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Conservation biology of Bryophytes

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Conservation biology is a discipline that is framed by ecology and biodiversity science on one side, and by management and environmental politics on the other.

Conservation is a process that starts with the identification of threatened habitats/species/genotypes, continues with analyses of threats and finally results in actions to ensure the long-term survival of the species.

This paper focuses on species conservation, not habitat conservation or conservation of genetic variation, which are equally important and distinct aspects of conservation biology. This paper addresses threats to bryophytes, and provides an evaluation process to determine how threatened a species is, along with suggested actions to conserve bryophytes and bryophyte diversity. The latter includes both the selection of sites for conservation, and some possible approaches for artificially saving species and genetic material for the future.

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In 1985, the landmark paper "What is conservation biology?" was published (Soulé 1985). This paper was significant because it attempted to define a new field characterised by few disciplinary boundaries. Soulé argued that conservation biology was eclectic, synthetic and multi-disciplinary because all aspects of human activity (law, economics, sociology, etc.), are ultimately linked to the state of Earth's biological diversity. Conservation biology is holistic; processes need to be studied at macroscopic levels, and reductionism alone cannot lead to explanations of community and ecosystem processes. Because of its complex nature, conservation depends on biological and social disciplines. It is also a crisis discipline, where scientists and managers must often find it necessary to tolerate uncertainties.

Bryophytes started to appear in conservation literature some 20–30 years ago. The oldest paper I have found is in Biological Conservation (one of the oldest journals devoted to conservation) from 1986 (During and Willems 1986). After this, papers that include or concern bryophytes can be easily found in the main conservation journals (Table 1).

Conservation aims to secure the long-term survival of habitats and species in nature. In order to do that, species that are under threat must first be identified.

Table 1. Number of papers on bryophytes or including bryophytes published annually in Biological Conservation and Conservation Ecology.

Year	Total papers	Bryological papers	% of total papers
1968–1974	647	0	0
1975–1979	226	0	0
1980–1984	271	0	0
1985–1989	540	3	0.6
1990–1994	1019	31	3.0
1995–1999	1540	7	0.5
2000–2004	2082	13	0.6
2005	392	7	1.8
Total	6717	61	0.9

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Table 2. Rarity categories from Rabinowitz (1981) and examples of bryophytes in each category after Longton and Hedderson (2000). Number in parenthesis is the number of variables that classifies a species as rare.

	Wide geographic range		Narrow geographic range	
	Low habitat specificity	High habitat specificity	Low habitat specificity	High habitat specificity
Large populations	*Pleurozium schreberi*	*Schistidium maritimum* (1)	*Campylopus setifolius* (1)	*Zygodon gracilis* (2)
Small populations	*Anomobryum filiforme* (1)	*Zygodon forsteri* (2)	*Weissia multicapsularis* (2)	*Ditrichum cornubicum* (3)

The next step is to determine why the species is threatened. When this information is known, appropriate conservation measures can be taken. Taxonomists produce checklists to describe and delimit taxa, while field botanists identify what occurs where. Red Lists include a great deal of information about species requirements and life history, and ideally should be produced with the help of ecologists, who should also be involved in the production of action plans.

This paper will concentrate on species conservation, not habitat conservation, even though the latter is equally important and in many cases inseparable from the former. I will give examples of recent studies that illustrate the four steps of conservation biology: identifying threats to bryophytes, evaluating the threat status, creating action plans for conservation, and conservation measures in action.

Rarity vs threats

Most papers in conservation biology have been focused on threats, the study of which is a true scientific field on its own, independent of management considerations and the value of a particular species or habitat.

Bryophytes are commonly rare. Many species occur in small populations that do not appear to be decreasing, or struggling to survive; in fact, these species have probably been rare for a very long time, if not forever. Does this make them threatened?

First of all, what is a rare species? Most of us probably use the term in the sense of "difficult to find", which means that the species has a restricted distribution area that requires you to go to very specific places to find them, and/or that they occur in small populations so that you have to search hard for them. However, there are several other, more objective criteria that can be used to determine if a species can be considered rare. One of the most well-known set of criteria has been proposed by Rabinowitz (1981), who defines three parameters for rarity: a species can have large or small distribution ranges, wide or narrow habitat requirements, and at least one large, or an always small population. All these criteria can be matched in a total of eight possible combinations. The only species that are common are those that occur over a large geographical area, are habitat generalists and have large populations somewhere. All others show some form of rarity for one, two or all three criteria. Longton and Hedderson (2000) identified some bryophyte species in each group (Table 2).

Rabinowitz's (1981) system considers species as rare only if they meet the rarity criteria over their entire range. However, many species are rare only in a part (sometimes a large part) of their range, usually at the edge of their range. This type of rarity is called pseudorarity by Rabinowitz (1981), extraneous species by Hedderson (1992) and diffusive rarity (as opposite to suffusive rarity) by Schoener (1987). Suffusive rarity is probably the most common rarity. For example, an analysis of the proportion of diffusive and suffusive rarity among species on the Swedish and Norwegian Red Lists of hepatics (Weibull and Söderström 1995) shows that 28% of the 87 species are rare everywhere, while the rest are rare only in a part of their range, including Sweden and/or Norway. Very few of the forest species that are rare in Scandinavia are rare over their entire range, which probably reflects Scandinavia's location at the fringe of the Eurasian taiga. Arctic species, on the other hand, show a larger proportion of suffusively rare species. This may, however, reflect the fact that large parts of the arctic are poorly explored compared to the boreal region.

However, the question important for conservation biology remains: are all rare species threatened? The World Conservation Union (IUCN) defines a threatened species as a species that will go extinct in the near future if nothing is done to reverse the trend (IUCN 2001). Thus, rare species with stable populations do not necessarily meet the threat criteria, but instead show a form of adaptation to rarity. The fact that it is common for bryophytes to be rare (in the traditional sense) does not necessarily mean that species are declining and approaching extinction. Many species seem to survive well in small populations, in a few special habitats and/or in a small geographical area. Species that are threatened instead must show some form of decline in population sizes or distribution ranges, a phenomenon that is all too common today and that classifies many bryophytes as threatened according to the IUCN criteria. However, if the number of populations and population sizes is too small, the risk that a stochastic event will exterminate a species is so large that it may qualify them as threatened even though the species is not known to be in decline.

What are the threats to bryophytes?

There are two main forms of threats, habitat deterioration/destruction and interruption or termination of vital life history stages, such as reproduction and dispersal. By far the most well-known and well-documented threat is habitat destruction. Habitat destruction may come in the form of forestry, ditching of mires, overgrazing, and urbanisation (including tourism). Pollution may have an impact on the survival of species in several ways. First, pollution may result in such severe habitat deterioration that the habitat can no longer support the species, which effectively turns pollution into habitat destruction. Secondly, there may be an impact, direct or indirect, on a species' life cycle that may prevent long-term survival, or at a minimum make it more problematic. Fragmentation may have that effect.

Habitat destruction

Boreal forests

Boreal forests are rich in bryophytes, partly because they include many different suitable microhabitats. Natural boreal forests are now rare in Europe outside of Russia, but large parts of the boreal region of Europe are covered by managed forests that are used for timber production. Managed forests differ, however, from natural forests in many ways. Managed forests are typically composed of all young trees, as a result of earlier clear-felling of the natural forest and regrowth of new trees that are all of approximately the same age and size. Very old, dying or dead trees are lacking and a natural structure has not yet developed, which is characterised primarily by the lack of dead wood, either as standing dead trees or as decaying logs on the ground. This means that the substrate for epixylic species is to a large extent missing and that the pieces of dead wood that are found are usually all in the early stages of decay and/or are very small.

Söderström (1988) compared the occurrence and state of dead wood and associated bryophytes and lichens in a managed and a natural forest stand in northern Sweden. The managed forest was more often exposed to drought due to its more open structure; it also lacked dead wood in some (mainly intermediate) decay stages. The dead wood in the managed stand had almost no liverworts but were more lichen rich. Gustafsson and Hallingbäck (1988) also found that hepatics found only on logs in intermediate to late decay stages were lacking in managed forests in southern Sweden, while Andersson and Hytteborn (1991) found the same trend in a forest in central Sweden.

Epixylic species are among the most threatened species in the Nordic countries. Hytteborn et al. (1999) identified Swedish species that grow almost exclusively on dead wood, those that prefer dead wood, and those that sometimes occur on dead wood. Among the specialists, most of the hepatics are Red Listed in Sweden (Gärdenfors 2000), Norway (DN 1999), Finland (Rassi et al. 2001) and/or Europe (ECCB 1995) while a much smaller fraction of the mosses are Red Listed (Table 3).

Mires

Mire habitats (especially rich fens) have been heavily affected by human activity and are now a rare habitat in some areas, especially in southern and central Europe. There are two different ways that mires have been affected, habitat loss and habitat change (degradation). Many mires are ditched to provide more land for agriculture and, in some areas, silviculture. The cutting of peat may also be involved. Secondly, the nature of the mires has been changed. Acidification has made many rich fens into poorer fens (Kooijman 1992). In many cases, this has resulted from a change in hydrology due to groundwater extraction for drinking water or agricultural water management, or a change in ground water flow due to road construction or similar disturbances in the surrounding area. Acid precipitation has probably also contributed. Another problem is eutrophication, due to increased amounts of N and P. All of these affect bryophytes, with the result that many rich fen species, such as *Paludella squarrosa, Meesia* spp. and *Scorpidium* spp., are now Red Listed in large parts of Europe.

Kooijman (1992) investigated the past and present occurrences of three species of *Scorpidium* in the Netherlands by checking the present occurrence in all localities where it had been previously reported. She found that *S. scorpioides* had decreased from the

Table 3. Threat classification of epixylic bryophytes (from Hytteborn et al. 1999). *** species totally confined to dead wood and ** species mainly occurring on dead wood. The threat classification follows Gärdenfors (2000) for Sweden (Se), DN (1999) for Norway (No), Rassi et al. (2001) for Finland (Fe) and ECCB (1995) for Europe (E). Categories are the IUCN categories Critically Endangered (CR), Endangered (EN), vulnerable (VU), near threatened (NT), regionally extinct (RE) and the non-IUCN categories care demanding (DM), endangered (E), vulnerable (V) and rare (R).

Hepatics		Se	No	Fe	E	Mosses		Se	No	Fe	E
Anastrophyllum hellerianum	***	NT				*Aulacomnium androgynum*	***				
Blepharostoma trichophyllum	**					*Buxbaumia viridis*	***	NT	DM	EN	E
Calypogeia integristipula	**					*Callicladium haldanianum*	**		DM		
Calypogeia neesiana	**					*Dicranum flagellare*	***				
Calypogeia suecica	***	VU	DM	VU		*Dicranum fragilifolium*	**				
Cephalozia affinis	**			VU		*Dicranum montanum*	**				
Cephalozia catenulata	***	NT		RE		*Herzogiella seligeri*	***				
Cephalozia lunulifolia	**					*Herzogiella turfacea*	**	NT			
Cephalozia macounii	***	CR		EN	V	*Orthodontium lineare*	***				
Chiloscyphus profundus	**					*Plagiothecium laetum*	**				
Geocalyx graveolens	**					*Plagiothecium latebricola*	**	NT		VU	
Harpanthus scutatus	**	EN		VU		*Tayloria tenuis*	**	NT			
Lepidozia reptans	**					*Tetraphis pellucida*	***				
Lophozia ascendens	***	VU	DM		R						
Lophozia ciliata	***	NT									
Lophozia incisa	**										
Lophozia longidens	**										
Lophozia longiflora	**	NT									
Mylia taylorii	**										
Nowellia curvifolia	***										
Odontoschisma denudatum	**										
Ptilidium pulcherrimum	**										
Riccardia latifrons	**										
Riccardia palmata	***										
Scapania apiculata	***	EN	E	EN							
Scapania massalongi	***	CR		CR	E						
Scapania umbrosa	**										
Tritomaria exsectiformis	**										

59 5×5 km squares where it had been recorded since 1900 to only 12 squares in 1990. *S. cossonii* had declined from 37 to 4 and *S. revolvens* was absent from all three of the localities where it had been reported from earlier. In many of the localities *Scorpidium* had been replaced by *Sphagnum* spp., indicating acidification, but in some localities *Calliergonella cuspidata* and *Calliergon cordifolium* had increased, indicating eutrophication.

Flow regulation

Englund et al. (1997) investigated the effects of flow regulation on stream bryophytes in northern Sweden, and found that regulated rivers had fewer species than unregulated rivers. Regulated rivers have a more stable water regime over the year, which can allow dominant competitors to monopolise habitat. This did not happen as the two most common species sometimes forming large populations, *Fontinalis antipyretica* and *F. dalecarlica*, were less common than expected in regulated rivers.

The highest diversity of bryophytes in rivers is, however, not among obligate submerged species but among amphibic species that are submerged only when the water table is high. When the water regime evens out as a result of river regulation, the water level is kept more constant and the zone that is periodically submerged becomes narrower, which restricts the area where bryophytes can grow.

Air pollution

Mountain heathlands that were once dominated by *Racomitrium lanuginosum* are now decreasing in Britain and being replaced by graminoids. It is believed that increased N-deposition is the reason. Pearce and van der Wal (2002) experimentally tested this by adding NO_3^- and NH_4^+ in two doses (10 and 40 kg N ha^{-1} yr^{-1}) over two years. The growth of *R. lanuginosum* was severely inhibited by increased N, while *R. lanuginosum* declined and graminoids increased even at a low increase in N deposition.

Huttunen (2003) compared the reproductive success of *Pleurozium schreberi* and *Pohlia nutans* along a 12 km transect near a smelter in SW Finland. She found that only the largest shoots of *P. schreberi* produced gametangia and the weight of shoots and thus the reproductive success increased the farther the plants were from the smelter. *Pohlia nutans* produced more capsules farther from the smelter, and fewer of the spores were aborted.

Fragmentation

Fragmentation of habitats is a problem today, with forest habitats among the most heavily affected. When habitats are fragmented, two things happen. First, the size of the local fragments decreases, which decreases the maximum local populations and thus increases the extinction rate. The edges are also proportionally larger in smaller fragments and may additionally decrease population sizes if the edges are unsuitable. Fragmentation also increases the distances between fragments so that dispersal must be more efficient in order to (re-)colonize fragments. Both the extinction rate and the colonisation rate are important factors in metapopulation dynamics; fragmentation would thus reduce survival for some species dependent on metapopulation dynamics.

Zartman and Nascimento (2006) investigated the occurrence of epiphyllous bryophytes in fragments of rain forest in Amazonia. The fragments were 1, 10 and 100 ha in size, and were compared to a "continuous" forest. Fragments were 22–25 years old and the distances between them 150–680 m. The largest fragment (100 ha) and continuous forest had significantly more epiphylls than the two smallest fragments. The edge effect was also investigated, with the finding that in the 100 ha fragment, the epiphyll abundance was much less in the first 20 m from the edge than in the interior, but that there was no trend after 20 m. However, in the smaller fragments, no increase was seen even more than 100 m from the edges. The researchers thus concluded that the edge effect was much less important than the size of the fragments. They also concluded that a distance of an average of 380 m (range 150–680 m) is enough to disrupt recolonisation of small habitats. The patterns observed must have arisen from local survival after fragmentation. The largest patch did have large enough populations to survive, while the 1 and 10 ha did not support viable populations. This explanation requires a high stochastic extinction rate. An alternative hypothesis, not discussed by the authors, is that the edge effect may have been much larger at the time of fragmentation before the edges were "sealed" by new vegetation, and that only the 100 ha fragment was large enough to have an unaffected core where species could survive and from which they could spread outwards when conditions improved. However, both explanations require that re-colonisation from the outside be restricted.

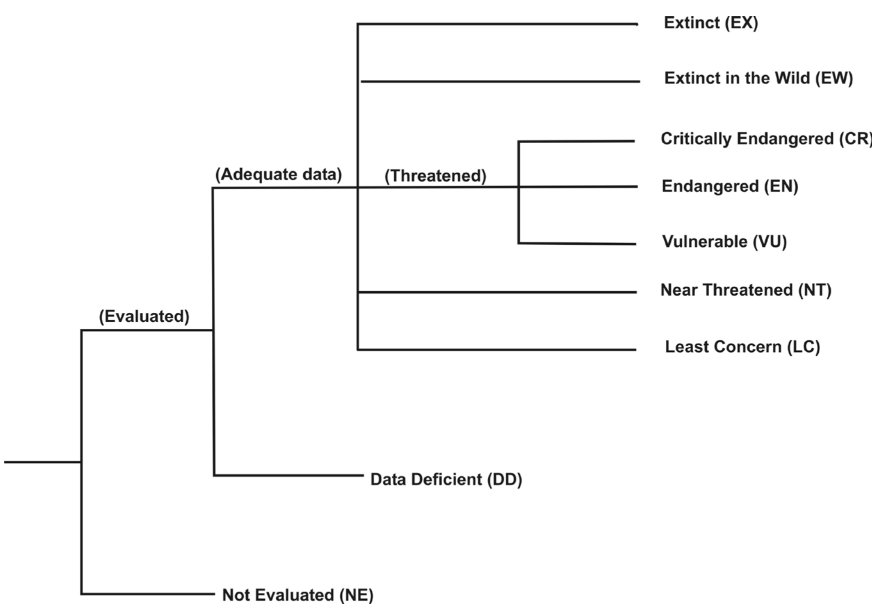

Fig. 1. Classification scheme of species threat status (IUCN 2001)

What bryophytes are threatened? Evaluation process

How large a proportion of bryophytes are threatened? As stated above, the IUCN defines a threatened species as a species that with a certain probability will go extinct in the near future if nothing is done to reverse the process. Their classification system (IUCN 2001; Fig 1) consists of 9 categories, of which organisms in 3 (vulnerable, endangered and critically endangered) are regarded as threatened while a fourth (data deficient) is included in the Red Listed categories. The other categories are extinct (EX), near threatened (NT), least concerned (LC) or not evaluated (NE).

The IUCN (2001) uses five main criteria to evaluate how threatened a species is.

A) *Large decline*. In order to fall within the threatened categories (critically endangered, endangered or vulnerable) a species must have an observed, estimated, inferred or suspected reduction of at least 50% over the last 10 years or 3 generations (whichever is longest) when the causes are understood and reversible, and at least 30% when the causes are not understood or irreversible. A projected or suspected reduction of at least 50% and 30%, respectively, over the next 10 years or 3 generations also qualifies.

B) *Restricted area of occupancy, few localities, decline*. The extent of occurrence (geographical range) should be less than 20 000 km², or the area of occupancy (actually inhabited area) less than 2000 km², AND the geographical range severely fragmented, or occurring in a maximum of 10 localities, or populations/ranges are decreasing, or populations/ranges are fluctuating.

C) *Small population and decline*. Fewer than 10 000 mature individuals AND continuing population decline of at least 10%, or very small subpopulations, or all individuals in one subpopulation, or extreme fluctuations in the number of mature individuals.

D) *Very small or restricted populations*. Populations should be less than 1000 mature individuals or the area of occupancy less than 20 km², or the number of populations fewer than 5.

E) *Quantitative analysis*. Probability of extinction in the wild should be at least 10% in the next 100 years.

These criteria may appear straightforward, but for bryophytes, several concepts are not easy to use. In response to this difficulty, Hallingbäck et al. (1998) developed guidelines on how to apply these terms to bryophytes.

Individual. The concept of an individual in bryophytes is difficult, especially if one is required to estimate the number of genetic individuals. A pragmatic definition has therefore been recommended, where colonies or discrete patches can be considered individuals.

Fragmentation. For practical reasons, a minimum distance of 50 km has been recommended for species without spore production and 100-1000 km for species with spore production (shorter for those with low spore production or large spores, longer for those with high spore production and small spores).

Location. The IUCN definition is "a geographically or ecologically distinct area in which a single event (e.g. pollution) will soon affect all individuals". For bryophytes, a pragmatic definition could be what we usually define as a locality.

Generation time. The IUCN defines a generation time as "average age of parents in populations". For bryophytes, a generation time can be inferred from life strategies. It has thus been recommended that 1-5 years be used for short-lived species (colonists s.str., fugitives sensu During 1992), 6-10 years for medium-lived species (pioneers colonists, short-lived shuttle species) and 11-25 years for long-lived species (long-lived shuttle, perennial stayers).

Is it possible to use these criteria for bryophytes along with the recommendations from ECCB? Hallingbäck et al. (1998) tried this approach on eight species. They found that criterion E could not be used, but all other criteria could be used with some success. One example is *Distichophyllum carinatum*, which was evaluated for Europe. Criterion A is not applicable, even though the species is declining, but there are no figures on how rapid the decline has been the last 10 years. Criterion B classifies the species as critically

Table 4. Published Red Lists of bryophytes using IUCN (2001) criteria, the size of the bryoflora and the proportion of species that are Red Listed (Critically endangered, Endangered, Vulnerable or Data deficient).

Country	No. of species	Percentage of species Red Listed
Switzerland (Schnyder et al. 2004)	1093	38%
Czech Republic (Kučera and Váňa 2003)	849	40%
Serbia and Montenegro (Sabovljević et al. 2004)	643	28%
Sweden (Gärdenfors 2000)	c. 1000	14%
Finland (Rassi et al. 2001)	595	15%
Britain (Church et al. 2001)	983	17%

endangered since it has declined from 6 localities in 4 10 × 10 km squares to only 1 locality in 1 square. Criterion C also classifies the species as critically endangered since it certainly has fewer than 250 mature individuals (probably fewer than 50) and is declining. Criterion D also classifies it as critically endangered if the number of mature individuals is fewer than 50. *Distichophyllum carinatum* is thus a critically endangered species at least based on criteria B and C, and perhaps also on D.

It should be noted that species for which there is so little known that they are classified as data deficient are still Red Listed until more information allows them to be placed in a category outside the threatened categories.

The categories above have been used to Red List bryophytes in 6 countries (Table 4). The result is that between 15 and 40% of the bryoflora can be considered to be threatened in various parts of Europe. However, most of the species are probably not threatened in other areas than in the areas examined. On the other hand, some species may not be threatened in some areas because these areas actually contain the main world population. If those areas are considered on a global level, the species may meet the criteria that qualify them as threatened. From an international perspective, such species should be treated as "responsibility species", which would require countries to assume great responsibility in their care. However, before this classification can be fully evaluated, a threat assessment needs to be done on a global level. This special designation may have to wait until a country or area issues a Red List that assesses the status of their species from a global perspective.

Actions suggested for conservation

Identifying threats, and what species are threatened, does not help the species survive. The threats need to be eliminated and the population trends reversed. This can be achieved with three main approaches: in situ conservation, by both protecting sites or by increasing the survival potential for individual species by removing the specific threat; and ex situ conservation, where the plants are conserved but must await an opportunity for reintroduction.

In situ conservation

The commonest way to conserve species is to create some type of reserve where human impact is eliminated or at least reduced. A common strategy has been to target species-rich areas, which is probably the most efficient way to conserve many bryophytes that we do not know much about. However, how should the sites be selected? Should we choose sites rich in bryophytes, rich in bryophyte species, or rich in rare bryophyte species?

Vanderpoorten et al. (2004) used a GIS-based system to identify hot spots for conservation in southern Belgium. They divided the study areas into 104 4 × 4 km squares, and scored the percentage of different land use (9 categories) and soil conditions (10 categories) for all squares, together with number of bryophyte species, frequency of the species, and number of species with high conservation values. First they had a high correlation between total number of species and number of species with a high conservation value. The diversity was further positively correlated with steep slopes, cover of broadleaf trees and military land, and negatively correlated with permanent meadows. They could then construct a formula for how diverse an area was based on land use and soil conditions. By using this formula they were able to predict which areas were species rich if only the land use (the four identified variables) was known, which is often easier to determine than the actual number of bryophyte species growing there.

Ex situ conservation

Another approach that may be of great importance for conservation is ex situ conservation, especially for species where the reason for decline is not understood or the reasons are irreversible (at least in the short term). There are several approaches to ex situ conservation. The most obvious is growing the species in greenhouses or botanical gardens (or similar). Fletcher (1995) described cultivation techniques for many types of bryophytes. Another obvious way is to store diaspores for future sowing.

Duckett et al. (2004) described successful in vitro cultivation of many British bryophytes. Once an axenic culture has been established, they were able to maintain it almost indefinitely and the material can be used for a variety of purposes: experimental manipulation, cryo-preservation, molecular studies, and re-introduction. To keep the culture in vitro requires regular subpropagation. Another, more permanent, way of keeping the cultures is by cryo-preservation. Burch and Wilkinson (2002) developed a protocol that includes first dehydration to reduce the damage to cells. They pre-treated the material with sucrose and/or ABA (abscisic acid) and then froze it rapidly to –196°C by immersing it in liquid nitrogen. However, storage has limited value if it is not possible to recover the material and use it. This was achieved by warming the material rapidly in a 40°C water bath for 2 min. All pre-treated samples recovered, and samples pre-treated with both ABA and sucrose did not show any necrotic tissue after recovery.

Re-introductions

Storage of material is not the ultimate goal for ex situ or any other conservation. Whenever possible, the species should be reintroduced into the wild. Such experiments are so far rare. However, Pressel and Duckett (2004) were successful in reintroducing *Zygodon gracilis* and *Didymodon glaucus*, two epilithic species. Both species produced gemmae in under culture, which were then planted on surface-sterilised rocks in a nutrient-free Phytogel. The species established itself well and the researchers were able to plant *Z. gracilis* at a locality where it was known to occur. The species continued to grow and form healthy cushions, but did not produce gemmae, sporophytes, or daughter colonies, indicating that the threats had not been eliminated and that it was unable to form self-sustainable populations. However, once threats are eliminated, a reintroduction method has been developed and material is ready.

Sphagnum angermanicum is a rare species in Sweden (classified as near threatened) and is only once found with sporophytes in Scandinavia. There are not many immediate threats to its localities, but given its lack of sexual reproduction, colonisation (and re-colonisation) can only occur by fragments. Gunnarsson and Söderström (unpubl.) tested the establishment ability in different sized fragments under some disturbance regimes. They sowed small fragments, whole capitulas and whole shoots on plots that had not been disturbed and on plots with various degrees of disturbance. They found that the larger the fragments, the better the establishment frequency. Disturbance did not enhance establishment at all. Thus, if it were to be necessary to (re-)introduce this species to any mire, whole shoots should be used and the shoots should be placed in intact vegetation.

Another reintroduction experiment was done by Kooijman et al. (1994) on a locality where *Scorpidium scorpioides* had occurred earlier but had been extinct for many years. The reasons for the extinction were unknown but it was suspected that either acidification or eutrophication was the cause. Thus, the researchers first tested the chemistry of the mire to understand the mire conditions and see if the chemistry was acceptable for the species. They then planted out a small colony. This established and produced new shoots throughout the spring channel up to 2 meters in 3 years. This confirmed that reintroduction may be a possible way to help this species.

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