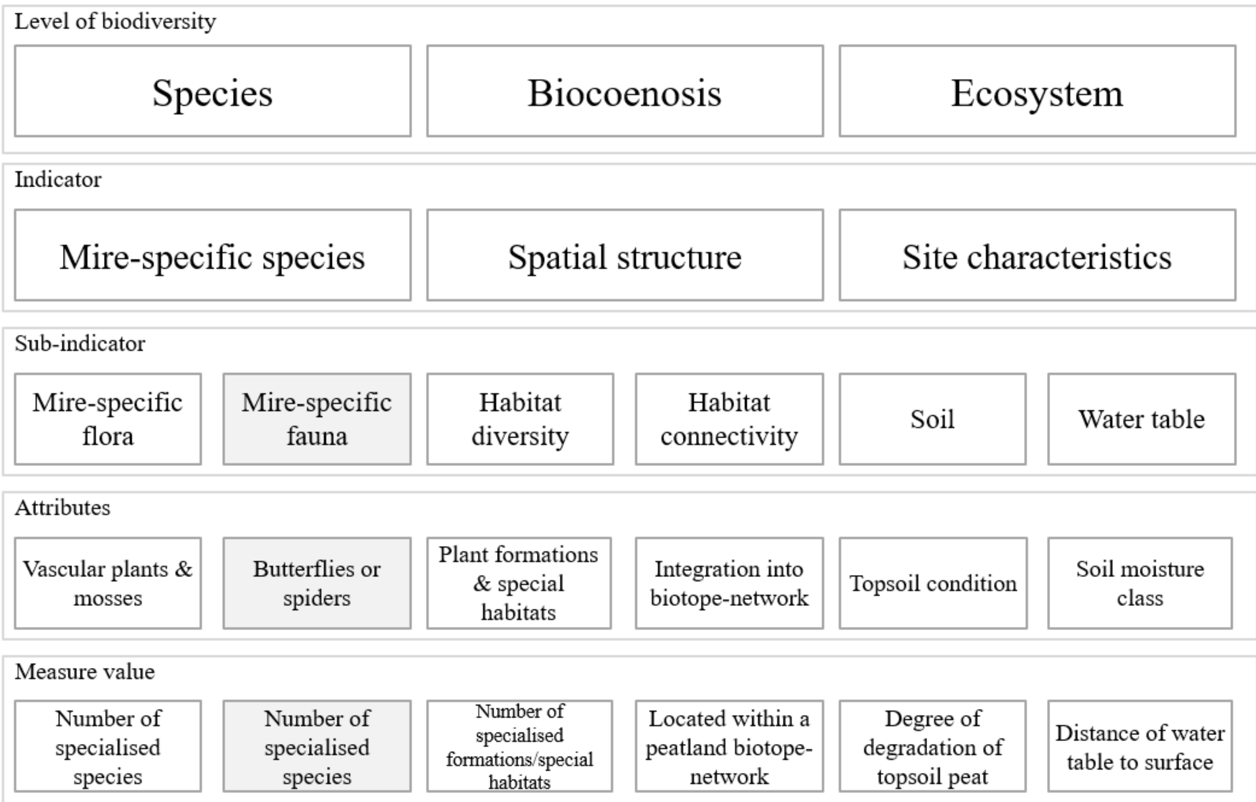

Figure 1. System of indicators for assessing mire-specific biodiversity. The attribute ‘Butterflies or spiders’ within the level of species was proposed as possibly available, but needed to be excluded within the suggested approach due to lack of data.

were derived from botanical and peatland literature (e.g. Zimmermann *et al*. 2004) and was checked by regional experts in botany and peatland science.

To describe 'Mire-specific fauna' we only suggest the attribute 'butterflies or spiders'. Data for butterflies and araneomorph spiders were not available for the sampled peatlands, so the sub-indicator 'mire-specific fauna' was excluded. There is no complete list of mire-specific and mire-typical fauna for our study region although some insights are provided by Luthardt & Zeitz (2014) who describe specialisation of mammals (Dolch 2014), birds (Flade 2014), amphibians (Brauner 2014a), butterflies (Gelbrecht 2014), dragonflies (Mauersberger 2014) and locusts (Brauner 2014b) as well as ground beetles, cicada, bugs, web spiders, pseudoscorpions and millipedes (Barndt 2014). Within this research, butterflies show a high specialisation on mires and peatlands and there are many practising lepidopterists (Gelbrecht 2014). Furthermore, araneomorph spiders show potential usability for a biodiversity assessment and 17 species are known to be mire-specific (Barndt 2014, Platen 1989).

Biocoenosis

The indicator for the biocoenosis level is the 'spatial structure' representing different plant sociologies and their associated fauna. It consists of two sub-indicators, 'habitat diversity' and 'habitat connectivity'.

'Habitat diversity' is described by the attribute 'plant formations and special habitats'. To assess the diversity of spatial structures at microtope level (Minayeva *et al.* 2017), we used the classification of physiognomic heterogeneity "Tentative physiognomic-ecological classification of plant formations of the earth", which describes plant formations as "combinations of plant life forms, i.e. as physiognomic units" (Ellenberg & Müller-Dombois 1966) and can be applied to describe different, adjoining formations in a single peatland area. Plant formations have the advantage of being

Table 2. Mire-specific vascular plant and moss species occurring in the federal state of Brandenburg (north-east Germany).

Mire-specific vascular plant species (Luthardt 2014c)	Mire-specific moss species (Klawitter & Luthardt 2014)
Andromeda polifolia, Betula humilis, Betula nana, Betula pubescens, Blysmus compressus, Calla palustris, Carex (C.) appropinquata, C. cespitosa, C. chordorrhiza, C. davalliana, C. diandra, C. dioica, C. echinata, C. elata, C. flacca, C. flava, C. lasiocarpa, C. lepidocarpa, C. limosa, C. panicea, C. paniculata, C. pulicaris, C. rostrata, C. vesicaria, Cladium mariscus, Comarum palustre, Drosera intermedia, Drosera longifolia, Drosera x obovata, Drosera rotundifolia, Eleocharis mamillata, Eleocharis multicaulis, Eleocharis quinqueflora, Epipactis palustris, Eriophorum (E.) angustifolium, E. gracile, E. latifolium, E. vaginatum, Gentianella uliginosa, Hammarbya paludosa, Hottonia palustris, Juncus alpinus, Juncus filiformis, Juncus subnodulosus, Ledum palustre, Liparis loeselii, Lycopodiella inundata, Menyanthes trifoliata, Myrica gale, Parnassia palustris, Pedicularis palustris, Pedicularis sylvatica, Rhynchospora alba, Rhynchospora fusca, Saxifraga hirculus, Scheuchzeria palustris, Schoenus ferrugineus, Schoenus nigricans, Stellaria crassifolia, Trichophorum alpinum, Trichophorum cespitosum, Triglochin palustre, Utricularia australis, Utricularia intermedia, Utricularia minor, Utricularia stygia, Vaccinium macrocarpon, Vaccinium oxycoccus, Viola epipsila	*Bryum longisetum, Calliergon stramineum, Calliergon trifarium, Calypogeia sphagnicola, Cephalozia connivens, Cephalozia macrostachya, Cephalozia pleniceps, Cephaloziella elachista, Cephaloziella spinigera, Cladopodiella fluitans, Dicranum bergeri, Drepanocladus cossonii, Drepanocladus lycopodioides, Drepanocladus revolvens, Fissidens osmundoides, Hamatocaulis vernicosus, Helodium blandowii, Leiocolea rutheana, Lophozia laxa, Meesia hexasticha, Meesia longiseta, Meesia triquetra, Meesia uliginosa, Mylia anomala, Paludella squarrosa, Pohlia sphagnicola, Polytrichum commune, Polytrichum strictum, Scapania paludicola, Sphagnum (S.) affine, S. angustifolium, S. balticum, S. capillifolium, S. centrale, Sphagnum compactum, S. contortum, S. cuspidatum, S. denticulatum* var. *denticulatum, S. denticulatum* var. *inundatum, S. fallax, S. fimbriatum, Sphagnum flexuosum, S. fuscum, S. magellanicum, S. majus, Sphagnum molle, S. obtusum, S. papillosum, S. platyphyllum, S. riparium, S. rubellum, S. subsecundum, S. tenellum, S. teres, S. warnstorfii, Splachnum ampullaceum, Tomentypnum nitens, Warnstorfia fluitans*

globally recognisable and can easily be defined and described at regional level. By reviewing the zonation of vegetation on natural mires in our study area, we derived 15 regionally occurring mire-specific and mire-typical plant formations (Table 3). To represent a smaller-scale physiognomic level we also defined special habitats (based on Luthardt 2014b, Minayeva *et al.* 2017) that are mire-specific or mire-typical and occur in natural mire ecosystems (Table 4). The attribute 'habitat diversity' is evaluated as the number of different specialised plant formations and special habitats.

'Habitat connectivity' is described by the attribute 'integration into biotope network'. The biotope networks described for the federal state of Brandenburg (Herrmann *et al*. 2013) identify core and connecting areas within which species exchange is possible. They include two well-connected

Table 3. Mire-specific and mire-typical plant formations occurring in the federal state of Brandenburg (north-east Germany). Remark: Species inventory and micro-relief as described in Ellenberg & Müller-Dombois 1966, but hydromorphologically no bogs are present in Brandenburg)

Formations class	Formation subclass	Formation group	Formation
Closed forests	Mainly deciduous forests	Cold deciduous forests without evergreen leaves	Cold-deciduous swamp or peat forest
Fourrés (shrubs)	Mainly deciduous fourrés (shrubs)	Cold deciduous shrublands (or thickets)	Deciduous peat shrubland (or thicket)
Dwarf-shrubs and related communities	Mossy bog formations with dwarf-shrubs	Raised bogs	Subcontinental woodland bog
		Non-raised bog	Blanket bog
Terrestrial herbaceous communities	Sedge swamps and flushes	Sedge peat swamps and similar swamps	Tall sedge swamp with creeping sedges
			Tall sedge swamp with caespitose sedges
			Low sedge swamp
		Flushes	Forb flushes (calcareous)
			Forb flushes (non-calcareous)
			Moss flush (calcareous)
			Moss flush (non-calcareous)
Aquatic plant formations	Floating meadows	Mainly herbaceous floating meadows	Temperate and subpolar herbaceous floating meadows
		Mainly mossy floating meadows	Mossy floating meadow
	Reed swamps	Reed swamp formations of fresh water lakes	Temperate and subpolar fresh water reed swamps
		Reed swamp formations of flowing water	Temperate reed swamps on river banks

Table 4. Mire-specific and mire-typical special habitats occurring in the federal state of Brandenburg (north-east Germany).

Mire-specific special habitats	Mire-typical special habitats
Hummock, hollow, lagg ("fen strip separating a bog from the surrounding mineral soil" (Joosten *et al.* 2017a), running spring water	Lying and upright dead wood, root plates, open water bodies (temporary or permanent), mineral islands, solitary trees, areas with no vegetation (e.g. mud banks)

networks involving peatlands, namely ‘small mires and peatlands in forests’ and ‘wet pastures and fens of the glacial valley’ (Figure 2). These were derived by defining criteria (size, protected areas, wet biotopes) for delineation of the core zones, then adding 1000 m buffer areas to form the networks. An indicator value (1) is recorded for this attribute if the peatland under examination is located within one network, using the network ‘small mires and peatlands in forests’ for peatlands located in forests and the network ‘wet pastures and fens of the glacial valley’ for peatlands located in the glacial valley and/or in agriculturally characterized surroundings.

Ecosystem

The indicator for this level refers to the abiotic components of the ecosystem, or ‘site characteristics’. It consists of two sub-indicators, namely ‘soil’ and ‘water table’.

‘Soil’ is described by the attribute ‘topsoil condition’ and is measured in terms of degree of degradation of the first upper homogenous horizon of the soil profile. To assess peat degradation, different development stages of the topsoil ranging from peat accumulation (undegraded peat) to murshified peat (highly degraded peat) are defined, based on Schulz *et al.* (2019) (Table 5).

‘Water table’ is described by the ‘soil moisture class’. Koska (2001) developed the concept of ‘vegetation forms’ for peatlands and wetlands in north-eastern Germany, which employs vegetation as a proxy for water table relative to the ground surface. It is thus possible to determine areas with different water tables, which are described by long-term median values of (positive or negative) standing water depth during wet and dry seasons (Table 6). The soil moisture class 5+ is most favourable for peat formation (cf. Parish *et al.* 2008, Joosten *et al.* 2015). The attribute ‘soil moisture class’ is evaluated as the distance from the water table to the soil surface, which is close to zero in natural mires.

In order to determine the dominant soil moisture class as well as the dominant degree of topsoil degradation, each site is subdivided into homogenous vegetation units (if there is more than one) firstly. Therefore, areas with homogenous floristic dominances and physiognomic structure are segregated from each other. All units are outlined on recent satellite images and transferred into a geographic information system to create spatial maps of each site. For each vegetation unit all plant species and their cover are recorded. To transfer these data

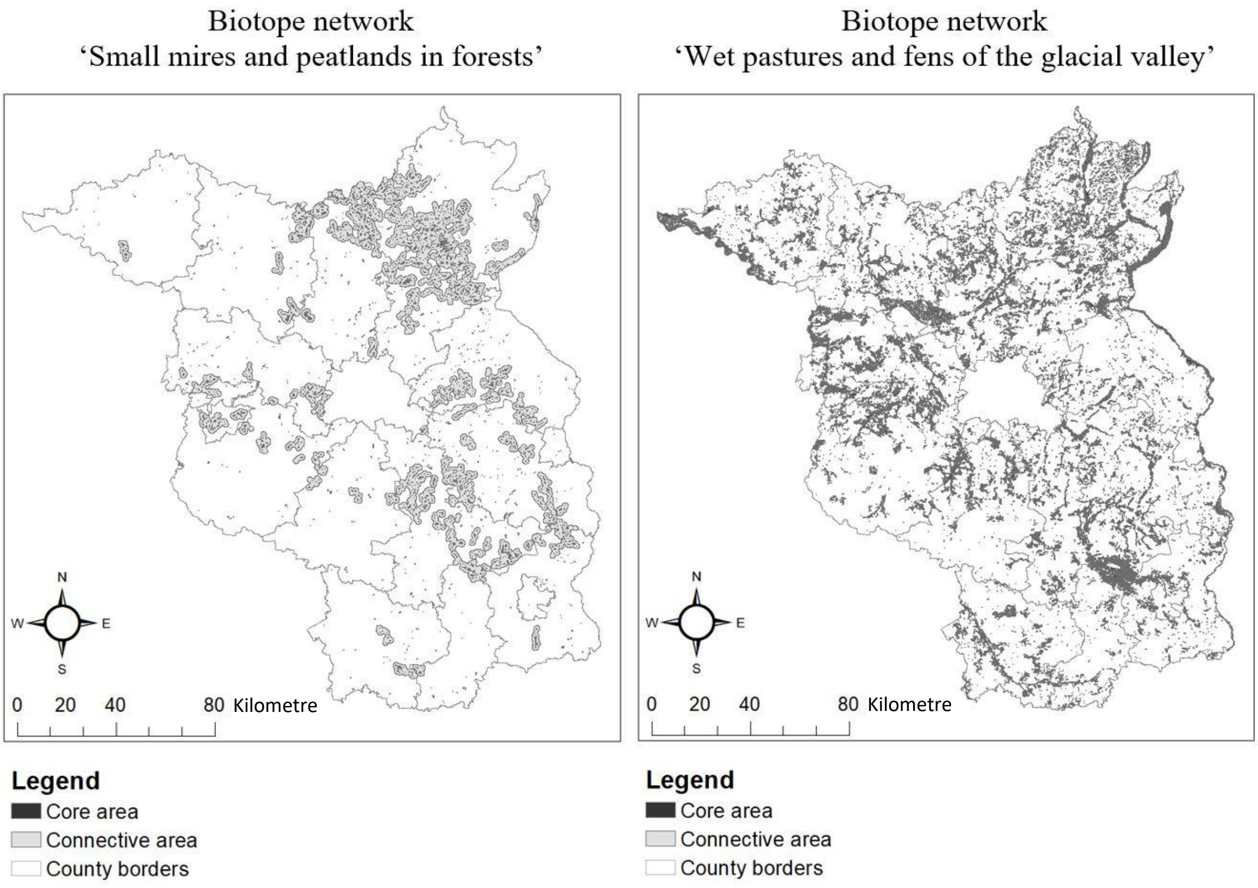

Figure 2. Biotope network of peatlands in Brandenburg, north-east Germany (Herrmann *et al.* 2013).

into soil moisture classes, the water table indication of each plant species described by Koska 2001 is applied to determine the soil moisture class of each vegetation unit. Further, for each vegetation unit the first upper homogenous horizon of topsoil peat is estimated in the field and classified into the different stages (Table 5). Thereby, the dominant topsoil degradation can be spatially described, too.

The ordinal scales for mire-specific biodiversity

The data from the 30 sampled peatlands is summarised in Table 7. In the sub-sections that follow, we explain the scoring system for each level of biodiversity in turn, and then the derivation of the overall site score for mire-specific biodiversity. The resulting survey sheet for field assessment of mire-specific biodiversity is provided in Appendix 1.

Table 5. Stages of peat topsoil (uppermost 30 cm) degradation from non-degraded peat (currently forming) to no peat.

Stage	Description
Non-degraded peat (currently forming)	Peat of low decomposition ('fibric' (Joosten *et al.* 2017b)) in nutrient poor, acidic, base-rich or calcareous mires (e.g. moss peats, herbaceous peats with radicels and rhizomes); in naturally eutrophic mire ecosystems with or without natural water level fluctuations, such as alder forests, also moderately decomposed ('hemic') peat can occur (e.g. herbaceous peats with radicels and rhizomes or wood peat) (Schulz *et al.* 2019).
Non-degraded peat (currently not forming) or gyttja	Dry peat of low to moderate decomposition ('hemic' (Joosten *et al.* 2017b)) (divisions as above) as well as gyttja, meaning a sedentarily accumulated material that consist of at least 5 % (dry mass) of organic matter (Schulz *et al.* 2019).
Slightly degraded peat (highly decomposed peat)	Highly decomposed peat ('sapric' (Joosten *et al.* 2017b)); 'Compact, mainly homogeneous, dark brown to black mass; unstructured (amorphous) or aggregated into larger pieces; muddy to mushy consistency when wet, comparable to a squeezed-dry sponge when dry; no or a small amount of recognisable plant remains; plant remains usually limited to more highly decomposed wood or fibre fragments' (Schulz *et al.* 2019).
Moderately degraded peat (earthified peat)	'Dark brown to black-brown mass with crumb grain structure, consisting of bonded soil particles of various sizes (but mainly >1 mm); similar to garden mould; smeary consistency when wet, crumbly but never powdery-dusty when dry; no or only a small amount of recognisable plant remains' (Schulz *et al.* 2019).
Highly degraded peat (murshified peat)	'Black-brown to deep black, loose mass with fine granular structure, consisting of small (mainly <1 mm) bonded soil particles; thick, silty mass when very wet, smeary-granular when moist, distinctly granular and powdery-dusty when dry (resembling loose coal slack); no recognisable plant remains' (Schulz *et al.* 2019).
No peat	All soil substrates that are not peat (defined in Germany as sedentarily accumulated material that consists of more than 30 % (dry mass) of incompletely decomposed plant remains and humic substances or gyttja (Schulz *et al.* 2019).

Table 6. Soil moisture classes and associated water tables for peatlands (Joosten *et al.* 2015 after Koska 2001). NV = no value.

Soil moisture class	Verbal description	Water table relative to ground surface (+ above, - below)		
		Long-term median water table in the wet season	Long-term median water table in the dry season	Water supply deficit
6+	Lower eulittoral	+150 to +10	+140 to +0 cm	NV
5+	Wet	+10 to -5 cm	+0 to -10 cm	NV
4+	Very moist	-5 to -15 cm	-10 to -20 cm	NV
3+	Moist	-15 to -35 cm	-20 to -45 cm	NV
2+	Moderately moist	-35 to -70 cm	-45 to -85 cm	NV
2-	Moderately dry	NV	NV	<60 L m^{-2}

Table 7. Mire type, mire-specific flora (total number and number of mire-typical and mire-specific vascular plants and mosses), spatial structure (number of mire-typical plant formations and special habitats, integration into biotope network), topsoil state (no peat to non-degraded peat in % of total area) and soil moisture class (2- to 6+ in % of total area) for the 30 sampled peatlands in Brandenburg (north-east Germany), classified according to stages of naturalness (Wagner & Wagner 2005).

			Species					Biocoenosis			Ecosystem												
			Mire-specific species					Spatial structure			Site characteristics												
Naturalness	Study site	Mire type	Mire-specific flora								Topsoil state (in % of total peatland area)						Soil moisture class (in % of total peatland area)*						
			A	**B**	**C**	**D**	**E**	**I**	**II**	**III**	**5**	**4**	**3**	**2**	**1**	**0**	**6+**	**5+**	**4+**	**3+**	**2+**	**2-**
Natural	1	a	47	9	11	0	4	4	5	1	100	0	0	0	0	0	0	100	0	0	0	0
	2	a	64	21	13	2	3	5	7	1	85	15	0	0	0	0	12	88	0	0	0	0
	3	a	31	17	6	0	1	3	5	1	54	46	0	0	0	0	0	100	0	0	0	0
	4	b	102	43	19	11	7	7	5	1	nv	nv	nv	nv	nv	nv	20	60	20	0	0	0
	5	a,c	64	31	15	1	4	5	5	1	55	45	0	0	0	0	45	55	0	0	0	0
	6	a	48	16	11	1	2	3	5	1	50	35	15	0	0	0	0	100	0	0	0	0
	Mdn		**56**	**19**	**12**	**1**	**4**	**5**	**5**	**1**	**55**	**25**	**0**	**0**	**0**	**0**	**6**	**94**	**0**	**0**	**0**	**0**
Near-natural	7	c,b	73	38	8	2	1	3	4	1	0	0	47	53	0	0	0	72	28	0	0	0
	8	a	27	4	8	1	4	2	3	1	8	2	90	0	0	0	0	8	2	90	0	0
	9	c	38	18	3	0	0	4	3	1	0	93	7	0	0	0	0	93	7	0	0	0
	10	c,a	66	26	7	0	1	5	7	1	0	8	66	24	2	0	0	22	58	20	0	0
	11	a	48	23	12	1	2	4	2	1	0	60	40	0	0	0	0	60	0	40	0	0
	12	c	42	19	4	0	1	1	3	1	0	18	12	8	62	0	0	38	62	0	0	0
	Mdn		**48**	**21**	**8**	**0.5**	**1**	**4**	**3**	**1**	**0**	**13**	**44**	**4**	**0**	**0**	**0**	**49**	**18**	**10**	**0**	**0**
Culturally-accentuated	13	c	99	42	5	2	1	2	6	1	0	31	12	0	0	57	0	31	12	57	0	0
	14	b,c	47	30	2	0	0	4	3	1	nv	nv	nv	nv	nv	nv	0	100	0	0	0	0
	15	c,b	97	46	2	1	0	3	4	1	0	0	0	0	99	1	0	0	36	63	0	1
	16	c,a	31	10	5	0	1	2	4	1	15	20	55	0	0	10	0	15	15	45	25	0
	17	c	143	46	4	1	0	3	7	0	nv	nv	nv	nv	nv	nv	0	0	55	45	0	0
	18	a	29	10	5	0	1	2	3	1	0	87	13	0	0	0	0	13	0	87	0	0
	Mdn		**72**	**36**	**5**	**0.5**	**1**	**3**	**4**	**1**	**0**	**26**	**13**	**0**	**0**	**5.5**	**0**	**14**	**14**	**51**	**0**	**0**
Culturally-characterized	19	c,a	67	17	6	3	3	2	7	0	2	0	0	74	24	0	0	2	24	63	11	0
	20	c	31	16	0	3	2	2	nv	1	nv	nv	nv	nv	nv	nv	0	0	32	68	0	0
	21	c	83	44	2	0	0	3	3	1	0	0	0	0	25	75	0	0	30	70	0	0
	22	c	106	41	1	0	0	3	7	1	0	1	3	89	5	2	0	2	28	60	0	0
	23	c	96	34	0	0	0	1	3	1	0	0	0	0	63	37	0	0	0	36	27	22
	24	c,b	60	27	4	1	0	2	7	1	10	0	26	0	48,3	16	0	10	26	64	0	0
	Mdn		**75**	**31**	**2**	**0.5**	**0**	**2**	**7**	**1**	**0**	**0**	**0**	**0**	**25**	**16**	**0**	**1**	**27**	**64**	**0**	**0**
Non-natural	25	c	176	50	4	0	0	1	3	0	nv	nv	nv	nv	nv	nv	nv	nv	nv	nv	nv	nv
	26	c	81	26	0	0	0	3	2	1	0	0	0	0	46	54	0	0	33	66	1	0
	27	c	50	12	2	0	1	1	2	1	0	0	0	55	45	0	0	0	0	60	40	0
	28	c	21	5	0	0	0	0	2	1	0	17	37	46	0	0	0	0	0	83	17	0
	29	c	75	26	0	0	0	2	2	1	0	0	0	0	100	0	0	0	18	82	0	0
	30	c	96	27	1	0	0	0	0	1	0	0	0	0	80	20	0	0	19	61	0	20
	Mdn		**78**	**26**	**1**	**0**	**0**	**1**	**2**	**1**	**0**	**0**	**0**	**0**	**46**	**0**	**0**	**0**	**18**	**66**	**1**	**0**

Abbreviations:

a: Nutrient poor, acidic
b: Nutrient poor, base-rich/calcareous
c: Nutrient rich

A: Total number of species of vascular plants & mosses
B: Mire-typical vascular plants
C: Mire-specific vascular plants
D: Mire-typical mosses
E: Mire-specific mosses

I: Number of plant formations
II: Number of special habitats
III: Integrated into biotope network (1=Part of network, 0=Not part network)

Mdn: Median
*definitions see Table 7

5: Non-degraded peat (currently forming)
4: Non-degraded peat (currently not forming) or gyttja
3: Slightly degraded peat (highly decomposed)
2. Moderately degraded peat (earthified peat)
1. Highly degraded peat (murshified peat)
0: No peat

nv: no value

Species

Table 7 shows that the numbers of mire-specific vascular plants recorded for the 30 sampled peatlands range from a median value of 12 in natural peatlands to almost zero in non-natural peatlands; whereas mire-specific mosses seem to occur in natural to culturally-accentuated peatlands but hardly at all in culturally characterised and non-natural peatlands. On the other hand, the number of mire-typical vascular plant species is higher in degraded peatlands then in natural and near-natural sites. On this basis, we excluded mire-typical plant species from the assessment.

The derivation of ordinal values for the ‘mire-specific species’ indicator is shown in Table 8. The final value is based mostly on the number of mire-specific vascular plants, with a single point added if mire-specific mosses are also present. In other words, it is the overall presence, rather than the number, of moss species that is rated; and if mosses are not determined and cannot be accounted for, the effect on the overall evaluation is not severe. This approach was adopted because mosses are not typically identified to species level in common practice, on account of the need for expert knowledge.

Biocoenosis

Amongst the 30 sampled peatlands, the number of mire-specific and mire-typical plant formations increases with increasing naturalness (Table 7). Most of the non-natural and culturally-characterised peatlands have only one or two mire-specific and mire-typical formations which are mainly dominated by reeds or sedges. In contrast, the formations in natural and near-natural peatlands are divers, often comprising a combination of peat forests with sedge, reed and moss dominated formations. The number of special habitats per peatland fluctuates widely, but also generally increases with increasing naturalness. Laggs, hummocks, hollows and open water bodies are mostly recorded in the less-degraded peatlands. Almost all of the sampled peatlands are located within one of the peatland biotope networks (Figure 2).

The calculation of ordinal values for the ‘spatial structure’ indicator is illustrated in Table 9. Scores up to 3 are awarded on the basis of ‘number of mire-specific and mire-typical plant formations’, then one point is added if the number of special habitats is at least 3, and another if the peatland lies within a biotope network.

Ecosystem

Topsoil condition in the sampled peatlands shows a shift from highly degraded in non-natural peatlands to non-degraded with current peat formation in natural peatlands, while the soil moisture class ranges from 2+/3+ in non-natural peatlands to mainly 5+ in natural peatlands (Table 7).

The matrix of ordinal values for the ‘site characteristics’ indicator is shown in Table 10. Each peatland is scored on the basis of the spatially dominant (most extensive) topsoil condition and soil moisture classes observed. Although open water (soil moisture class 6+) was very seldom recorded in the sampled peatlands, the second highest ranking for ‘water table’ is awarded if the dominant soil moisture class is found to be 6+. Peatland restoration measures can lead to surface flooding if the peat is so degraded that it cannot absorb inflowing water, i.e. if the peatland has lost its ‘surface oscillation’ (Mooratmung) function and acts hydrophobic due to oxidisation (Zeitz 2014 & 2016); and similar scenarios may arise in less-disturbed peatlands as the incidence of drought conditions increases due to climate change. On this basis, we decided that areas of shallow open water should score four points in

Table 8. Value scale for indicator ‘mire-specific species’ based on number of mire-specific vascular plants and presence of mire-specific mosses (species diversity).

Number of mire-specific vascular plants	Value	Mire-specific mosses present?	Total value ‘mire-specific species’
≥ 10	4	Yes	5
		No	4
≥ 7	3	Yes	4
		No	3
≥ 4	2	Yes	3
		No	2
≥ 1	1	Yes	2
		No	1
0	0	Yes	1
		No	0

order to attach value to the presence of a high water table under such circumstances, even though gyttja rather than peat will form in this situation.

Because the water table is the driving factor that enables peat accumulation (Joosten 2008), it is of higher impact than the topsoil state (Table 10).

Overall assessment of mire-specific biodiversity

After assessing the levels of biodiversity individually, the ordinal scores (0 to 5) are summed to give a cumulative score for the peatland and the cumulative scores are again classified from zero (no mire-specific biodiversity) to five (very high mire-specific biodiversity) in line with the five stages of naturalness by Wagner & Wagner (2005) (Table 11).

Using the scores as an overall description, the mire-specific biodiversity can be compared between two or more sites or, for a single peatland, before and after rewetting or across another defined time interval. Possible visualisations are shown in Figure 3 and, for the example of our 30 study sites, in Figure 4.

Table 9. Value scale for the indicator ‘spatial structure’ based on number of mire-specific and mire-typical plant formations, number of special habitats and integration into biotope network (biocoenosis diversity).

Number of mire specific & mire-typical plant formations	Value	Number of special habitats	Added value	Located within a biotope network	Total added value ‘spatial structure”
≥ 5	3	≥ 3	4	Yes	5
				No	4
		0–2	3	Yes	4
				No	3
≥ 3	2	≥ 3	3	Yes	4
				No	3
		0–2	2	Yes	3
				No	2
≥ 1	1	≥ 3	2	Yes	3
				No	2
		0–2	1	Yes	2
				No	1
0	0	≥ 3	1	Yes	2
				No	1
		0–2	0	Yes	1
				No	0

Table 10. Matrix of values for the ‘site characteristics’ indicator, based on soil moisture class and topsoil state (ecosystem diversity).

Topsoil state / Soil moisture class	Non-degraded peat (currently forming)	Non-degraded peat (currently not forming) or gyttja	Slightly degraded peat (highly decomposed peat)	Moderately degraded peat (earthified peat	Highly degraded peat (murshfied peat)	No peat or gyttja
5+	5	5	4	4	3	3
4+ or 6+	4	4	4	3	3	2
3+	4	3	3	3	2	2
2+	3	3	2	2	2	1
2-	3	2	2	1	1	1
Lower than 2-	2	2	1	1	0	0

Table 11. Overall assessment of mire-specific biodiversity based on the accumulated indicator values for species, biocoenosis and ecosystem levels.

Class	Accumulated values	Verbal description	Colour code
5	14, 15	Very high mire-specific biodiversity	
4	11, 12, 13	High mire-specific biodiversity	
3	8, 9, 10	Moderate mire-specific biodiversity	
2	5, 6, 7	Low mire-specific biodiversity	
1	2, 3, 4	Very low mire-specific biodiversity	
0	0, 1	No mire-specific biodiversity	

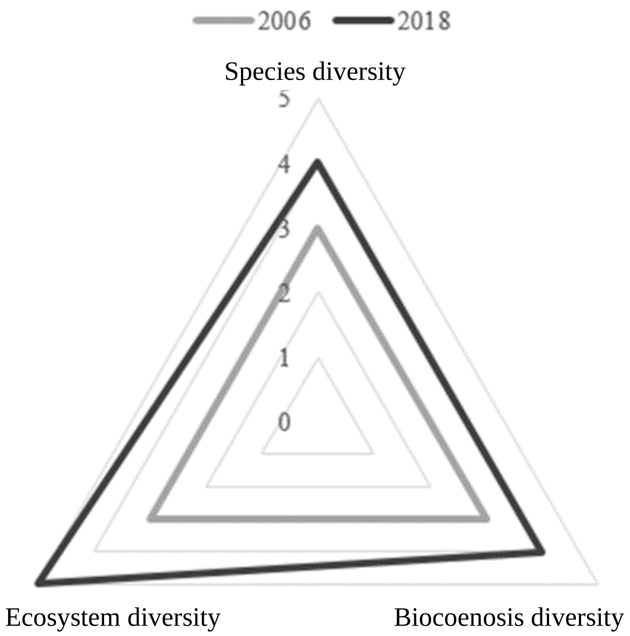

Figure 3. Visualisation of overall mire-specific biodiversity of “Großes Brennbruch” before (2006) and after (2018) restoration.

Expert validation

The experts and practitioners who participated in the evaluation returned very similar assessments of mire-specific biodiversity, both overall and for the individual levels (Table 12). By comparing the assessment via the indicator system and the median of the evaluation by practitioners, a high conformity is visible. Eighty-one percent of the assessments were identical. Comparing the indicator assessment with expert assessment (median), 70 % of the assessments were identical. The similar outcomes of the mire-specific biodiversity assessments by the indicator-system and the practitioners and experts confirms the indication by our objectified system. So further adaptations were assessed as not necessary.

Case study

Before restoration in 2006, the topsoil at the ‘Großes Brennbruch’ mainly consisted of earthified peat and the dominant soil moisture class was 3+ (Table 13). Only the central *Sphagna*-*Betula pubescens*-peat forest (15 % of total area) had a higher water table and non-degraded peat profile. The other vegetation formations were mostly not mire-typical or specific. Areas dominated by *Calamagrostis epigejos* and *Rubus ideaus*, an alder forest with *Dryopteris cathusiana* in the herb layer and a *Betula pendula* pioneer forest were present (Figure 5). The only mire-specific formations were a cold-deciduous peat forest with *Betula pubescens* and *Sphagna*, and a temperate freshwater reedbed dominated by *Phragmites australis*. Five different mire-specific vascular plants were present, namely *Betula pubescens*, *Eriophorum vaginatum* and *Oxycoccus palustris* mainly in the central part of the peatland, but with *Carex elata* and *Carex paniculata* in the periphery.

In 2018, the topsoil showed reinstated peat formation, mainly by peat mosses over highly decomposed peat, and the dominant soil moisture class was 5+. In addition to the cold deciduous peat forest with *Betula pubescens* and peat mosses recorded in 2006, two other mire-typical formations were present, namely a reed swamp dominated by *Phragmitis australis* and a tall sedge swamp dominated by *Carex acutiformis*. The formerly dry alder forest was characterised by species indicating wetness (e.g. *Lemna minor*, *Hottonia palustris*, *Utricularia vulgaris*) and some sedges (e.g. *Carex acutiformis*, *Carex riparia*) (Figure 5). Special habitats (dead wood, open water pools, hummocks) could be found within all vegetation areas. Seven mire-specific vascular plants were present in nearly all vegetation areas, and peat mosses were growing on more than 50 % of the total area.

The overall rating for mire-specific biodiversity changed within 12 years from moderate (8/15 points) to high (13/15 points) (Figure 3).

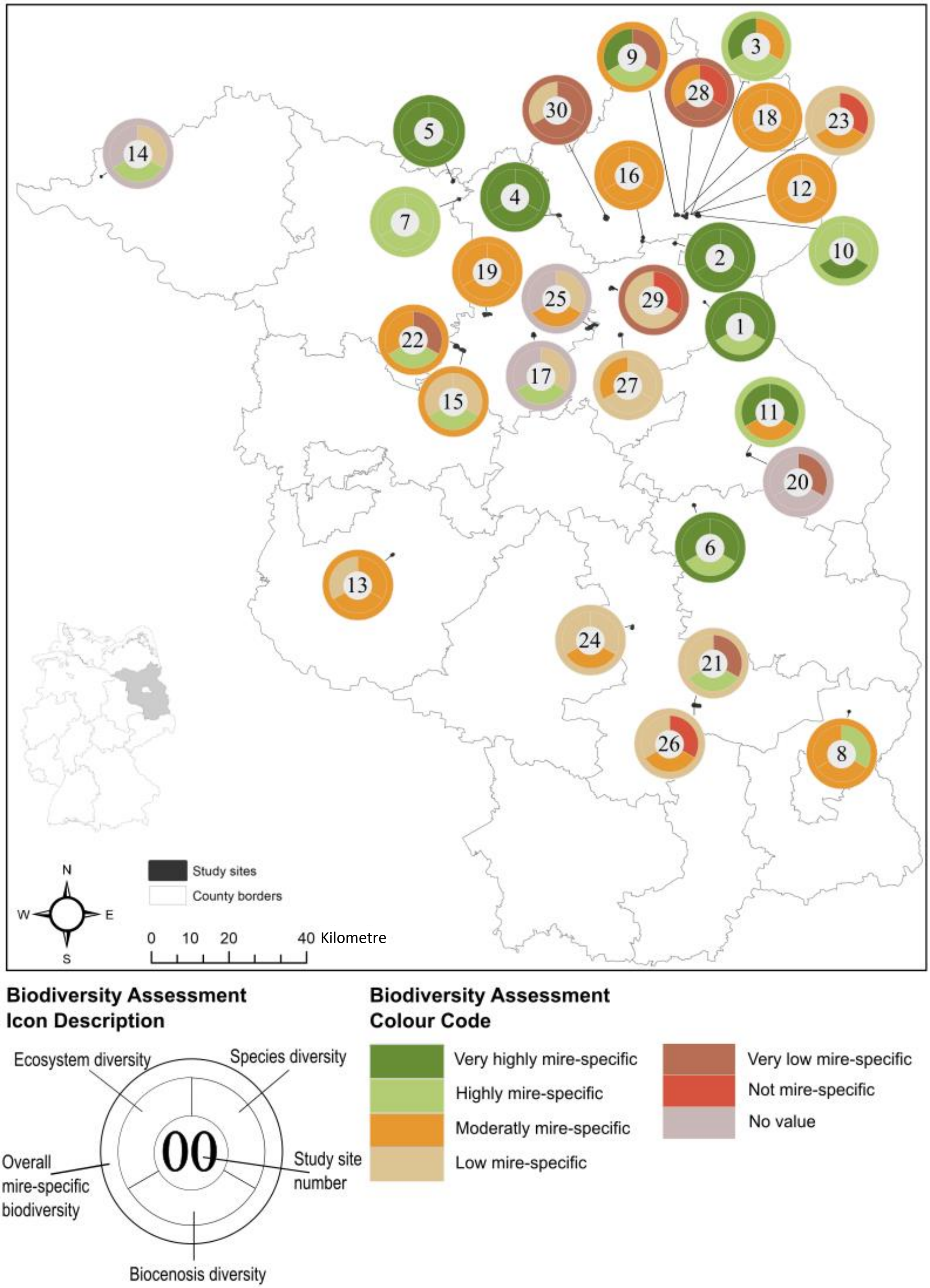

Figure 4. Visualisation of mire-specific biodiversity for the 30 sampled study sites in Brandenburg (north-east Germany (edited by J. Hammerich, source: County borders: VG250®ATKIS, ©BKG 2006).

Table 12. Comparison of assessment (species, biocenosis and ecosystem level as well as overall biodiversity) via indicator system and experts/practitioners

Practitioner Workshop (n=42)																								
Study case	Species level						Biocoenosis level						Ecosystem level						Overall assessment					
	I	Practitioners					I	Practitioners					I	Practitioners					I	Practitioners				
		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf
1	5	4.5	5.0	3	5	5	4	4.3	4.0	3	5	5	5	4.5	4.5	4	5	5	5	4.4	4.0	3	5	5
2	2	1.7	2.0	1	3	2	2	2.1	2.0	1	3	2	1	1.4	1.0	1	4	1	2	1.8	2.0	1	4	2
3	2	1.7	2.0	1	3	2	2	1.9	2.0	1	3	2	3	1.4	1.0	1	2	1	2	1.9	2.0	1	3	2
4	2	2.4	2.0	1	4	3	3	2.9	3.0	2	4	3	4	3.6	4.0	2	5	4	3	3.0	3.0	2	4	3
Expert Interviews (n=11)																								
Study case	Species level						Biocoenosis level						Ecosystem level						Overall assessment					
	I	Experts					I	Experts					I	Experts					I	Experts				
		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf		M	Mdn	Min	Max	Mf
5	4	3.4	3.0	2	4	4	4	4.0	4.0	3	5	4	5	4.7	5.0	4	5	5	4	3.9	4	3	5	3
6	1	0.7	1.0	0	2	0	3	2.4	2.0	1	4	2	2	2.1	2.0	1	5	2	2	1.7	1.5	1	3	1
7	5	4.5	5.0	3	5	5	5	4.4	4.0	3	5	5	5	4.4	5.0	2	5	5	5	4.8	5	4	5	5
8	1	1.4	1.0	0	3	1	3	3.0	3.0	2	4	3	3	2.2	2.0	1	4	2	2	2.2	2.0	1	4	2
9	1	1.2	1.0	0	4	1	3	3.0	3.0	0	5	4	4	4.0	4.0	2	5	5	3	3.0	3.0	1	4	3

Abbreviations:	Study cases:
I= Indicator based assessment n = Total sample size M = Mean Mdn = Median Min = Minimum Max = Maximum Mf = Most frequent value	1 = ‘Große Mooskute’ 2 = ‘Römerwiese’ 3 = ‘Eiserbuder Erlenwald’ 4 = ‘Kranichbruch’ 5 = ‘Großes Brennbruch’ 6 = ‘Koppainz’ 7 = ‘Plötzendiebel’ 8 = ‘Sernitz’ 9 = ‘Rothsche Wiese’

DISCUSSION

Indicators, attributes, measured values

We developed a multi-indicator assessment tool for mire-specific biodiversity, which considers the vegetation, habitat heterogeneity and connectivity, water table and topsoil degradation of the focus peatland. Existing suggestions on how to assess peatland biodiversity mainly focus on vegetation and fauna alone. Tiemeyer *et al*. (2015) suggest an approach where mire-typical vegetation is assessed by biotope value. Biotope values are a procedure that assigns a value to biotopes on the basis of their importance for nature conservation. This procedure is used in parts of Germany to compensate for interventions in nature (Deutscher Bundestag 2018). This value is then augmented by awarding ‘peatland points’ for natural, peat accumulating or peat preserving biotope types and their degraded states. The method for biodiversity of fauna is not fully developed, but the authors suggest an assessment based on the Red-List endangerment and the binding of species to mire-typical biotope types. In the context of integrating additional ecosystem services into carbon credits, Joosten *et al.* (2015) suggest two assessments for the biodiversity of mires - a cost-effective standard approach and a premium approach. The first of these aims to compare the biotope value before and after restoration. The second is based on field surveys and suggests rating the abundance of vascular plants and mosses, amphibians, birds and arthropods. The model by Görn & Fischer (2011) is used for birds and arthropods, whereas no assessment model is developed for amphibians, vascular plants and mosses. The Görn & Fischer (2011) approach is based on evaluation of fens for nature conservancy purposes via faunistic indicators, rather than direct assessment of mire-typical or mire-specific

Table 13. Overview of mire-specific biodiversity components at ‘Großes Brennbruch” in the years 2006 (before restoration) and 2018 (after restoration).

Mire-specific vascular plants	Mire-specific mosses	Mire-specific plant formations	Special habitats	Located within peatland biotope network	Dominant topsoil condition	Dominant soil moisture class
2006						
Betula pubescens, Carex elata, Carex paniculata, Eriophorum vaginatum, Oxycoccus palustris	*Spagnum sp.*	cold-deciduous peat forest, temperate freshwater reed	hummocks, upright dead wood, mineral islands, areas with no vegetation	yes	Moderately degraded peat (earthified peat)	3+
2018						
Betula pubescens, Calla palustris, Carex elata, Carex lasiocarpa, Comarum palustre, Eriophorum vaginatum, Hottonia palustris	*Polytrichum commune, Sphagnum fallax, Sphagnum fimbriatum, Sphagnum magellanicum*	cold-deciduous peat forest, temperate freshwater reed, tall-sedge swamp	hummocks, hollows, lying dead wood, upright dead wood, open water body, mineral islands, areas with no vegetation	yes	Non-degraded peat (peat forming)	5+

biodiversity. Therefore, they suggested locusts, ground beetles, butterflies and birds as suitable taxa, listed all fen-typical species, chose criteria upon which they should be assessed, and developed value scales based upon distribution as well as national and international endangerment. Otherwise, where the term ‘biodiversity’ is used in various publications on peatlands, the authors often research and refer to diversity of vegetation and fauna only (e.g. Agus *et al.* 2019, Payne *et al.* 2018, Harrison & Rieley 2018, Renou-Wilson *et al.* 2019, Sundari *et al.* 2020).

In line with the literature (Bragg & Lindsay 2003, Prentice 2011, Minayeva *et al.* 2017) on recommendations for mire-typical and mire-specific biodiversity assessment, we do not think that individual taxa or a focus on vegetation and fauna alone are suitable indicators for the entirety of mire-specific biodiversity, even though studies show that, for example, vascular plants can function as strong indicators for overall biodiversity across environmental gradients (Brunbjerg *et al.* 2018). In peatlands, often long degradation processes due to drainage as well as peatland restoration lead to diverse states. For example, vascular plants and mosses often remain in retention areas or still-natural central areas even though the site is increasingly degrading overall. Taking additionally into account the dominant site conditions as well as structural heterogeneity gives a better understanding of the overall mire-specific biodiversity. In this way the maturity and functionality of the peatland ecosystem, which plays an important but often undervalued role for less-researched taxa such as ground beetles (Barndt 2014), are better taken into account.

The ecological conditions, in particular nutrient content and pH value, are commonly used in conservation projects or peatland description (Klingenfuß *et al.* 2015) to assess the peatland’s state relative to the original or natural state (target state of restoration) of a specific mire type. Bragg & Lindsay (2003) also stress that the evaluation of peatland biodiversity needs to be based on assessment of the

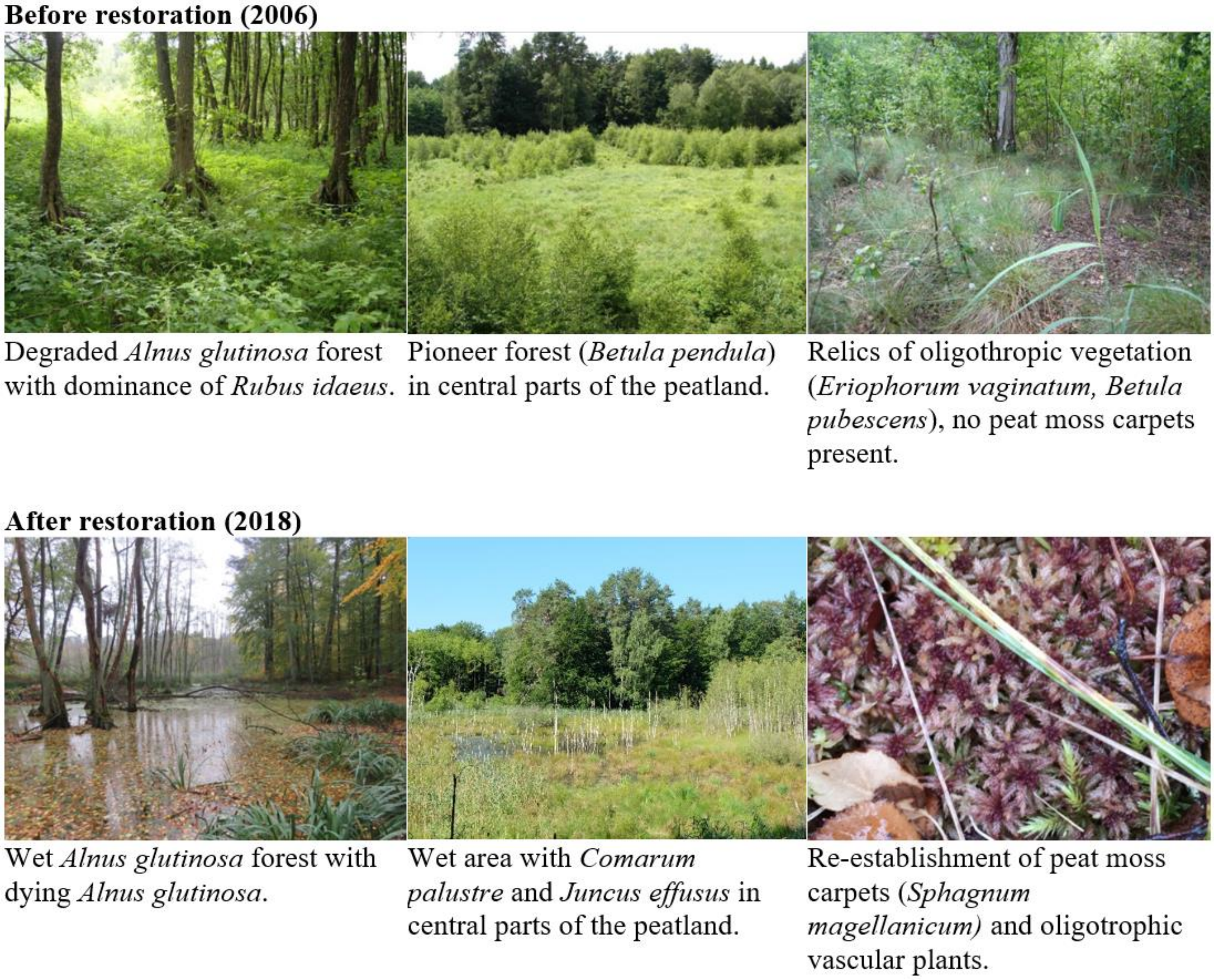

Figure 5. Photo documentation „Großes Brennbruch“ 2006 (before restoration) and 2018 (after restoration).

same mire type based on the criteria naturalness and diversity (representativeness and rarity). Although the measurement of nutrient content and pH is not directly included, these and other ecological traits are represented within the ecological amplitudes of mire-specific vascular plants and mosses. Furthermore, our indicator system targets a state of stable ecosystem functioning where peat is dominantly accumulating, the water table is predominantly at or above the ground surface, the mire-specific habitat structure is diverse, and mire-specific species are present. In this way, we do not target a specific eco-hydrological mire type, but rather we target the specific characteristics that all mire types share.

Each of the attributes chosen for inclusion in our assessment has been defined in terms of regional characteristics, offers good data availability, and is practically applicable.

Tiemeyer *et al.* (2015) and Görn & Fischer (2011) include endangerment (Red Lists) within their assessment, whereas we evaluate peatland attributes in terms of mire-specificity. We consider that integrating Red-List endangerment in an assessment of mire biodiversity is not constructive, at least in the case of our study region. Of the mire-specific vascular plants for Brandenburg, 62 % are listed as highly endangered, at risk of extinction or extinct and only 7 % are not listed at all (LUA 2006). If we were to focus on Red-List status, nearly all mire-specific species would be valued for endangerment, but so would all other (not mire-specific) Red-List-species - such as species adapted to degradation stages of mires or even dry ecosystems.

Biotope values, as suggested by Joosten *et al.* (2015) and Tiemeyer *et al.* (2015), are not widely developed and are based upon different characteristics in different regions, so they would not be applicable across all regions. Also, they do not aim to directly highlight mire-specific characteristics and could, therefore, be misleading.

We considered butterflies and araneomorph spiders for assessing peatland fauna, which show high specialisation on mires. Görn & Fischer (2011) suggest birds, butterflies, locusts and ground beetles covering a range of different spatial scales. Lehmitz *et al.* (2020) suggest the inclusion of vegetation, ground beetles, oribatid mites and araneomorph spiders in an ecological assessment of peatlands, finding good correlations concerning moisture and habitats for the last two. Dragonflies were considered, but were excluded because their habitat is not the mire itself but the open water bodies within mires (Mauersberger 2014). Batzer *et al.* (2016) evaluate the roles of terrestrial invertebrates in peatlands of Europe, Canada, USA, and China and their value for peatland biodiversity assessment and state that further research is greatly needed. In general the use of fauna in environmental assessments is complicated by the effort required for data acquisition due to their high mobility, transient or hidden lifestyles and their adaptation to multiple spatially separated and differently structured habitats, as well as the highly specialised knowledge required for determination of some species (Bastian & Schreiber 1999). The use in practitioner friendly assessments is questionable. Still, it is plausible that, with further research, additional taxa could be included in the indicator system.

The assessment of biotope connectivity is based on a single study from the year 2006. Therefore, it will only be possible to detect changes in biotope connectivity (for example after rewetting) if the biotope network is updated on a regular basis.

The plant formations are described globally and can readily be adapted to individual regions by adding or removing mire-specific and mire-typical formations based on their regional manifestations.

In the indicator system developed here, peatland size is addressed only indirectly through the dataset, which includes peatlands with total areas ranging from 1 to 51 hectares. The number of species belonging to a taxonomic group generally increases with increasing area (species-area relationship; inter alia Preston 1962) whereas mire-specific species often show high specialisation but low demand on habitat size. To evaluate whether peatland size influences the number of mire-specific species within the same peatland hemeroby class, further research is needed.

Transferability

We placed special emphasis on explaining how the attributes and measured values were developed and which data they were based on, in order to create an example for adaptation to other regions. This form of assessment can be applied elsewhere, by defining the mire-specific components (species, plant formations, special habitats, biotope networks) of the region addressed and analysing data from degraded to natural peatlands occurring within that region. A precondition is the availability of reference systems, which are in a natural state.

To determine the degree of the peatlands naturalness we referred to Wagner & Wagner (2005). Joosten & Clarke (2002) define the naturalness of peatlands as ‘the quality of not having been deliberately influenced by human beings’. Bragg & Lindsay (2003) refer to naturalness as either the ‘full display of all expected components of natural diversity’ or the “lack of evident human disturbance” and name vegetation and surface patterns as valuable components for the evaluation of a peatlands naturalness. Mendes *et al.* (2019) show an example on how to cluster peatlands in four classes of naturalness based on the level of human interference: disturbed, altered, conserved and wild.

We think the list of mire-specific plants and mosses provided by Klawitter (2014), Klawitter & Luthardt (2014) and Luthardt (2014c) is valid for north-east Germany and could be used for whole Germany with slight modifications. Concerning mire-typical and mire-specific species, a good basis for determination of mire-specific plants is provided by Joosten *et al.* (2017b), who offer insights about the characteristic vascular plants and mosses of mires and peatlands in various European countries at different levels of detail (e.g. Risager *et al.* 2017 (Denmark), Krebs *et al.* 2017 (Georgia), Stefanut *et al.* 2017 (Romania)). Literature from the research fields of botany and environmental science offers methodologies for developing a list of peatland-typical or peatland-specific vascular plants for a focus area; for example, Sotek 2010 (Pomerania) and Anderson & Davis 1997 (Maine) researched distribution patterns and/or habitat conditions of peatland plants. Also, routine publications from nature conservation can be taken into account, such as the lists of characteristic species prepared for the European Union NATURA 2000 directive and descriptions of plant sociology or biotope types.

There are various publications on mire-typical and mire-specific fauna including ground beetles ((Holmes *et al.* 1993 (Wales), aquatic invertebrates (Horwitz 1997 (Australia), non-biting midges (Rosenberg *et al.* 1988 (Canada) and oribatid mites (Behan-Pelletier & Bissett 1994 (Canada), Wisdom *et al.* 2011 (Ireland)). As mentioned above, the major challenge will be listing all mire-specific species and setting value scales for the region under consideration.

Plant formations for each region can be derived from Ellenberg & Müller-Dombois (1966). Special habitats will need to be adjusted for the focus region. Examples of possible additions to reflect habitat heterogeneity in different regions are frailejones (*Espleletia* spp.) for the páramo region of South America (Cárdenas *et al.* 2018) and palsa formations for Norway (Moen *et al.* 2017).

Concerning biotope connectivity, previous research can be applied either to develop a regional biotope network or to implement data on existing networks. Available guidelines for developing a biotope network employ different approaches, for example spatial conservation prioritisation (Jalkanen *et al.* 2020) or the use of focal species (Bani *et al.* 2002). A good overview of international (transboundary) networks which include (but do not focus on) peatland habitats can be found in Bennett & Wit (2001). Established regional biotope networks often provide descriptions of the methodology employed in their development and can, therefore, be used not only directly but also as guidelines/models for new networks (e.g. Metropolregion Hamburg 2019).

The sub-indicators 'soil' and 'water table' show good transferability, due to the ubiquitous ecohydrological processes (based on permanent water saturation and the accumulation of organic matter as peat) of peatlands (Parish *et al.* 2008). In this study, we chose to work with soil moisture classes because that is a regionally accepted methodology with good spatial resolution. For other regions it might be practical to use water tables measured at gauging stations. In some locations it may be necessary to consider other influencing factors, such as permafrost.

We encourage scientists to apply our research as a model for other geographical regions. Assessing the biodiversity of peatlands on the basis of mire-specific characteristics highlights their importance for biodiversity in general, and provides tangible evidence to support conservation planning at regional to global scales.

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AUTHOR CONTRIBUTIONS

JH, CD, VL and FT designed the study. JH and CD did the literature review and set up the first draft of the indicator system. JH revised the indicator system and sampled the data. The data were collected by JH, CD, CS and other researchers at Eberswalde University for Sustainable Development. JH prepared the manuscript with the help of CS and VL. VL critically reviewed the study and contributed central ideas and discussion points. All authors contributed to the final version of the manuscript.

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Appendix: Assessment of mire-specific diversity - working instructions

Mire-specific biodiversity – Assessment sheet		
Mire-specific biodiversity is measured at three levels: species (Section 2), biocoenosis (Section 3) and ecosystem (Section 4.). For each level, attributes are evaluated and recorded on this form. At the end of each section is a point classification which will be summed up at the end of the evaluation sheet for an overall assessment of the mire-specific biodiversity of the peatland in focus.		
1. General information		
Site:	Latitude/Longitude:	
Date:	Size (ha):	
Editor/Editing organisation:		
Hydrological mire type:	□ known □ presumed	
Ecological mire type (current):		
Ecological mire type (former):	□ known □ presumed	
2. Species diversity		
2.1.Mire-specific vascular plants		
Instructions: Please mark all of the mire-specific vascular plants occurring within the peatland area.		
□ *Andromeda polifolia,*	□ *Betula humilis*	□ *Betula nana*
□ *Betula pubescens*	□ *Blysmus compressus*	□ *Calla palustris*
□ *Carex appropinquata*	□ *Carex cespitosa*	□ *Carex chordorrhiza*
□ *Carex davalliana*	□ *Carex diandra*	□ *Carex dioica*
□ *Carex echinata*	□ *Carex elata*	□ *Carex flacca*
□ *Carex flava*	□ *Carex lasiocarpa*	□ *Carex lepidocarpa*
□ *Carex limosa*	□ *Carex panicea*	□ *Carex paniculata*
□ *Carex pulicaris*	□ *Carex rostrata*	□ *Carex vesicaria*
□ *Cladium mariscus*	□ *Comarum palustre*	□ *Drosera intermedia*
□ *Drosera longifolia*	□ *Drosera x obovata*	□ *Drosera rotundifolia*
□ *Eleocharis mamillata*	□ *Eleocharis multicaulis*	□ *Eleocharis quinqueflora*
□ *Epipactis palustris*	□ *Eriophorum angustifolium*	□ *Eriophorum gracile*
□ *Eriophorum latifolium*	□ *Eriophorum vaginatum*	□ *Gentianella uliginosa*
□ *Hammarbya paludosa*	□ *Hottonia palustris*	□ *Juncus alpinus*
□ *Juncus filiformis*	□ *Juncus subnodulosus*	□ *Ledum palustre*
□ *Liparis loeselii*	□ *Lycopodiella inundata*	□ *Menyanthes trifoliata*
□ *Myrica gale*	□ *Parnassia palustris*	□ *Pedicularis palustris*
□ *Pedicularis sylvatica*	□ *Rhynchospora alba*	□ *Rhynchospora fusca*
□ *Saxifraga hirculus*	□ *Scheuchzeria palustris*	□ *Schoenus ferrugineus*
□ *Schoenus nigricans*	□ *Stellaria crassifolia*	□ *Trichophorum alpinum*
□ *Trichophorum cespitosum*	□ *Triglochin palustre*	□ *Utricularia australis*
□ *Utricularia intermedia*	□ *Utricularia minor*	□ *Utricularia stygia*
□ *Vaccinium macrocarpon*	□ *Vaccinium oxycoccus*	□ *Viola epipsila*
2.2 Mire-specific mosses		
Instructions: Please mark all of the mire-specific mosses occurring within the peatland area.		
□ *Bryum longisetum*	□ *Calliergon stramineum*	□ *Calliergon trifarium*
□ *Calypogeia sphagnicola*	□ *Cephalozia connivens*	□ *Cephalozia macrostachya*
□ *Cephalozia pleniceps*	□ *Cephaloziella elachista*	□ *Cephaloziella spinigera*
□ *Cladopodiella fluitans*	□ *Dicranum bergeri*	□ *Drepanocladus cossonii,*
□ *Drepanocladus lycopodioides*	□ *Drepanocladus revolvens*	□ *Fissidens osmundoides*
□ *Hamatocaulis vernicosus*	□ *Helodium blandowii*	□ *Leiocolea rutheana*
□ *Lophozia laxa*	□ *Meesia hexastich*	□ *Meesia longiseta*
□ *Meesia triquetra*	□ *Meesia uliginosa*	□ *Mylia anomala*
□ *Paludella squarrosa*	□ *Pohlia sphagnicola*	□ *Polytrichum commune*
□ *Polytrichum strictum*	□ *Scapania paludicola*	□ *Sphagnum affine*
□ *Sphagnum angustifolium*	□ *Sphagnum balticum*	□ *Sphagnum capillifolium*
□ *Sphagnum centrale*	□ *Sphagnum compactum*	□ *Sphagnum contortum*
□ *Sphagnum cuspidatum*	□ *Sphagnum denticulatum var. denticulatum*	□ *Sphagnum denticulatum var. inundatum*
□ *Sphagnum fallax*	□ *Sphagnum fimbriatum*	□ *Sphagnum flexuosum*
□ *Sphagnum fuscum*	□ *Sphagnum magellanicum*	□ *Sphagnum majus*
□ *Sphagnum molle*	□ *Sphagnum obtusum*	□ *Sphagnum papillosum*
□ *Sphagnum platyphyllum*	□ *Sphagnum riparium*	□ *Sphagnum rubellum*

□ *Sphagnum spec.*	□ *Sphagnum subsecundum*	□ *Sphagnum tenellum*
□ *Sphagnum teres*	□ *Sphagnum warnstorfii*	□ *Splachnum ampullaceum*
□ *Tomentypnum nitens*	□ *Tomentypnum nitens*	
Total number of mire-specific vascular plants:		
Total number of mire-specific mosses:		

2.3 Classification for 'species diversity'

Number of mire-specific vascular plants:					Mosses present?		**Total score for species diversity**
≥ 10	≥ 7	≥ 4	≥ 1	0	Yes	No	Sum of points for mire-specific vascular plants and mosses
□ 4 points	□ 3 points	□ 2 points	□ 1 point	□ 0 points	□ 1 point	□ 0 points	**__ of 5 points**

3. Biocoenosis diversity

3.1 Habitat diversity

3.1.1 Mire-specific & typical plant formations *(Ellenberg & Müller-Dombois 1965, descriptions shortened). Remark: Species inventory and micro-relief as described in Ellenberg & Müller-Dombois 1966, but hydromorphologically no bogs are present in Brandenburg.*

Instructions: Please mark all of the mire-specific and mire-typical plant formations that are present within the peatland area.

□	**Cold-deciduous swamp or peat forest (mainly broadleaved)** *(Flooded until late spring or early summer, relatively poor in tree species; ground cover mostly continuous; mainly broadleaved.)*
□	**Deciduous peat shrubland (or thicket)** *(Upright caespitose nano-phanerophytes with Sphagnum and (or) other peat mosses.)*
□	**Blanket bog** *(The microsurface of the bog is less undulating and less rich in actively growing mosses than in a typical raised bog. Scattered evergreen dwarf shrubs, caespitose hemicryptophytes (sedges or grasses) and some rhizomatous geophytes.)*
□	**Subcontinental woodland bog** *(Temporarily covered by low-productivity open woodland which, in a sequence of wetter years, may be replaced by Sphagnum formations similar to those of a typical raised bog.)*
□	**Tall sedge swamp (with creeping sedges)** *(Frequently flooded, often for long periods; as a rule natural. Foliage taller than 30–40 cm, sedges dominant throughout; creeping sedges forming large homogeneous stands, with very few other life forms.)*
□	**Tall sedge swamp (with caespitose sedges)** *(Frequently flooded, often for long periods; as a rule natural. Foliage taller than 30–40 cm, sedges dominant throughout; caespitose sedges forming tufts or hummocks, with very few other life forms.)*
□	**Low sedge swamp** *(Flooded only little or only for short periods, mostly anthropogeneous. Dominated by small sedges (Carex, Juncus, Scirpus, etc. with foliage no taller than 30 cm) of low productivity, intermixed with many other herbaceous life forms.)*
□	**Forb flushes (subdivision: calcareous)** *(Mostly dominated by small forbs - calcareous; older parts of plants covered by a white or brownish crust of precipitated carbonate.)*
□	**Forb flushes (subdivision: non calcareous)** *(Mostly dominated by small forbs - non-calcareous.)*
□	**Moss flush (subdivision calcareous)** *(Dominated by mosses – calcareous; older parts of plants covered by a white or brownish crust of precipitated carbonate)*
□	**Moss flush (subdivision non calcareous)** *(Dominated by mosses - non calcareous.)*
□	**Temperate and subpolar herbaceous floating meadows** *(Densely interwoven forbs covering permanent freshwater accumulations. Most of the phanerogams being halophytes, not true water plants. Herbacous floating meadow with pronounced seasonal aspects.)*
□	**Mossy floating meadow** *(Mainly mosses covering permanent freshwater accumulations. Mosses dominating throughout, but phanerogams may be present.)*

□	**Temperate and subpolar freshwater reedswamps** *(Mostly broadleaved plants which cannot endure high salt concentration. All shoots upright, only exceptionally floating in the water. In temperate and subpolar freshwater reedswamp, most plants yellow or dormant in winter.)*	
□	**Temperate reedswamps on riverbanks** *(Shoots more flexible than in freshwater reedswamps or reedswamp formations of saltwater lakes. Sometimes with floating leaves.)*	
Total number of mire-specific and mire-typical plant formations:		

3.1.2 Mire-specific and mire-typical special habitats

Instructions: Please mark all mire-specific and mire-typical special habitats present within the peatland area.

□ Lagg	□ Hummock	□ Hollow
□ Solitary trees	□ Running spring water	□ Upright dead wood
□ Lying dead wood	□ Open water body (temporary or permanent)	□ areas with no vegetation (e.g. mudbanks)
□ Mineral isles		
Total number of mire-specific and mire-typical special habitats:		

3.2 Habitat connectivity

3.2.1 Integration into biotope network

Instructions: The peatland biotope network of Brandenburg can be accessed at http://www.oeko-log.com/. For small mires and peatlands in forest, please choose the shapefile 'Small mires and peatlands in forests'; and for wet pastures and peatlands of the glacial valley, choose the shapefile 'Wet pastures and fens of the glacial valley'. The peatland needs to be part of a core or connecting area to be scored.

Chosen biotope network:	□ Small mires and peatlands in forests □ Wet pastures and fens of the glacial valley
Peatland is part of:	□ Core area □ Connecting area □ Development area □ Not part of biotope network

3.3 Classification for 'biocoenosis diversity'

Number of plant formations				Number of special habitats		Part of core or connecting area in biotope network?		**Total value**
≥ 5	≥ 3	≥ 1	0	≥ 3	≤ 2	Yes	No	Sum of plant formations, special habitats & integration into biotope network
□ 3 points	□ 2 points	□ 1 point	□ 0 points	□ 1 point	□ 0 points	□ 1 point	□ 0 points	**__ of 5 points**

4. Ecosystem diversity

In order to determine the dominant soil moisture class as well as the dominant degree of soil degradation, each site is subdivided into homogenous vegetation units (if there is more than one) firstly. Therefore areas with homogenous floristic dominances and physiognomic structure are segregated from each other. All units are outlined on recent satellite images and transferred into a geo information system to create spatial maps of each site. For each vegetation unit all plant species and their cover are recorded. To transfer this data into soil moistures classes, the water table indication of each plant species described by Koska 2001 is applied to determine the soil moisture class of each vegetation unit. Further, for each vegetation unit the upper 30 cm of topsoil peat are estimated in the field and classified into the different stages. Thereby also the dominant soil degradation can be spatially described.

4.1 Condition of topsoil peat

Instructions: For the condition of topsoil peat, please choose the spatially dominant stage.

	Stage	**Description**
□	Non-degraded peat (currently forming)	Peat of low decomposition ('fibric' (Joosten *et al*. 2017b)) in nutrient poor, acidic, base-rich or calcareous mires (e.g. moss peats, herbaceous peats with radicels and rhizomes); in naturally eutrophic mire ecosystems with or without natural water level fluctuations, such as alder forests, also moderately decomposed ('hemic') peat can occur (e.g. herbaceous peats with radicels and rhizomes or wood peat) (Schulz *et al*. 2019).
□	Non-degraded peat (currently not forming) or gyttja	Dry peat of low to moderate decomposition ('hemic' (Joosten *et al*. 2017b)) (divisions as above) as well as gyttja, meaning a sedentarily accumulated material that consist of at least 5 % (dry mass) of organic matter (Schulz *et al*. 2019).

□	Slightly degraded peat (highly decomposed peat)	Highly decomposed peat ('sapric' (Joosten *et al*. 2017b)); 'Compact, mainly homogeneous, dark brown to black mass; unstructured (amorphous) or aggregated into larger pieces; muddy to mushy consistency when wet, comparable to a squeezed-dry sponge when dry; no or a small amount of recognisable plant remains; plant remains usually limited to more highly decomposed wood or fibre fragments' (Schulz *et al.* 2019).
□	Moderately degraded peat (earthified peat)	'Dark brown to black-brown mass with crumb grain structure, consisting of bonded soil particles of various sizes (but mainly >1 mm); similar to garden mould; smeary consistency when wet, crumbly but never powdery-dusty when dry; no or only a small amount of recognisable plant remains' (Schulz *et al*. 2019).
□	Highly degraded peat (murshified peat)	'Black-brown to deep black, loose mass with fine granular structure, consisting of small (mainly <1 mm) bonded soil particles; thick, silty mass when very wet, smeary-granular when moist, distinctly granular and powdery-dusty when dry (resembling loose coal slack); no recognisable plant remains' (Schulz *et al*. 2019).
□	No peat	All soil substrates that are not peat (defined in Germany as sedentarily accumulated material that consists of more than 30 % (dry mass) of incompletely decomposed plant remains and humic substances or gyttja (Schulz *et al*. 2019).

4.2 Water table

Instructions: For the water table, choose the spatially dominant soil moisture class.

	Soil moisture class	**Water table relative to surface (+ above, - below)**	
		Long-term median water table in the wet season	**Long-term median water table in the dry season**
□	6+ (lower eulitoral)	+150 to +10	+140 to +0 cm
□	5+ (wet)	+10 to -5 cm	+0 to -10 cm
□	4+ (very moist)	-5 to -15 cm	-10 to -20 cm
□	3+ (moist)	-15 to -35 cm	-20 to -45 cm
□	2+ (moderately moist)	-35 to -70 cm	-45 to -85 cm
□	2- (moderately dry)	no value, water supply deficit <60 L m^{-2}	no value, water supply deficit <60 L m^{-2}

4.3 Classification for 'ecosystem diversity'

Topsoil peat / **Soil moisture class**	Non-degraded peat (currently forming)	Non- degraded peat (currently not forming) or gyttja	Slightly decomposed peat (highly decomposed peat)	Moderately degraded peat (earthified peat)	Highly degraded peat (murshfied peat)	No peat or gyttja
5+	□ 5	□ 5	□ 4	□ 4	□ 3	□ 3
4+ / 6+	□ 4	□ 4	□ 4	□ 3	□ 3	□ 2
3+	□ 4	□ 3	□ 3	□ 3	□ 2	□ 2
2+	□ 3	□ 3	□ 2	□ 2	□ 2	□ 1
2-	□ 3	□ 2	□ 2	□ 1	□ 1	□ 1
2- or lower	□ 2	□ 2	□ 1	□ 1	□ 0	□ 0

5. Classification for 'total mire-specific biodiversity'

Total points for species diversity:	
Total points for biocenosis diversity:	
Total points for ecosystem diversity:	
Sum:	

Class	**Accumulated points**	**Verbal description**	**Colour code**
5	14, 15	Very high mire-specific biodiversity	
4	11, 12, 13	High mire-specific biodiversity	
3	8, 9, 10	Moderate mire-specific biodiversity	
2	5, 6, 7	Low mire-specific biodiversity	
1	2, 3, 4	Very low mire-specific biodiversity	
0	0, 1	No mire-specific biodiversity	