2 RAISED BOGS OF GERMANY (NATIONAL ASSESSMENT)

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BACKGROUND TO NATIONAL RED LIST OF HABITAT TYPES IN GERMANY

In 1994 the first edition of the German Red List on Threatened Ecosystems was published (Riecken et al. 1994) based on a first proposal for categories and criteria (Blab et al. 1995). Twelve years later a second edition was completed (Riecken et al. 2006). This Red List is based on a hierarchical classification system of habitat types in Germany which covers 100 % of the surface including freshwater and marine ecosystems. Altogether 690 different habitat types have been identified (764, respectively, if 'technical' habitat types like streets, buildings etc. are included). 590 types (72.5 %) are actually threatened in one of the categories CR to VU and two types have already become extinct. The evaluation is based on two criteria: 'historical decline of area' and 'decline of quality' looking back 150 - 200 years. Both criteria are qualitatively defined only. With regard to 'decline of area' there is nevertheless a good correlation to the quantitative criteria for historical decline presented in this paper. The degree of threat is also assessed on higher classification levels (Riecken et al. 2006, in German); for the later assessment an English version is available (Riecken et al. 2009). In this case study we have tried to apply the criteria from the IUCN Red list of Threatened Ecosystems as proposed in this paper to the national situation in Germany as far as the required data were available. From our list of habitat types we have chosen the type '36.01 raised bogs' which represents the second level of classification.

CLASSIFICATION

National and International: The German habitat type '36.01 raised bogs' corresponds to habitat type *7110 (active raised bogs) of Annex 1 of the European Habitats Directive.
IUCN Habitats Classification Scheme (Version 3.0): 5. Wetlands (inland) / 5.4 Bogs, Marshes, Swamps, Fens, Peatlands.

ECOSYSTEM DESCRIPTION

Characteristic native biota

Raised bogs (Fig. 1) are characterised by a very special vegetation dominated by peat mosses (e.g. *Sphagnum magellanicum*, *Sphagnum fuscum*) and insectivorous plants like sundew (*Drosera* sp.). Other typical species for raised bogs in Germany are the vascular plants Bog-rosemary (*Andromeda polifolia*) and Cranberry (*Vaccinium oxycoccos*), the butterfly species *Boloria aquilonaris* (Cranberry Fritillary), the moth *Carsia sororiata* (Manchester Treble-Bar) and the ground beetle *Agonum ericeti*. Raised bogs are also very poor in nutrients. The few nutrients naturally available are absorbed by the peat mosses in exchange for humic acids resulting in a very low pH-level. Some plants like sundew species (*Drosera* spp.) rely on catching insects to collect the nutrients they need to exist.

Abiotic environment and Distribution

Raised bogs used to have a wide distribution in the north western and the pre-alpine regions of Germany in the past. Raised bogs are the final ecosystem developing in a series of succession starting from lakes, with various intermediate states of silting up. Typically they have organic soils consisting of the decomposition products of peat mosses (genus Sphagnum) which have been conserved through the centuries due to very specific hydrological, anaerobic and acid conditions. Their hydrological regime is depending on rain water only with no

contact to the ground water. Therefore the distribution of raised bogs in Germany is limited to areas with at least 800 mm of rainfall per year.

Figure S2. 1. Typical raised bog in northern Germany (Budschimoor, Schleswig-Holstein).

Threatening processes

Raised bogs have been very unattractive for people for centuries because in a natural state they are regularly very difficult to access and for a long time were not useful for any kind of agricultural utilization. The situation changed at the beginning of the industrialisation during the 18th century. Since most forests had already been destroyed at that time, peat became the most important energy source especially in the north western parts of Germany but also in other places in Europe. At that time some smaller peat extractions were already operating mostly at the edges of raised bogs which often covered several hundreds of square kilometres each. This situation changed dramatically: Organised by big companies or regional governments a special type of settlement was developed and installed at nearly all large bog ecosystems in Germany. In a first step channels were built to be used for transportation, especially of the peat. In a second step small houses were built on both sides of the channels and exploration started. The bogs were drained and all the peat was cut, dried and shipped. The peat was used as a surrogate for fire wood in houses but also in industrial production. Later mineral coal became more important but peat still remained a source for heating houses. In the 19th and 20th century a growing demand for peat as planting substrate for private and market gardens sustained this destructive use of raised bogs until today (Berg 2004).

When raised bogs are drained a lot of nutrients become available. As a result higher plant species like grasses, scrubs and trees, which are not able to survive in undisturbed bogs, are able to colonize these drained areas. Most of them are much taller than sphagnum mosses and therefore can successfully compete for light. Especially trees like birch (*Betula pubescens*) have a much higher rate of evapotranspiration than sphagnum mosses. This results in additional draining (Succow & Joosten 2001). After the exploitation of most of the peat, agricultural utilization (life stock farming and arable land) followed and finally spread into most bog areas that had not been disturbed by then. To enable this, further draining was necessary. In all drained peat soils the process of peat degradation starts with huge emission of CO_2 and nutrients (Freibauer et al. 2009). Agricultural utilisation of former bogs is still proceeding and has increased in intensity during the last decades.

Ecosystem collapse

For assessment of criteria A and B, Raised bog ecosystems were assumed to collapse when their mapped distribution declines to zero. Reductions in mapped distribution occur when bogs are drained and replaced by agriculture, or when their native vegetation is replaced by non-bog species such as grasses, scrubs and trees, which outcompete typical bog species for light and result in further drying. For assessment of criterion C, nutrient enrichment is a key process of environmental degradation, and collapse was assumed to occur when the nutrient loads in bog soils reach 'critical levels' at which significant harmful effects on the raised bogs occur.

ASSESSMENT

This assessment applies to the distribution of raised bogs only within Germany. Their distribution extends over a much larger area in Europe (see below) and consequently their status may be different in the global context compared with the German national context assessed here.

Summary

Criterion	A	B	C	D	E	overall
subcriterion 1	EN	NE	VU	NE	DD	CR
subcriterion 2	LC	LC(LC-VU)	DD	NE		
subcriterion 3	CR	NE	CR	NE		

Criterion A

For this case study we have decided to use the change in occupied area in absolute numbers (km^2), as we have done in the German Red List. The data are based on habitat mappings conducted on behalf of the nature conservation authorities of the German Federal States. The total area of raised bogs for 2007 has been reported to the European Commission in the context of the German national report on implementation measures (Article 17, Habitats Directive) (BfN 2007). The actual remaining distribution of the habitat type 'raised bogs' in Germany is shown in Fig. 2.

Current decline: Today the totals area of raised bogs in Germany in a natural or near natural state covers some 62.4 km^2 (BfN 2007). The respective area that still existed 50 years ago is difficult to estimate exactly, but we calculate it to be at least 150 km^2. According to mapping data from the nature conservation authority of the Federal State of Lower Saxony (one of the main areas of distribution of raised bogs in Germany) the area of natural raised bogs covered about 20 km^2 in Lower Saxony in 1984 (Drachenfels et al. 1984). This area had been reduced to roughly 10 km^2 by 2006 (BfN 2007). The resulting estimation of a decline in occupied area within the last 50 years of 58 % is substantially more than 50 % and thus leads to the category Endangered under criterion A1.

Future decline: Due to a lot of practical and legal measures to regenerate and protect raised bogs in the past years (e.g., Riecken 2002, Ssymank et al. 1998) we expect, that there will be no more reductions or even a smaller increase in the spatial extend of raised bogs. Hence,this ecosystem would not be listed as threatened under criterion A2 (i.e. Least Concern).

Historic decline: In 1750 most raised bogs in Germany were still mainly intact and human impact was restricted to relatively small areas along their edges. The total area covered by bogs at that time is estimated to have been around 3,360 km^2 (Succow & Joosten 2001).

Hence, since that time the occupied area of raised bogs has been reduced by more than 98%. Raised bogs therefore are categorized in criterion A3 as Critically Endangered.

Criterion B

It is difficult to apply this criterion nationally because the thresholds given for B1 and B2 are developed for assessment of the global geographical distribution and area of occurrence of an ecosystem, respectively. In this case study we only looked at B2. Applying a grid with cell area of 128 km^2 (Fig. 2) to raised bogs in Germany (only 62.4 km^2 remaining) produces an estimate of just over 200 occupied grid cells. There are continuing declines and serious plausible threats to the ecosystem (subcriteria a and b, respectively). If less than 50 of the 200 cells are occupied by more than 1 km^2 of raised bog, the ecosystem may be categorized as Vulnerable under criteria B2a and B2b, or otherwise as Least Concern. For comparison, the distribution of raised bogs across Europe is much larger than than the distribution within Germany (Fig. 3). Thus at the level of Europe the ecosystem would be categorized as Least Concern under criterion B

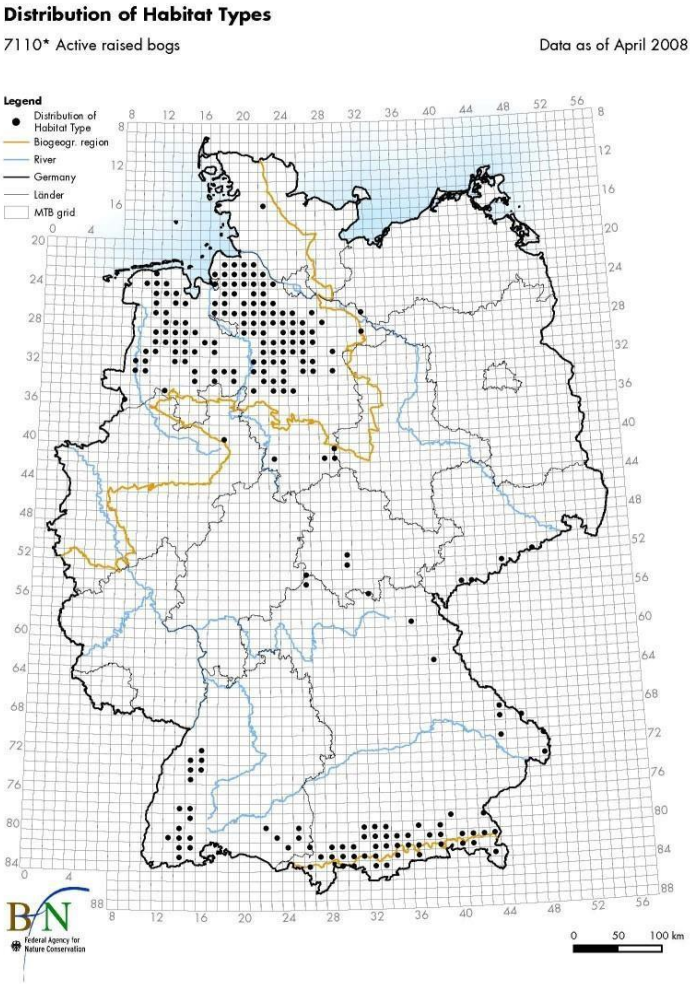

Figure S2. 2. Remaining distribution of 'raised bogs' in Germany based on a geographical grid (MTB grid) with an approximate area of 128 km^2 for each grid cell (1/10° of geographical longitude, 1/6° of geographical latitude). Cells occupied by raised bogs are marked.

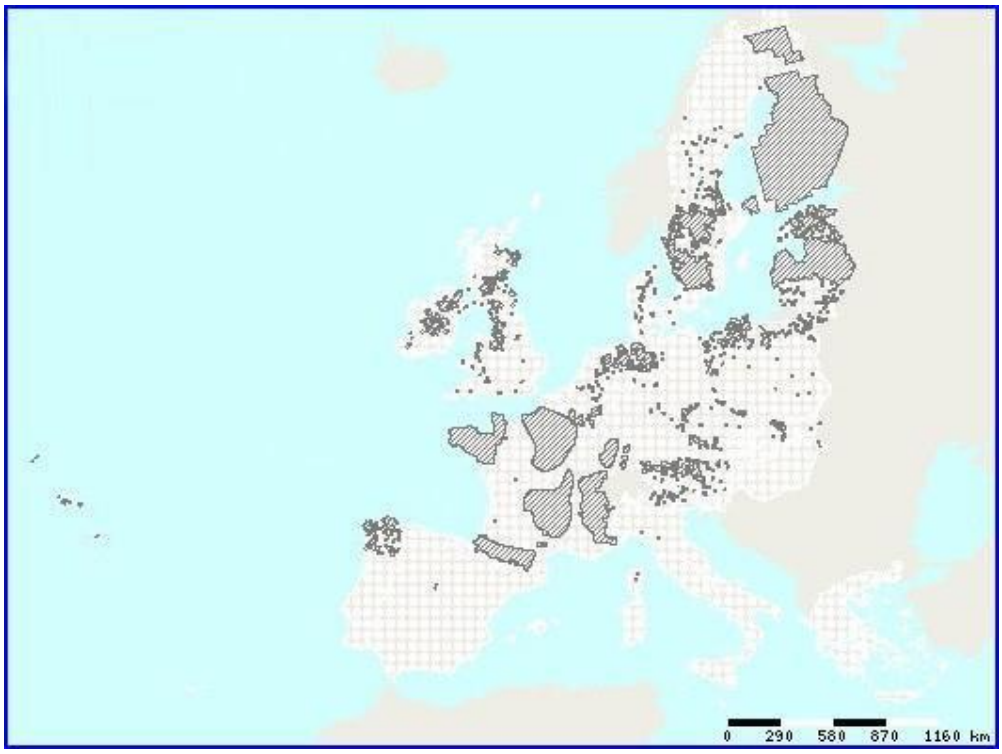

Figure S2. 3. Distribution of raised bogs in the EU based on geographical grids. Grid cells with an occurrence of raised bogs are marked (Eionet 2011). Grid sizes vary between the countries.

Criterion C

It is difficult to differentiate this criterion from the decline in occurrence. As we pointed out earlier the destruction of raised bogs always commenced with severe changes in ecological functions mainly caused by draining. Additionally all raised bogs in Germany are subject to nutrient leakage from intensive agricultural use in their vicinity as well as aerial deposition of nutrients. Raised bogs are naturally poor in nutrients and in more than 70 % of the area of sensible habitats in Germany the critical loads of nitrogen were still exceeded in 2007, coming down from almost 100 % of the corresponding area in 1990 (UBA 2011). This is especially true for the north-western part of the country, one of the main areas of the original distribution for raised bogs. If the nutrient input exceeds the 'critical loads', significant harmful effects on the raised bogs occur. The sphagnum mosses are no longer able to use all available nutrients. Especially if additional draining occurs, raised bogs become more and more suitable for higher plants like grasses, scrubs and trees which are better competitors for light and also add to the draining due to their high rate of evapotranspiration (Bobbink et al. 2001, 71ff, Succow & Joosten 2001: 462ff).

Current decline: It is clear from the above data that more than 80 % of the area of occupancy of raised bogs are facing a reduction in ecological quality during the last 50 years caused by nutrient input and byongoing draining. To assess relative severity of environmental degradation, we assume that critical nitrogen loads represent a decline in environmental quality of at least 50 %, and that most bogs had loads well below critical levels 50 years ago. Summarized, declines of > 50 % relative severity across > 70 % of the extent would result in category Vulnerable under criterion C1.

Future decline: Nobody knows exactly what effects the ongoing impacts of nutrients will have on raised bogs in the next 50 years. We therefore assign the ecosystem to category Data Deficient under criterion C2.

Historic decline: As pointed out earlier human use and input on raised bogs started with severe impacts in ecological functions. Given that historic nitrogen levels were likely to be well below critical loads (pre-dating use of industrial-scale agricultural fertilizers), and that more than 70 % of bogs are currently above those levels, we assume that since 1750 more than 90 % of all raised bogs have had a decline of ecosystem quality which more than 90 % relative severity resulting in the category Critically Endangered.

Criterion D

We are sure that the changes in ecological functions caused bychanges in water and nutrient regime are impacting the main biotic interactions to a similar extend as we have estimated under criterion C, however, we have not evaluated data on biotic interactions directly. This would result in category Not Evaluated for criterion D.

Criterion E

As we do not really know what will happen to raised bogs in the future, if the nutrient impacts continue or to what extend climate change will change the situation of rainfalls in Germany, we are not able to apply criterion E seriously, which means Data Deficient for this criterion.

Overall status

The overall status of raised bogs is estimated as being Critically Endangered (criteria A2, C3). This result corresponds exactly to the result of Riecken et al. (2006) who also listed raised bogs in the category Critically Endangered.

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