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Conservation Assessment

for

Sword Moss

(*Bryoxiphidium norvegicum* (S.É. Bridel) W. Mitten)

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Center for Biodiversity
Technical Report 2002 (26)

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photo:

Bryoxiphium norvegicum (Brid.) Mitt. subsp. *japonicum* (Berggr,) Löve & Löve, Kyushu, Japan, from: http://www7.ocn.ne.jp/~hattorib/mossworld-j.html

This Conservation Assessment was prepared to compile the published and unpublished information on the subject taxon or community; or this document was prepared by another organization and provides information to serve as a Conservation Assessment for the Eastern Region of the Forest Service. It does not represent a management decision by the U.S. Forest Service. Though the best scientific information available was used and subject experts were consulted in preparation of this document, it is expected that new information will arise. In the spirit of continuous learning and adaptive management, if you have information that will assist in conserving the subject taxon, please contact the Eastern Region of the Forest Service - Threatened and Endangered Species Program at 310 Wisconsin Avenue, Suite 580 Milwaukee, Wisconsin 53203.

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EXECUTIVE SUMMARY

This Conservation Assessment is a review of the distribution, habitat, ecology, and population biology of the Sword Moss, *Bryoxiphium norvegicum* (Brid.) Mitt., throughout its range, and in the U.S.D.A. Forest Service lands, Eastern Region (Region 9), in particular. This document also serves to update knowledge about the status, potential threats, and conservation efforts regarding the Sword moss to date. The Sword moss is a small but distinctive perennial moss that is very widespread in range and has been found on the continents of Europe and North America (including the West Indies). It also has one additional subspecies, subsp. *japonicum* (Berggr,) Löve & Löve in eastern Asia. This moss has very flat shiny stems 8-25 mm long with 2 rows of closely overlapping leaves and it has been mistaken for a grass at times. The plants can be in large or small colonies. In the United States it is considered to be rare, and it is known from fifteen states, namely, Alabama, Alaska, Arizona, Arkansas, Indiana, Iowa, Kentucky, Minnesota, Missouri, North Carolina, New Mexico, Ohio, Tennessee, Washington, and Wisconsin. It grows mainly on moist or wet shaded acidic rocks in gorges in mature forests. Globally, it has been ranked as G3 (vulnerable world-wide), G3G4 (somewhat secure to vulnerable world-wide), or G5 (secure globally) depending on the source. In Minnesota, it is currently listed as of Special Concern, in Alabama it is state listed but no status has been assigned, and it has also been listed as Endangered in Missouri. It has been extirpated from Colorado and was erroneously reported for Pennsylvania. The Sword moss has been included on the Regional Forester Sensitive Species List (RFSS) for the Daniel Boone National Forest, the Hoosier National Forest, but not the Shawnee National Forest and it has never been found in Illinois. It faces several risks that could result in its extirpation in portions its range if it is not properly managed.

In additional to species listed as endangered or threatened under the Endangered Species Act (ESA), or species of Concern by U.S. Fish and Wildlife Service, the Forest Service lists species that are Sensitive within each region (RFSS). The National Forest Management Act and U.S. Forest Service policy require that National Forest System land be managed to maintain viable populations of all native plant and animal species. A viable population is one that has the estimated numbers and distribution of reproductive individuals to ensure the continued existence of the species throughout its range within a given planning area.

The objectives of this document are to:

-Provide an overview of the current scientific knowledge on the species.

-Provide a summary of the distribution and status on the species range-wide and within the Eastern Region of the Forest Service, in particular.

-Provide the available background information needed to prepare a subsequent Conservation Approach.

NOMENCLATURE AND TAXONOMY

Scientific Name:	*Bryoxiphium norvegicum* (Brid.) Mitt. (1869)
Common Names:	Sword moss; Norway bryoxiphium moss
Synonymy:	based on: *Phyllogonium norvegicum* Brid. (1827)
Division and Class:	Bryophyta - Bryopsida
Family:	Bryoxiphiaceae (the Sword moss family)
Plants Code:	BRNO6 (USDA NRCS plant database, W-2) http://plants.usda.gov/cgi_bin/topics.cgi

There is a single species of *Bryoxiphium* in North America north of Mexico, and it has no close relatives here. Only one other closely related species of the genus is known, and only the single genus is included within the family. *Bryoxiphium* is often considered to be among the basal (primitive) genera of mosses and this has been supported by molecular data (Goffinet & Cox 2000, Hax & Goffinet 2001).

Löve and Löve (1953) recognized two subspecies of *Bryoxiphium norvegicum*, subsp. *norvegicum* and subsp. *japonicum*, distinguished on the degree of serrulation on the distal parts of the perichaetial leaves. In subspecies *norvegicum* they recognized two varieties, *norvegicum* and *mexicanum* (the latter variety recognized at the species level by Sharp *et al.* 1994), based on differences in the length of marginal cells in perichaetial leaves. According to Löve and Löve, North American populations north of Mexico belong to subsp. *norvegicum* var. *norvegicum*, having leaves only slightly serrulate and marginal cells much longer than the inner laminal cells.

The common name Sword moss is widely used, with equivalents in other languages (*e.g.*, "Sverðmosi", Icelandic). *Bryoxiphium* means 'sword moss' (Greek). The name refers to the shiny, elongate, flat appearance. The alternate common name above was seen only in the USDA plant database (W-2). In spite of the specific epithet, the first collection of this moss was made in Iceland and it does not occur in Norway.

DESCRIPTION OF SPECIES

Bryoxiphium norvegicum is a perennial moss, usually bright-green, shiny, occasionally light-green to brownish green, with very flat unbranched stems 4-30 mm long and about 0.5-1.5 mm wide covered with crowded and scale-like overlapping keeled-conduplicate (folded) leaves 1-2 mm long in two rows. The leaves have a strong midrib, and the narrow tips are twisted. In well-developed plants, these stems are sometimes mistaken for grass seedlings (Britton 1913; Crum & Anderson 1981). The spore-bearing capsule is about 1 mm long, cylindrical to subglobose, and has a stalk (seta) about 2 mm long that is usually somewhat curved. Capsules are only rarely

found in North American populations, and mature spores have been found only once (Hague & Welch 1951). The green portion of the moss is a gametophyte, and antheridia (male structures) and archegonia (female structures) are found on separate plants.

Sword moss can grow gregariously in small or large colonies, and the stems can be erect or pendulous, depending upon where it is growing. In large colonies, this shiny moss with grass-like stems can be very conspicuous, and some might mistake it for a filmy fern as well. *Bryoxiphium* can also be confused with another moss genus, *Fissidens*. In both genera, the stems are similarly flattened and the leaves are distichously arranged (W-3).

HABITAT AND ECOLOGY

Concerning the Sword moss, Löve and Löve (1953) stated: "*Bryoxiphium* seems to prefer a substratum porous enough to hold water and at the same time might seem to avoid calcareous soils. Sandstone or volcanic material might seem to be preferred in most areas. Nevertheless, the moss has been collected in such solid material as granite in wet gorges, and in the Arctic as well as in more temperate regions, it might sometimes be found even on ordinary soils or perhaps on decaying organic substratum, where the vegetation is known to be of a heath character." In the United States, this moss is normally found on moist, shaded sandstone ledges or cliffs, which, at times, can be calcareous, particularly on the undersurfaces of ledges sometimes overhanging water, and less frequently on bluffs and boulders of conglomerate, gneiss and quartzite, soil, and overturned tree bases (Crum & Anderson 1981). In Kentucky, the Sword moss grows in "dark, damp sandstone rockshelters and is usually found in the extreme back, low-light areas of the shelters" (USDA, FS 1990, USDA, FS 2001). In North Carolina, Sword moss is a component of two plant communities, the Spray Cliff and Montane Acidic Cliff (Gaddy 2002).

Herbarium label information reveals some specific locations that suggest some consistencies in the habitat at the Sword moss' locations in North America. These locations are presented in Appendix 1, proceeding more-or-less from east to west within the continental United States (W-4). The location data reveals that from the eastern U.S. locations west to the Mississippi River basin, Sword moss grows along rivers and streams, generally in protected moist coves and hollows, on shaded cliffs, in glens, dells, gorges, canyons, valleys, gulches and at the mouth of caves. In the Rocky Mountains and west, Sword moss grows on exposed ridge crests at high elevations "on underside of rocks in holes" and "on rock ceiling of small cave" according to specimen labels. Substrate information is rather consistent with a few exceptions. Information recorded on labels includes "on sandstone rocks", "on sandstone cliff", "on moist sandstone cliff", "on vertical sandstone walls in the deep shade of a narrow gorge", "moist shaded sandstone cliff, at base of cliff", "on wet sandstone ledges", "in dug-out. On sandstone cliff", "on wet overhanging rocks of cave", "At mouth of cave. On sandstone rock.", and "On moist face of sandstone canyon wall". A few labels included these less-common substrates for the Sword moss: "on wet limestone cliff [Indiana]", "in swamp forest, in deep shade. On overturned tree base, damp soil and rocks. [Indiana]", "steep trail. on soil [Indiana]", and "on wet soil".

On these labels, the direction of exposure was generally not mentioned, but some indicated a northern or northeastern exposure. One Indiana label stated "from cliffs facing south; on face of the undercut". It has been found at several sites where Pink dot lichen (*Dibaeis absoluta*) grows, and so their habitats are somewhat similar, differing in microhabitat factors (Hill 2002a). As with the lichen, areas of silica rich rock or sandstone ledges along or near streams with a rather dense canopied mature forest surrounding them appear to be the preferred habitat of the Sword moss in the United States. The plants are rarely, if ever, exposed to direct sunlight, at least at mid-day. The air in this habitat is normally still and very humid. These areas are often near rock shelters or rock houses (Francis *et al.* 1993) because people have used the more protected sites within these areas as protection from the weather since prehistoric times. This species, unlike the lichen, can grow under ledges as well as on the exposed, yet shaded, mostly vertical faces of them. The species appears to require this relatively cool shaded habitat, and it grows with a few other bryophytes and lichens. Therefore, there is little competition from vascular plant species for substrate and the Sword moss often grows alone on bare rock or soil in large mats. The species appears unable to stand much heat or drying, which is to be expected considering its generally northern and high elevation preferences.

Associates have occasionally been recorded with this moss. In Wisconsin, recorded associates include the hepatics *Lepraria* and *Conocephalum conicum*, the bryophytes *Dicranella heteromalla*, *Leucobryum glaucum*, *Mnium punctatum*, and *Tetraphis pellucida*, the ferns *Gymnocarpium disjunctum* and *Thelypteris phegopteris*, the trees *Acer rubrum*, *Betula allegheniensis*, *Pinus strobus*, and *Tsuga canadensis*, the shrubs *Staphylea trifolia* and *Taxus canadensis*, and the dicot herbs *Adoxa moschatellina*, *Gnaphalium uliginosum*, *Saxifraga forbesii*, and *Sullivantia renifolia*. In Illinois, Skorepa (1973) compiled a listing of 78 lichens known to grown on sandstone outcrops, 59 of which were limited to it. Expected associated lichens in southern Illinois and Indiana may include species of *Parmelia* and *Cladonia*, *Dirinaria frostii*, *Ramalina intermedia*, *Lecanora dispersa*, and *Porpidia* (*Lecidea*) *albocaerulescens*. The bryophytes *Hedwigia ciliata*, *Dicranum* spp., and *Scapania* spp. are also expected associates. The sandstone cliffs where the Sword moss grows are generally surrounded by mature mesic upland forest or floodplain forest elements (White & Madany 1978) dominated by tall mature trees, primarily post oak, white oak, southern red oak, black oak, beech, maples, mockernut hickory, pignut hickory, and hop hornbeam. Skorepa (1973) suggested that while the general aspect of the lichen, moss, and vascular plant vegetation on the sandstone outcrops could lead one to believe that succession is taking place, the lichens and mosses on the exposed rocks actually represent a stable climax. Winterringer and Vestal (1956) likewise saw little evidence of succession on sandstone bluffs in southern Illinois.

DISTRIBUTION AND ABUNDANCE

The Sword moss is very widespread in range (W-3, Crum & Anderson 1981, Löve & Löve 1953), it is considered to be a moss of the north temperate zone, and it has been found on the

continents of Europe and North America, including the West Indies. Its additional subspecies, subsp. *japonicum*, occurs in eastern Asia.

In the United States, *Bryoxiphium norvegicum* appears to be at its southern limits in North Carolina, Alabama, and Arkansas. In the north, it has been found on the island of Attu, westernmost of the Aleutian Islands, as well as in Washington State. It is considered rare nationally by bryologists, and it is known to be present in fifteen states, namely, Alabama, Alaska, Arizona, Arkansas, Indiana, Iowa, Kentucky, Minnesota, Missouri, North Carolina, New Mexico, Ohio, Tennessee, Washington, and Wisconsin (W-2, W-3, Crum & Anderson 1981). However, Sword moss has been found in only a few isolated locations in each state. Weber and Wittman (W-5) have indicated that it has been extirpated in Colorado at its only known site. Globally, it has been ranked as G3 (vulnerable world-wide), G3G4 (somewhat secure to vulnerable world-wide), or G5 (secure globally) depending on the source, and NatureServe (W-6) states that its distribution data for U.S. states and Canadian provinces is known to be incomplete. Regarding previous reports of its range, Pursell has stated (W-3) "The report of *B. norvegicum* from Pennsylvania cannot be substantiated. Porter (1904) first reported the occurrence of the species in western Pennsylvania, based on a collection made by Lesquereux in Lawrence County. Steere (1937) listed this station and collection, but it is unclear if he examined the plants. Britton (1913), and Crum and Anderson (1981) included Pennsylvania among the states where the species has been found, but gave no further information. Löve and Löve (1953) did not examine the specimen, and I have been unable to locate it." Additional details on the distribution of *Bryoxiphium norvegicum* as obtained from herbarium specimens and the literature have been presented in Appendix 2. A list of representative specimens has been presented in Appendix 3.

The Sword moss has been included on the Regional Forester Sensitive Species List (RFSS) for the Hoosier National Forest but not the Shawnee National Forest. It has not been found in Illinois (McKnight 1987). In Indiana, this moss is best known in Sword Moss Gorge, 14.25 mi west of Greencastle, as well as Turkey Run State Park. In southern Illinois, possible suitable sites may occur within the Southern Uplands Section of the Wabash Border Natural Division as well as in the Shawnee Hills Natural Division (Schwegman *et al.* 1973) where the Pink spot lichen (*Dibaeis absoluta*) has been found (Hill 2002a). Even more likely habitat for the Sword moss occurs in northwestern Illinois in the Wisconsin Driftless Natural Division at known *Sullivantia renifolia* sites.

The North American distribution of *Bryoxiphium norvegicum* resembles closely that of vascular plants considered to have a relict distribution governed by glacial movements (Steere 1937). Steere suggested that it survived on isolated nunataks in eastern North America, and this idea stimulated useful discussions and is still interesting even though the nunatak explanation of the scattered distribution of *Bryoxiphium* and of western disjuncts in eastern North America has fallen into disrepute. The species does appear to have a distribution that was greatly affected by glaciation, however. Other examples of currently uncommon and isolated species thought to have had a more widespread distribution before the last ice age include the Appalachian bristle

fern (*Trichomanes boschianum*), the Appalachian shoestring fern (*Vittaria appalachiana*), and yellowwood (*Cladrastis*) among others. These species found refuge among the diversity of protected sites of rocky or mountainous habitats beyond the reach of the glaciers and have not moved north of this line since. Current distribution suggests a once continuous northern distribution from the northern Atlantic region west to Asia until disrupted by glaciation. All of the populations of this moss in Iowa, Wisconsin, and Minnesota, for example, still occur in an area that was not glaciated, known as the Driftless Area, and this moss is one of the best examples of a plant that survived glaciation there and has not migrated from this refugium.

PROTECTION STATUS

As stated above, in the United States the Sword moss is considered uncommon and a relict, and it is known from fifteen states. Globally, it has been ranked variously as G3 (Smith *et al.* 2002), G3G4 (W-7), and G5 (W-6; see Appendix 4 for the ranking system used). It has not been proposed as a candidate for listing as threatened or endangered by the U.S. Fish and Wildlife Service. In Minnesota it is listed as of Special Concern (W-8), in Alabama it is listed but without status, and it has also been listed as Endangered in Missouri (W-9) and is still being monitored, but current law in that state only allows the listing of federally listed taxa as state endangered (Yatskievych, pers. com.). Therefore, this moss is somewhat protected state-wide only in Minnesota. The Sword moss has been included on the Regional Forester Sensitive Species List (RFSS) for the Hoosier National Forest but not the Shawnee National Forest. It is also a RFSS species in the Daniel Boone National Forest in Kentucky. According to the Forest Service (W-10), the Sword moss is likely to be impacted in roadless areas in Forest Service Region 8 (Southern). It has never been found in Illinois although suitable habitat appears to exist (Mohlenbrock 1978, Voigt & Mohlenbrock 1964). Data on its occurrence in Indiana and in the Hoosier National Forest is limited to few locations.

Protection programs for this moss, and most other mosses, either have not been established or else they are in their infancy. Few mosses have been proposed for protection in this country, and this may be due to the lack of data on these organisms as well as a lack of experts on the group. They are small plants and somewhat difficult to identify by non-experts, and they are generally studied by moss specialists (bryologists). Protection for this group and other groups with non-showy individuals is currently more dependent on habitat protection, and so its survival will probably depend more on this than on species protection. *Bryoxiphium norvegicum* appears to be restricted to a specialized and scarce habitat, moist shaded sandstone cliffs and ledges along stream gorges and at the mouths of caves, and this habitat (Sandstone overhang, Sandstone cliff) has been given a priority for protection in some states including Indiana (see W-11). Protection of the habitat and the species within them (such as French's shootingstar, Pink dot lichen, filmy fern, and others) will help in protecting this moss as well. Inclusion of this moss on the Regional Forester Sensitive Species List and other lists of rare or sensitive species has drawn attention to it, and is necessary in highlighting the need for more data collection as well as the sensitivity of its habitat.

Table 1 lists the official state rank assigned by each state's Natural Heritage program according to the Nature Conservancy at their Internet site (W-6) and other sites. Appendix 4 explains the meanings of the acronyms used (W-12). A summary of the current official protection status for the Sword moss follows:

U.S. Fish and Wildlife Service: Not listed (None)

U.S. Forest Service: Region 9, Sensitive (Hoosier National Forest only); Region 8, Sensitive (Daniel Boone National Forest)

Global Heritage Status Rank: G5 ? [G3, G3G4]

U.S. National Heritage Status Rank: N4?

Table 1: S-ranks for *Bryoxiphium norvegicum* [element BRNO6]

State	Status
Alabama	S1
Alaska	S?
Arizona	S?
Arkansas	S?
Colorado	? extirpated [see W-5]
Indiana	S?
Iowa	S?
Kentucky	S3S4
Minnesota	S3
Missouri	S1
New Mexico	?
North Carolina	S1
Ohio	S?
Pennsylvania	S? [but record erroneous]
Tennessee	S?
Washington	S?
Wisconsin	S3S4

LIFE HISTORY

Bryoxiphium norvegicum is a perennial moss but its average life-span is not known. The large size of some of the patches (mats) of the moss and the relict nature of the habitat, combined with the fact that, in the United States, fertile spores have been found only once, suggest that individual plants may be of great age because of a lack of sexual reproduction.

In a few cases, data is available for the size of the colonies. In Wisconsin, some herbarium labels stated: "1 colony, 1m. x 25 cm.","In scattered dense patches, in area 2 m. x 1 m.", and "Two 15 x 15 cm. patches and scattered smaller patches". An Indiana label from Turkey Run stated "Makes a complete carpet."

Spore-bearing specimens of the Sword moss (with fertile spores) have been collected only once in the United States (Wisconsin) in July, according to most literature. However, one specimen from Ohio at the New York Botanical Garden with limited label data (Ohio, 1802-1803, A. *Schrader s.n.*) also bore sporangia. According to Hague and Welch (1951), antheridia (male) are present from March to August and archegonia (female) are evident from May to August, and they attributed the lack of sporangia to the fact that the sexes are segregated. Even in the only fruiting population seen, from the Wisconsin Dells, they found only archegonia (structures which produce the egg), and often no gamete producing cells of any kind could be found (and the stems were sterile). This limited but significant data suggests that in its current distribution in the United States, nearly all Sword moss reproduction, if any, is vegetative.

POPULATION BIOLOGY AND VIABILITY

The population biology and viability of the Sword moss appears to vary significantly within its wide range. Populations in Iceland, Greenland, and of its subspecies in Japan appear to reproduce regularly and successfully by means of spores, and their colonies often appear as large mats (W-13). However, very little information on population dynamics and life history for this moss has been found in the literature. For the United States populations, some information is available, primarily as a result of the studies of Hague and Welch (1951) and Löve and Löve (1953). In the previous section, some of the results of these observations were presented. Of major significance is the fact that nearly all populations known in the United States are infertile, *i.e.*, they do not produce sporangia nor fertile spores. One of the reasons for this apparent infertility is the fact that some populations are composed of a single sex, and so sexual reproduction is impossible. Even the male and female plants are only rarely fertile, so that most colonies appear completely sterile. This could be the result of the chance isolation of individual plants in isolated refugia during the last glaciation event. With no sexual reproduction or spores produced, the plants are unable to disperse. One could surmise from this that the Sword moss in the United States survives almost exclusively through vegetative, clonal reproduction. Furthermore, those colonies that remain have limited opportunity for dispersal, even if they can produce spores, because of the nature of their habitat (moist, still air among protecting sandstone outcrops) and also they may not be able to establish well except on bare moist shaded rock where competition from other organisms is not a problem. This may also help to explain the distribution of localized isolated patches of this moss over a wide area of the United States. Habitats that have dry, hot weather are inhospitable for this moss, yet these are the common conditions found between these relict moss colonies since the time of the last retreat of the glaciers about 10,000 years ago.

The species may be locally secure in its isolated populations, but changes in the habitat may result in its extirpation even within a state where it occurs. It would appear that it can survive only if its habitat remains stable.

POTENTIAL THREATS

The Sword moss is thought by most to be relatively secure globally because with its wide distribution, and so this primitive moss may persist indefinitely. However, upon closer inspection, there are actually relatively few precise locations known for the moss world-wide, and almost nothing is known about the number of actual individuals within a site. In the United States, its habitat is not common and it appears that the moss cannot stand some types of disturbance.

One of the greatest threats to the survival of the Sword moss is simply that most states do not have programs in place to protect mosses and other non-vascular plants. It appears from the herbarium information currently available, that Sword moss should be listed as endangered in Alabama, Arizona, Arkansas, Iowa, Minnesota, Missouri, New Mexico, and Tennessee, and it should be listed as threatened in Alaska, Indiana, Kentucky, North Carolina, Ohio, and Washington. It should be listed as extirpated in Colorado. Its recorded presence in Pennsylvania should be considered erroneous. Instead, as seen in Table 1 above, its status is considered to be generally unknown in most states and it has almost no protection as a species. Progress has only been made on the protection of its interesting habitat. Its state status where it occurs appears to require review.

A serious threat that has actually eliminated the species in Colorado is that of impoundment. Creation of artificial lakes and drowning of the deep gorges where the moss occurs will certainly destroy the entire population (W-5).

Additional potential threats to the Sword moss include physical damage from humans and animals walking or climbing on its exposed sandstone habitats, competition from other organisms suited to its habitat, erosion (primarily as an influx of smothering deposits as well as rock falls), heat, and drying. The latter two or three threats can result from logging or other cutting of the mature trees that shade these unusual habitats and that protect the watersheds. Organisms of this habitat are particularly vulnerable to an influx of nutrients from above. In such conditions, species adapted to a low-nutrient regime can be suddenly overwhelmed by eutrophication or 'biofouling', often seen as thick growths of algae ('slimes') comparable to those algal blooms in lakes, streams, and oceans which eliminate the slower growing organisms. Habitats with an impervious layer, such as the sandstone outcrops, are especially vulnerable. The general principles on the detrimental effects of nutrient-rich runoff can be seen in studies such as that by Bormann *et al.* (1974) at Hubbard Brook. Therefore, an influx of nutrient rich runoff as a result of logging or agricultural activity, should it occur, may present a serious threat to the species.

Botanists generally believe that most native plants and lichens have reached the limit to which they can travel under present conditions of climate (that is, temperature and rainfall), substrate, dispersal mechanism, and other pertinent factors. In other words, species are in balance with their environment as long as the environment is stable. In many biological simulations, ecological extremes are more important than the means in controlling plant distribution (Webb *et al.* 1975). An obvious example is that of frost tolerance (temperature extremes). An organism completely intolerant of freezing can persist in a site indefinitely until the first time extreme temperatures cause it to freeze. One such freeze in a century may be enough to eliminate a species entirely from a wide area of its range, and changes in climate historically have caused the greatest changes in plant distributions. Likewise, extreme heat and drought events in an area can decimate a species, as is often seen with woody plants.

In the case of *Bryoxiphium norvegicum*, current distribution appears to be dependent primarily on historical factors (lack of glaciation within its current range, resulting in a 'relict' distribution), substrate and bedrock type, age of surrounding forest (and the degree of canopy closure), drying, as well as from temperature extremes (heat). With limited spore production and a means of spore dispersal, it is unable to increase its range very quickly. The climatic factor of moisture (particularly high humidity) appears to be crucial, along with a stability of the rock substrate and lack of competition. Under natural conditions these habitats are stable, but if trees surrounding the colonies are cut or if human or animal traffic increases (especially from recreational activity), the fragile habitat balance can be destroyed and the populations can be lost. The use of fire as a management tool does not appear to be a beneficial factor for this species; the habitat actually appears to provide some protection from natural fires and a combustible component is not part of its immediate environment. Burning of the surrounding forest shading the habitat may be detrimental by increasing light, heat, and erosion.

It is generally believed among biologists that habitat fragmentation can have profound effects on the success and persistence of local populations. Any activities that result in barriers to dispersal, such as developments, clearcuts, road/utility line corridors, and mining limit the possibility of population expansion and genetic exchange in many species. Deleterious effects of fragmentation could possibly go unnoticed for a long period of time, making the short term effects on species' viability less apparent. Over time, as populations become increasingly more isolated, the effects of fragmentation can potentially be observed at the molecular level by reduced genetic frequencies caused by random drift (Barrett & Kohn 1991). When one is considering populations that are already naturally isolated, as in the case of the Sword moss, random genetic drift may have already occurred. In the case of unisexual colonies consisting of a single clone, even more serious fragmentation has already occurred.

Restricted access to any known sites to recreational activity, relocation of any trails in the vicinity, and complete elimination of logging, camping, rock climbing, off trail vehicles, and fires in areas where it grows would be indicated as a means to ensure the survival and viability of

species in this fragile natural community (Starkey *et al.* 2001). Most of these activities are currently illegal where this species grows in the National Forest and state parks.

Suitable habitat for the species in Illinois and Indiana occurs only along a narrow band of sandstones (and limestones ?) in the area of the Shawnee Hills and north in west-central Indiana, and there appears to be additional habitat for the moss where it may occur. It may yet be found in Illinois. Its habitat is a very popular one among hikers and botanists, but relatively few searches have been conducted for it, and additional searches are suggested. At the current time, it does not appear that any populations of *Bryoxiphium norvegicum* in the Hoosier National Forest are immediately threatened with elimination because of habitat loss. However, in the absence of future management of the forest and sandstone outcrops for this species, it could decrease or be eliminated.

RESEARCH AND MONITORING

The Sword moss is not being monitored to any great extent except in Minnesota. Certainly, limited monitoring has taken place in Indiana, Kentucky, Wisconsin (where most research on it has taken place), and Missouri. However, a continuing problem is that there is neither sufficient funding nor are there enough botanists or bryologists available to survey the immense area that needs to be covered in the monitoring of the large numbers of sensitive organisms, including this one (Hill 2002). There is the potential of additional suitable habitat in both northwestern and southern Illinois where *Bryoxiphium norvegicum* could exist, and continued searches for the species should be conducted in suitable habitats, starting with areas where shaded, sandstone gorges are known to occur. These searches are needed to determine the total viability for the Sword moss in the United States first of all. Second, when new populations are found, they should be carefully documented and, wherever possible, the site with its surrounding forest and drainage should be protected from any unnatural disturbance to allow the species to survive. Third, regular monitoring will be needed to determine the sex and reproductive potential of each population to determine future viability.

In addition to the basic effort of locating additional populations of the species, it would be useful to conduct more extensive monitoring of known populations. The genetics of individuals within and between groups would be an important area of research, because it may become necessary to cross-fertilize clones in order to achieve spore production, in a manner similar to that being done now with rare animals. The techniques for these and other aspects of monitoring and studying rare plant and lichen species are explained well in Collins *et al.* (2001), Philippi *et al.* (2001), and Imm *et al.* (2001). Of particular importance is the monitoring of the same populations over time to determine population dynamics. More research is needed on the longevity of individuals, their phenology and reproductive potential, and the establishment of colonies. Particular attention must be shown to avoid invasive monitoring (climbing on, or trampling) of the sites. In the case of potential disturbance from above, a plan may be needed to construct a sediment or nutrient baffle to protect a colony.

It may be useful to conduct research on the success or failure of attempts to establish new populations of this moss, though these projects are very controversial among botanists and plant ecologists.

The Hoosier National Forest has instituted an agreement with the Indiana Department of Natural Resources, Division of Nature Preserves, to conduct surveys of rare and exotic organisms in special areas. The populations of rare organisms are to be documented, former sites revisited, and plot information collected, and each exact location is to be noted with Global Positioning System technology (Day 2000). However, this moss is not included on the listing of state rare, threatened or endangered organisms in Indiana, and perhaps it should be added. As discussed above, it also needs further evaluation for listing and protection in the other states where it occurs.

RESTORATION

There are no known restoration efforts being conducted on *Bryoxiphium norvegicum* anywhere in its range. Little, if any, attention has been given to the restoration of mosses and other non-vascular plants nationally. More data is needed on these organisms and its listing in the RFSS list should help in this regard. The National Forests appear to be among the greatest refuges for this narrowly distributed moss in the United States.

Mosses are normally not available commercially. In the case of native vascular plants, restorations are recommended using only nursery propagated material grown from native, local populations to avoid interbreeding with genotypes not adapted to the local conditions and to avoid compromising the local gene pool. If this rule is not followed, the result is generally the loss of plants because they are not competitive under local conditions or the result could be the success of a plant or plants that can not be considered truly native (considered by some to be a plant community reconstruction rather than a restoration). The introduction of the Sword moss in Illinois or Indiana, if it is even possible, from unknown sources would not be encouraged in a restoration effort. Local individuals should, instead, be propagated for establishment in such an effort. This procedure would, undoubtedly, require considerable expertise.

SUMMARY

Documented as native in the United States, but rare and in only fifteen states, *Bryoxiphium norvegicum*, the Sword moss, is found on two other continents as well, in cool temperate climates. It is currently thought to be secure but discontinuous and isolated globally, and its very narrow and restricted habitat preferences make it vulnerable for extirpation in several states nationally if its habitat is not protected. The moss's distribution within the United States is limited primarily by its preferences for cool, shaded, moist, protected sandstone outcrops or ledges that were never glaciated. Its reproduction and dispersal have suffered from the isolation of often unisexual clones in a specialized habitat.

The Sword moss is vulnerable to incidental physical damage by humans and animals, the effects of erosion, from drying and excess heat due to the loss of surrounding forests, and from any other degradation of the habitat. *Bryoxiphium norvegicum*, in Minnesota, is currently listed as of Special Concern, in Alabama it is state listed, but no status has been assigned, and it has also been listed as Endangered in Missouri. It has been extirpated from Colorado and was erroneously reported for Pennsylvania. It has not been found in Illinois but it could occur in the state. Within Forest Service Region 9, the Sword moss has been included on the Regional Forester Sensitive Species List (RFSS) for the Hoosier National Forest but not the Shawnee National Forest. Casual access to the vicinity of the populations should be limited, but continued population monitoring is needed and searches should be conducted for additional populations in both Illinois and Indiana within suitable habitat. Management through protection of its habitat may be needed for it to persist at its few currently known locations.

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APPENDIX 1

Selected specific location information from herbarium labels of *Bryoxiphium norvegicum* at the New York Botanical Garden.

East to west within the continental United States (more-or-less) :

OHIO	"Shennebarger's Cave", "Cedar Falls", "Cantwell Cliffs", "Rock Run"
NORTH CAROLINA	"Chattooga River at Horse Cove", "Wolf Creek"
KENTUCKY	"Cumberland Falls", "along Red River Gorge", "Tight Hollow", "Carter Caves", "spray zone of Eagle Falls", "by Swift Creek"
TENNESSEE	"Clear Fork River", "Hickory Creek"
INDIANA	"Fern", Rocky Hollow (Turkey Run Park)", Fallen Rock cliff", "along White River near Shoals", and, of course, "Sword Moss Gorge"
WISCONSIN	"along Kickapoo River", "Valley of the Wisconsin", Witches Gulch (Wisconsin Dells)", "Coldwater Canyon", "Pine River valley", "above Pine River", "along Baraboo River", "near boat landing", "above Willow Creek", "Honey Creek", "Pine Hollow", "Artist 's Glen", "Parfrey's Glen", "Melancthon Creek"
MINNESOTA	"Lamoille Cave"
IOWA	"along Bear Creek"
MISSOURI	"Pickle Springs", "Cedar Springs"
ARKANSAS	"Beech Herrican ravine", "Blanchard Springs"
NEW MEXICO	"near crest of ridge above Seven Springs"
WASHINGTON	"crest of Alta Vista, Mt. Ranier".

APPENDIX 2.

The Distribution of *Bryoxiphium norvegicum* in the United States. Information from herbarium specimens and the literature.

STATE	COUNTIES	NOTES
Alaska	N/A	Attu Island
Alabama	Franklin, Marion, Winston [?]	see W-7
Arkansas	Madison, Stone	
Colorado	Montezuma	6 mi NNW of Dolores; locality has since been destroyed by water impoundment
Indiana	Crawford, La Porte, Marshall, Martin, Parke, Putnam	Parke County: in Sword Moss Gorge; Turkey Run State Park
Iowa	Allamakee	[driftlessarea]
Kentucky	Carter, McCreary, Menifee, Powell, Wolfe	
Minnesota	Winona	Lamoille Cave [driftless area]
Missouri	Franklin, Johnson, Madison, Newton, Stone, Saint Clair, Saint Genevieve	see Majestyk 2001
New Mexico	Sandoval	Santa Fe National Forest
North Carolina	Jackson, Macon	see Gaddy 2002
Ohio	Fairfield, Franklin, Hocking	
Tennessee	Campbell, Morgan	
Washington	Pierce	Mt. Rainier National Park
Wisconsin	Adams, Columbia, Dane, Iowa, Richland, Sauk, Vernon	The Dells [driftless area]

APPENDIX 3

Representative United States specimens of *Bryoxiphium norvegicum*, either examined or cited in the literature

Herbaria: COLO = University of Colorado, Boulder. NY = New York Botanical Garden, Bronx

ALASKA: [see Löve, A. and D. Löve. 1953]

ALABAMA: [see Löve, A. and D. Löve. 1953]

ARKANSAS: FRANKLIN CO., Ozark National Forest, White Rock Wildlife Management Area, 0.9 mi E of AR 23, 8 Jun 2000, *Buck 37291* (NY); MADISON CO., along tributary to Beech Creek & "Beech Herrican" ravine, about 2 miles S of Boston, "very abundant", 18 Mar 1966, *Redfearn 18841 & 18845* (NY); STONE CO., near Blanchard Springs, *Hatcher 86* (NY)

COLORADO: MONTEZUMA CO.; 6 mi NNW of Dolores, Pursell 3246a (COLO). The locality has since been destroyed by water impoundment.

INDIANA: CRAWFORD CO., [HNF?]10 May 1941, *Welch 11449* (NY); 2 miles west of Leavenworth along highway 62 [HNF?], *Michaud s.n.* (NY); LA PORTE CO., near Otis, on wet overhanging rocks of cave, 28 Jun 1932, *Flowers s.n.* (NY); near Smith, in swamp forest, in deep shade, Jul 1930, *Flowers s.n.* (NY); MARSHALL Co., *Test s.n.* (NY); MARTIN CO., along White River, near Shoals [HNF?], *Michaud s.n.* (NY); PARKE CO. Rocky Hollow, Turkey Run State Park, 6 Aug 1947, *Welch 9123, 9124* (NY); Sword Moss Gorge, 14.25 miles west of Greencastle, just beyond Fallen Rock, 2 Jul 1947, *Welch 9111* (NY); Sword Moss Gorge, 23 Aug 1958, *Redfearn & Houk 3961* (NY); Fallen Rock cliff, 14 miles west of Greencastle, 10 Jun 1947, *Welch 9131* (NY); PORTER CO., Tremont, *Flowers s.n.* (NY); PUTNAM CO., Fern, Jan-May 1907, *Banker 1217* (NY); Fern, 7 miles west of Greencastle, 30 Sep 1947, *Welch 10483* (NY)

IOWA: ALLAMAKEE CO., Waterloo Twp., to the west of Quandahl along Bear Creek, *Peck 80-1* (NY)

KENTUCKY: CARTER CO., Carter Caves region, *collector unknown* (NY); POWELL Co., along Red River Gorge, in dense forest, on vertical surface of huge siliceous boulder [DBNF], 12 Jun 1947, *Sharp 475* (NY); MCCREARY CO., near Cumberland Falls, on wet cliff [within DBNF], 15 Sep 1936, *Sharp 36228* (NY); in spray zone of Eagle Falls, Cumberland Falls State Park [within DBNF], 1963, *Norris 63-200* (NY); MENIFEE CO., by Swift Creek [DBNF], *Harvill 3143* (NY); WOLFE CO., Tight Hollow [DBNF?], Welch 14530, 14531 (NY); Red River Valley near Pine Ridge [DBNF], *Shanks s.n.* (NY)

MINNESOTA: WINONA CO., Lamoille Cave, Aug 1894, *Holzinger s.n.* (NY); at the mouth of Lamoille Cave, near Lamoille, 12 miles below Winona, *Holzinger s.n.* (NY)

MISSOURI: SAINT CLAIR CO., about 6 miles east, 2 miles north of Cedar Springs, *Ireland 10092* (NY); SAINT GENEVIEVE CO. Vicinity of Pickles Spring, 15 Oct 1965, *Bowers 78* (NY); Pickle Spring, about 6 miles east of Farmington on Road AA, abundant in narrow sandstone gorges on moist vertical sandstone beneath overhanging ledges at base of sandstone bluff, 25 Jan 1964, *Redfearn 13753* (NY)

NEW MEXICO: SANDOVAL CO., above Telephone Canyon near crest of ridge above Seven Springs, about 20 miles east of Cuba, Santa Fe National Forest, on moist diffusely lit basaltic outcrop on north-facing slopes, in forest of *Abies* and *Pseudotsuga*, 16 Jun 1993, *Norris 81646* (NY)

NORTH CAROLINA: JACKSON CO., [3 populations known in Nantahala/Pisgah National Forests, Gaddy 2002]; MACON CO., near Highlands Chattooga River at Horse Cove, near stream, on underside of siliceous boulder, 3 Sep 1947, *Patterson T-49* (NY); along Chattooga River above bridge on county road number 1100, 5 miles southeast of Highlands, *Hermann 15294* (NY); same location *Steere E-25* (NY)

OHIO: FAIRFIELD CO., Lancaster, 6 Jan 1845, *Bigelow s.n.* (NY); 6 miles south of Lancaster, Shennebargers Cave, 22 Nov 1912, *Mark 6* (NY); near Revenge, *Wareham 3233* (NY); FRANKLIN CO., Columbus, 1841, *Sullivant s.n.* (NY); HOCKING CO., in deep shaded ravines where there is an abundance of moisture, on the Blackhand Conglomerate, 28 May 1927, *O'Neal s.n.* (NY); Cantwell Cliffs, at the head of Buck Run, O'Neal s.n. (NY); Rock Run, *Sharp s.n.* (NY)

TENNESSEE: CAMPBELL CO., near Hickory Creek, between La Folette and Jellico, *Sharp 3623* (NY); MORGAN CO.; Clear Fork River, Rugby, *Sharp s.n.* (NY)

WASHINGTON: PIERCE CO., crest of Alta Vista, Mt. Rainier, 12 Aug 1909, *Foster 1038* (NY); Mt. Rainier Park, Paradise Park, Alta Vista Trail, about 0.5 mile from ranger station, on rock, 5 Jul 1963, *Lawton 4809* (NY); Mt. Rainier National Park, above Paradise Inn, trail to Alta Vista, on rock ceiling of small cave, 5 Jul 1963, *Ireland 7910* (NY)

WISCONSIN: ADAMS CO., Witches Gulch, The Dells, 31 Jul 1894, *Cheney s.n.* (NY); Dells of Wisconsin River, Coldwater Canyon, 1 May 1948, *Evans s.n.* (NY); COLUMBIA CO., near boat landing, Kilbourne City, on banks of the river, Wisconsin Dells, 7 Jul 1883, *Britton s.n.* (NY); DANE CO., Madison, Dells, *Britton s.n.* (NY); IOWA CO., 1 mile west of Ridgeway, *Jaunzems s.n.* (NY); RICHLAND CO., 2.5 miles east of Loyd, 25 Aug 1974, *Nee 13663* (NY); above Willow Creek, 2 miles south of Loyd, 22 Apr 1973, *Nee 5758* (NY); along the Pine River valley, 0.5 mile northeast of Rockbridge, 14 Jul 1977, *Nee 15456* (NY); Above town road and

Willow Creek, 2 miles south of Loyd, about 12 m. above level of creek on SE facing Cambrian sandstone cliffs, 24 Jul 1977, *Nee 15496* (NY); SAUK CO., Baraboo, Perirt's Nest, 26 Mar 1939, *Thomson 125* (NY); Honey Creek, on Baraboo quartzite, 5 Sep 1953, *McGregor 7510* (NY); Pine Hollow Nature Conservancy Preserve, 2 miles NNW of Denzer, 19 Aug 1965, *Smith 2478* (NY); along Baraboo River, 1 mile northwest of La Valle, 31 Jul 1973, *Nee 6486* (NY); VERNON CO., along Kickapoo River, 1 mile north of Rockton, 27 Jul 1974, *Nee 13126* (NY); along Kickapoo River 3.5 miles south of Ontario, 27 Jul 1974, *Nee 13109* (NY)

APPENDIX 4.

Natural Diversity Database Element Ranking System

modified from: http://www.cnpsci.org/html/PlantInfo/Definitions2.htm [W-12]

Global Ranking (G)

G1
Critically imperiled world-wide. Less than 6 viable elements occurrences (populations for species) OR less than 1,000 individuals OR less than 809.4 hectares (ha) (2,000 acres [ac]) known on the planet.

G2
Imperiled world-wide. 6 to 20 element occurrences OR 809.4 to 4,047 ha (2,000 to 10,000 ac) known on the planet.

G3
Vulnerable world-wide. 21 to 100 element occurrences OR 3,000 to 10,000 individuals OR 4,047 to 20,235 ha (10,000 to 50,000 ac) known on the planet.

G4
Apparently secure world-wide. This rank is clearly more secure than **G3** but factors exist to cause some concern (i.e. there is some threat, or somewhat narrow habitat).

G5
Secure globally. Numerous populations exist and there is no danger overall to the security of the element.

GH
All sites are historic. The element has not been seen for at least 20 years, but suitable habitat still exists.

GX
All sites are extirpated. This element is extinct in the wild.

GXC
Extinct in the wild. Exists only in cultivation.

G1Q
Classification uncertain. The element is very rare, but there is a taxonomic question associated with it.

National Heritage Ranking (N)

The rank of an element (species) can be assigned at the national level. The **N-rank** uses the same suffixes (clarifiers) as the global ranking system above.

Subspecies Level Ranking (T)

Subspecies receive a **T-rank** attached to the G-rank. With the subspecies, the G-rank reflects the condition of the entire species, whereas the T-rank reflects the global situation of just the subspecies or variety.

For example: *Chorizanthe robusta* var. *hartwegii.* This plant is ranked **G2T1.** The G-rank refers to the whole species range (i.e., *Chorizanthe robusta,* whereas the T-rank refers only to the global condition of var. *hartwegii.* Otherwise, the variation in the clarifiers that can be used match those of the G-rank.

State Ranking (S)

S1
Critically imperiled. Less than 6 element occurrences OR less than 1,000 individuals OR less than 809.4 ha (2,000 ac). **S1.1** = very threatened; **S1.2** = threatened; **S1.3** = no current threats known.

S2
Imperiled. 6 to 20 element occurrences OR 3,000 individuals OR 809.4 to 4,047 ha (2,000 to 10,000 ac). **S2.1** = very threatened; **S2.2** = threatened; **S2.3** = no current threats known.

S3
Vulnerable. 21 to 100 element occurrences OR 3,000 to 10,000 individuals OR 4,047 to 20,235 ha (10,000 to 50,000 ac). **S3.1** = very threatened; **S3.2** = threatened; **S3.3** = no current threats known.

S4
Apparently Secure. This rank is clearly lower than S3 but factors exist to cause some concern (i.e., there is some threat, or somewhat narrow habitat).

S5
Secure. Demonstrably secure to ineradicable in the state.

SH
All state sites are historic; the element has not been seen for at least 20 years, but suitable habitat still exists. Possibly extirpated.

SR
Reported to occur in the state. Otherwise not ranked.

SX
All state sites are extirpated; this element is extinct in the wild.

Notes:

1. Other considerations used when ranking a species or natural community include the pattern of distribution of the element on the landscape, fragmentation of the population/stands, and historical extent as compared to its modern range. It is important to take a bird's eye or aerial view when ranking sensitive elements rather than simply counting element occurrences.

2. Uncertainty about the rank of an element is expressed in two major ways: by expressing the rank as a range of values (e.g., **S2S3** means the rank is somewhere between S2 and S3), and by adding a ? to the rank (e.g. S2?). This represents more certainty than S2S3, but less than S2.