A GUIDE TO THE NATURAL HISTORY OF THE CEDARBURG BOG
PART I

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PREFACE

The boardwalk that extends to the center of the Cedarburg Bog is the UWM Field Station's most heavily used teaching facility. Research is also conducted in the Bog, which holds an understandable fascination for researchers and students of natural history because of its size, complexity, diversity and geographical isolation from similar communities. Because of the increasing research and teaching use of the Bog, it has become essential that some of what is known about the natural history of the Bog be assembled and summarized in an easily accessible introduction and guide. The guide contains too much material to fit into one issue of the Field Station Bulletin. The first issue contains a narrative on each of the vegetation zones through which the boardwalk passes. The second issue has the selected species lists, annotated with natural history notes, which are also arranged by vegetation zones along the boardwalk. The second issue also contains vertebrate and vascular plant species lists for the Cedarburg Bog. An index to both volumes and the literature cited for both volumes are contained in Part I. As research on the Bog continues, I plan to revise this guide periodically to incorporate additional information. The Field Station would appreciate suggestions regarding ways that future editions of this guide might be improved.

Calling these two issues of the Bulletin a guide, suggests a booklet that is meant to be carried and read while taking the boardwalk. Here, however, I use the word "guide" to refer to the fact that the organization of this publication matches the physical layout of the walk. This guide is not the sort that you would want to read in its entirety while "walking the planks". It may be useful to carry in the field as a reference, but it is primarily intended as background material. Those having a keen interest in the Bog, or instructors bringing classes to the Bog, will want to read it before traveling the boardwalk. While it would be impossible to include all that is known about the Bog, this guide contains more detail and more information than the casual nature hiker may wish to read. I hope that instructors may find here the raw material upon which to build lessons that they would like to impart to their classes. Some suggestions for class activities that have been used in the Bog are included and I would like to expand on these in the future. Some teaching aids (e.g., tree cores, bog sediment corers of various types, identification guides, etc.) are available from the Field Station upon request. The Station has also begun to assemble a set of laboratory lessons for use in the Bog and contributions will be welcomed.

I have come to realize that organizing any guidebook is a formidable task. A guide to the Cedarburg Bog could be arranged in several ways: 1) a linear organization to parallel the boardwalk, 2) a seasonal organization, or 3) an organization by subject. Most of the readers will experience the Bog from the boardwalk, so I chose an organization which matches the vegetation zones through which the walk passes. This organization is not always the most convenient and instructors will recognize many options to move the treatment of topics to different areas.

While I have included selected references for further reading, I did not present a complete literature review on topics relating to the Bog. Unless otherwise referenced, all information about Wisconsin's plant communities was obtained from Curtis (1959). Part II contains selected species lists of the most important or conspicuous plants in each vegetation zone. The species lists are annotated with natural history notes; however, I recommend that the guide be used in conjunction with identification manuals. Identification notes or keys are not included in this guide. Plant species' ranges were taken from Gleason (1968).

I have received a great deal of help in the writing and production of the guide. Kate Redmond provided the initial idea for the guide, discussions concerning its format and many natural history contributions. Other contributors to the content of the guide include: Susan Borkin, Penny Ficken, Glenn Guntenspergen, Margaret Kuchenreuther, Andy Larsen, Paul Matthiae, Lee Olsen, Donald Quintenz, Forest Stearns and Charles Weise. Charles Weise prepared the annotated list of vertebrates of the Field Station which appears in Part II of the guide. Forest Stearns provided a great deal of editorial help. Most of the information on insects in the guide is due to Susan Borkin, and Lee Olsen provided most of the information on plant phenologies. Bernard Lohr drew all the illustrations, and Kay Mueller typed many rough, and the final drafts.

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INTRODUCTION

Characterization of the Wetland

The Cedarburg Bog is a bog. The Cedarburg Bog is not a bog. Bog it is, in that its soil is peat and many of its plant species are typically found in true bogs. In other more important ways, the Cedarburg Bog is not a bog. From a hydrologic perspective, true bogs depend only on rain as their source of water. From this view, the Cedarburg Bog is a fen, i.e. a wetland with major groundwater inflow influencing its water chemistry.

Viewed from the plant perspective, the Cedarburg Bog is highly varied but not a typical bog. The flora of the Bog consists of the plant species that are present; the term vegetation refers to a description of how the plant species are assembled into plant communities. The flora of Cedarburg Bog includes components of many different Wisconsin plant communities, including species normally found in bogs. The vegetation types of Cedarburg Bog include typical examples of submerged and emergent aquatic communities, southern cattail marsh, sedge meadow, string bog, northern lowland forest (or conifer swamp), and southern lowland forest (or swamp hardwood forest). However, typical open leatherleaf-sphagnum bog, with open areas dominated by hummocks of Sphagnum moss, is not found in the Cedarburg Bog. Excellent examples of most of the vegetation types of the Bog can be viewed from the boardwalk.

Uniqueness, Ownership and History

The Cedarburg Bog is unique. It is the largest peatland in southern Wisconsin with an unusually great diversity of plant and animal communities. Most of the Bog is undisturbed and has excellent examples of many plant communities, including some typically found farther north. There are at least 32 wetland vascular plants and 12 species of birds that are at, or near, the southern edge of their Wisconsin range in the Cedarburg Bog.

In recognition of its value for teaching, research, and the preservation of wildlife, the Cedarburg Bog has been made both a Wisconsin State Scientific Area, and a National Natural Landmark, and has been included in the national system of Experimental Ecological Reserves.

Not only is the Cedarburg Bog a large peatland, but it is also located close enough to Lake Michigan to receive some cooling from the lake during the growing season. This may, in part, explain why so many northern species are found in the Bog. Curtis (1959) noted that several of Wisconsin's northern plant communities are found far south in a narrow zone along Lake Michigan. He explained this extension of the "tension zone" between northern and southern communities as resulting from the lake's cooling effect. If the lake effect helps to explain the northern vegetation, presumably the vegetation explains the presence of northern species of animals. Several of the birds that reach the southern edge of their ranges here, nest only in boreal regions and require a large area to breed. Cedarburg Bog is the southernmost location filling these requirements.

The boardwalk extending into the Bog is an invaluable feature for access to the wetland. Beginning on University land and maintained by the University, the boardwalk extends for the last two-thirds of its length into the Department of Natural Resources owned State Scientific Area. The UWM Field Station land was purchased in 1964 through a public fund drive by the Wisconsin Chapter of the Nature Conservancy. The land was then donated to the University which recognized the importance of the site for enhancing research and education in the environmental sciences. The DNR began acquiring land in the Bog with a 519 acre purchase in 1946 on the recommendation of, then commissioner, Aldo Leopold. In 1952, it was designated one of the first State Scientific Areas. DNR owned or recognized State Scientific Areas are selected from the best remaining natural areas that contain nearly intact plant and animal communities, or unique and significant geological or archaeological features. Scientific areas are set aside and dedicated to scientific research, the teaching of conservation and natural history, and to the preservation of natural areas for future generations.

View from the Hill

Mud Lake

Perhaps the best introduction to the Bog can be obtained from the hill on the west side of Blue Goose Road opposite the Bog entrance gate. From this hill, you can see Mud Lake to the southeast and one of its two upland islands. The island in best view is in the northwest quarter of Mud Lake; the other island is surrounded by the cat-tail marsh at the north end of the lake. Mud Lake, occupying about 165 acres, is a shallow (4.5 ft.) muck-bottomed lake, as are each of the three lakes in the southern part of the Bog (see Fig. 1, at the center of this Issue). Mud Lake's shores support dense stands of hard-stemmed and soft-stemmed bulrush (*Scirpus acutus* and *S. vallidus*), cat-tails (*Typha* spp.) and water willow (*Decodon verticillatus*). In addition to the glacial till islands, several muck "islands" of bulrush, cat-tail, and pickerel-weed (*Pontederia cordata*) are surrounded by the open water of Mud Lake.

Szmania (1973) studied the fish populations and water chemistry of Mud Lake. Snow and ice cover in the winter prevent oxygen from diffusing into the water and because of the small volume of water in this shallow lake, the dissolved oxygen content of the water typically falls as low as 0.2 parts per million (ppm) during the month of February (Fig. 2). Levels of dissolved oxygen less than 1.0 ppm result in extensive fish mortality. Szmania found 11 species of fish in Mud Lake over the course of a year (Table 1).

Of all the species found in the lake, the population of Mud minnows may be the only one that is able to sustain itself through the low winter oxygen concentrations without immigration or recruitment from Mud Lake Creek. A small population of Iowa darters may also survive year-round in Mud Lake since the species was never found in Mud Lake Creek.

Table 1. Fish Collected in Mud Lake during 1972 (from Szmania, 1973).

Common white sucker	*Catostomus commersonnii*
Golden shiner	*Notemigonus crysoleucas*
Fathead minnow	*Pimephales promelas*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Tadpole madtom	*Noturus gyrinus*
Mudminnow	*Umbra limi*
Northern pike	*Esox lucius*
Iowa darter	*Etheostoma exile*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis machrochirus*

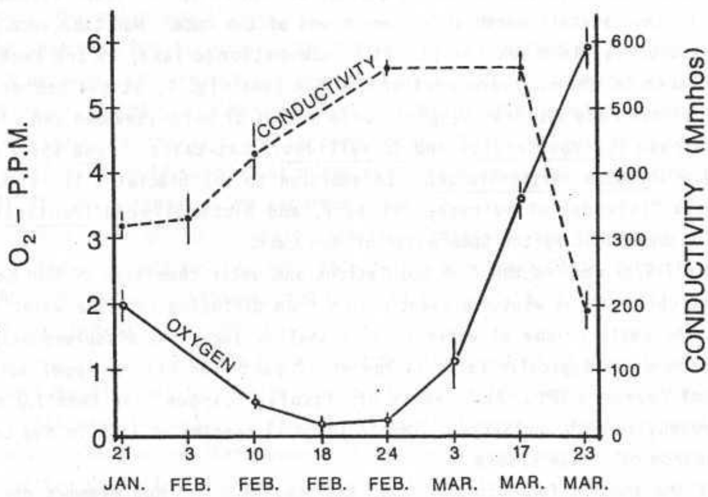

Fig. 2. Relationship between specific conductance and dissolved oxygen for weekly samples on Mud Lake in 1972. Circles indicate means and vertical lines are standard deviation. From Szmania (1973).

Complementing the precipitous decrease in dissolved oxygen over the winter, Szmania found an opposite trend in the specific conductance (or mineral content) of the water (Fig. 2). Two factors probably contribute to this relationship. Over 50% of the water volume of Mud Lake freezes during a typical winter and it is largely pure water that freezes. The solutes, which are excluded from the ice, are greatly concentrated in the remaining unfrozen water. Another possible source of increase in the mineral content of the water is the addition of iron and manganese from the lake sediments. These elements become more soluble when the water is nearly free of dissolved oxygen.

While the winter water chemistry (especially dissolved oxygen content) prevents all but a few of the fish of Mud Lake from surviving over the winter, the lake still plays an extremely important role in maintaining the fish populations of Mud Lake Creek and Cedar Creek into which it flows. Northern pike move into Mud Lake from Mud Lake Creek and Cedar Creek to spawn during the spring (late March and the first three weeks of April). About 500 Northern pike make this annual trek into Mud Lake, lay an estimated 1.5-2.0 million eggs, and then leave the breeding grounds shortly after spawning. The estimated annual production of pike fingerlings in Mud Lake is 5-10,000. The lake provides a very good source of the small invertebrates that the young pike eat. Many of the Northern pike that move into Mud Lake to spawn are large fish (Fig. 3). The average length of males in the spring spawning run is 15 inches; females (which are normally larger) average 18 inches. Fish as large as 36 inches run into the lake to spawn.

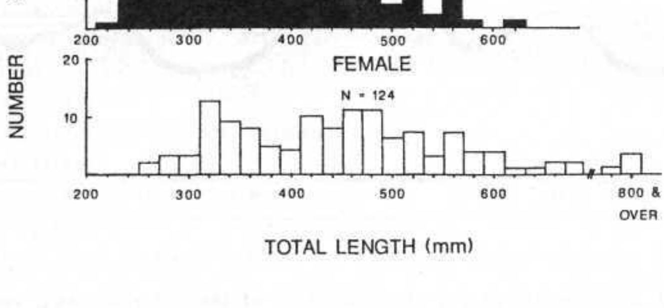

Fig. 3. Distribution of the lengths of male and female Northern pike in the 1972 spawning run in Mud Lake Creek. From Szmania (1973).

The Basin: Glacial History and Hydrology

From the hill there are power lines visible across Mud Lake on the southeast horizon. These run along the border of the Bog and their distance gives a sense of the Bog's immense size (Fig. 1). The Bog is approximately 3 1/4 miles from the northeast to the southwest and 1 to 1 1/2 miles wide. From the hilltop you actually view only a small part of the whole wetland. About 1,500 of its 2,200 acres are in public ownership.

As you look out over the Bog, picture it as a whole. It began 12,000 years ago as a large postglacial lake which was carved out by the action of the glaciers. As the glaciers receded, a tight, gray clay was deposited, which lines most of the basin today. This layer of clay created a shallow, irregularly shaped bowl with an overflow point at its southwest corner near Mud Lake. This lake had an undulating basin with scattered islands of till. In some places the lake was over 50 ft. deep. For thousands of years, oozy gray lake sediment (aquatic plant parts, shells, marl, silt, diatoms, pollen and material transported from the surrounding uplands) was deposited on the bottom. This sediment currently fills the basin to within 8 to 9 ft. of the wetland's surface. As the lake basin filled in, the patterns of water movement and chemistry became more complex than they had been in the mixed open water. Eventually the lake became shallow enough to support emergent aquatic plants, whose remains we see today as a layer of organic peat deposited over the lake sediments (Fig. 4).

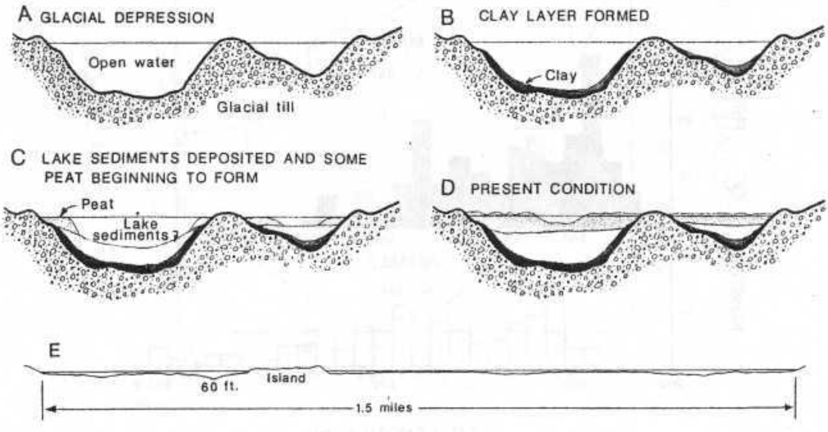

Fig. 4. A-D, Development of the basin deposits of the Cedarburg Bog; vertical dimension greatly exaggerated. E, Typical cross-section (15-60 ft. x 1.5 miles) of the Bog drawn to scale.

The 8 to 9 ft. deep peat is composed of the partially decayed remains of dead plants. Peat accumulates in wet areas where the rate of production of organic material exceeds the rate of decomposition by microorganisms. As peat accumulates, vegetation changes from floating to emergent aquatics and then to sedge meadow, shrub carr and eventually to forest. All of these successional stages from open water to swamp forest are still present in the Cedarburg Bog and contribute to its great habitat diversity. In the forested areas around the Bog perimeter, enough peat has accumulated to provide almost firm ground.

Within the next several thousand years, barring some catastrophic event, peat will continue to accumulate until the entire Bog will support swamp forest. At that time, much of the present diversity will have been eliminated. However, several types of catastrophic events are capable of returning the system, or parts of it, to earlier successional stages. For example, a series of dry years after the peat has built up could allow the top layers to dry to the point where a fire could burn in the peat. When dry peat oxidizes and is lost, fire could actually lower the peat surface enough so that, with the return of normal water levels, a much earlier successional stage (perhaps emergent aquatics) would recolonize the site.

Water, its depth, rate of flow, and chemical composition are vital to the development and maintenance of the whole Bog system (Fig. 5). Rainfall is by far the major source of water for the Bog. Spring water entering the basin 3 miles to the north is chemically altered as it moves along a complex path to the southwest toward Mud Lake and the outlet stream. The several vegetation types, the islands, the Bog stream, the lakes and the springs all contribute to the complexity of water movement and chemistry of the Bog. Each vegetation type forms a different type of peat differing in water conducting properties.

The guide is divided into a discussion of 10 vegetation zones which occur along the boardwalk (Fig. 6 and 7).

1. The Shrubby "Moat"
2. Cedar-Tamarack Conifer Swamp
3. Willow-Bog Birch-Dogwood Shrub Carr
4. Sedge Meadow-Emergent Aquatics Bordering the Stream
5. Stream
6. West Island
7. Swamp Hardwoods-Conifers (Between Islands)
8. East Island
9. East Island to the String Bog
10. String Bog

Each of these zones progressing from west to east is described in the following pages.

Despite years of study by researchers from the Field Station, we still know only a small fraction of the Bog's secrets. For example, it is still a frequent occurrence to discover plants and animals which are not on our species lists. In just the past few years, species new to the state and an insect that was previously unnamed, have been discovered in the Bog. Exploration of, and research on, the Cedarburg Bog are still grand adventures with many unknowns!

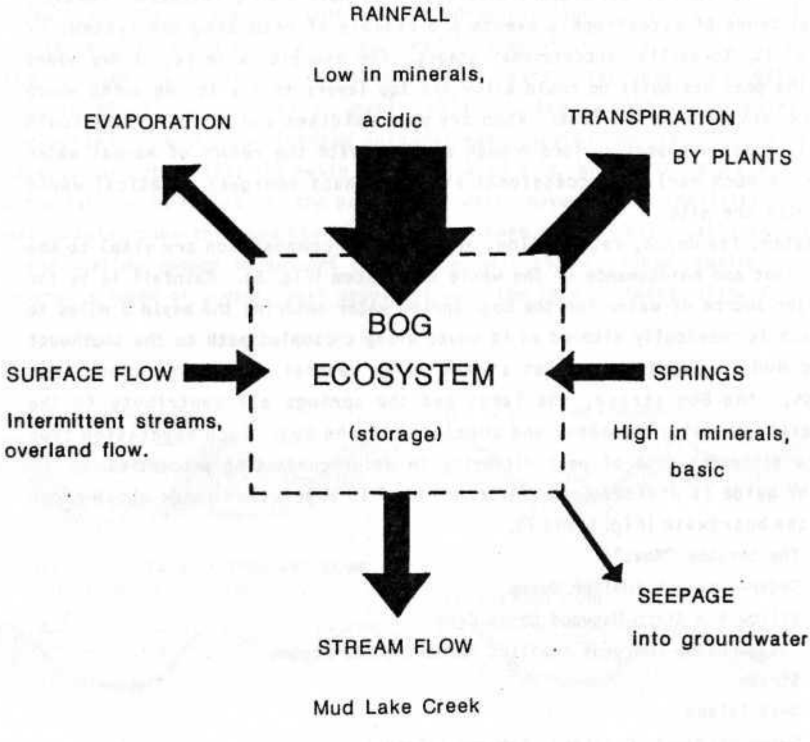

Fig. 5. Hydrologic (mass balance) budget of the Bog. INFLOW = OUTFLOW + CHANGE in storage.

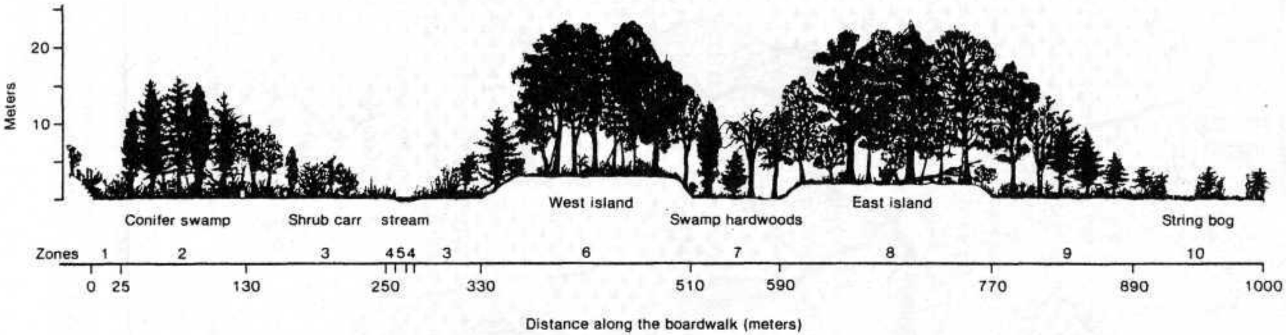

Fig. 6. Vegetation zones along the boardwalk. The vertical scale (height of the vegetation) is greatly exaggerated but is drawn to scale.

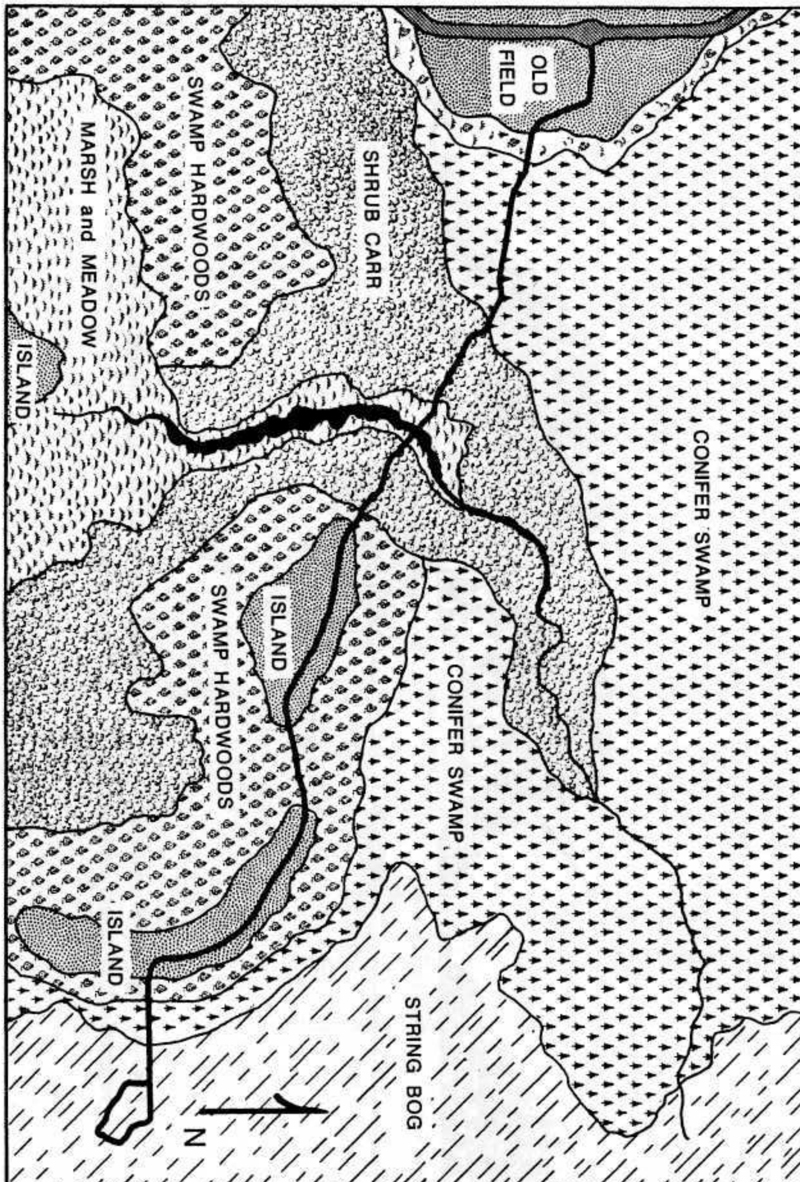

Fig. 7. The boardwalk and surrounding vegetation.

ZONE 1: THE SHRUBBY "MOAT"

Mounds and Moats

Before you descend the steps onto the boardwalk, you will notice that you pass over a slight mound with several conspicuous boulders protruding above the soil. This mound, ringing most of the undisturbed perimeter of the Bog, is an ice push ridge that stands as evidence of the thousands of years that this basin contained a lake. The repeated expansion and contraction of ice in the lake created a tremendous force, capable of heaving huge boulders. The Bog's ice push ridge is 3 to 4 feet higher than is typical for a lake with a surface elevation of the present peat surface, suggesting that the lake surface may have at one time been that much higher than the present bog water levels.

The narrow zone of vegetation between the edge of the Bog and the cedar-tamarack forest is dominated by shrubs (willows, Salix sp.; dogwood, Cornus stolonifera; poison sumac, Rhus vernix; and gooseberries, Ribes sp.) which fill the moat around much of the Bog's perimeter. A moat, often open water, is common around the perimeter of wetlands and probably results from fluctuations in water levels and winter frost action. In the Cedarburg Bog, water levels fluctuate by almost 1.5 feet over the course of the season and the peat surface rises and falls to some extent with the change in level. Why are moats so common around wetlands? Could the physical disturbance in the peat of the rooting zone prevent growth of the bog conifers? Could the shallow peat and close proximity of glacial material inhibit their growth?

Wildlife Ponds

The pond on your left is one of a series of small ponds that were blasted in the peat in early November 1965. These ponds are used for research and function as wildlife habitat. The extreme chemical and biotic enrichment that occurs in the very thin surface microlayer of freshwater bodies has been studied intensively in these ponds. The Northern Waterthrush, (Seiurus noveboracensis), a secretive bird at its southern limit in the Bog, can often be heard singing in the shrubs around the pond and usually nests in the nearby conifer swamp among the tangled root systems of upturned trees.

A luxurious growth of stonewort (Chara sp.) is found in most of the ponds. Stonewort is a rather complex green alga that forms multicellular reproductive organs. This fact led some to believe that it is related to the ancestors of the first land plants. Stonewort only grows in calcareous water and precipitates limestone during cell wall formation, hence its gritty texture and name. Stonewort is extremely important in the deposition of marl at the bottom of ponds and lakes. Here it serves as an indicator of the calcareous groundwater entering the Bog through the bottom of the ponds. The blasts that formed these ponds probably disturbed the clay lining on the bottom of the Bog's basin and may have created a point of entry for groundwater.

Poison Sumac

Three species of willows abound in this zone along with poison sumac (Rhus vernix), the plant some people call "the guardian of Wisconsin bogs". Allergic reaction to poison sumac is often more severe than to poison ivy. Both contain a heavy oil called urushiol. Contrary to much folklore, it is impossible to contract dermatitis just by standing near the plants. Urushiol is a heavy oil that does not vaporize. Moreover, the oil is contained in resin canals inside leaves, stems, and roots; an undamaged plant has no urushiol on its surface. A case of sumac poisoning can be contracted easily, however, through contact with even just the bark, so it is imperative that anyone traveling through the Bog in winter learns to recognize poison sumac when leafless. Severely allergic people may even react to old wood from stems and roots preserved within the peat and it is possible for the oil to float on the surface of the water in the Bog! Take a good look at the large individual in the open sedge area between the boardwalk and the pond. It shows the typical open, sparsely-branched growth form of the shrub.

Invertebrates

During early to mid-summer look for the egg cases of a spider that is common in this part of the Bog. This spider, of the genus Clubiona, lays its eggs in a case neatly made from the leaves of the sedge, Carex aquatilus (Fig. 8). The spider folds the leaves twice at precise angles in order to form a small three-sided silk-lined case in which the eggs are protected from the elements. In doing this, the spider does not damage the conductive tissue of the leaf. The entire case is, therefore, made of living leaf tissue. The female spider remains on guard near the nest until the young have hatched (Jones, 1983).

The Spring Azure, Celastrina ladon, is a small blue butterfly commonly seen on the red-osier dogwood along the boardwalk. It developes on the buds and flowers of dogwood and the larvae are often attended by ants. The adults usually survive less than 5 days.

Even more common insects on the red-osier dogwood are scale insects which make the lower bark of many stems white because of their density. An interesting class activity might be to observe and record which stems and clumps of dogwood have scale and which don't. Some plants are densely covered, others completely free of scale insects. Do plants differ in their susceptibility or palatability? Does very local microenvironment affect the distribution of scale? Do the scale insects noticeably reduce the growth or vigor of the dogwood?

Fig. 8. Clubonia. egg case.

Various bees, wasps, long-horn beetles, butterflies and moths visit the swamp milkweed (Asclepias incarnata) flowers for nectar, but few insects feed on the plant tissues which contain toxic compounds. Those insects which do feed on milkweed are often conspicuously colored, like the caterpillar of the monarch butterfly (Danaus plexippus) or the bright red and black milkweed bugs (Lygaeus kalmii and Oncopeltus fasciatus). These insects themselves are poisonous or distasteful because of the plant compounds they eat and they advertise this fact to potential predators with their bright "warning coloration".

Other plants that are important nectar sources include joe-pye weed (Eupatorium maculatum), boneset (E. perfoliatum), and meadowsweet (Spinea alba). A few of the more conspicuous butterflies that can be seen along the boardwalk are:

Monarch (Danaus plexippus). Large, orange and black; can be recognized by smooth, gliding flight.

Question Mark (Polygonia interrogationis) & **Comma** (Polygonia comma) **Anglewings.** Medium-sized, with silvery (?) or (,) markings on the underside of the hindwings; feed at sap flows and rotted fruit.

Mourning Cloak (Nymphalis antiopa). Maroon brown with yellowish border and blue markings; overwinters as an adult and is well camouflaged when resting against dark tree bark.

Great Spangled Fritillary (Speyeria cybele). Large, bright orange, with metallic silver spots on the underside of the hindwings; a swift flier but often seen feeding at nectar sources.

Tiger Swallowtail (Papilio glaucus). Large, yellow butterfly with black stripes across the wings and black "tails" on the hindwings.

Red Admiral (Vanessa atalanta). Black above with a red bar across the forewings and mottled black, brown and blue beneath; a "feisty" butterfly often seen chasing others.

(From S. Borkin, pers. comm.)

ZONE 2: CEDAR – TAMARACK CONIFER SWAMP

Most of the northern third of the Bog and much of the periphery of the southern two-thirds supports a white cedar-tamarack swamp forest. Although this forest is classified as a northern lowland forest by Curtis, it has very little black spruce (Picea mariana), a typical dominant of wetter sites in the north. Curtis (1959) described two kinds of northern lowland forests: wet sites dominated by black spruce and tamarack (Larix laricina) and slightly dryer sites dominated by white cedar (Thuja occidentalis) and balsam fir (Abies balsamea). Most of the stands Curtis studied were in the northern part of Wisconsin where this plant community is widespread. Here, near the southern extent of northern lowland forests, we find a swamp forest dominated by tamarack and white cedar.

Balsam fir is absent from the Bog and only a few scattered black spruce are found. The Cedarburg Bog is, therefore, an interesting combination of the elements of the two types considered by Curtis.

One might expect shallow basin depth to correlate with the presence of cedar-tamarack forest because of its peripheral location, but that is not the case. Here the basin depth under the boardwalk is 10-15 feet, however, cedars and tamaracks grow over basin depths in the Cedarburg Bog from 1-45 feet!

Logging

Most of the cedar-tamarack forest of the Cedarburg Bog was logged for its valuable white cedar and tamarack lumber. The forest in this zone along the boardwalk was logged in the 1940's or early 50's, accounting for the relatively small size of the trees. Early logging in the Bog probably occurred between 1860 and 1890. The tamarack of Cedarburg Bog were, before logging, some of the tallest and straightest trees in southeast Wisconsin. Most of the old barns and several of the houses in this area are constructed with tamarack timbers from the Bog. Tamarack logs were so tall and straight that they were used by Port Washington fishermen to hold up their nets in Lake Michigan. Water pipes in many cities were also once made of tamarack logs which were cut lengthwise and hollowed out. When buried well below ground, tamarack is virtually indestructible, however, when old tamarack pipes are occasionally exhumed today in Milwaukee, they turn to powder very rapidly upon exposure to the air. The importance of paper birch (Betula lutea) in this conifer swamp today serves as additional evidence of a relatively recent logging episode. Over time, we expect paper birch to decline as the tamarack and cedar shade intensifies and prevents birch seedling establishment. White cedar thickets can create some of the most dense shade of any Wisconsin forest.

Dominants

White Cedar (Thuja occidentalis) received the name Arbor Vitae (tree of life) from French explorers who found that the Indians chewed its leaves during the winter to prevent scurvy. White cedar is a good example of a tree with a wide moisture tolerance. It grows in perpetually wet soils and also in well-drained uplands. The wet and dry forms of cedar are distinct genetic types (ecotypes) as evidenced by differences in the root structure of the seedlings of the two forms (Musselman, Lester and Adams, 1975). Careful study would undoubtedly reveal a whole range of morphological and physiological characters which distinguish the two types and suit them to their particular environments. The existence of over 120 cultivars of northern white cedar used in ornamental plantings reflects the extensive genetic variation in the species. Cedar reaches its greatest size on well-drained sites. Curtis mentioned the island in the marsh at the north end of Mud Lake where he found several white cedar stumps over 4 feet in diameter. Many of the large cedars on the island were knocked over in a windstorm in the 1960's and most of the others have since died or toppled.

Tamarack or larch (Larix laricina) also has a broad moisture tolerance and is able to grow in somewhat wetter sites than cedar. Tamarack (the only deciduous conifer in Wisconsin), under favorable conditions, may grow more rapidly than any other swamp conifer. The root system of tamarack is shallow. Seldom deeper than 1 foot from the peat surface, the widespread root system typically covers an area greater in diameter than the height of the tree. Tamarack has the ability to reproduce vegetatively by sprouts arising from these shallow roots. These roots can sometimes appear at a great distance from the parent tree.

Both tamarack and cedar produce heavy seed crops about every five years. Tamarack seeds which are held until winter, are at times heavily used as a winter food by various small birds such as chickadees. Many species of plants both in this and in other environments, retain most of their seeds until winter. Then seeds are dispersed all winter long, especially during dry periods. What are the advantages of seed release during cold, dry winter weather?

Seeds of both cedar and tamarack germinate well on rotted logs and stumps and can sometimes form remarkably straight lines of trees by this process. Cedar trees often continue to grow after they have been uprooted, and in this way, they may also form a straight row of even aged trees as the lateral branches grow into tree size and the horizontal log becomes covered with peat.

Other species of trees that are important along this section of boardwalk are black ash (Fraxinus nigra), paper birch (Betula papyrifera), and yellow birch (B. lutea). Black ash is the only hardwood species that is an important component of the northern lowland forest in Wisconsin. Black ash produces seeds that require a warm, moist after-ripening period after they are shed. This after-ripening must then be followed by another cold treatment before the seeds are able to germinate. In nature, therefore, most seeds do not germinate until the second spring after they are shed! What kinds of selective forces could lead to the evolution of such a delayed germination?

Black ash is the most flood tolerant tree species in the Cedarburg Bog. When flooding occurs, the soil in the rooting zone loses all its oxygen (becomes anaerobic) because oxygen diffusion is slow through the increased depth of water. Most trees can survive only a short period of flooding, however, black ash has the capacity to produce adventitious roots from the stems into the surficial oxygenated zone. Tamarack lacks this ability and has one of the lowest flooding tolerances of trees in the Bog. During periods of severe stress, black ash trees also seem to be able to "self-prune" or sacrifice much of the top of the tree and yet survive with the much reduced leaf area of the lower branches. Have you ever noticed how some species (e.g., staghorn sumac) drop branches in response to drought? How could "self-pruning" increase survival?

Both paper birch and yellow birch are also found in much more mesic (moderate moisture or dryer) sites than the Cedarburg Bog, especially farther north in Wisconsin. Paper birch, yellow birch and bog birch (Betula pumila) hybridize readily and form all possible combinations of hybrids between them. Paper birch x bog birch hybrids can be seen along the boardwalk in the next vegetation zone. The hybrids are intermediate in most respects between the parent species. Their leaves are too small and waxy for paper birch, yet too large and thin for typical bog birch. In stature and bark, they are also intermediate between the large, paper-barked paper birch and the almost shrubby, reddish gray-barked bog birch. It has been suggested that some of the wide environmental tolerance of yellow and paper birch may result, in part, from genetic introgression with hybrids between these species and the bog birch.

The Bog's Microclimate

Small scale climatic differences (microclimate) between the Bog and the surrounding uplands may help, in part, to explain the northern "flavor" of the Bog's vegetation. Continuous rainfall, temperature, and humidity records were collected for over 11 years at a weather station located in the cedar-tamarack forest and at another in the upland field next to the lab building. These records allow comparison of the microclimates in the Bog and adjacent uplands. To date, only two years of data have been analyzed in detail but some subtle differences are apparent (Smith, Kroeger and Reinartz, 1981). Bog temperatures are cooler than upland temperatures during the spring and early summer months (April-July) and in general, warmer than upland temperatures during the early fall. The temperature differences can be explained as the result of the large heat capacity of the water in the saturated Bog. The winter-cooled water causes the Bog to warm up more slowly in the spring and the summer-warmed water makes the Bog cool down more slowly in the fall.

Each spring Dr. Weise takes note of the date when the subsurface ice disappears from the conifer swamp. The last ice in the soil usually does not disappear until April, well after snow melt and the opening of the lakes and ponds. In some years, this frozen peat does not thaw completely until May. At the same time, the drainage of cold air into the Bog basin causes killing frosts later in the spring and earlier in the fall than in the surrounding uplands. The frost-free season in the Bog can be three weeks to a month shorter than that in the uplands.

Not surprisingly, precipitation and humidity in the Bog also differ from the uplands. Monthly precipitation totals averaged lower at the Bog station, undoubtedly a result of interception of some rainfall by the tree canopy and evaporation before it reaches the rain gage. As one might expect, relative humidity during the growing season is higher in the Bog than it is in the open upland field. How does a higher relative humidity affect the rate of plant water loss (transpiration)?

Hydrologic Studies

Near the Bog weather station, and at other locations along the boardwalk, visitors will notice pipes protruding from the peat. These are water level observation wells, or peizometers. By comparing water pressure at points in the peat, measured as the height to which water rises in the peizometers, the rate and direction of water flow within the peat can be estimated. Because of the importance of wetlands in recharge to and discharge from our groundwater supplies and because of the ability of wetlands to remove nutrients and sediments from, and hence purify surface waters, there is much scientific interest in the flow of water within wetlands. Despite this interest, very little is yet known about movement of water within and over the peat of wetlands. Is there much water movement deep in the peat, or only at or near the surface? Is the water in the peat essentially a stagnant pool, perhaps dating from the time of the glaciers? If there is movement, is it primarily vertical or horizontal movement? How do the various strata of peat and peat types compare in their relative ability to conduct water? These are some of the questions which are being examined in the Cedarburg Bog. The peizometers that you will notice in various locations along the boardwalk are part of this research effort.

<u>The Bog's Mammals</u>

Most of the mammals of the Bog are also found in other habitats at the Field Station and most are widespread in the state. The only two species found in the Bog that are probably not widespread are the river otter (<u>Lutra canadensis</u>) and the red-backed vole (mouse) (<u>Clethrionomys gapperi</u>). The otter is very uncommon in southeastern Wisconsin. An otter was sighted swimming in the stream at the boardwalk bridge in 1985. The vole is confined to tamarack bogs in southern Wisconsin and is common in the Bog's Cedar-Tamarack Swamp. It occupies more varied habitat in nothern Wisconsin. The vole, well named for its red back, can occasionally be seen during the day, as it seems to be more diurnal than many other mice.

Other mammals occuring in the Bog include three species of weasels: least (<u>Mustela rixosa</u>), short-tailed (<u>M. erminea</u>), and long-tailed (<u>M. frenata</u>). These form a size-graded series of small carnivores, the smaller two feeding on mice and the long-tailed on chipmunk-sized prey. All are brown in summer, becoming white (except for the black tip of the tail) in winter.

Two species of fox are found in the area. The gray fox (<u>Urocyon cinereoargentatus</u>) sometimes climbs trees and is more diurnal than the more common red fox (<u>Vulpes fulva</u>). Other common larger mammals include raccoons (<u>Procyon lotor</u>) and opossums (<u>Didelphis virginiana</u>). The white-tailed deer (<u>Odocoileus virginianus</u>) herd is large and causes some damage to the Bog vegetation. Muskrats (<u>Ondatra zibethicus</u>) are abundant in the Bog. See Part II of the guide for a listing of the mammals of the Field Station.

In the vicinity of the bird blind, you come to a narrow transition zone between the northern lowland forest and the next vegetation zone, the shrub carr. This transitional zone has a high plant species diversity because it combines the elements of both vegetation types.

ZONE 3: SHRUB CARR

Shrub Carrs

A carr is a wet ground plant community dominated by shrubs. Shrub cover in these communities typically ranges from 80% to over 100%. Curtis recognized two types of shrub carr in Wisconsin. In southern Wisconsin the shrub carr is most commonly dominated by red-osier dogwood (Cornus stolonifera) and the willows, Bebb's, pussy, and slender (Salix bebbiana, S. discolor and S. petiolaris). In northern Wisconsin the most common shrub carr is the alder thicket, often dominated by almost pure stands of speckled alder (Alnus rugosa).

Shrub carr is an intermediate successional stage. In the south, succession proceeds from sedge meadow to southern shrub carr to swamp hardwood forest. In the north, succession typically passes from sedge meadow to alder thicket and then to conifer swamp. Although these shrub communities are transitional, they may persist for long periods. Their duration can be lengthened greatly by disturbance, especially occasional moderate water level changes. Along the boardwalk you see a good example of a persistent shrub carr, in which you will notice several dead tamarack trees. In 1959-60, water levels were raised for about a year in the southern third of the Bog by a stop-log dam on the outlet stream. Tamarack is very sensitive to flooding since it lacks the ability, possessed by most of the shrub species, to produce new roots in the oxygenated zone. Those pioneer trees that had begun to invade the shrub carr were killed and the community was returned to an "earlier" successional stage.

Complexity

Along the boardwalk, shrub carr is found between the cedar-tamarack woods and the sedge meadow adjacent to the Bog stream. In this guidebook, this area is treated as one zone because tall shrubs control the environment (i.e., they are dominant) throughout. This shrub carr is, however, actually composed of two distinctly different vegetation types with different geographical and habitat affinities.* As you move out from the transition zone between the cedar-tamarack and the shrub carr, you encounter first a typical southern shrub carr community as described by Curtis (Fig. 9). This shrub carr is dominated by four species of willows (Bebb's, pussy, slender and autumn) and red-osier dogwood. Poison sumac is also important in the area close to the conifer forest. I will refer to this community as the willow-dogwood carr.

About midway through the shrub carr (about 250-150' from the stream) an at first subtle, but increasingly obvious, change begins to occur. The four willow

*Before I progress, a methodological note, or perhaps disclaimer, is in order. Most of the interpretation of this complex shrub carr zone has been from rather casual estimates of cover made at points along the 500' section of boardwalk from forest to stream. A rigorous quantitative analysis is still required and I hope that in future editions of this guide, this section and Fig. 9 may be substantially revised.

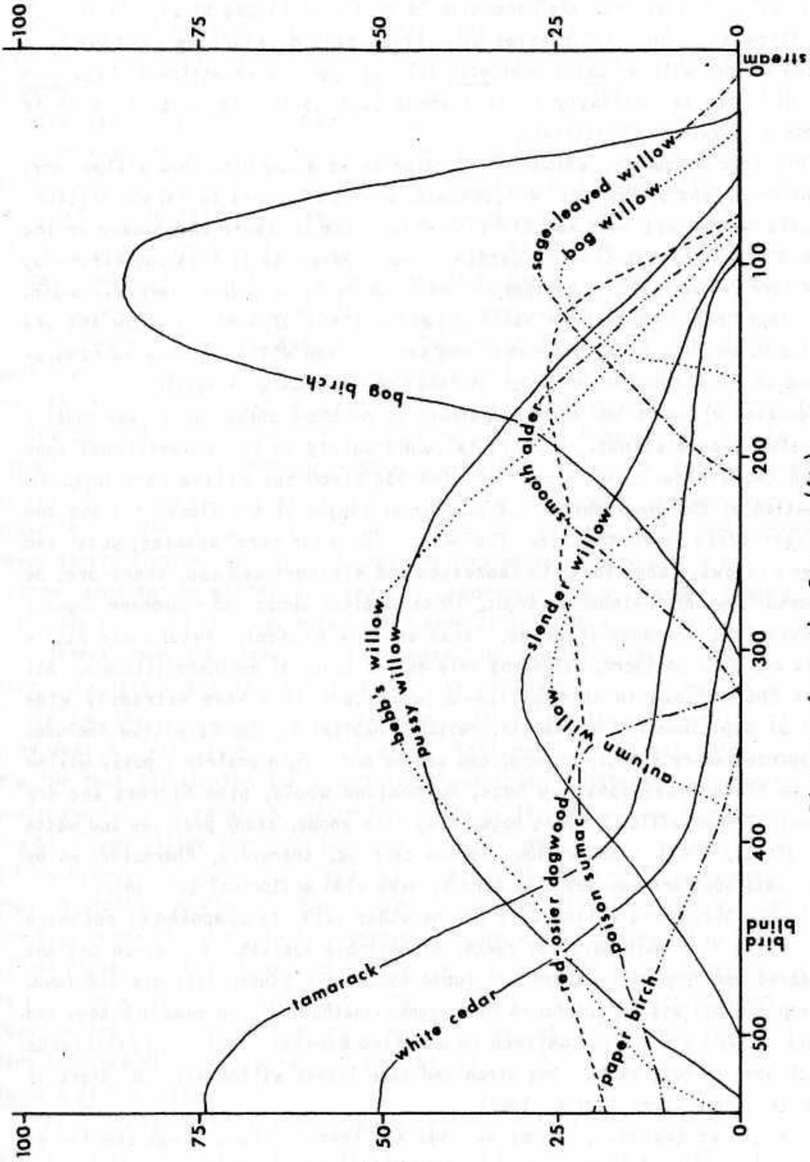

Fig. 9. Percent cover of woody vegetation along the boardwalk from the cedar-tamarack forest (left) to the Bog stream (right).

species which dominate the willow carr gradually become less important and speckled alder (Alnus rugosa) and bog birch (Betula pumila) take their place. Within 125' of the stream, the community is dominated by bog birch; all four of the "willow-dogwood carr" species of willows have disappeared and have been replaced by bog willow (Salix pedicellaris) and sage-leaved willow (S. candida) (Fig. 9). This is obviously still a shrub carr community, but one that is completely different floristically!

This last community, which I will refer to as a bog birch-bog willow carr, was not described by Curtis. Nonetheless, here it appears to form a distinct vegetation type that does not fit into either the southern shrub carr or the northern alder thicket classification. How widespread is this bog birch-bog willow carr community? In a study of the shrub carrs of southeastern Wisconsin, White (1965) found that large basal diameter stems of Bebb's willow and the presence of bog birch, poison sumac and sage-leaved willow indicated nondisturbance of the shrub community for at least the preceding 35 years.

Speckled alder is the normal dominant of northern shrub carrs, and usually forms almost pure stands. Here it is found mainly in the transitional zone between the willow-dogwood carr and the bog birch-bog willow carr (Fig. 9). Examination of the geographical and ecological ranges of the flora of these two shrub carr types is worthwhile. The "willow-dogwood carr" species, pussy and slender willows, range south to Tennessee and Missouri and can, therefore, be considered "southern" elements (Argus, 1964). Poison sumac and red-osier dogwood grow even farther south (Florida, Texas and New Mexico). Autumn and Bebb's willows are more northern, extending only as far south as northern Illinois. All four of the willows in this willow-dogwood carr also have extremely wide ecological amplitudes. For example, suitable habitat for Bebb's willow includes black spruce-tamarack bogs, swamps, oak scrubs and virgin prairies; pussy willow grows in leatherleaf-sphagnum bogs, bottomland woods, pine barrens and dry prairies; slender willow in peat bogs, damp rich woods, sandy prairies and waste places (Argus, 1964). Our willow-dogwood carr is, therefore, characterized by more or less southern species that tend to have wide ecological tolerances.

The bog birch-bog willow carr on the other hand, is composed of northern species which have much narrower ranges of suitable habitat. Bog birch and the sage-leaved and bog willows are not found south of northern Illinois and Iowa. Bog birch and bog willow are found in sphagnum-leatherleaf and tamarack bogs and the sage-leaved willow is confined to alkaline habitats including calcareous tamarack bogs (Argus, 1964). Bog birch and sage-leaved willow are indicators of undisturbed shrub carrs (White, 1965).

As might be expected, the herbaceous and less dominant shrub species of these two distinct carr communities also differ. Lists of the most important species in each community (Part II) show that only about 40% are shared, despite the fact that the communities are adjacent and both are dominated by tall shrubs. Curtis recognized 34 native Wisconsin plant communities and listed the community in which each species was "modal" (i.e., in which community a species was found to achieve maximum presence). The herbaceous stratum of our willow carr has more species modal in shrub carr and northern wet forests while the bog birch-bog willow carr has more species modal in emergent aquatic, alder thicket and fen plant communities. Is it generally true that the composition of the dominant species determines the rest of the community?

Since our shrub carr extends from the sedge mat adjacent to the open water of the stream to the conifer swamp, it is tempting to interpret this zone as a successional series: open water-->sedge meadow-->bog birch-bog willow carr--> willow-dogwood carr-->conifer forest. However, if this shrub zone represents a successional series, it seems to be an unusually complex one; changing from sedge mat to an unusual shrub community with northern affinities then to a common southern shrub community and finally, to a northern conifer swamp community. What environmental factors cause this complexity? Basin depth varies from 20-35 feet in the shrub zone and does not appear to correlate with the transition from willow-dogwood carr to bog birch-bog willow carr. What other factors might be important? Does water chemistry change appreciably as one moves farther from the stream? Does the rate of subsurface water movement through the peat vary with distance from the stream? Are historical factors important in the development of these distinct shrub communities? The presence of very large Bebb's willows and poison sumac in the willow-dogwood carr argues against any recent large scale disturbance. Could the area have been grazed in the 1930's?

Several possible class activities have been suggested for use in the shrub carr: 1) Have students make a key to the willows (see Fig. 10). How many "types" can they recognize? What characters can be used to tell them apart? Can they design a dichotomous key using descriptions or drawings? 2) Prepare a diagram that illustrates the interactions and interrelations among some of the environmental factors which may influence the shift from willow-dogwood carr to bog birch-bog willow carr. 3) Equipped with tape measures, students can perform a line transect sample of the vegetation along the boardwalk and construct a diagram similar to Fig. 9. The vertical projection of the canopy coverage over the line formed by the tape is recorded for each woody species. For each individual plant encountered, the point at which the line first intercepts its canopy is recorded as is the point at which the line passes from under the canopy. The coverage for each species is calculated as the percent of the total length of the line transect which is covered by each species.

Animals of the Carr

Consideration of plant communities often leads to a curiosity about associated animal communities. Little is known about spatial variation in animal communities of the bog.

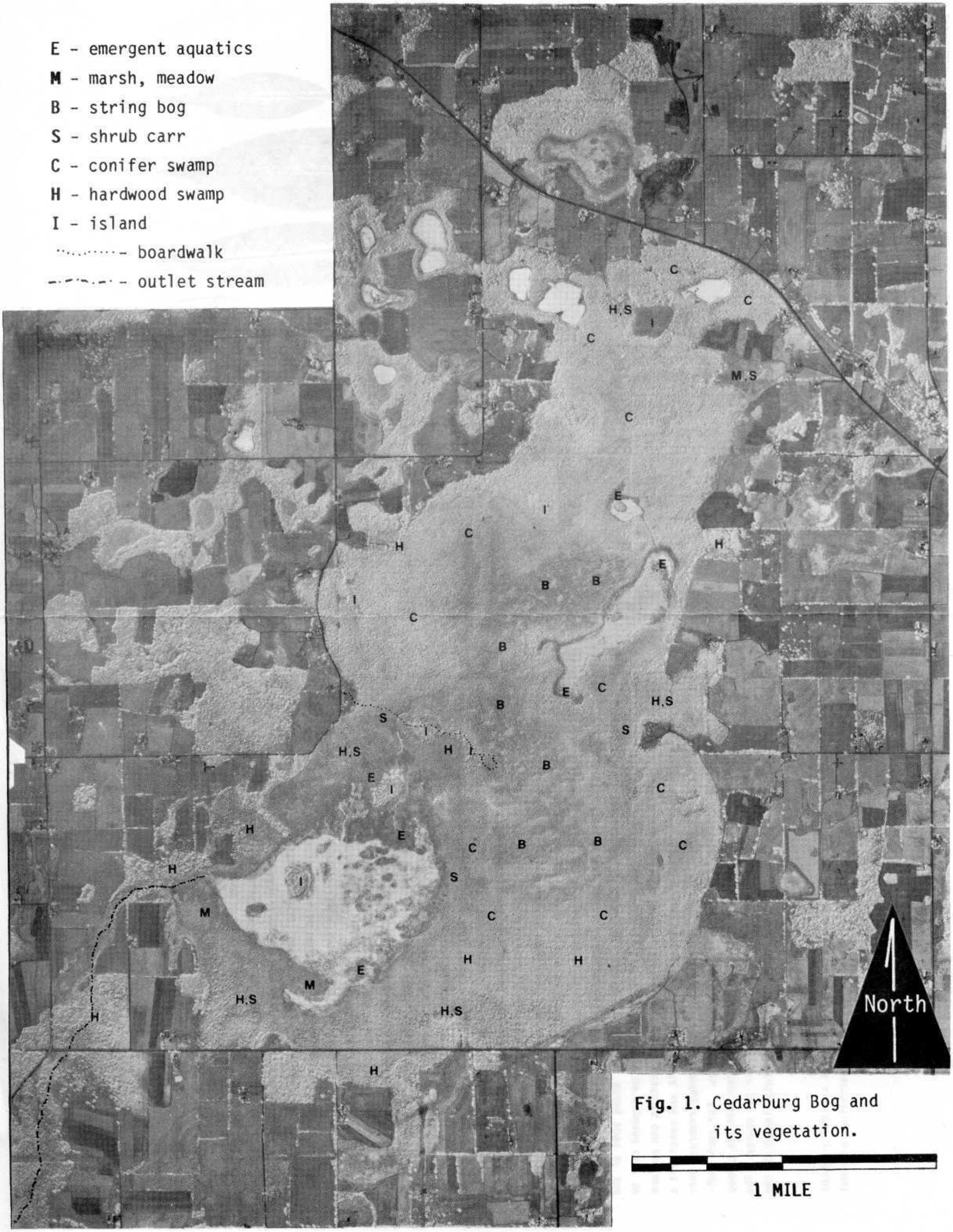

Fig. 1. Cedarburg Bog and its vegetation.

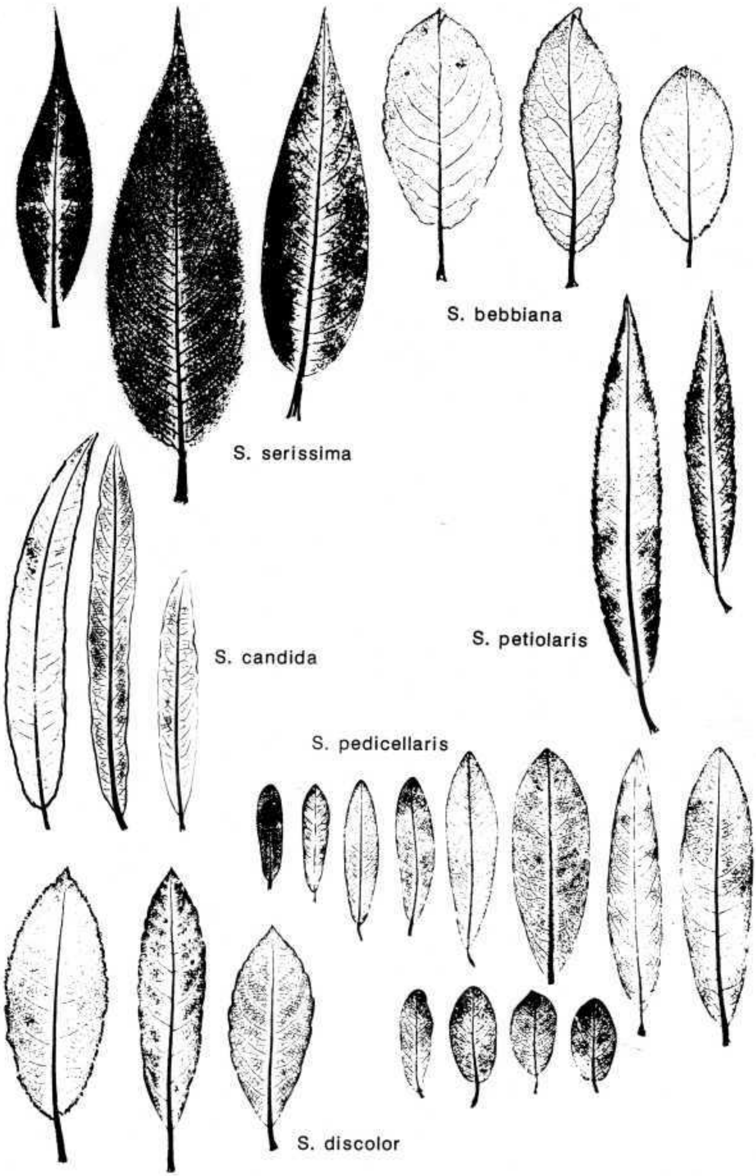

Fig. 10. Willows (Salix spp.) of the shrub carr.

Mound building ants are relatively common in this carr and in other shrub carrs of southeast Wisconsin. At least 11 species of ants are found in the Bog (Schultz, 1975):

Crematogaster lineolata	Camponotus noveboracensis
Leptothorax canadensis	Camponotus pennsylvanicus
Leptothorax ambiguus	Formica rubicunda
Myrmica emeryana	Formica fusca
Tapinoma sessile	Lasius alienus
Camponotus herculeanus	

Both species of Formica build the large mounds in the shrub carr. When I first encountered these mounds, I was surprised to find them in a wetland habitat and thought that surely they were built by a wetland "specialist". In fact, both of these species also build mounds in the upland fields and woods, a rather remarkable habitat range! White (1965) found mound building ants in 20 of the 76 Wisconsin shrub carrs that he studied and noted that the mounds were nearly always coverd by Muhly grass (Muhlenbergia racemosa and M. mexicana). Ant colonies thermoregulate by the manner in which they construct their nests and by movements between chambers in the mound. The adults and larvae enter a state of diapause to overwinter.

The bird blind, located in the transition from the cedar-tamarack to shrub carr zones, is one of six on the Field Station. These blinds are used to observe and to capture for banding, Black-capped Chickadees (Parus atricapillus) during the winter when flocks can be attracted to a feeder. The entire chickadee population in the Field Station/Bog area wears color-coded bands as part of a long-term (over 20 years!) program of research in the behavior and ecology of chickadees.

Two birds, one male and one female, share the current record for longevity in the Station flock; each lived to be 10 1/2 years old. Many chickadees live to be 3-5 years old, once they have survived their first 6 months during which mortality is high. Some of the work on Black-capped Chickadees at the Station has been summarized in the Field Station Bulletin (e.g. Ficken, 1982).

Chickadee winter flocks have an almost strictly linear dominance order which is expressed in their interactions at concentrated food sources such as feeders. Much of the behavioral research has involved describing behavioral, vocal and ecological differences among flock members differing in dominance rank. Among other things, this research has explored whether dominant and subdominant birds differ in the size of their vocal repertoires, in the frequency with which they use various aggressive postures and in their breeding success. Do dominant birds leave more offspring than their subordinates? Do the offspring of dominant birds also tend to become dominant in the flock? If so, how much of this difference is inherited versus learned?

Several species of the Bog's bird fauna nest in the shrub carr including the Swamp Sparrow, Song Sparrow, Red-winged Blackbird, Yellowthroat, Yellow Warbler, Willow Flycatcher, Gray Catbird, Northern Cardinal, Mourning Dove, etc. Most of these are wide-ranging species found in all kinds of shrubby wetlands.

ZONE 4: SEDGE MEADOW – EMERGENT AQUATICS BORDERING THE STREAM

A sedge meadow is a wet soil community where more than half of the cover is contributed by various species of sedge (Carex spp.). Floristically, sedge meadows are related to fens, bogs and wet prairies and to the ground cover of shrub carrs and wet forests among the closed canopy communities. The sedge meadow is an intermediate, successional community which becomes established after much organic material has been deposited by emergent aquatic plants, and which, in turn, may be invaded by shrubs and trees. Along the stream, you will notice that in wetter places, the sedge meadow grades into cat-tail and bulrush stands. The transition to shrub carr is likewise obvious. Succession of sedge meadow to shrub carr may be arrested by fire, mowing, or, as is probably the case in our sedge meadow, by natural water level fluctuations. Typically, sedge meadow communities are restricted to a narrow band along stream and lake banks, except where frequent fire or mowing maintain larger meadows.

In Wisconsin, sedge meadows north and south of the tension zone are much alike, sharing over 60% of their characteristic species (Curtis, 1959). Most sedge meadow species, however, attain their maximum prevalence in some other plant community. Sedge meadows, therefore, appear to be a composite community containing elements of many other communities. Our sedge meadow contains what are thought to be indicator species for both northern and southern meadows. Southern species include: marsh marigold, Caltha palustris; spring cress, Cardamine bulbosa; and northern bedstraw, Galium boreale. Red-stemmed aster, Aster puniceus; fringed brome grass, Bromus ciliatus; marsh bellflower, Campanula aparinoides; cut-leaved water hemlock, Cicuta bulbifera; bog goldenrod, Solidago uliginosa; and meadow sweet, Spiraea alba are all more common in northern sedge meadows. Many of the sedge meadow species are circumboreal (found around the world in northern latitudes). This gives our sedge meadow and others in Wisconsin a close floristic relationship with sedge meadows across North America and around the world.

Tussocks

Another name in common use for sedge meadows is "tussock meadow". This name refers to the characteristic humps, hummocks or tussocks formed by many sedges. Our sedge community is dominated by tussock forming sedges (especially Carex stricta) which produce two kinds of rhizomes, one for spread and the colonization of adjacent openings, the other for the production of culms (individual shoots) and the formation of tussocks. A rhizome (horizontal stem) grows in length, often more than a foot, and then its terminal bud sends up leaves and a new tussock is initiated. Continued growth and branching from the bases of the culms produce a dense tussock. The mass of dead leaves and roots that are added each year forms a fibrous peat favorable for further growth of the sedge. Tussocks may also permit the plant to tolerate widely fluctuating water levels. When water levels are high, the leaves are seldom submerged because of their position atop the tussock. When water levels are low, the sedge still has roots below the water table.

Sedge meadows form peat that differs greatly in its structure, texture and water conducting properties from the peat formed either by Sphagnum moss or by conifer swamp vegetation. In addition, when water levels are high enough to produce flow over the peat surface, this flow is greatly affected by the tussock structure of the sedge community. Thus, the complex patterning of present and past vegetation in the Bog, produces complicated patterns of surface and subsurface water flow. Since the nutrients necessary for plant growth are carried by water, vegetation in different parts of the Bog may experience a wide range of effective water chemistry. Differences in water flow and chemistry probably both influence and are influenced by the development of the Bog vegetation (Fig. 1).

ZONE 5: STREAM

The swamp stream collects water from the area west of Long Lake and flows into the cat-tail and bulrush marsh at the north end of Mud Lake (Fig. 1). Although the stream clearly drains the area around Long Lake and flows into Mud Lake, it doesn't actually connect with the open water of either lake. To the north, the stream emanates from a shrubby area at the south end of the large, open string bog southwest of Long Lake, and at its south end, near Mud Lake, it becomes diffused in dense stands of cat-tail and bulrush before reaching open water.

While the stream contains water year-round, visually perceptible flow only occurs in spring and after heavy rainstorms. At other times of the year, the water in the stream is merely an indication of the height of the "ground" water table in the peat. Even though the stream is nearly stagnant for most of the year, there are some places along it that freeze solidly only during the coldest winters and those having light snowfall. The ice in these areas is perpetually treacherous. Just out of sight to the north is one such area. Another large area of weak ice is found where the stream flows into the cat-tails and bulrushes at the north end of Mud Lake. The cause of these open areas is apparently upwelling from springs. Most springs in the Bog originate from the glacial till under the Bog basin; the springs at the north and west borders of the Bog clearly do. Water that comes from the glacial till is very calcareous and carries many mineral constituents which give it a different water chemistry from water that has been altered by the vegetation of the Bog. The springs associated with the swamp stream, however, have a water chemistry indistinguishable from Bog water. Perhaps these springs are upwellings of water from elsewhere within the Bog. Could there be channels deep within the peat which transport water under pressure from farther north in the Bog?

Animals of the Stream Area

From the bridge over the stream, the Bog's Sandhill Cranes (Grus canadensis) can often be heard calling from near Mud Lake. Each year one pair of cranes returns to nest in the marsh northeast of Mud Lake. Most years one of the pair's non-breeding young from the previous year also returns to the area. The cranes generally return in early March as the pussy willows emerge, and begin courtship which is one of their noisiest phases of the year. Occasionally two pair attempt to nest around Mud Lake. In those years, they have been observed to spend so much time arguing over territories, that neither pair was successful in raising young. A pair usually fledges two young, however, in an average year, only the stronger survives. Although they are a marsh-nesting bird, Sandhill Cranes do most of their feeding in the uplands and are especially fond of the grain, plants, insects and amphibians that they find in hay fields.

Other birds which nest in the marshes around Mud Lake and the stream include: Pied-billed Grebe (Podilymbus podiceps), Mallard (Anas platyrhynchos), American Coot (Fulica americana), American Bittern (Botaurus lentiginosus), Least Bittern (Ixobrychus exilis), Sora (Porzana carolina), Virginia Rail (Rallus limicola), Red-winged Blackbird (Agelaius phoeniceus), Marsh Wren (Cistothorus platensis) and Swamp Sparrow (Melospiza georgiana).

There have been recent sightings of river otter (Lutra canadensis) in the stream. Other mammals common in the stream area are muskrat (Ondatra zibethicus) (some houses can been seen from the bridge in the winter), raccoon (Procyon lotor), and mink (Mustela vison). The spring of 1986 is the first time we have record of beaver (Castor canadensis) in the Bog and beaver have been sighted from the bridge.

While winter kill prevents game fish from becoming established in the shallow Bog lakes, brook stickelbacks (Eucalia inconstans) and mud minnows (Umbra limi) burrow into the mud in winter and survive the low oxygen levels. Both can be found in the Bog stream. Crayfish and spiralled snails are also common in the stream. Green frogs (Rana clamitans) are abundant in the Bog and in the early to mid-summer of some years the stream teams with tadpoles. Their call, which sounds like the twang of a loose banjo string, can be heard day and night over most of the summer. Several species of frogs occur in the Bog. They are more often heard than seen, so familiarity with their calls is an important aid to locating them. We probably do not yet have a complete list of the amphibians and reptiles of the Bog area (see Part II), and would like to learn of any additions to the list. The only unusual reptile is the Blanding's Turtle (Emydoidea blandingi), a species with a dark carapace with small yellow flecks. A semiaquatic species, it once was more common in the Bog, and we have few recent sightings. Painted Turtles (Chrysemys picta) are commonly seen. In June we sometimes see Common Snapping Turtles (Chelydra serpentina) laying their eggs in the gravel on the edge of Blue Goose and St. Augustine Roads.

The only two common snakes of the Bog are also found in upland areas: the Eastern Milk Snake (Lampropeltis triangulum) and the Eastern Garter Snake (Thamnophis sirtalis). On summer days they sometimes may be seen sunning themselves on the road. They also occur in the Bog, but are rarely seen.

The various dragonflies and damselfies (Table 2) that are found along the stream offer a good opportunity to observe territorial behavior by insects. Perching, patrolling, signalling and ovipositing can all be readily seen and differences between species compared.

Table 2. List of Odonata species of the University of Wisconsin-Milwaukee Field Station. Prepared by Susan S. Borkin, 1986.

Anisoptera (dragonflies)

family Aeshnidae
- Aeshna canadensis
- Aeshna constricta
- Anax junius

family Corduliidae
- Epitheca spinigera
- Somatochlora walshii
- Cordulia shurtleffi
- Dorocordulia libera

amily Libellulidae
- Celithemis eponina
- Libellula julia
- Libellula luctuosa
- Libellula lydia
- Libellula pulchella
- Leucorrhinia intacta
- Sympetrum obtrusum
- Sympetrum rubicundulum
- Sympetrum semicinctum
- Sympetrum vicinum

Zygoptera (damselflies)

family Calopterygidae
- Calopteryx maculata

family Lestidae
- Lestes disjunctus
- Lestes dryas
- Lestes rectangularis

family Coenagrionidae
- Nehalennia irene
- Coenagrion resolutum
- Enallagma ebrium
- Enallagma hageni
- Enallagma vernale
- Ischnura verticalis

Water and Plants

The water in the stream maintains a nearly neutral pH (pH 7.0) for most of the year, except when acid precipitation accumulated during the winter enters the Bog during the spring snowmelt. At this time, the Bog becomes more acidic (pH 6.3-6.5) for 2 to 3 weeks before the natural buffering capacity of the Bog quickly returns the system to neutral. Despite what seems like a relative constancy of water chemistry, year-to-year changes in the vegetation in the stream can be very pronounced. Some years the open water of the stream is nearly obscured by a dense growth of coontail (Ceratophyllum demersum); other years the predominant aquatic plant is water millfoil (Miriophyllum sp.) and in yet other years, an insectivorous plant, bladderwort (Utricularia vulgaris) is most abundant. All three of these species are very similar in overall morphology, having finely dissected, whorled leaves born on a sparingly branched main axis. What factors could cause such a marked fluctuation of the dominant plant species within one, seemingly stable, stream? Is some long-term cycling a possibility? Why do the submerged aquatic plants all resemble one another so?

Overview

The open areas surrounding the stream, and the elevation of the bridge, provide an excellent vantage point to view two aspects of the Bog vegetation that we have already discussed. First, looking back to the west and northwest, you can readily see the changes in vegetation zones progressing from cat-tail to sedge meadow to bog birch-bog willow shrub carr to willow-dogwood shrub carr to the cedar-tamarack forest. Secondly, looking all along the stream, and especially southwest toward Mud Lake, you gain an impression of the tamarack mortality caused by the 1960 flooding. Sensitivity to water level manipulations renders wetlands exceedingly fragile with respect to such disturbance! One measure of the stability of an ecosystem is its ability to return to its original state after disturbance. Throughout the area of dead tamaracks, young tamaracks are recolonizing. This points out the importance of preserve size in the preservation of native ecosystems. Since only a small part of this large Bog was disturbed, seed is still available for colonization of the disturbed area. A small system could be permanently destroyed by the same scale of disturbance. How closely will these disturbed woods eventually approach their original condition? What environmental and biotic factors will affect the outcome of these post-flooding vegetation dynamics? (See discussion of swamp hardwoods in the Bog, Zone 7.)

As you move from the stream through the shrub carr to the east and toward the first island, you pass over an area where the basin is 30-40 feet deep. Just to the south the basin depth exceeds 50 feet, and yet this area is within 200 feet of the island, illustrating the sharp relief of the basin.

ZONE 6: WEST ISLAND

This island, which stood for thousands of years in a lake, holds some evidence that the lake may have had at least two different levels. Two distinct tiers, cut by wave and ice action, can be seen around the island's perimeter. The two tiers, differ by 5-6 feet in elevation. Lake levels could have been lowered by 5-6 feet as erosion or the natural removal of some major obstruction changed the elevation of the discharge point of the outlet stream. Could this 5-6 foot drop in water depth have been the time at which rooted aquatic plants began to flourish and peat began to form? This event may have dramatically accelerated the transition from lake to wetland (Fig. 4).

The beech-maple woods on the island were cut over around 1940. After cutting, the black cherries (Prunus serotina), normally an understory tree in Wisconsin, were able to bolt up and reach the canopy. Studies of ring widths of these cherries show that some of them had been suppressed in the understory for many years before cutting of the canopy brought a dramatic increase in growth rate. Some of the aspens (Populus tremuloides) which entered the woods after cutting still remain, but in an obvious state of decline. The clumped growth form of all the basswoods (Tillia americana) is the result of stump sprouting after the main stem was logged. Eventually we expect that American beech (Fagus grandifolia) and sugar maple (Acer saccharum) will once again dominate the woods because of their ability to become established in dense shade.

One species which will probably never be as prominent on this island as it once was is the Canada yew (Taxus canadensis). Canada yew, which once carpeted the forest floor, is highly desirable winter deer food and is now almost entirely confined to the deer exclosure which was built in 1965. Deer exclosures on the north island in Mud Lake once again have a dense growth of Canada yew. The south island in Mud Lake has some large dense patches of yew without exclosures; apparently deer are hesitant to cross the ice to that island. Before the 1940's the deer herd was very small in this part of the state and did not make a major impact on the vegetation. Now that the herd is managed at a much larger size, it has been estimated that in some winters 200-250 deer yard up in the Bog. When severe winters coincide with a large herd, deer can cause a great deal of damage to the vegetation. Outside the exclosures, only small yews which are completely covered by snow survive.

Insularity

It is intriguing to speculate about the insularity of this island. Separated by almost 1/2 mile from the more extensive stand of upland hardwood forest, it is surrounded by habitat which for most of its plants and perhaps for many insects is just as unsuitable for survival as is open water. If a species was extirpated from the island, how long would it take for it to recolonize from the "mainland"? In large measure this would depend on the innate dispersability of the species or movement of seed by animals. How isolated are the island populations genetically? How frequently do different species exchange genes (through pollen or seed exchange leading to the establishment of a reproductive individual) with plants on the mainland? Surely the different pollination mechanisms of species could result in drastically different levels of gene flow. Questions concerning insularity also apply to the Bog as a whole. For many of the Bog species, the nearest population outside of the Bog is many miles away. How genetically isolated are they? For how many of the species in the Bog has time and isolating distance been great enough and population size small enough for the Bog population to evolve into a distinctive genetic type? For many species, exchange of genes with other populations has surely been very rare for a long period of time.

ZONE 7: SWAMP HARDWOODS - CONIFERS (BETWEEN ISLANDS)

The area between the two bog islands is a composite community in which cedar and tamarack are mixed with swamp hardwood species and more tall shrub species than one would expect to find in a typical swamp hardwoods. This section, however, is clearly dominated by the swamp hardwood species, especially black ash (Fraxinus nigra). These woods, and the swamp to the north of the east Bog island, are the best examples we have of typical swamp hardwoods along the boardwalk.

Dietz (1950), Ware (1955) and Curtis (1959) have all studied swamp hardwoods in Wisconsin. None of these authors, however, have studied lowland hardwood forests adjacent to, or associated with, bogs or peatlands. Their work has been confined to river flood plains, or swamps which become much more mesic (drier) after the spring floods. Rich (1970), the only other author to study lowland hardwood forests in the Great Lakes region, found that the origin of the swamp hardwoods in the Lawrence Lake Bog in Michigan was related to disturbance during early land use. A swamp hardwoods community was not present in the presettlement vegetation of that bog.

Farley (1974) has constructed a similar history for the swamp hardwood forest found along Blue Goose Road just north of Mud Lake. Extensive swamp hardwood stands were probably not present in the Bog prior to 1920 when timber harvest and drainage attempts temporarily altered conditions in that part of the Bog. Swamp hardwood species (American elm, Ulmus americana; the ashes, Fraxinus spp.; and silver maple, Acer saccharinum) were probably always present in naturally disturbed and transitional areas around the margin of the Bog and along the outlet stream. These species spread after logging in the 1920's and analysis of tree ring data shows that the trees grew rapidly during the drought years of the 30's and 40's (Farley, 1974).

As a result of the 1959-60 flooding, the swamp hardwoods, in turn, declined from 1961 to 67. By 1970, almost all the swamp hardwood trees but the black ash were dead. It appears that the swamp hardwoods in the Cedarburg Bog is a disturbance community similar to that reported by Rich (1970). Are swamp hardwoods associated with peatlands and bogs invariably indicators of disturbance when they are found? How can we use historical records, tree ring measurements and peat structure to reconstruct the history of a stand?

The swamp hardwoods between the two islands contain both white cedars, which were here before the hardwoods, and some cedars and tamaracks that have invaded since the weakening of the hardwoods. Most of the swamp hardwood forest in the Cedarburg Bog is in the southern and southwestern one-quarter of the swamp (Fig. 1). Much of this area to the south is currently being invaded by tamarack.

Typical swamp hardwood communities along Wisconsin streams and rivers are generally dominated either by American elm (Ulmus americana) or silver maple (Acer saccharinum), often in combination with green ash (Fraxinus pennsylvanica). The swamp hardwoods that became established in the Bog after logging, were dominated by American elm, however, most of these have been lost to the Dutch elm disease. In fact, the disturbance resulting from the 1960 flooding in the southern part of the Bog is confounded with the loss of the major overstory species to Dutch elm disease. Some observers have argued that the elimination of a tree of such importance may have had as much or even a greater impact on this area than the flooding.

The complexity, level of disturbance, and apparent admixture of communities along this section of the boardwalk may, therefore, have several causative factors. The mixture of conifer and swamp hardwood may be a natural assemblage where the two more typical communities come together in the Bog, or more likely, it is a disturbance community. Some conifers may have survived the original disturbance and others may now be invading the area. The importance of shrubs in this section is almost surely a response to disturbance of the forest overstory, which is apparent from the number of trees that are dead or that show a severe die-off of their upper branches. All of the once dominant American elms have been lost from this area.

In addition, this zone between the islands is an important surface water flow zone during parts of the year. Periodically, surface water flows not only in the Bog stream, but over the surface of the peat. This most often occurs in the spring and fall of the year. Where surface flow occurs it forms complexly structured water tracks as it finds the path of least resistance downstream. As water flow is constricted between the islands, water accumulates in the peat on the north sides of the islands and produces an important surface flow zone between the islands. This flow has an important effect on water chemistry, peat structure and perhaps the level of disturbance in the community.

Given the history of disturbance and the possibility that either conifers or swamp hardwoods may achieve a dominant role in the future, it will be worthwhile to record subsequent changes in these woods. Since disease will prevent the post-cutting, post-drainage, pre-flooding dominant, American elm, from regaining dominance, it appears that the area could become a silver maple-black ash hardwood forest (Farley, 1974), a conifer swamp, or a mixed community. As of 1974, in the area studied by Farley, many black ash had survived the flooding and silver maple saplings seemed to be largely taking the place of elm. Since that time, tamaracks have also been successful at colonizing the area. It would be very difficult to predict the outcome at this time, but the process will surely produce an interesting show to watch.

ZONE 8: EAST ISLAND

This long, narrow island is shaped somewhat like an esker or glacial river deposit, but in an esker you would expect to find sorted till. Instead, this island has a bouldery composition which can be seen at a large tip-up on the north side of the island. The island is curved so that you begin walking almost due east and by the time you reach the island's east end, you are walking south. Along this island, ice push ridges and lake terraces are also apparent. The tall basswoods and black cherries on this island form a beacon visible for some distance in the lower and more open wetland vegetation to the east and south. This island used to be called Birch Island for the many large paper birches at the south end. Now most of these old birches are dead.

ZONE 9: EAST ISLAND TO THE STRING BOG

The wooded area between the east island and the string bog is a transitional community going from conifer-swamp hardwoods, dominated by three species of ash (Fraxinus spp.), to cedar-tamarack woods and then to string bog. In this zone, the boardwalk takes you along a cline (or gradient) in some factors which affect the growth rate of the trees. As you move out along this gradient, growth rate slows dramatically.

A series of cores have been obtained from a sample of the oldest tamaracks growing in three zones between the island and string bog. As you walk toward the string bog, the tamaracks become smaller, but at the same time much older, indicating very slow growth (Fig. 11). In the string bog, a 10-12 foot tall tamarack is about 200-250 years old and the rings are so narrow (Fig. 12) they must be counted with a microscope! Some factors (water chemistry? nutrients? oxygen? peat depth?) are causing a dramatic decline in growth rate of trees along this cline.

One factor which undoubtedly affects the growth rate of trees in the Bog is the amount of oxygen present in the saturated peat soils. Most species cannot develop roots without a ready supply of oxygen in the soil. Since below about 1 foot, the peat is completely anaerobic (lacking oxygen), the trees develop extensive, shallow root systems. A graphic demonstration of the shallow rooting depth

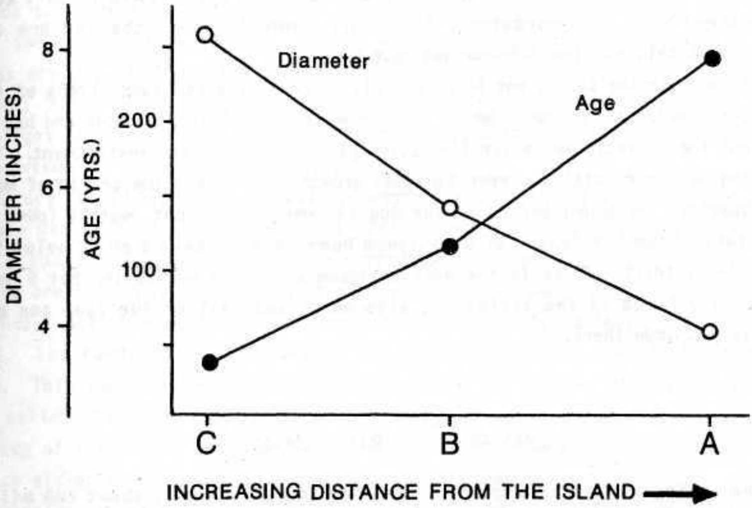

Fig. 11. Average diameter and age of the largest tamaracks sampled from: A, in the string bog; B, midway between the east island and the string bog; C, near the east island.

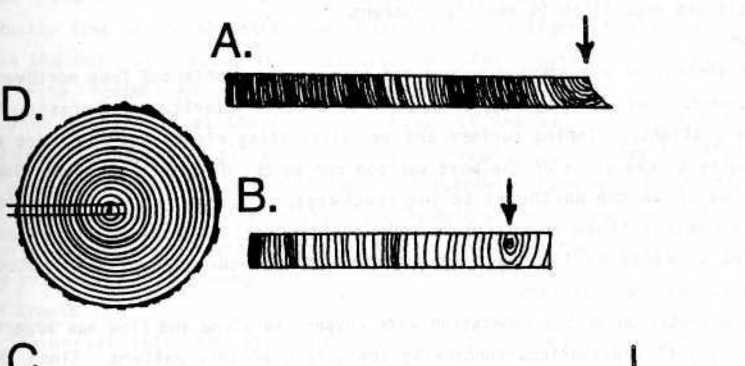

Fig. 12. Tree cores showing annual rings of tamaracks, sampled from: A, in the string bog; B, midway between the east island and the string bog; C, near the east island; D, idealized tree cross section showing placement of core. Arrows mark the center of the tree. Tree cores were traced and are actual size.

of the Bog's trees is provided by the large tip-up "discs" formed in this zone where trees have been uprooted. The plant communities of the Bog are all supported on this shallow intertwined root system.

As you near the string bog loop, you will encounter a few lush clumps of two different species of Sphagnum moss. Sphagnum is typical of acid bogs and has an efficient ion exchange mechanism for "acidifying" its immediate environment. The resulting acidic conditions favor Sphagnum growth but inhibit the growth of many other species. Although the pH of the Bog in general is about neutral (pH=7.0), water taken from the center of a Sphagnum hummock will have a pH of below 5.0 (much more acidic). There is not much Sphagnum along the boardwalk, but 5 or 6 species are found in the string bog area north and east of the loop and are relatively common there.

ZONE 10: STRING BOG

The string bog or "strangmoor" found in Cedarburg Bog is about 200 miles south of the nearest string bog, located near Seney in Upper Michigan. Most string bogs are restricted to the far north with only a few found as far south as Northern Minnesota and Upper Michigan. From the ground, the string bog pattern appears as open, wet, sedge areas alternating with narrow hedgerows of stunted, woody vegetation (cedars and tamaracks). From the air, the "stringy" texture of this patterned vegetation is readily apparent.

Formation

The strings of low stunted cedars and tamaracks are oriented from northwest to southeast. This string bog, like others in North America and Eurasia, is found on a slightly sloping surface and the alternating ridges and flats are at right angles to the slope of the peat surface and to the direction of water flow. Water flows from the northeast to the southwest, crossing the strings which resemble contour lines on the slope. On a fine vertical scale, the pattern resembles terraces having flat, open areas with all the change in elevation occuring in the woody strings.

The orientation of the vegetation with respect to slope and flow has suggested a variety of explanations concerning the origin of this pattern. Since the strings are always found at right angles to the slope and flow, attempts to explain their origin have been related to this slope. Furthermore, where the slope is gentle, it appears that the strings are farther apart and the flat (or flark) areas are large, while on steeper slopes, the strings are more prominent and closer together (Grittinger, 1984). Though no totally convincing explanation is yet available, four mechanisms have been suggested as contributing to string formation: 1) downslope sagging, 2) the flow of water and debris over frozen peat, 3) frost action, and 4) biotic effects (Grittinger, 1984).

Downslope sagging may occur on slopes great enough for the whole loose peat surface to slide slightly downhill. It has been hypothesized that as this happens, the peat surface buckles, leaving wavelike ridges and depressions; as the ridges dry out, they are colonized by species requiring slightly drier soils. However, Sjors (1961) has argued that the slopes present in string bogs are much too slight to produce this movement. Detailed studies of the peat profile have not provided any evidence of downslope movement.

Drury (1956) hypothesized that sheets of water flowing over a frozen peat surface can explain the formation of pattern in string bogs. A sheet of water from a sudden snow melt or downpour of rain flows over the frozen peat and riffles are formed leaving ridges of debris after the water level is lowered.

Frost action was one of the first explanations offered (Auer, 1920; Troll, 1944). Ice forms in the hollows in the autumn before it does in the higher areas. This squeezes the peat into ridges. Over the winter, the ridges freeze more solidly because they have a thinner cover of snow, which accentuates the vaulting of the ridges. In this way, frost action may help to exaggerate slight surface elevation differences initiated by other mechanisms.

Finally, vegetation almost certainly augments and emphasizes any microtopographic pattern which was initiated by one of these other mechanisms. Slight elevations in the peat present different conditions for germination and, therefore, may develop a different suite of plant colonizers than lower areas. Once different forms of vegetation are established in an area having a surficial "sheet" flow of water, they may accumulate organic debris at different rates. Eventually tree establishment becomes possible on the higher "string" areas, but not in the hollows. Woody vegetation accumulates organic residue at an even faster rate, further accentuating the ridge and hollow pattern.

When you arrive at the boardwalk loop, if you walk straight ahead (go clockwise around the loop), you pass first through an open flark (or flat) and then pass at an angle through a string. The boardwalk then runs the length of a large flark before you arrive at the elevated bridge. After you cross the bridge you will return to the main boardwalk line by traversing the length of the dense woody vegetation of a string.

Plant Growth

The unfavorable conditions for plant growth in the string bog have a profound effect on the structure of both individual plants and the vegetation as a whole. The slow growth rate in the string bog affects not only the trees but is also expressed in the other plant growth forms and is attributable to a combination of at least three environmental factors: 1) low oxygen concentration in the rooting zone, 2) low soil temperatures, and 3) low nutrient availability.

Temperatures in the peat soil of the bog are much lower than those in the surrounding uplands during most of the growing season. Because of the tremendous heat capacity of water, the Bog microclimate and soils warm up more slowly than the uplands in the spring. Perpetual waterlogging also results in low oxygen concentrations in the string bog peat. Oxygen never diffuses to a depth of more than 4-6 inches in the Bog. In the rest of the Bog the water level, relative to the rooting zone of the plants, rises and falls as does the Bog water level. The string bog, however, appears to be more or less floating on loose expandable organic debris so that the peat surface rises and falls with the water level. During the 1 1/2 foot fluctuation in Bog water level, the "apparent" water depth fluctuation relative to the string bog peat surface is less than 6 inches. During low water periods, the peat of the cedar-tamarack forest is not water-logged to the surface, allowing a tremendous infusion of oxygen, while the string bog is always saturated at or above the surface of the flarks. Oxygen never has a chance to diffuse below the surface.

Both the low temperatures and lack of oxygen result in poor conditions for the growth of most organisms. Not only is higher plant root growth slow, but bacterial growth, and hence, decomposition of organic matter is also slow under these conditions. Organic debris accumulates because it is not decomposed as fast as it is made. Since the plants sequester all the nutrients that are available while they are alive, and since only a small part of these nutrients are returned to the available pool when the plants die, nutrient availability to the growing plants is low. A tremendous pool of nutrients is locked inextricably into the accumulating peat.

Insectivorous Plants

What other evidence of the low nutrient conditions can we find? Perhaps the most striking is the prevalence of insectivorous plants in the string bog. Three genera and six species of plants found in the string bog supplement their nutrient intake by capturing and digesting insects for their nitrogen, phosphorous, potassium, calcium, iron, and micronutrient content. Pitcher plant (Sarracenia purpurea) is one of the dominant plants in the flarks. It captures insects in its leaves or "pitchers". The pitcher plant petiole (leaf stalk) has evolved to form a vase or pitcher which collects rainwater into which the plant secretes digestive enzymes. The leaf blade has become specially modified to have a fly-attracting, mottled purple coloration, a waxy surface, and hairs that are curved downward toward the base of the pitcher. Insects attracted to the pitcher find it easy only to move down over the hairs toward the slippery, waxy surface of the pitcher. Insects then lose their footing and fall into the pitcher and drown. The pitchers, while trapping and digesting some insects, provide a home for others, including the fly, Sarcophaga sarraceniae and the pitcher plant mosquito, Sycomyia smithii (Salamun, 1970) and a host of microorganisms. How do these specially adapted organisms avoid being digested? A worthwhile class activity is to use eyedroppers or aspirators to suck the liquid from some pitchers and examine their contents. If liquid is removed from a sample of different aged pitchers a succession of colonizers can be found.

The linear-leaved sundew (Drosera linearis) found in the flarks, and the round-leaved sundew (Drosera rotundifolia) found primarily in the strings, have on their tiny leaves, specialized hairs bearing sticky droplets at their tips. When a small insect has become entrapped in this glue, the leaves slowly curl around the insect to digest it. When only the exoskeleton remains, the unfurling of the leaf once again sets the trap. The bladderworts (Lemna minor,L.coronuta and L. vulgaris) are most conspicuous during the summer when their yellow snapdragon-like flowers are held on leafless stalks above the peat. The bladderworts produce underwater insect traps on finely dissected leaves or on small specialized branches. The traps are tiny bladders in which the plants are able to physiologically produce a negative water pressure. When small aquatic invetebrates swim past the bladder and activate a "trip" hair, the bladder lid pops open and a tiny mouthful of water is drawn in with the prey (Fig. 13). The animal is digested; eventually the bladders become packed with exoskeletons and debris and new bladders are produced. These nutrient meals are not absolutely required for the growth of most of these animal eaters. However, insect capture does seem to promote their growth, vigor and, as Darwin as one of the first to point out, their reproductive success.

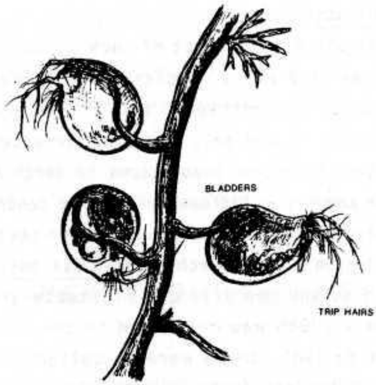

Fig. 13. Bladderwort (Lemna sp.) insect trap.

Water, Water Everywhere

Notice that many of the string bog plants have tough and waxy leaves. Many of them (e.g., leatherleaf (Chamaedaphne calyculata) and bog rosemary (Andromeda glaucophylla), etc.) have a small stomatal area and stomata (pores for gas exchange) that are located on the undersides of leaves having inrolled margins or hairs on the lower surface. These characters resemble the adaptations to avoid excessive water loss found in plants growing in arid regions. Yet these plants have roots submerged in water! What might explain this morphological incongruity? Because of low oxygen concentration, plant roots grow very slowly. Only actively growing roots can efficiently take up water. The plants you see here, growing with their roots submerged, are therefore actually in a physiological desert.

Some species (e.g., bog bean, Menyanthes trifoliata and some sedges, Carex spp.) have evolved physiological mechanisms for pumping oxygen from the leaves to the roots where it is required. Bog bean is thus able to send roots to much greater depth than any of the other plants with which it grows, thereby tapping an otherwise unexploited pool of resources.

Rare Plants

As one might expect of such an unusual habitat, the string bog is the home for some rare plant species. The linear-leaved sundew is found only in calcareous or minerotrophic fens. The Cedarburg Bog population numbering in the thousands, is the only known occurrence of this plant in Wisconsin and one of less than 20 extant populations in North America (Stromberg-Wilkins, 1984). Most of the known populations range from central Canada to the Northwest Territories. The string bog is also the home for several species of orchids, including the rare dragon's mouth orchid (Arethusa bulbosa). The blooming population of this orchid at any one site can fluctuate greatly in size from year-to-year. The dragon's mouth was collected in the Bog in the 1920's and 30's, but from the 1930's to 1981, there were no collections or substantiated sightings of this orchid from any southern Wisconsin county, including Ozaukee County and the Cedarburg Bog. In 1982, a few were found blooming in the string bog area, and from mid to late June 1983 there was a blooming population through a large part of the string bog, estimated to number at least in the hundreds.

One of the best vantage points to appreciate the uniqueness and aerial extent of this patterned wetland vegetation is from the elevated "bridge" roughly at the center of the loop. Looking at the repeated patterns to the east and north of the bridge, you will notice larger "islands" of somewhat taller cedar and tamarack trees. These "islands" are floating on 8-30 feet of loose peat and lake sediments, just as is the rest of the string bog. These teardrop-shaped "islands" have formed where the root mat of the dominant trees has become so thick and firm that it provides a much firmer base, elevated higher than the strings. Because of their slight elevation, the surface of these floating "islands" is not in intimate contact with the groundwater of the Bog. The predominance of rainwater moving through these "islands" and the presence of various species of Sphagnum moss produce much more acidic conditions on the "island" surfaces than are found elsewhere in the Bog. Some of the acid-loving bog species are able to thrive in these localized acidic conditions.

You have now completed your trip through the natural history of the largest and most diverse peatland in southern Wisconsin. I hope that you have gained an awareness of the tremendous diversity of communities encountered along this 3/4 mile-long boardwalk. In addition, many of you will have found in the Cedarburg Bog, one of the most unusual plant communities (i.e., the string bog) and some of the rarest plants (e.g., the linear-leaved sundew) that you will ever encounter.

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