**1. Introduction**

**1.1 General information about mosses**

Mosses are the second most species group of plants, after the enormously richer angiosperms.

(Crosby 1999, P. 1)

*Mosses hold many attractions as mode] organisms for research in plant science. Their position as the simplest of land plants makes them central to the study of plant evolution, particularly in shedding light on how their aquatic predecessors evolved to survive on land.*

(Cove 1997, P. 99)

An attempt is made to compare bryophyte histories with recent models of life strategies of animals and phanerogams. Important life history traits in bryophytes include the balance between sexual and asexual reproduction, the reproductive effort spent on both kinds of reproduction, the size and number of the spores, and annual production and standing crop. Age of first reproduction is generally low for asexual reproduction, but low or high for sexual reproduction, depending on the species and the population included. Density-dependent mortality appears to be rare in bryophytes; in some groups of species mortality is for the greater part caused by abiotic environmental stress, whereas in other groups biotic factors such as competition and predation are more prominent. Life expectancy varies from some weeks in extreme ephemerals to hundreds of years; in the longer lived species wide variation in life span of different individuals occurs. Tolerance and avoidance of environmental stress are two distinct alternative possibilities in bryophytes as well as in phanerogams. A preliminary system of six different bryophyte life strategies is pre sented. It is stressed that the choice of a fitness measure for a species or population should be made in accordance to its life strategy. Finally, some distinctive traits of bryophyte life histories are outlined.

(During 1979, P. 879)

Asexual reproduction s. l. is widespread in plants and also a basic reproductive mechanism in bryophytes. Today, three types of asexual reproduction are recognized: (1) the asexual reproduction s. str. by regeneration from ± specialized caducous organs (leaves, leaf apices, shoots, branches, bulbils) and by production of specialized propagules (gemmae, protonemal brood cells, tubers), (2) fragmentation of plants, resp. part of plants into ± unspecialized fragments, and (3) clonal reproduction (cloning). The latter occurs in bryophytes by protonema decay, by disintegration of modules, resp. formation of ramets (dividuals, “daughter plants”) that leads to self-cloning or forced-cloning of parts of the gametophyte (shoots, stoloniferous and rhizomatous axes, rhizoid wicks, basiscopic innovation plants). Clonal reproduction (cloning), in former time scarcely noted, gained great interest within the last decade mainly in vascular plants showing clonal growth. This reproduction mechanism is thought to be a keystone factor for asexual reproduction, habitat colonization and habitat maintenance. Species which reproduce clonally are able to colonize and maintain habitats in an effective way by the so-called “consequent vegetative multiplication”. The review presents an overview of the current state of knowledge of asexual reproduction types in bryophytes, with a focus on fragmentation and clonal reproduction (cloning), the mechanisms of habitat colonization and habitat maintenance, which all are of important signiﬁcance in the dynamic processes of development of bryophyte populations.

(Frey 2011, P. 173)

Mosses in northern ecosystems are ubiquitous components of plant communities, and strongly inﬂuence nutrient, carbon and water cycling. We use literature review, synthesis and model simulations to explore the role of mosses in ecological stability and resilience. Moss community responses to disturbance showed all possible responses (increases, decreases, no change) within most disturbance categories. Simulations from two process-based models suggest that northern ecosystems would need to experience extreme perturbation before mosses were eliminated. But simulations with two other models suggest that loss of moss will reduce soil carbon accumulation primarily by inﬂuencing decomposition rates and soil nitrogen availability. It seems clear that mosses need to be incorporated into models as one or more plant functional types, but more empirical work is needed to determine how to best aggregate species. We highlight several issues that have not been adequately explored in moss communities, such as functional redundancy and singularity, relationships between response and effect traits, and parameter vs conceptual uncertainty in models. Mosses play an important role in several ecosystem processes that play out over centuries – permafrost formation and thaw, peat accumulation, development of microtopography – and there is a need for studies that increase our understanding of slow, long-term dynamical processes.

(Turetsky et. al. 2012, P. 49)

Bryophytes are excellent indicators for a wide range of contaminants. This is in consequence of a series of morphological and physiological properties like the lack of a cuticle or the existence of large cationic exchange properties within the cell wall. Mosses have mainly been used as accumulation indicators especially for heavy metals, radionucleides and for toxic organic compounds. Reviewing a wide range of investigations on this topic, advantages and further needs for research are discussed. Sulphurous and nitrogen depositions can hardly be analysed by methods in the ﬁeld of accumulation monitoring but by investigating the frequency, distribution, fertility and vitality of bryophyte species and populations. Similar methods are targeted by global change research, especially for the analysis of climate warming and the inﬂuence of land-use intensity on biodiversity.

(Zechmeister 2003, P. 329)

Many species of bryophyte, including most of those which have been studied intensively, are confined to habitats which are so severe that vascular plants are largely excluded and the growth of mosses and liverworts appears to be intermittent and slow (Keever 1957; Tallis 1959a, b; Clymo 1970; Rastorfer 1970: Kallio & Heinonen 1973; Pitkin 1975). Considerably less information is available on the growth of bryophytes in communities dominated by vascular plants. In particular, the substantial moss component of many productive tall herb communities has received little attention. This neglect is surprising in view of the widespread interest in the vascular plants present in such vegetation. However, in an investigation conducted by Al-Mufti et al. (1977) seasonal sampling of the shoot material within several tall herbaceous communities revealed that Brachythecium rutabulum\* was the most abundant bryophyte, often forming a single-species mat which accounted for up to 25% of the above-ground biomass and showed a bimodal pattern of growth with peaks in spring and autumn. The abundance of the species raises questions concerning the role of bryophytes in nutrient recycling within the community and the large amplitude of the fluctuations in moss biomass also leads to speculation regarding the potential rate of growth of the species and the influence of temperature and other factors upon its periodicity.

(Furness 1982, P. 513)

Although observations have been made on the growth of bryophytes in the field (e.g. Tamm 1953; Tallis 1959a, b; Clymo 1970; Longton 1974; Pitkin 1975) very little is known concerning potential rates of growth and variation between species in this respect. Apart from casual comparisons of plants growing in culture or rare experiments, such as the one reported by Tallis (1959a), in which he grew Funaria hygrometrica\* and Racomitrium lanuginosum from spores and measured the length of the protonema after a period of cultivation, comparative growth experiments involving bryophytes have not been attempted. The results of the experiments described in Furness & Grime (1982) demonstrate that it is possible to grow Brachythecium rutabulum under controlled conditions and to measure the mean relative growth rate, R. In the studies described here, the same techniques have been used with a wide range of bryophytes to determine whether differences in potential mean relative growth rate and response to temperature are related to differences in ecology.

(Furness 1982, P. 525)

**1.2 The problem of species delimitation**

Whatever a species might be, there is no question that most groups of plants and animals can readily be classified to species. Most problems actually are in the failure to observe characters correctly or to ascertain the significant characters. For centuries naturalists and systematists never questioned that all forms of life could be assigned to separate and distinct species. It is only very recently that and more sophisticated techniques have revealed groups of both plants and animals in which the classical concept of the species is difficult (but not impossible) to apply. Most of the older bryologists thought they knew what species are. They described species and erected systems of classification in mosses and liverworts in the firm belief that there were just so many and that they had only to be described, classified, and, in effect, pigeonholed. It was from this kind of taxonomic base that the exploratory and descriptive phases of moss taxonomy in North were launched, and it was the prevailing atmosphere in which most of the earlier works on mosses were written. Principally because of the scarcity of workers, progress in moss taxonomy is years behind that in vascular plants. The field is still in the exploratory, floristic stage of development, and many of the commonest species are very poorly understood taxonomically, floristically, and ecologically. It was not until relatively recently, when Grout's"Moss Flora of North America" (1928-1940) was published, that and descriptions of mosses from the northern boundary of Mexico to the Arctic were available. Grout's treatment and Conrad's (1960) extremely useful but woefully incomplete book and a few state and regional manuals provide the only guides to the mosses of this vast region. It is not surprising, therefore, that bryologists have been few or that taxonomic investigations in the Musci have lagged far behind interest, for example, in the phytogeography and ecology of the group. Vast areas of the tropics, particularly South America, Africa, the South Pacific islands, Australasia, and large parts of eastern Asia are still poorly collected. But even in the British Isles and in many other parts of Europe where collectors have been active for two centuries, new species are still being described. Only a beginning has been mad toward monographic work in North America. Relatively few genera have been revised, even by traditional methods. Family limits in many groups are vaguely drawn and the systematic positions ofcountless genera are still uncertain.

(Anderson 1963, P. 107)

The issue of species delimitation has long been confused with that of species conceptualization, leading to a half century of controversy concerning both the deﬁnition of the species category and methods for inferring the boundaries and numbers of species. Alternative species concepts agree in treating existence as a separately evolving metapopulation lineage as the primary deﬁning property of the species category, but they disagree in adopting different properties acquired by lineages during the course of divergence (e.g., intrinsic reproductive isolation, diagnosability, monophyly) as secondary deﬁning properties (secondary species criteria). A uniﬁed species concept can be achieved by treating existence as a separately evolving metapopulation lineage as the only necessary property of species and the former secondary species criteria as different lines of evidence (operational criteria) relevant to assessing lineage separation. This uniﬁed concept of species has several consequences for species delimitation, including the following: First, the issues of species conceptualization and species delimitation are clearly separated; the former secondary species criteria are no longer considered relevant to species conceptualization but only to species delimitation. Second, all of the properties formerly treated as secondary species criteria are relevant to species delimitation to the extent that they provide evidence of lineage separation. Third, the presence of any one of the properties (if appropriately interpreted) is evidence for the existence of a species, though more properties and thus more lines of evidence are associated with a higher degree of corroboration. Fourth, and perhaps most signiﬁcantly, a uniﬁed species concept shifts emphasis away from the traditional species criteria, encouraging biologists to develop new methods of species delimitation that are not tied to those properties. [Species concept; species criteria; species delimitation.

(De Queiroz 2007, P. 879)

This paper examines the theoretical and practical status of species relative to two major issues: the recognition of the importance of epigenetic constraints in evolution and the rise of Hennigian phylogenetic systematics (cladistics). Theories advanced to explain the origin and maintenance of basic morphological clusters of organisms (species) have usually involved two main classes of causal factors: selection (ecological constraints) and gene flow (breeding barriers vs. the integrating effect of gene exchange). However, in many plants non-correspondence of patterns of discontinuities among basic morphological, ecological, and breeding groups has been noted. The "biological species concept" is flawed because it is biased towards explanations at the genetic level. A third class of causal factors (epigenetic constraints) has come into favor as an explanation for the distinctness of higher-level morphological clusters, but the relevance of epigenetic factors as primary constraints on morphological variation at the species level remains to be examined. A phylogenetic species concept is advocated, which views species as monophyletic groups of organisms, the smallest such groups recognized in a formal classification. Assignment of species rank to a particular group should depend on the causal factors acting to maintain that group as an independent lineage. Epigenetic constraints may prove to be the most important factor producing and maintaining species lineages. Bryophytes are useful organisms for investigating this question because they are readily manipulated under experimental conditions, both sexual and asexual species exist, and a diversity of ecological and geographic specificities.

(Mishler 1985, P. 207)

**1.3 Moss usability**

The antifungal and antifeedant activity of bryophytes is widely known, but mainly from in vitro studies. The first in vivo experiments have been performed at Bonn University. Alcoholic extracts of all twenty bryophytes used had an effect on a variety of crops infected with different fungi. Two liverworts showed systemic effects. Based on these results, commercial products from bryophytes have been developed and are sold in Germany. Additional field experiments using extracts derived from native bryophyte species were successfully completed in Peru and Bolivia. Bryophyte extract also has effects on human pathogenic fungi and may cure skin diseases, but currently are not sold for that purpose. However, a patent has been obtained to cure fungal infections of horses with bryophyte extract. This same extract shows antifeedant effects against slugs.

(Frahm 2004, P. 277)

Mosses modify soil conditions and thereby affect the distribution of certain arthropods. Under extreme environmental conditions (such as those that prevail in Antarctica) arthropod survival and abundance often depend upon the mosses present. Several liverworts and a moss are symbiotic on New Guinean beetles, apparently conferring a degree of protection to the insects. Flies are attracted to the capsules of some Splachnaceae and disseminate their spores. Representatives of the insect orders Collembola, Diptera, Hemiptera, Hymenoptera, and Orthoptera, and the acarine orders Cryptostigmata and Prostigmata are known to feed on mosses. Bryophytes, along with other cryptogams, often constitute the initial stages in the plant succession series in newly colonized habitats, and it is postulated that their associated faunas form similar stages in the faunal success.

(Gerson 1969, P. 495)

**1.3.1 Mosses used for Biomonitoring**

**„** Moose messen beispielsweise die Schadstoffbelastung der Luft…**“**

(Nentwig et. Al. 2009, P. 299)

The use of mosses for developmental studies hinges on the ability to observe development in living material at the level of the individual cell. However, more recently techniques for the molecular analysis of mosses have provided tools for new approaches for determining the mechanisms controlling plant development, incorporating both cell and molecular biology.

(Cove 1997, P. 99)

“Bryophytes are excellent indicators for a wide range of contaminants.”

“Mosses have mainly been used as accumulation indicators especially for heavy metals, radionucleides and for toxic organic compounds.”

(Zechmeister 2003, P. 329)

**“** Trace metals are major pollutants because they are persistent in the environment and are very widely dispersed by man-made emission sources. Biomonitoring of trace metals from atmospheric deposition can be currently evaluated by environmental biomonitors such as mosses, lichens and plant leaves (Ruhling and Tyler,1973; Sloof and Wolterbeek, 1991; Steinnes et al., 1992;Ruhling, 1994; Herpin et al., 1996; Freitas et al., 1999;Alfani et al., 2000; Bargagli et al., 2002).**”**

(Giordano et. Al. 2005, P. 431)

In recent decades, mosses have been used successfully as biomonitors of atmospheric deposition of heavy metals. Since 1990, the European moss survey has been repeated at ﬁve-yearly intervals. Although spatial patterns were metal-speciﬁc, in 2005 the lowest concentrations of metals in mosses were generally found in Scandinavia, the Baltic States and northern parts of the UK; the highest concentrations were generally found in Belgium and south-eastern Europe. The recent decline in emission and subsequent deposition of heavy metals across Europe has resulted in a decrease in the heavy metal concentration in mosses for the majority of metals. Since 1990, the concentration in mosses has declined the most for arsenic, cadmium, iron, lead and vanadium (52e72%), followed by copper, nickel and zinc (20e30%), with no signiﬁcant reduction being observed for mercury (12% since 1995) and chromium (2%). However, temporal trends were country-speciﬁc with sometimes increases being found.

(Harmens et. al.2010, P. 3145)

The Paciﬁc Northwest is the main source of commercially harvested forest moss in North America, but management guidelines have only included this nontimber forest product for ca. 15 years and research on sustainable harvest practices is barely a decade old. This review summarizes the results of recent research, identiﬁes future research needs, and proposes guidelines for the sustainable management of tree moss (a mixture of mosses and liverworts). The epiphytic species most affected by harvest are Isothecium myosuroides, Neckera douglasii, and Porella navicularis, but dozens of taxa are thought to be impacted. Harvest impacts include reductions in biomass and cover and changes in relative species composition, but it is too early to tell if the species composition will return to pre-harvest conditions. Biomass recovery is slow and estimated rotation periods are 15–25 years. Inventory estimates are still lacking, but harvestable quantities of epiphytic moss are most abundant in low elevation and riparian areas and absent in stands that are very dark and/or lack hardwood tree and shrub species (e.g., <70-year-old Douglas-ﬁr (Pseudotsuga menziesii) plantations). Future research should focus on locating unimpacted reference sites and evaluating the ecosystem functions provided by harvestable moss mats, including the provision of habitat and nutrient and water cycling. Management recommendations include prohibiting commercial moss harvest in forests managed toward old-growth condition, obtaining region-speciﬁc estimates of resource inventory and recovery rates, and rotating areas open for moss harvest to allow sufﬁcient recovery between harvest entries.

(Peck 2006, P. 289)

**“** Mosses and lichens have several advantages when compared to higher plants (Tyler, 1990; Bargagli, 1998). They lack a root system, so they rely on atmospheric wet and dry deposition for their mineral nutrition, especially epiphytic species; they have a high surface/volume ratio and ion exchange properties; unlike many other plants, they lack variability in morphology throughout the growing season and they have no cuticle. Thus mosses and lichens are used for biomonitoring purposes in many ways. Mosses and lichens also accumulate large amounts or trace metals, making them good bioaccumulators to estimate metal pollution (Steinnes et al., 1992; Bargagli,1998; Vasconcelos and Tavares, 1998; Ceburnis and Valiulis, 1999; Reimann et al., 2001; Bargagli et al.,2002; Bettinelli et al., 2002; Carreras and Pignata, 2002;Figueira et al., 2002). The bioaccumulation eﬃciency of mosses and lichens comes from their substantial cation exchange capacity, which is due to cell wall negative-charged constituents (mostly carboxylic acid groups) that may establish ionic bonds with cationic elements in soluble form (Figueira et al., 2002). Elements can also be retained in particles trapped in intercellular spaces (Figueira et al., 2002) or on uneven surfaces (Jalkanen et al., 2000). Eﬃciency of element retention depends on the number and nature of the extracellular binding sites, tissue age and growth condition (Brown and Bates, 1990).**”**

(Giordano et. Al. 2005, P. 432)

**Bryophytes as indicators for climate change**

Interest in climate change has increased tremendously in the past 10 to 15 yr, both within and outside the scientific community. The reason for this interest is directly related to the anticipated global warming that will result from increased concentrations of greenhouse gases in the atmosphere. As a result of this interest, several questions have been raised relative to climate warming. For example, how can we predict long term climatic change? How accurate are the predictions? What will be the severity and extent of the changes? How will biodiversity, ecosystems, and habitats be affected if climate change occurs as predicted? How long will it take for species and ecosystems to react to climate change? This essay will focus on the utilization of bryophytes to answer those questions. Bryophytes grow in almost all terrestrial and freshwater environments where plants can be found. These environments have a global distribution and are found in all climatic regimes with the exception of those on permanent ice. The success of bryophytes is largely due to their unique and very effective physiological water relation system that permits them to survive in the wide variety of climates in which they are found. This poikilohydric system permits them to grow during periods when water is available and to suspend their metabolism when water is lacking. Most genera are ectohydric and take up water through the whole surface of the plant and therefore do not need a root system to draw water from the soil. Also, nutrients are taken up through all surfaces from solutes in water that is in contact with the plants. As a result, bryophytes can grow on such very hard surfaces as rocks and tree trunks where higher plants cannot because their roots cannot penetrate the surface. Although most bryophytes have the same water relation system, there are very few truly cosmopolitan species that can be found under all climatic conditions. Most species have evolved relatively narrow variations in physiological tolerances to drought, insolation, and temperature extremes that limit their growth to geographically restricted areas or to specific habitats (Proctor 2000).

(Gignac 2001, P. 410)

With climate change and the massive extinction of biodiversity, this chapter seeks to address the ecological and economic significance of bryophytes. The objective of this chapter is to contribute to the general knowledge of this plant group to spur research and interest in conservation efforts. Ecologically, this chapter x-rays their habit, habitat, distribution, ecophysiology, and reproduction. Bryophytes terrestrialization begun several millions of years ago but is currently threatened by climate change and poor conservation efforts. Economically, this chapter highlights the multifarious uses and applications of bryophytes with a view to promoting diversification, sustainable utilization, and innovative application.

(Ogwu 2019, P. 54)

**1.3.2 Mosses lately in the focus of nature preservation measures**

**„** Moose standen bedingt durch ihre geringe Größe und Unauffälligkeit bisher nie im Mittelpunkt des Naturschutzes. Durch die Aufnahme einiger Moosarten in die Anhänge der FFH-Richtlinie ist das Interesse an dieser Artengruppe in den letzten Jahren deutlich gestiegen. So müssen nicht nur die Moose des Anhangs II geschützt und überwacht werden, auch Biotope wie Felsen, Blockhalden, Moore oder Bäche müssen bewertet und überwachtwerden, was bei diesen Biotoptypen ohne die Berücksichtigung von Moosen kaum sinnvolldurchzuführen ist. Obwohl sich Moose in vielen Fällen als wertvolle Indikatoren für den Zustand von Biotoptypen eignen, blieben Moose bei der Bewertung von FFH-Biotoptypen bisher teilweise unbeachtet, da für Hessen keine Rote Liste der Moose vorlag. Dieses Fehlen einer Roten Liste der Moose ist umso überraschender, da Hessen eine ungewöhnlich lange Geschichte der bryologischen Forschung besitzt, wurden doch die ersten Moose weltweit 1718 von DILLENIUS aus der Umgebung von Gießen beschrieben. Diese Lücke soll durch die hier vorgelegte Rote Liste geschlossen werden, zugleich wird eine Artenliste der Moose vorgelegt, die dem aktuellen Kenntnisstand entspricht. Hiermit soll den Moosen eine stärkere Beachtung im Naturschutz verschafft werden sowie auch die Kartierung der Artengruppe angeregt werden. Vor allem bei der Durchsicht der Verbreitungskarten in MEINUNGER & ScHRöDER (2007) fallen bei zahlreichen Arten in Hessen auffällige Verbreitungslücken auf, die jedoch nicht auf das Fehlen der Arten sondern eher auf eine unzureichende Kartierung zurückzuführen sind. Gerade im Vergleich zu Bundesländern, die seit längerer Zeit eine Mooskartierung durchführen, sind weite Teile von Hessen aktuell schlecht bearbeitet. Um dennoch eine zuverlässige Bewertung der Arten zu gewährleisten, wurden alle Bryologen in Hessen und angrenzenden Gebieten aufgerufen, sich an der Erstellung dieser Roten Liste zu beteiligen.**“**

(Drehwald 2013, P. 5)

**„** Für die Erstellung der Roten Liste der Moose wurden 21 Moosarten, die seit längerer Zeit in Deutschland nicht gefunden wurden, nachgesucht, darunter die Arten FFH-Anhang II-Arten Buxbaumia viridis und Hamatocaulis vernicosus. Ausgewählt wurden vor allem Arten, bei denen eine gewisse Hoffnung bestand, dass sie heute noch vorhanden sind. Zur besseren Lokalisierung der Fundorte wurden Herbarbelege aus den Herbarien Futschig (Senckenberg in Frankfurt) und Grimme (Naturkundemuseum Kassel) durchgesehen, da die Originaletiketten oftmals genauere Fundortdaten enthalten. Zudem sind gerade von J. Futschig zahlreiche Funde niemals veröffentlicht worden. Weiterhin wurden Belege aus dem Herbarium Göttingen durchgesehen, da sich hier einige Duplikate von A. Geheeb aus der Rhön befinden sowie weitere Belege aus Nordhessen, wie z.B. vom Bilstein bei Albungen von Beug. Insgesamt konnten 11 der 21 Arten wieder gefunden werden, die meisten davon an den bekannten Stellen.**“**

(Drehwald 2010, P. 2)

**1.3.3 Mosses as indicators for forest integrity**

Management of forest for timber values presents potential threats for forest ﬂoor bryophytes, as localized disturbances are applied across landscapes. Dispersal limitation may exacerbate local extirpation, by preventing recolonization within a cut-block rotation period. Populations of forest ﬂoor bryophytes that persist under those patches of tree canopy remaining after clear-cutting could reduce dispersal distances and thereby contribute to conservation of species across the landscape. We examined bryophyte guilds (liverworts, forest-habitat mosses and colonist–pioneer mosses) and community composition in relation to habitat quality (microclimate and substrate) in ﬁve treatment classes in New Brunswick Acadian forest, 4 years after harvest. Four potential refugium classes with intact substrate were examined: three were characterized by remnant canopy height, one was treeless. These were compared to clear-cut areas with substrate disturbance. Microclimate (temperature, total daily photosynthetically active radiation and vapour pressure deﬁcit) diﬀered signiﬁcantly between areas with and without remnant canopy, but diﬀered little among refugium classes. This suggests that any remnant canopy moderates microhabitat relative to treeless areas. Liverworts and forest-habitat mosses were more frequent under remnant canopy than in open and clear-cut areas, with 25 species present only under remnant canopy. Environmental variation explained approximately 24% of bryophyte pattern, highlighting the potential inﬂuence of the pre-harvest community, which we could not document. In the absence of substrate disturbance, patches of remnant canopy provide potential refugia for some forest-habitat bryophytes. Characteristics of eﬀective refugia (size and shape) should be determined by assessments of their impacts on: (i) change in bryophyte communities in refugia relative to natural dynamics and (ii) recolonization of adjacent areas.

(Fenton 2005, P. 417)

Forest integrity has been proposed as one conservation endpoint that integrates desirable characteristics such as natural biodiversity, stand structure and continuity. Although its deﬁning criteria are still under discussion, any surrogates must effectively represent or predict their status, and be easier to measure than the criteria themselves. Bryophytes have been proposed as such surrogates, because they are important components of forest integrity, and considerable research indicates that some groups are sensitive to the changes associated with speciﬁc forest management regimes. The objectives of this paper are (1) to review the issues in determining indicators of forest integrity, including desirable qualities in such indicators, (2) to review the state of knowledge concerning bryophytes as components of forest integrity (i.e. their responses to forest management practices), and (3) to assess bryophytes as potential indicators of forest integrity, in terms of both qualities desirable in indicators and our understanding of bryophyte response patterns. Although bryophytes possess some characteristics that suggest potential indicator value, many challenges prevent their reliable application. I highlight key areas in which research is required to identify operational bryophyte indicators of forest integrity. Along with a standardized protocol to select and calibrate such indicators, we urgently require strategic research to compile data on undisturbed reference forests on which to base selection of endpoints; species-speciﬁc ecological tolerances, with consideration of complex interactions; mechanisms of response to disturbance, with consideration of temporal aspects; population viability thresholds; and recruitment effects on community assembly. Whether we succeed in ﬁnding bryophyte indicators of forest integrity, this research would also provide the data to monitor and interpret the integrity of the bryophyte community.

(Frego 2007, P. 66)

Conservation and sustainable forestry are essential in a multi-functional landscape. In this respect, ecological studies on epiphytes are needed to determine abiotic and biotic factors associated with high diversity. The aim of the present study was to evaluate relative sensitivity of conservation targets (epiphytic bryophytes and lichens) in relation to contrasting environmental variables (tree species, tree diameter at breast height, bark crevice depth, pH, tree inclination, pH, forest stand age, area and type) in boreonemoral forests. The study was conducted in Latvian 34 woodland key habitat (WKH) boreo-nemoral forest stands. Generalized linear mixed models and canonical correspondence analysis showed that tree species and tree bark pH were the most important variables explaining epiphytic bryophyte and lichen composition and richness (total, Red-listed WKH indicator species). Forest stand level factors, such as stand size and habitat type, had only minor inﬂuence on epiphytic species composition and richness. The results of the present study indicate a need to maintain the diversity of tree species and large trees, particularly Acer platanoides, Carpinus betulus, Fraxinus excelsior, Populus tremula, Tilia cordata, Ulmus glabra and Ulmus laevis in conservation of epiphytic bryophyte and lichencommunities in the future.

(Mezaka 2012, P. 3221)

- kurz warum Moose allgemein interessant ist, „was bringt unsere Untersuchung für die Forschung?“

- Quelle AG-Burgwald regional interest in saving mosses

- the need to monitor moss species (Quelle: Rote Liste)

- mosses as pollution markers (Quelle: Atmospheric trace metal pollution in the Naples urban area based on results from moss and lichen bags)

- Mosses as a habitat for insects (Quelle: Moss-Arthropod Associations)

- Mosses as a natural water container (Quelle:)

-Moss havest (Source: Towards sustainable commercial moss harvest in the PacificNorthwest of North America)

- climate change indicator (source: Bryophytes as indicators of climate change)

- Untersuchung mit „nested plot design“ (Quelle: A nested-intensity design for surveying plant diversity)

- Stand der Forschung (hier v.a. bzgl. des Aufnahmedesigns) „gibt es sowas schon, wie machen das andere, was ist bei uns neu? (Quelle: A Modified-Whittaker nested vegetation sampling method) (Quelle: MVS in der Ökologie)

- Hypothesen

- ähnliche Moosgesellschaften nach Wald typ

- Abhängigkeit der Gesellschaften von Substrat

- Ähnliche Epiphyten nach Baumart (Nadel vs Laub)