ECOLOGICAL RELATIONSHIPS OF THE MOST COMMON MOSSES IN A CERTAIN VICINITY NEAR BLOOMINGTON, INDIANA

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Introduction. That there is some type of succession in mosses is obvious to the non-professional observer who notes the patches of a black moss on the surface of one rock whereas on a neighboring rock there are also patches of whitish or green mosses.

The purpose of this study has been (a) to study moss succession in relation to sub-strata and to acidity and alkalinity, (b) to note the mosses which have a tendency to be xerophytic, mesophytic, and hydrophytic, (c) to find the species of mosses which are most common in the vicinity of Bloomington and those which seem to be indicators of soil conditions, and (d) to discover whether or not there is a true succession of mosses which passes from living wood to dead and thence to decaying wood and eventually to soil.

In 1912-13 Pickett and Nothnagel collected, identified ,and published a list of mosses of this region. Their collection is in the herbarium of Indiana University. Indiana mosses have been reported by Deam, Naylor, Underwood, Wilson, Young, and the total list has been compiled by Yuncker (15) (16).

No ecological work on mosses has been published for this part of Indiana. Miss Taylor (10) studied in the region of Chicago, reporting from counties in Indiana, with special reference to sand dune succession, which condition is in no way paralleled in this section. She did, however, discuss ravine succession. Miss Braun (1) includes mosses in her discussion of succession on conglomerate rocks in the region of Cincinnati, Ohio. Cooper (2) has written concerning succession of mosses on Isle Royale, Lake Superior, being particularly interested in lake shore and bog succession. In England, Watson (12) (13) listed mosses according to habitats; e.g., on calcareous rocks, in the water, and in xerophytic conditions. Other Bryologists have attempted classification according to habitat.

The area chosen for study is indicated by the map, with the exception of a railway cut immediately south of the southern limits of the map. Concentrated collections were made in this cut and along the track, on the west-facing slopes along North Pike, throughout the length of Seventh Ravine (which is the first large forked ravine east of Sheet's Hill), along small portions of the edge of the lake, and on Mossy Bank. The area under observation consists of approximately four square miles, a short distance northeast of Bloomington. This is a desirable tract for the study of moss succession inasmuch as there are many types of habitats and successions which may be studied. The wet ravines in most cases have limestone at the heads with sandstone progressively further down. Dry exposures of limestone ledges are frequent along North Pike on west-facing slopes. At times the water from the Bloomington Water Works Lake recedes and moss succession commences on the sandstone rocks thus exposed. The beginning of moss succession on soil is shown in some habitats. The soil on the extreme tops of the ridges is found to be more or less acid. The water in some of the small streams tests alkaline, due to the constant leaching of the limestone at the heads of the ravines.

Proc. Ind. Acad. Sci. 40: 87-101. (1930) 1931.

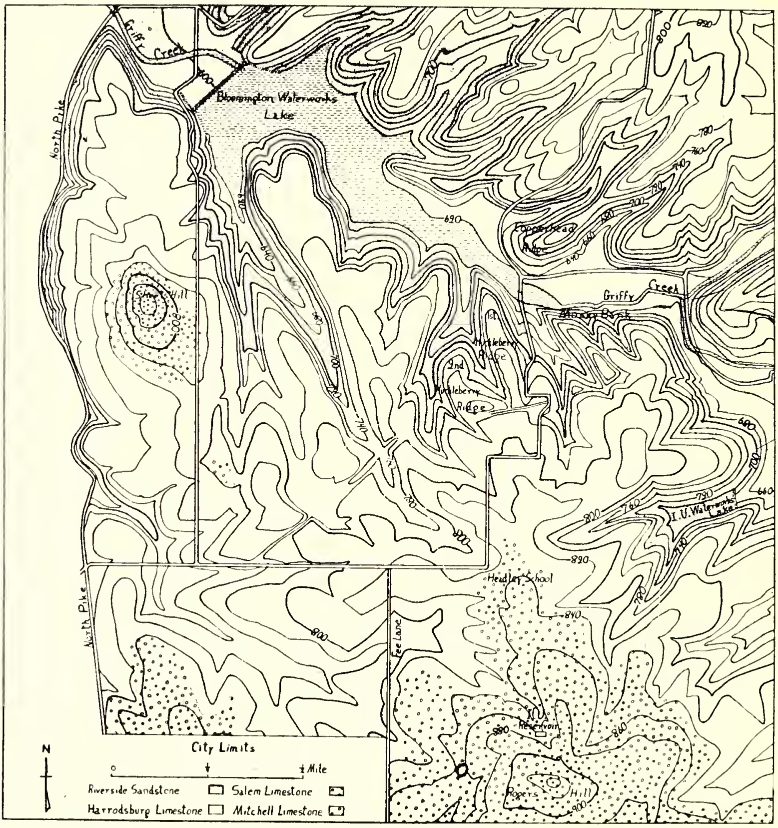

Fig. 1

Griffy Creek flows through this region from southeast to northwest. The area which it drains is much dissected by its tributaries. The ravines in their youth are V-shaped, and on reaching their base level become U-shaped (14).

Inasmuch as this portion of the state is unglaciated the formations are more or less intact, but exposed by dissection. The map shows the outcrops of the rocks, thickness of the strata, and the arrangements of the formations. In order from the highest to the lowest these formations of rock are the Mitchell, Salem, and Harrodsburg limestones, and the Knobstone or Borden. Only the upper portion of this formation is exposed. Since the latter two are the ones exposed in this area under study only their characteristics will be given.

The Harrodsburg limestone may be roughly divided into an upper and a lower portion, the latter being more important in this moss problem. "The two-fold nature of the Harrodsburg is at once apparent, a lower part, which is in the main very impure and variable, characterized by geodes, much chert, and irregularly spaced crinoidal layers, and an upper part of fairly pure limestone in the main, highly crystalline in places and often quite fossiliferous.

"The lower Harrodsburg includes all the irregular and variable impure unit lying between the Borden and the overlying, fairly massive more regular limestone. Except for crinoidal lenses this division is a highly siliceous, fine grained stone known as 'bastard rock.' In places it may well be called a calcareous sandstone. When fresh it is light gray to blue gray. A high iron content gives it a characteristic buff to yellow color when weathered. This siliceous phase is quite brittle, and upon weathering splits into irregular, flattened chips, broken off in a direction diagonal to the bedding.

"Interbedded within the Lower Harrodsburg and forming a large part of it in places are hard resistant crinoidal lenses. . . . In places the rock is shaly chert . . . some of the chert is silicified crinoidal limestone. Geodes characterize the Lower Harrodsburg and are also found in the underlying Borden strata, where they usually are much smaller and less numerous.

"The most persistent feature of the lower Harrodsburg which impresses one who has made many observations throughout the entire outcrop belt, is the hard limestone layer which often displays itself as an overhanging bench in sharp ravines producing a waterfall. Extensive study has revealed a persistent shaly to siliceous zone, weathering buff to yellow above this layer, and between it and the overlying 'typical' Harrodsburg limestone of the upper division. Below this waterfall forming layer is the variable 'bastard' rock" (9).

The average temperature for this region for January is 33 degrees F.; for July, 79 degrees F. (8). The mean annual temperature is 52 degrees F. The average rainfall is 42 inches, more or less evenly distributed throughout the year, (3). The mean relative humidity for Indianapolis and environs is 78 per cent at 7 a. m., 59 per cent at noon, and 64 per cent at 7 p. m. (11).

During this study all mosses, whether fruiting or sterile, were collected and full data recorded. A soil sample was taken in each case, if at all possible. The colorometric method of soil testing (Morgan Soil Testing Set) was used in preference to the electric method, because in many cases it was impossible to obtain sufficient quantities of soil from rocksubstrata to use in the Quinhydrone apparatus. For the most common species approximately 10 tests were made; in many instances even more samples were tested. All testing was done in the laboratory, and the soil was air-dried before using. Between each test all apparatus was washed carefully with distilled water.

Because of the lack of sporophytes in perhaps 50 per cent of the cases identification was difficult, but all species reported in this paper have been checked or identified by A. J. Grout, and are deposited in the Indiana University Herbarium. The nomenclature is that which is used by Grout in "Mosses with a Hand-lens and Microscope."

The writers wish to express their appreciation of the aid in identifications which Dr. A. J. Grout has given.

The following list Table I, includes the mosses which were collected during this study. All have been checked by Dr. Grout. △ and bold face type denotes those not reported previously as occuring in Indiana. —denotes those formerly reported as occuring in Monroe county.

TABLE I. MOSSES INCLUDED IN THIS STUDY:

— 1. Amblystegiella adnata
△ 2. **Amblystegiella minutissima**
3. Amblystegium fluviatile
— 4. Amblystegium irriguum
— 5. Amblystegium Kochii
— 6. Amblystegium orthocladon
— 7. Amblystegium riparium
△ 8. **Amblystegium riparium fluitans**
— 9. Amblystegium serpens
— 10. Amblystegium varium
— 11. Anomodon attenuatus
— 12. Anomodon minor
— 13. Anomodon rostratus
14. Anomodon tristis
— 15. Aphanorhegma serratum
— 16. Aulacomnium heterostichum
△ 17. **Barbula convoluta**
18. Barbula fallax
— 19. Barbula unguiculata
— 20. Bartramia pomiformis
21. Brachytlecium acutum
— 22. Brachythecium oxycladon
△ 23. **Brachythecium oxycladon dentatum**
24. Brachythecium plumosum
— 25. Brachythecium rivulare
26. Brachythecium rutabulum
— 27. Brachythecium salebrosum
— 28. Bryhnia graminicolor
— 29. Bryum argenteum
— 30. Bryum caespiticium
— 31. Campylium chrysophyllum
△ 32. **Campylium chrysophyllum brevifolium**
— 33. Campylium hispidulum
— 34. Catharinea angustata
— 35. Ceratodon purpureus
— 36. Cirriphyllum Boscii
△ 37. Climacium Kindbergii (approaching Americanum)
38. Desmatodon Porteri
— 39. Dicranella heteromalla
— 40. Dicranella varia
— 41. Dicranum scoparium
42. Ditrichum tortile
— 43. Entodon seductrix

— 44. Eurhynchium hians
— 45. Eurhynchium serrulatum
△ 46. **Fissidens incurvus exiguus**
— 47. Fissidens minutulus
— 48. Fissidens taxifolius
49. Forsstroemia (perhaps a new species)
— 50. Funaria flavicans
— 51. Funaria hygrometrica
— 52. Grimmia apocarpa
53. Homalotheciella subcapillata
— 54. Hypnum curvifolium
△ 55. **Hypnum fertile**
— 56. Hypnum molluscum
— 57. Hypnum patientiae
58. Hypnum recurvans
△ 59. **Hypnum Schreberi**
— 60. Leptobryum pyriforme
61. Leskea gracilescens
62. Leskea nervosa nigrescens
63. Leskea polycarpa
64. Leskea polycarpa paludosa
— 65. Leucobryum glaucum
— 66. Leucodon julaceous
— 67. Mnium affine ciliare
— 68. Mnium cuspidatum
△ 69. **Oncophorus Wahlenbergil**
△ 70. **Orthotrichum anomalum**
71. Orthotrichum strangulatum
— 72. Philonotis fontana
— 73. Physcomitrium turbinatum
— 74. Plagiothecium deplanatum
— 75. Plagiothecium Roseanum
△ 76. **Plagiothecium Roseanum propogulifera**
— 77. Platygyrium repens
△ 78. **Pogonatum brachyphyllum** (collected by Dr. Flora Anderson Haas)
— 79. Pogonatum brevicaule
— 80. Pohlia nutans
— 81. Polytrichum commune
— 82. Pylaisia Schimperi
83. Raphidostegium adnatum
— 84. Thelia hirtella
— 85. Thuidium delicatulum
— 86. Thuidium phgmaeum
— 87. Tortella caespitosa
— 88. Webera sessilis (collected by Dr. Flora Anderson Haas)
—89. Weisia viridula
△ 90. **Zygodon sp.**

Note: *Brachythecium plumosum* was reported by Pickett, but later identified by G. R. Kaiser as *B. campestre.*

Moss Succession on Sandstone Substrata

Two very important factors which influence plant succession upon sandstone and limestone rocks are, according to modern ecology, acidity and alkalinity of the respective rocks or the soil produced from them. In this discussion we are particularly interested in two rock formations, the Harrodsburg limestone and the Riverside sandstone. In the limestone the presence of calcium carbonate causes the rock to test alkaline. Its absence, according to geologists who seldom speak in terms of acidity, gives only neutrality. It is, however, this absence of a carbonate plus the acid which growing plants form which gives the tendency toward acidity. Thus a sandstone soil from which calcium carbonate is absent will be more or less acid through the agency of plants.

The lower layer of the Harrodsburg limestone in contact with the Riverside sandstone is a more or less impure limestone. (See Introduction.) This fact rendered identification of some of the rocks more or less difficult until the stones were tested with acid. A dilute solution of hydrochloric acid (25 percent) was used. If effervescence occured, the rock was considered to be a limestone. In this work it is one of the chief purposes to show that on a bare rock area the early mosses particularly are indicative of the type and composition of the substratum. The first under consideration is the succession of mosses on sandstone.

For such study an excellent opportunity is found at the edge of the Bloomington Water Works Lake in the Seventh Ravine where intensive collecting was done. There are exposures of sandstone and large fragments of the same at the water line, which during part of the winter and the spring are completely covered with water, and which during the summer and the fall are exposed and dry. On these stones are found the first mosses of the sandstone succession, *Fissidens minutulus* and *Fissidens incurvus exiguus*, minute mosses which are collected rarely unless in fruit, since their three or four pairs of leaves are scarcely noticeable. One attention is called to them because of the reddish tinge which the thousands of setae and capsules give to the rock surface. One is led to believe that the two enter a bare sandstone area very quickly after its exposure, and that they fruit immediately, since the stones upon which they are growing are covered with water throughout the greater portion of the year. These two mosses are found on practically every sandstone rock in any situation. They grow either alone or as relics among the mosses which enter later. In the identification of other mosses growing on sandstone one usually finds tiny bits of the last of the pioneers.

Search along the water line revealed one rock on which vast quantities of *Fissidens* were being covered by two mosses, *Plagiothecium deplanatum* and *Brachythecium salebrosum*, the two entering at about the same time. In another kind of situation, the middle of a ravine, *Amblystegiella adnata* was following the pioneer. In like situations *Amblystegiella minutissima* was found growing with *Fissidens*, and *Brachythecium salebrosum* and *Plagiothecium deplanatum* in turn with *Amblystegiella minutissima*. In other cases it seems that *Brachythecium oxycladon* and *Amblystegium varium* entered a short time after the *Amblystegiella* spp. Thus the early succession appears to be more or less in this order, *Fissidens minutulus* and *Fissidens incurvus exiguus* as the invariable pioneers, *Amblystegiella minutissima* and *A. adnata* following as the secondary mosses, while the third stage is represented by an abundance of the members of the *Hypnaceae*, especially *Brachythecium salebrosum*, *B. oxycladon*, *B. plumosum* *Plagiothecium deplanatum*, and *Amblystegium varium*. Of course it is to be understood that once established on an area these mosses tend to creep over adjacent bare area, but the above order of succession seems to be more or less typical.

Those mosses which tend to grow on soil and humus enter upon the accumulation of debris and soil, which is brought about through various agencies such as the decay of mosses, the disintegration of the stone through acid action and physical causes, and the deposition of dust and soil by wind and water. The early mosses remain more or less persistent. The species of *Brachythecium* become more abundant and *Eurhynchium hians* appears. *Entodon seductrix* and *Mnium cuspidatum* enter in especially moist places. In other situations *Plagiothecium Roseanum, Eurhynchium serrulatum,* and *Aulacomnium heterostichum* are late transitional stages, growing partially on soil and partially on stones. In one location *Hypnum curvifolium* was growing in dense mats aiding in the formation of more soil and thus preparing for the entrance of *Catharinea angustata.* In still another instance *Cirriphyllum Boscii* and *Raphidostegium adnatum* had prepared the substratum so that *Catharinea angustata* had entered.

In the last stages of succession in situations in which the soil has a low pH value, conditions such as one finds on the Mossy Bank point, one collects the hairy cap, *Polytrichum commune,* together with *Dicranum scoparium, Dicranella varia, D. heteromalla, Ditrichum tortile,* and *Plagiothecium Roseanum.*

Thus in the typical sandstone succession *Fissidens incurvus exiguus* and *F. minutulus* are the pioneers on a primary bare area. The intermediate mosses are numerous species of *Hypnaceae* and the climax is represented by such mosses as *polytrichum commune* and *Dicranum scoparium* which, with other species, form dense mats and survive for long periods of time invasion of the higher plants.

TABLE 2. Mosses Found on Sandstone and Substrata Reactions

Mosses	pH Values and Ranges
Ditrichum tortile	4.1
Catharinea angustata	5.2 to 6.2
Hypnum curvifolium	5.2 to 7.0
Amblystegium serpens	no soil
Eurhynchium hians	6.2 to 6.5
Brachythecium salebrosum	6.2 to 7.0
Fissidens incurvus exiguus	6.0 to 6.2
Amblystegiella minutissima	6.4 to 6.6
Amblystegiella adnata	6.4 to 7.0
Fissidens minutulus	6.4 to 7.0
Campylium chrysophyllum	6.6
Entodon seductrix	6.6
Amblystegium orthocladon	6.6
Brachythecium plumosum	6.6
Plagiothecium deplanatum	6.8 to 7.0
Mnium cuspidatum	6.8
Brachythecium osycladon	6.8
Amblystegium varium	6.8 to 7.0

Note: Where no range is given (a) the pH values are identical in all cases, or (b) there was not sufficient soil for a test, or (c) or in rare instances only one specimen was found.

Succession on Limestone Substrata

It is an accepted fact that *Grimmia apocarpa* is indicative of alkalinity, of the presence of calcium carbonate, and of limestone rock. Apparently it does not grow in acid conditions. The observations upon Harrodsburg limestone as a substratum in relation to *Grimmia* are in accord with those of other investigators; i.e., that it invariably grows upon exposed limestone rocks, and follows immediately, in most instances, the crustose lichen stage as the moss pioneer (1) (10).

On several exposures in the railway cut a rare moss, *Desmatodon Porteri*, is the first to enter. It is so small, however, that when other mosses enter it soon becomes obscure.

There are mosses which are closely associated with *Grimmia* in early succession; e.g., *Leskea nervosa nigrescens*, *Bryum argenteum* and *Amblystegiella adnata*, the latter being very abundant. *Amblystegium varium*, *A. serpens*, *Thuidium pygmaeum*, *Barbula unguiculata*, *Ceratodon purpureus*, and *Brachythecium oxycladon dentatum* are also found, in the more xerophytic situations. In a few instances *Grimmia*, atlhough in a more moist habitat, was found with *Amblystegium orthocladon*.

If the limestone rock upon which *Grimmia* is growing is near exposed roots and bases of trees upon which *Anomodon* spp. is abundant the two will readily become associated, and the invader will become dominant. Many instances of this were found.

Leskea polycarpa, *L. gracilescens*, *E. sebuctrix*, *B. salebrosum*, and *B. oxycladon* are to be found in abundance as the moss and soil cushion becomes deeper. *Plagiothecium deplanatum*, *Eurhynchium serrulatum*, *E. hians*, *Campylium hispidulum*, *C. chrysophllum*, *Mnium cuspidatum*, and *Brachythecium acutum* follow, more or less in the order named.

Barbula unguiculata and *Pohlia nutans* are found on soil which is alkaline. The latter species grows in moist situations in which *Fissidens taxifolius* is abundant.

In relation to the problem of acidity and alkalinity it is interesting to compare results from the region of Bloomington with those obtained by Watson (12) in England. Among those that he classes as the most pronounced and the most common "calcifuge" species are *Polythricum* spp. and *Dicranella heteromalla*, with which Indiana data agree. Those classes as indifferent on both calcareous and siliceous substrata are *Grimmia apocarpa*, *Dicranum scoparium*, *Catharinea undulata*, *Amblystegium serpens*, and *Brachythecium rutabulum*. In this particular region *Grimmia* is found exclusively on limestone rocks, and *Dicranum scoparium* and *Catharinea angustata* are found exclusively on acid substrata.

To quote Watson further, "In regard to many bryophytes and lichens there seems little doubt that the chemical factor is more important (than the physical). Many calciole bryophytes and lichens are indifferent to the physical character of the substrata, they will grow on almost any rock or soil if calcium carbonate is present. *Hypnum molluscum* is a striking example of this indifference. In all cases which I have investigated the substratum has had lime contents." In relation to the above statement the tests for the substrata on which *Hypnum molluscum* was growing in this area under observation showed a rather conspicuous absence of calcium carbonate, the pH range being from 5.4 to 6.4.

Thus it will be noticed from the above discussion that there is, as in the case of the sandstone substrata, a definite succession of mosses on limestone, beginning with *Grimmia apocarpa* in most instances, and followed by typical secondary stages. The latter stages are not as definitely pronounced as those in the sandstone succession, since the calcium carbonate becomes leached out through the action of water, and the resulting soil tends toward acidity.

TABLE 3. Mosses Found on Limestone and Substrata Reactions*

Mosses	pH Value and Ranges
Amblystegiella adnata	7.0 to 7.8
Anomodon attenuatua	7.0 to 7.9
Anomodon minor	7.0 to 7.4
Barbula unguiculata	7.0 to 7.4
Bryum argenteum	7.0 to 8.2
Campylium hispidulum	7.0 to 7.4
Leskea nervosa nigrescens	7.0 to 7.8
Amblystegium orthocladon	7.2 to 8.0
Amblystegium varium	7.2 to 8.0
Brachythecium cyrtophyllum	7.2
Brachythecium rutabulum	7.2 to 7.8
Entodon seductrix	7.2 to 7.6
Brachythecium oxycladon	7.2 to 8.0
Eurphynchium serrulatum	7.2 to 8.0
Grimmia apocarpa	7.2 to 8.0
Plagiothecium deplanatum	7.2 to 8.0
Amblystegium fluviatile	7.3 to 7.8
Bryhnia graminicolor	7.3
Campylium chrysophyllum	7.3
Brachythecium plumosum	7.4
Brachythecium salebrosum	7.4 to 7.8
Desmatodon Porteri	7.4 to 8.2
Leskea polycarpa	7.4 to 7.6
Eurhynchium hians	7.5 to 8.0
Weisia viridula	7.5
Amblystegium irriguum	7.6
Amblystegium serpens	7.6 to 7.8
Brachythecium acutum	7.6 to 8.0
Leskea gracilescens	7.6
Amblystegium Kochii	7.7 to 8.4
Anomodon rostratus	7.8
Ceratodon purpureus	7.8
Orthotrichum anomalum	7.8
Mnium cuspidatum	7.9
Pohlia nutans	8.0

*See note following Table II.

Wood Succession

It is questionable whether or not one may term the progression of mosses from living to decayed wood and thence to soil a true ecological succession, yet there are indications of a series. One does not find many of the species which normally grow on the bark of living trees upon soil and humus and vice versa. On the other hand there are mosses which do not tend to discriminate. Certain mosses grow upon both the bases and the roots of living trees, but these are not a part of the above succession.

In the identifications made only one species, *pylaisia Schimperi*, was found growing on living trees exclusively. *Orthotrichum strangulatum*, *Platygyrium* *repens*, and *Amblystegiella adnata* belong to that group which does not discriminate between the bark of living trees and that of decaying stumps and fallen trees. These are considered to be the pioneers on decaying wood. *Amblystegiella adnata* tends more or less to be a cosmopolitan species, growing both upon wood and upon stones of any kind.

Among those mosses which tend to grow upon bases of living trees and which spread to soil the most important are the species of *Anomodon;* i.e., *A. rostratus*, *A. minor*, *A. attenuatus* and less frequently *A. tristis*. In many cases these plants entirely cover the roots and bases of trees, spreading to surrounding soil and to rocks on which soil has accumulated. In many instances one finds associated with the species of *Anomodon* the following members of the *Hypnaceae: Amblystegium varium*, *Entodon seductrix* (very frequent), *Amblystegiella adnata*, *Leucodon julaceus*, *Platygyrium repens*, *Orthotrichum* spp., *Campylium hispidulum*, *Brachythecium salebrosum*, *B. oxycladon* and *Eurhynchium hians*. In exposed situations the habit of growth of the species of *Leskea*, particularly *L. polycarpa*, is comparable to that of the species of *Anomodon*.

It is more or less impossible to name any definite order which is followed by the intermediates on decaying wood. An enumeration of the species must suffice. In addition to many of the above species one finds *Thelia hirtella*, *Campylium hispidulum*, *C. chrysophyllum*, *Leskea gracilescens*, *Eurphynchium serrulatum*, and *Amblystegium Kochii*. In many instances one finds in close association *Orthotrichum strangulatum*, *Platygyrium repens*, *Anomodon tristis*, *Leucodon julaceus* and *Forrstroemia* sp.

It is after considerable decay that the order becomes fairly definite, expecially on wet logs. *Mnium affine ciliare* and *M. cuspidatum* find more or less optimum conditions of substrata and moisture for their growth on decaying logs. In close succession one finds *Hypnum curvifolium* and *H. molluscum*, which in turn become associated with *Thuidium delicatulum*, *Leucobryum glaucum*, and *Dicranum scoparium*, the latter being a moss which tends to grow commonly on acid soil. In some instances one finds *Aulocamnium heterostichum* together with *Bartramia pomiformis* in these later stages of succession. To illustrate such succession one may cite specific logs on which these stages or steps are to be met.

There were three logs in extreme stages of decay which were quite indicative. On one there was *Platygyrium repens* as a remnant of the early mosses together with *Eurhynchium serrulatum*, *Hypnum curvifolium*, and *Dicranum scoparium*, entering in the order given. Growing on another log of a similar kind were *Platygyrium repens*, *Hypnum curvifolium*, *Leucobryum glaucum*, and *Dicranum scoparium*. A third showed *Aulacomnium heterostichum* and *Thuidium delicatulum* following *Hypnum molluscum*.

In certain conditions in which the acidity is not too low, from 5.3 to 6.8, and with a substratum of soil and humus one can find *Climacium Kindbergii*.

All these facts tend to show that a succession exists from living wood to soil, the latter stages of which are found on quite acid soil and humus. The latter statement is in accord with the fact that decaying wood has a low pH value when tested with the colorometric method. A natural consequence would be that the late stages of succession would include acid-loving mosses.

There are similarities between the last stages of the moss succession from wood to soil and that of sandstone to soil, due to similar conditions of acidity; in fact the two merge and blend on common ground on Mossy Bank point with such species as *Dicranum scoparium* and *Polytrichum commune*.

TABLE 4. Mosses Growing on Living Trees and Roots

Anomodon attenuatus	Entodon seductrix
Anomodon minor	Eurhynchium serrulatum
Anomodon rostratus	Forrstroemia sp.
Anomodon tristis	Leskea nervosa
Amblystegiella adnata	Leskea polycarpa
Aulacomnium heterostichum	Leucodon julaceus
Sampylium hispidulum	Platygyrium repens
Campylium chrysophyllum	Pylaisia Schimperi

TABLE 5.[1] Mosses Growing on Decaying Wood

Amblystegiella adnata	Dicranum scoparium
Amblystegium Kochii	Entodon seductrix
Amblystegium serpens	Furhynchium hians
Amblystegium varium	Eurhynchium serrulatum
Anomodon attenuatus	Leskea gracilescens
Anomodon minor	Leucodon julaceus
Aulacomnium heterostichum	Hypnum curvifolium
Bartramia pomiformis	Hypnum recurvans
Brachythecium acutum	Leptobryum pyriforme
Brachythecium oxycladon	Mnium cuspidatum
Brachythecium salebrosum	Platygyrium repens
Bryum caespiticium	Thelia hirtella
Campylium chrysophyllum	Thuidium delicatulum
Campylium hispidulum	

[1]Range of pH values for decaying wood which was tested was from 5.8 to 6.8.

Soil Mosses

Many of the mosses which grow on soil have been discussed previously in relation to the various successions.

In most instances the value of mosses which enter upon a bare soil is negligible as far as humus formation is concerned. The conditions which make it bare are such that the mosses are not permanent. The soil is perhaps that of a cultivated field, one that is lying fallow, an expanse of land that is covered for periods of the year by water, or a slope that is subjected to constant rapid erosion.

The only mosses found in the first condition were *Weisia viridula* and *Physcomitrium turbinatum.* They were growing with grass and thus the soil formation value is small.

For the study of areas which are alternately dry and flooded, the edge of the lake furnished excellent collecting ground for one species. *Aphanorhegma serratum*, which Grout terms a very common species. It evidently matures rapidly, for it was found in fruit and the ground was still damp from the receding water. Here was another instance in which the moss was of little economic value; not only is it a minute moss, but it would again be covered with water or with the vegetation of the margin of the lake, as the season might be.

It is impossible for mosses to gain a foothold on those slopes which are subjected to rapid and constant erosion.

The following list includes all the mosses which were collected on soil, many of which are climax mosses in successions on substrata other than soil.

†TABLE 6. SOIL MOSES AND SOIL REACTIONS

Mosses	pH Value and Ranges
Hypnum curvifolium	3.8
Dicranella varia	4.2 to 7.0
Dicranum scoparium	4.3 to 4.8
Polytrichum commune	4.3 to 4.7
Ditrichum tortile	4.5
Catharinea angustata	4.6 to 5.8
Bartramia pomiformis	4.7 to 5.3
Aulacomnium heterostichum	4.7 to 5.3
Thuidium delicatulum	4.8
Cirriphyllum Boscii	5.2
Mnium affine ciliare	5.3 to 6.7
Climacium Kindbergii	5.3 to 6.8
Eurhynchium hians	5.8 to 7.8
Eurhynchium serrulatum	6.0 to 7.6
Campylium chrysophyllum	6.4 to 6.6
Plagiothecium deplanatum	6.6 to 8.0
Anomodon attenuatus	6.7 to 7.3
Campylium hispidulum	6.8 to 7.3
Entodon seductrix	6.8 to 7.6
Mnium cuspidatum	6.8 to 7.4
Amblystegiella adnata	6.8
Fissidens taxifolius	7.0 to 8.2
Barbula unguiculata	7.2 to 7.8
Brachuthecium salebrosum	7.2
Amblystegium Kochii	7.2
Brachythecium oxycladon	7.2 to 7.4
Amblystegium varium	7.4 to 7.6
Pohlia nutans	7.4 to 8.2
Brachythecium rivulare	7.4 to 8.4
Raphidostegium sp.	8.0
Brachythecium acutum	8.0
Philonotis fontana	8.0

†See note, page 93.

HYDROPHYTIC AND XEROPHYTIC MOSSES

There are mosses in this region which tend to be hydrophytic, and others which tend to be xerophytic, but the greater percentage is mesophytic.

Those mosses which grow on trees and bases of trees, and upon exposures of limestone rocks are considered as xerophytic; e.g., *Grimmia apocarpa, Orthotrichum spp., Anomodon spp., Ditrichum tortile, Desmatodon Porteri, Barbula unguiculata, Bryum spp., Leskea spp.* Many other species can adapt themselves to such conditions.

Those which are hydrophytic are found in and at the edge of small streams or in seepage. *Brachythecium rivulare, B. acutum, B. rutabulum, Pohlia nutans, Amblystegium fluviatile, A. riparium fluitans, Philonotis fontana* and *Amblystegium orthocladon* are commonly found in such situations.

The small streams in which these mosses are found are those in which the water is very alkaline, carrying calcium carbonate in solution, testing from 7.6

to 8.2, since they drain from the limestone beds and exposures. Around two mosses as nuclei, *Amblystegium riparium fluitans* and *A. orthocladon*, calcareous incrustations or tufa are being formed. Such conditions are found frequently along the east side of North Pike across from the Cascades Park.

Daubenmire (4) found three mosses at Clifty Falls which were being similarly covered, *Mniobryum albicans*, *Amblystegium irriguum*, and *Gymnostomum curvirostre*. According to Miss Taylor (10) Cowles, at Turkey Run, reported *Cratoneuron filicinum* as being tufa forming. Emig (5) in his discussion on mosses as rock builders reported *Brachythecium rivulare* as aiding in iron ore deposition, and *Didymodon tophaceus* and *Philonotic calcare* in deposition of calcium carbonate. Algae are present many times with these mosses, but it is not known whether or not they take an active part or one similar to that of the mosses. Emig (5) states, "Mosses act only indirectly in the precipitation of calcium carbonate, principally by supplying a larger absorptive and absorptive surface for the evaporation of the calcareous water."

It is interesting to note that in the center of some ravines upon a substratum of sandstone calcareous species are found, such as *Thuidium pygmaeum*. Probably this is due to the fact that the calcareous water from the layers of limestone is giving the optimum condition of alkalinity for their growth.

SLOPE SUCCESSION

Concerning slope succession one may consider Mossy Bank as an example of a typical north-facing slope with a creek flowing at the base, with a xerophytic summit and more mesophytic conditions lower.

At the summit of the point *Dicranella varia*, *D. heteromalla*, and *Ditrichum tortile* grow together with *Dicranum scoparium* and *Polytrichum commune* in an open, exposed situation. A few feet below the top one finds the first three disappearing, and dense mats of *Leucobryum glaucum* and *Hypnum curvifolium* becoming frequent, which in many spots become the dominant mosses. These continue down the slope together with *Bartramia pomiformis* and *Aulacomnium heterostichum* in the absence of constant seepage. One finds an abundance of *Eurhynchium serrulatum*, *E. hians*, *Fissidens taxifolius*, *Mnium spp.* and *Plagiothecium deplanatum* growing where there is much seepage and in the drip-zones under small ledges. Near the base of the slope one finds these same species, and also *Climacium Kindbergii* (approaching *Americanum*). In no instance was this moss found growing near the top of the bluff.

These results are similar to those reported by Miss Taylor (10) for morainal clay bluff and pastured and unpastured woods.

SUMMARY

From the above discussions it will be noted that there are mosses which are indicative of the various types of substrata and of soil conditions.

The "*Anomodons*" are dominant mosses in many situations, such as dry limestone, bases of trees, etc., forming distinct portions of the cryptogamic society. In the succession on sandstone and on decaying wood *Polytrichum commune*, *Dicranum scoparium* and *Catharinea angustata* are the dominant mosses. In many situations members of the Hypnaceous group are dominant locally.

Fissidens incurvus exiguus and *F. minutulus* are indicative of sandstone rocks as *Grimmia apocarpa*, *Barbula unguiculata*, *Bryum argentuem*, *Desmatodon*

Porteri, and *Thuidium phymaeum* are of limestone. *Polytrichum commune, Dicranum scoparium, Catharinea angustata, Dicranella* spp., *Hypnum Curvifolium, H. Molluscum, Bartramia pomiformis Aulacomnium heterostichum, Thuidium delicatulum*, and *Cirriphyllum Boscii* all grow on more or less acid substrata, never occuring on alkaline in the area under study. *Pohlia nutans* and *Fissidens taxifolius* in this locality usually grow on alkaline soil.

CONCLUSIONS

1. In this region there is a definite succession of mosses on sandstone beginning on a bare area with *Fissidens incurvus exiguus* and *F. minutulus*, and reaching a climax with dominant mosses as *Polytrichum commune, Dicranum scoparium*, etc.

2. There is a succession beginning on living wood, passing to decayed wood and thence to soil. The later stages parallel sandstone succession, due probably to the acidity of decaying wood and humus.

3. The early stages of limestone succession include *Grimmia apocarpa, Desmatodon Porteri, Bryum* spp. and others, and the later stages include such mosses as *Barbula unguiculata Fissidans taxifolius, Pohlia nutans*, and species of the *Hypnaceae*.

4. There is a more or less definite progression of mosses from the tops of the slopes to their bases.

5. There is a definite constant relationship between acidity and alkalinity and the species of mosses to be found in the respective conditions. It is possible to classify certain mosses as indicators of conditions of acidity and alkalinity.

6. Certain of the hydrophytic mosses are tufa builders in the small streams in the vicinity of Bloomington.

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