THE PLANT LIFE OF ELLIS, GREAT, LITTLE, AND LONG LAKES IN NORTH CAROLINA.

By William H. Brown.

INTRODUCTION.

The study of the flora of Ellis, Great, Little, and Long lakes, North Carolina, was carried on from the United States Fisheries Laboratory at Beaufort, in that State, during the summer of 1908. The field work was done during the months of July and August, and the collections were worked over at the laboratory at Beaufort. My thanks are due to Mr. Henry D. Aller, director of the Fisheries Laboratory at Beaufort, for placing every possible convenience at my disposal, and to Mr. George A. Nicoll and Mr. William Dunn, of Newbern, North Carolina, for the use of their hunting camp, boats, and equipment while doing the field work. I am also indebted to Profs. D. S. Johnson and B. E. Livingston, of the Johns Hopkins University, for valuable suggestions and criticisms.

The four lakes form a compact group situated in the eastern coastal plain of North Carolina, about 10 miles north of Bogue Sound. The region around the lakes is very flat and has a gray, loamy soil. Owing to the flatness of the country the rain water does not run off rapidly but stands on the soil and makes a large part of it swampy. The only cultivated land near any of the lakes is a small patch near but not bordering on Lake Ellis. The rest of it is covered with either forest or low pocosin. The latter is a region kept almost clear of trees by forest fires and covered with an almost impassable growth of small bushes and briars.

The water supply of the lakes is obtained from the rain, either directly or through the neighboring swampy country. The depth of the water in the lakes depends on the amount of rainfall; but as the soil of the surrounding flat country is porous and covered with a dense growth, the water is held back, and there is a more or less constant supply.

The natural outlets can not be seen from the lakes themselves, but are swamps leading to a stream. Canals have been dug from Lake Ellis and Long Lake. All the lakes drain to the Neuse River, but

Great Lake also drains to Oak River. All four are close together, but the only two which are connected are Great and Ellis lakes. These are connected by a swamp through which water flows from Great Lake to Lake Ellis. The water in all the lakes is colored dark by organic matter. Great and Little lakes are about 8 feet deep, while Lake Ellis is generally less than 2 feet deep. The aquatic vegetation is scanty in all except Lake Ellis.

LAKE ELLIS.

PHYSICAL CHARACTERS.

Lake Ellis has the general shape of an ellipse and is about 3 miles long by nearly 2¼ wide.

The shore of the lake is covered with trees. The outer part of the water is overgrown with grasses and sedges, while the central part is largely filled with submerged vegetation.

At the time that the lake was examined the average depth of the greater part of it was about 22 inches, and it rarely exceeded 2 feet. Soon after this there were heavy rains for a week. When the lake was visited two days after the rains the water was 4 feet 6 inches deep. The next day it had fallen to 3 feet 4 inches. During the next week it fell only 2 inches more, but after this it fell somewhat more rapidly. Toward the edges of the lake the water gradually becomes shallower, and the bottom grades into the shore.

The only inlet to Lake Ellis is through a swamp which reaches from Great Lake to its western end. It receives, however, a large quantity of water from the surrounding country, which is very flat and in many places swampy. The quantity of water received from Great Lake and from the surrounding country is regulated largely by the amount of rainfall. I am told on reliable authority that there are times when no water runs from Lake Ellis, but these times must be very rare.

The lake is drained by two canals at the eastern end. The water flows into these through the part of the lake covered with grass. There is a considerable current in the canals, but very little in the open part of the lake. The canals empty into Bear Branch, this being tributary to Slocums Creek which, in turn, empties into Neuse River.

The water of the lake has a dark color from organic matter contributed by the plants of the surrounding swamps and of the lake itself.

For a long time there was a canal through the swamp between Lake Ellis and Great Lake, the same running through Lake Ellis and continuous with one of two issuing from the eastern end. The two latter completely drained the lake, and the water in them was utilized to turn a mill. About forty years ago the lake was planted in rice, but this is said not to have done well. Since that time the canals have filled up considerably, and the lake has been for some years about the same size as at present. From what has been said it will be seen that the growth in the lake is of recent origin.

In summer the temperature of the water rises from about 80° in the morning to anywhere between 90° and 105° about midday. The difference in temperature seems to be largely determined by the degree to which the sun is obscured by clouds.

The soil of the bottom was originally a coarse sand, but the inflow from Great Lake and the interior current have carried humus and small soil particles to certain places and have thus changed its character. The difference in the character of the soil seems to be the chief factor in determining the local character of the flora, as the different zones (to be described later) occur in the same depth of water and have the same amount of light and heat.

ZONES OF VEGETATION.[a]

The zones depending on the depth of the water, described by Magnin (1893) for the lakes of the Jura and by Pieters (1894) for Lake St. Clair, are not present in this lake, as the water is not as deep as the deeper parts of the phragmitetum or outer part of the littoral zone of Magnin. In Lake Ellis there are, however, three distinct growths, all in the same depth of water, but occuring on different kinds of soil. For convenience these will be called the central, intermediate, and marginal zones. The plants of the marginal zone are emergent forms, chiefly grasses and sedges, while most of the plants of the other two are submerged. Figure 56 represents in a diagrammatic way the distribution of these zones.

The vegetation of the central zone is chiefly composed of *Eriocaulon compressum* either by itself or with Myriophyllum or with *Eleocharis robbinsii*.

The intermediate zone is characterized by *Philotria minor*, Sphagnum, *Eleocharis interstincta*, *E. mutata*, *Panicum hemitomon*, *Nymphaea advena*, *Castalia odorata*, and Hydrocotyle.

The plants of the marginal zone, as has been said, are largely grasses and sedges. The chief species is *Sacciolepis striata*.

To understand the disposition of these zones it is necessary to examine the physical factors which have changed the character of the surface soil in some places from a coarse sand to a fine mud. The water coming through the swamp from Great Lake brings débris,

[a] The suggestions of the Commission of Phytogeographical Nomenclature of the Brussells Congress were not published at the time this paper was prepared. As no misunderstanding can result from the author's use of the term "zone," it is not thought advisable in his absence to disturb the form of the paper by substituting "girdle" as proposed by the commission.—EDITOR.

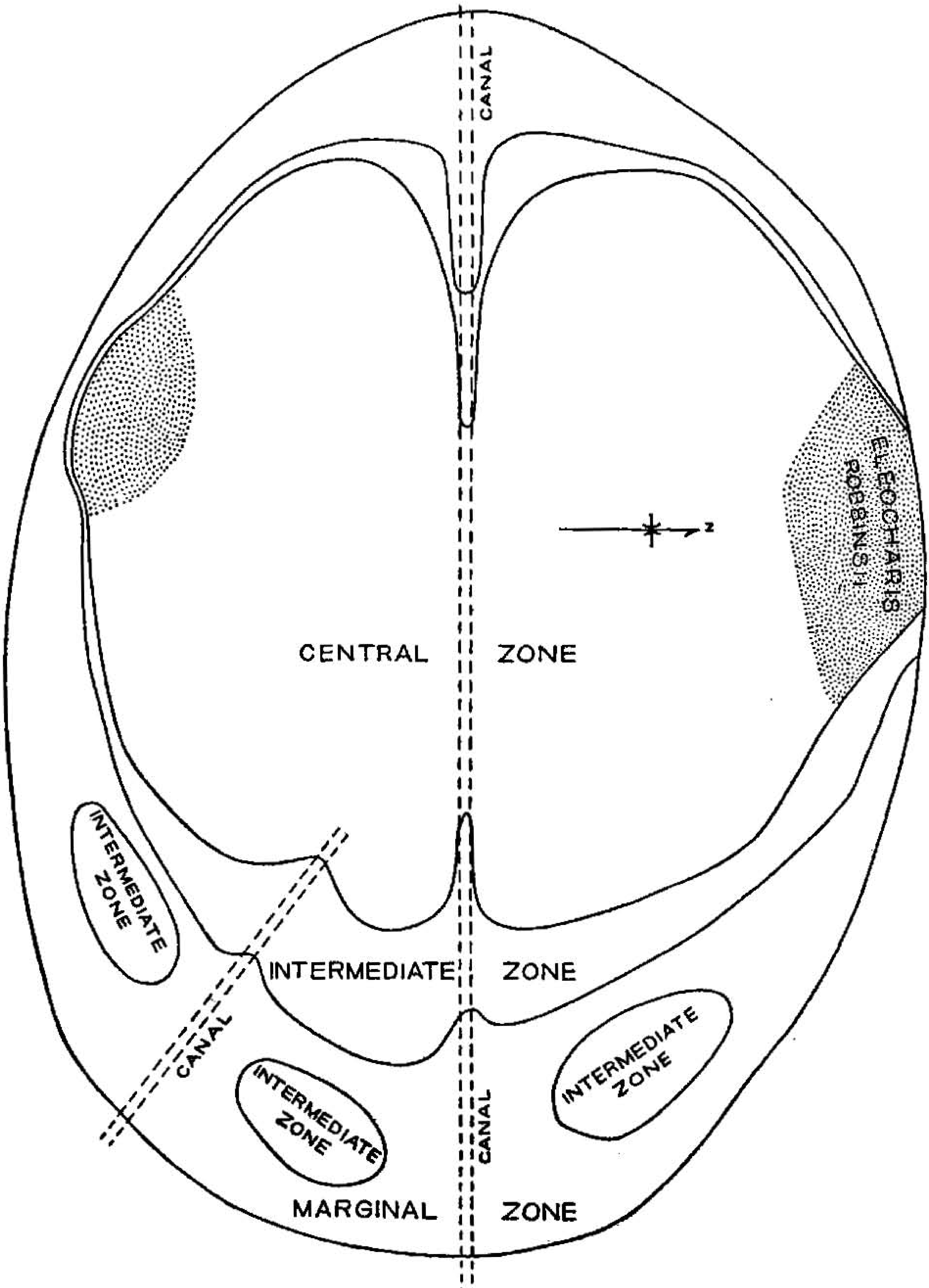

FIG. 56.—Diagram of Lake Ellis.

consisting of soil particles and vegetable matter, mainly the latter, some of which is deposited at the western end and has enriched that part of the lake. Most of the débris, however, comes from the lake itself and a large part of this is carried by the current to the eastern end. Some débris is washed in from the shore at the sides, or blown by the wind from the interior of the lake to the sides, but the character here has not been changed to nearly the same extent that it has at the ends. Where the débris has been deposited the surface soil has been changed to a soft mud. This change is more pronounced at the ends, especially the eastern. From the ends toward the center the change becomes gradually less pronounced, until in the second fifth of the distance from the western to the eastern the soil is left a coarse sand, which is packed by the waves. The canal across the lake has been filled up with humus.

The central zone is confined to the sandiest soil in the lake. The soil becomes muddier toward the outer part of this zone until it passes over into the intermediate zone. The soil here, in turn, gets muddier toward the outside until the intermediate gives way to the marginal zone. The marginal and intermediate zones extend around the central, but are widest at the ends and especially the eastern end.

MARGINAL ZONE.

The marginal zone is from 1,800 to 2,200 feet wide at the eastern end and about 1,300 feet wide at the western end. At the latter it extends into the lake along the line of the old canal as a narrow tongue for 1,450 feet, and at the former it extends farther along the canals than elsewhere. From the eastern end this zone decreases in width toward the sides until, in the second fifth of the distance from the western to the eastern end, it is about 500 feet wide on the southern side and disappears altogether for a short space on the northern side. Except at the narrowest parts, that is, in the second fifth of the distance from the western to the eastern end, this zone extends far out into the deepest water of the lake while it does not extend into the sand of the second fifth even when this is in shallow water. Between and on the sides of the canals at the eastern end where the soil is removed from the current there are rather sandy patches where the vegetation resembles that of the next zone. The principal growth on these patches is *Eleocharis mutata* and *Castalia odorata*.

The roots of the grasses and sedges of the marginal zone are mostly in the surface mud and large clumps can be readily pulled up. But it is not to be supposed that mud is necessary for the growth of all of these plants, as a large number of them are found on the land around the lakes. Here, however, the soil is a gray loam and much softer and better than the coarse packed sand of the lake.

INTERMEDIATE ZONE.

The intermediate zone borders on the inner side of the one just described and has the same general shape. At the eastern end of the lake this is 1,650 feet wide and is characterized by a dense growth of *Philotria minor*. Besides this, *Nymphaea advena*, *Pontederia cordata*, Hydrocotyle, and Sagittaria are found in great numbers, and patches of *Panicum hemitomon* and *Eleocharis interstincta* are scattered here and there. Toward the sides of the lake this zone becomes narrower and the soil is in general less muddy, resembling in this respect the inner part of the zone at the eastern end. About halfway up the lake the intermediate zone has narrowed in places to a width of only a few feet. *Panicum hemitomon* and *Eleocharis interstincta* are more prominent, while the growth of *Philotria minor* is much thinner. Most of the other plants disappear to a great extent. In the second fifth of the distance from the western to the eastern end of the lake the intermediate zone becomes irregular. It runs along the marginal zone and also appears as patches of *Panicum hemitomon* and *Eleocharis interstincta* intermingled with the *Eriocaulon compressum* and *Eleocharis robbinsii* of the wings of the central zone. A few scattered plants of Sagittaria are also found here.

At the western end of the lake the intermediate zone is much narrower than at the eastern end and the soil is in general less muddy. Here Sphagnum takes the place of the *Philotria minor* of the eastern end as the predominant plant in the vegetation. This zone extends around the tongue of grass of the marginal zone described above as following the canal. Here *Castalia odorata* is found in great numbers, and it extends out into the canal for some distance after the grass has disappeared. The other most prominent plant of this part of the intermediate zone is *Eleocharis interstincta*. Where this has fenced in small bodies of water, so that the débris from decaying plants has not been washed away, patches of *Castalia odorata* are found. As has been said, the soil is much less muddy at the western than at the eastern end, and this probably accounts for the different character of the vegetation found in the intermediate zone at the two ends.

The vegetation is in general more vigorous toward the outer or muddier edge of this zone than nearer the central zone. The water lilies in the canal grow in very muddy soil and extend far out into the lake. From these facts it seems probable that the soil toward the outer part of this zone does not become unfavorable, but that the plants of the intermediate zone are driven out by those of the marginal.

Since the soil of that part of the eastern end of the intermediate zone which is nearest the marginal zone is muddier than the soil of the intermediate zone at the sides and western end of the lake, it would seem that the plants of the marginal zone do not occupy the soil at the eastern end as fast as the soil would support them. There seem to be two reasons for this, the presence of competitors to be driven out and the method of invasion by the plants of the marginal zone. Single plants of the grasses and sedges of the marginal zone are rarely found in the intermediate zone, but the plants of the marginal zone seem to advance as a solid stand by means of their rootstocks.

CENTRAL ZONE.

The central zone is found on the sandiest soil. This is in the central part of the lake and occupies the greater part of it. Two wings also extend far toward the shore in the second fifth of the distance from the western to the eastern end. In this second fifth the soil is very sandy, and in the center, where the water is about 22 inches deep, there is almost nothing but a sparse growth of *Eriocaulon compressum*. Toward the sides where the water becomes shallower, 15 inches or less, there is a growth of *Eleocharis robbinsii*. This rarely extends into water over 15 inches deep and does not grow on soil which would support the plants of either the intermediate or marginal zones. This growth is included in the central zone because of its occurrence with *Eriocaulon compressum* on sandy soil as well as on account of the small size of the plant and its open growth. *Eleocharis robbinsii* extends in for 700 feet on the south side and 1,525 feet on the north side.

Proceeding in either direction from about the middle of the second fifth of the distance from the western to the eastern end, the growth of *Eriocaulon compressum* becomes more abundant and is soon associated with a thick growth of Myriophyllum. This extends to the intermediate zone. In that part of the canal which runs across the lake and is not filled with grass or any of the plants of the intermediate zone the Myriophyllum grows more luxuriantly than elsewhere, showing that the increase in débris is not detrimental to its success and indicating that when this gives way to the plants of the intermediate zone it is because it can not compete with the more vigorous vegetation found there.

COMPARISON OF ZONES.

The different zones are characterized by different plants, but at the edges of the zones there is often the usual intermingling.

The mass of the vegetation characteristic of the different zones is in proportion to the muddiness of the soil. *Eleocharis robbinsii* and *Eriocaulon compressum* of the central zone are both small plants and do not form dense patches, while Myriophyllum grows in a loose, fluffy mass with little bulk. The plants of the intermediate zone are much more robust than those of the central zone and form much denser masses, while the grasses and sedges of the marginal zone form a dense mass which extends high up above the water. The difference in the density of the stand of *Panicum hemitomon* and *Eleocharis interstincta* of the intermediate zone and the grasses and sedges of the marginal zone is very noticeable, the latter forming a much denser stand. It seems that the larger growth takes possession of the soil occupied by a smaller one after the soil has become capable of supporting the larger.

That the soil is the factor which determines the distribution is evident after a comparison of the zones. The depth of water, however, influences the distribution of some species in a zone. *Eleocharis robbinsii* of the central zone is rarely found in water over 15 inches deep; but if depth were the only factor we should expect to find the plants of the marginal zone where we find *Eriocaulon compressum* and *Eleocharis robbinsii*. Some of the sedges of the marginal zone are also affected by the depth, but the plants of the marginal zone are just as vigorous in the deepest water of the lake as elsewhere. It is evident, then, that the depth of the water does not determine the disposition of the zones, for where the soil is muddy the marginal zone is in the deepest water, while, where the soil is sandy, the central zone extends into the shallow water.

That light and heat are not important factors in this disposition is shown by the fact that the plants of all the zones are exposed to the direct sunlight, while the current is diffused and not strong enough to affect the heat to any appreciable extent.

That distance from the shore and protection from wind do not play any important part is shown by the projection of the tongue of the marginal zone out into the lake along the canal at the western end, and by the extension of the water lilies along the canal even farther, in separate patches—indeed nearly to the middle of the lake. The marginal zone is 2,200 feet wide at the eastern end, while at the sides it may disappear altogether. Another proof of this is afforded by the patches between the canals at the eastern end, where the soil is removed from the current and is sandy. Here a growth resembling that of the intermediate zone is completely surrounded by the marginal.

Summarizing, briefly, some of the more striking instances which seem to show that the character of the soil determines the zonation are: Between the canals at the eastern end where sandy patches are surrounded by muddy soil the intermediate zone is surrounded by the marginal. At the eastern end where the soil is muddy the marginal zone is 2,200 feet wide and extends far out into the deepest water of the lake, while at the sides where the soil is sandy it may disappear entirely and the central zone occur in the shallow water.

Where the canal has become filled with débris, the marginal and intermediate zones extend as a narrow tongue far out into the lake.

The migration of the plants from one zone into the ground occupied by the next seems to be going on rapidly, but, owing partly to a conflict with the plants present, the invaders probably do not occupy at once all the ground which is capable of supporting them.

The plants themselves are important factors in determining the deposition of débris and the consequent local change in the character of the soil. The plants of the marginal zone decay largely where they fall. The thick stand keeps débris from being washed into this zone and causes it to be deposited on the intermediate zone. The plants of the intermediate zone also catch a good deal of débris. Thus, as the marginal zone advances, new soil is prepared in the intermediate. The plants of the central zone by their decay and by catching débris also cause some change in that part of the lake, and especially near the intermediate zone; but the plants of the central zone, being submerged, must depend largely on that part of the débris which settles to the bottom.

It would seem probable that the marginal zone will finally extend over the whole lake. It also seems probable that by the decay of the plants in this zone the level of the ground will in time be raised sufficiently to support a growth of *Pinus serotina* and *Liquidambar styraciflua*. It is likely, however, that the grasses and sedges will occupy the whole of the lake a long time before the trees make any very great headway.

ISLANDS AND TREES.

In the water near the marginal or grass zone are a number of small places where the soil comes nearly or quite to the surface of the water. On these spots small trees of *Acer rubrum* are found, and around these is generally a growth of *Panicum hemitomon*, or sometimes *Sacciolepis striata*. A few small specimens of *Acer rubrum* are also found in the marginal zone. Where the canal banks near the edge of the lake are somewhat higher than the surrounding ground, there is found *Acer rubrum, Liquidambar styraciflua,* and *Pinus serotina*. A few small specimens of *Taxodium distichum* also occur in the lake. None of these trees are large enough or numerous enough to shade the lake to any appreciable extent except for a short distance along the northern canal at the eastern end. The trees in the lake do not seem to be under favorable conditions.

BANKS OF THE LAKE.

Small plants of *Pinus serotina* and *Liquidambar styraciflua* are invading the marginal zone where this grades into the shore. The shores of the lake are generally marshy and covered with *Pinus* *serotina* and *Liquidambar styraciflua.* Sphagnum often covers the ground. The undergrowth varies in different places. The most prominent constituents are small plants of *Pinus serotina* and *Liquidambar styraciflua, Ilex glabra, Drosera longifolia, Limodorum tuberosum, Rhexia mariana, Blephariglottis cristata, Magnolia virginiana, Lycopodium alopecuroides, Lycopodium adpressum, Persea pubescens, Arundinaria tecta, Viola* sp., Xyris, and some of the sedges of the lake. The trees are often festooned with *Dendropogon usneoides* or covered with lichens.

ALGAL FLORA.

The algal flora of Lake Ellis is rich in number both of species and of individuals. The great mass of plants growing in the lake gives a large surface for attached forms. All of the submerged plants and the stems and the under surface of the floating leaves are covered with these. The filamentous forms growing on these surfaces and the submerged plants themselves form habitats for diatoms and desmids, which occur in great numbers.

The green algæ are present in great abundance, but do not at this season form dense masses and do not seem to be in a vigorous condition. The blue green algæ are even more abundant than the green algae and seem to be in better condition. This seems to agree with the conclusions of Fritsch (1907) that the blue greens are better able to endure a high temperature than the green algæ.

The conditions for algal growth are fairly uniform over the whole lake, and the distribution of the species is fairly general.

Besides the algæ, there are large numbers of bacteria, especially at the surface.

The following is a list of the principal algæ found in Lake Ellis:

Anabaena flosaquae (Bg.) Kg.
Batrachospermum monibiforme Roth.
Bulbochaete sp.
Chantransia sp.
Hapalosiphon brebissonii Bg.
Lyngbia sp.
Merismopedia glauca Bg.
Oedogonium sp.
Spirogyra insignis (Hass.) Kg.
Spirogyra sp.
Ulothrix sp.
Zygnema purpureum Wolle.
Zygnema sp.

GREAT LAKE.

PHYSICAL CHARACTERS.

Great Lake lies to the west of Lake Ellis. It is kidney-shaped, and about 4½ miles long by 3⅓ wide in the widest part, with an area of about 3,000 acres. In the center of the lake the water is about 8 feet deep.

The lake has no inlet, but the water comes from the surrounding country, which is partly swampy. Owing to the flatness of this country, the porousness of the soil, and the dense growth with which it is covered, the rain water does not run off rapidly, but furnishes a more or less constant water supply to the lake. There are two outlets, both through swamps. One is at the eastern end and goes to Lake Ellis, while the other is at the northern side and goes to Hunters Creek, which flows into Oak River.

The water is coffee-colored from dissolved and suspended organic matter.

The temperature of the water rises from about 80° F. in the morning to anywhere between 90° and 102° at midday. The difference seems to be largely regulated by the brightness of the sun.

The soil, from the shore to a point where the water has a depth of about 5 feet, is composed of a coarse sand, while in the center of the lake it is a soft mud. This difference seems to be due to the fact that humus and fine soil particles are carried about by the waves until they settle in the deepest part and make that muddy, while the original coarse, sandy soil is left at the edges. There are small patches of peaty soil near the shore in the sandy part of the bottom. These are probably at places where *Taxodium distichum* has grown and then decayed, as these trees grow in this part of the lake and occupy spots of about the same size. The sand is packed hard by the waves and when struck resounds like rock. During storms, however, it is shifted about considerably, as is shown by the fact that a boat which was left anchored in a sheltered bay during four days of stormy weather was, at the end of that time, half full of sand.

The shore line has slight irregularities forming numerous miniature bays. The water is generally about 6 to 12 inches deep at the shore, but the slope of the bottom is quite gradual. The depth of the water at the shore seems to be caused largely by the waves washing up against the shore vegetation.

AQUATIC VEGETATION.

The aquatic vegetation of Great Lake is very scanty. As in Lake Ellis all of the plants would be included in the phragmitetum or outer part of the littoral zone of Magnin (1893). All of the species in Great Lake are found in the intermediate zone of Lake Ellis.

Taxodium distichum is found in the lake near the shore at the eastern end of Great Lake. The reasons for its absence at the western end will be apparent when the vegetation of the shore is discussed. Where the waves wash the bases of these and where stumps or knees come to the surface they are often covered with moss which is partly submerged. The only other vegetation, except algæ, found in the lake consisted of some patches of *Nymphaea advena*, a few patches of *Panicum hemitomon*, and one of *Xyris caroliniana*. These seem to get a start in the peaty places and probably lead a precarious existence owing to the shifting sand, which is likely to bury them or cause their roots to be exposed. The scarcity of aquatic vegetation is probably due to the packed and shifting sand where the water is shallow and, where it is deeper and the bottom muddy, to the dark color of the water which excludes the sunlight.

FLORA OF THE BANKS.

The vegetation on the edges of the lake presents quite a different aspect at the western and eastern ends. At the western end there is a low pocosin over which forest fires sweep at frequent intervals. The eastern half is protected by swamps from the fires and the ground is covered with a growth of large trees, consisting largely of *Taxodium distichum*, *Nyssa biflora*, *Quercus nigra*, *Ilex opaca*, and *Liquidambar styraciflua*. The undergrowth is quite dense and is characterized by *Morella cerifera*, *Leucothoe racemosa*, *Eupatorium maculatum*, *Cyrilla racemiflora*, *Pieris nitida*, *Ilex cassine*, *Arundinaria tecta*, *Magnolia virginiana*, *Clethra alnifolia*, and *Cornus alternifolia*. Wherever soil has been caught on the stumps or knees of the *Taxodium distichum* growing in the lake this soil supports a growth of some kind, generally *Eupatorium maculatum* or *Clethra alnifolia*. The trees are usually festooned with *Dendropogon usneoides* or sometimes Usnea. *Polypodium polypodioides*, lichens, mosses, and liverworts all grow on the trees in great abundance. Climbing over the trees and shrubs are a large number of vines. The chief species are *Vitis rotundifolia*, *Smilax laurifolia*, and *Apios apios*. Altogether this part of the shore supports quite a luxuriant vegetation, while all of the western half is covered with low pocosin, which consists of bushes a few feet high and briars.

Scattered through this growth are small pine trees, but the charred remains of those which have been killed by fire are about as numerous as the live ones. The physical conditions, except the humus content of the soil, seem to be the same here as at the eastern end, and it is probable that this part of the shore would be covered with trees but for the forest fires, which kill them and burn the humus out of the soil. These forest fires are frequent in this part of the country. The chief plants found in the low pocosin at the western end are *Persea pubescens*, *Pieris nitida*, *Hypericum* sp., and *Smilax laurifolia*.

ALGAL FLORA.

The algal flora of Great Lake is very scanty. Bacteria are present, however, in great abundance, especially floating at the surface, on the submerged parts of the mosses, and on the trees near the surface of the water.

The most abundant alga is Oedogonium which coats the stems and under surface of the leaves of *Nymphaea advena*. Algæ are also found to some extent on the stems of *Sacciolepis striata* and the submerged parts of the mosses and trees. The scanty growth on the mosses and trees is associated with the great abundance of bacteria. Aside from the Oedogonium on the leaves of *Nymphaea advena* the green algæ are much less abundant than the blue green algæ. The latter seem to be better able to stand the adverse conditions.

The growth of diatoms and desmids as well as other algæ is scanty. They are found to some extent in the mosses and in the mud at the bottom of the lake, but are very scarce at the surface. This scarcity is associated with the lack of supporting plants, the darkness of the water over the mud, and the presence of bacteria at the surface.

The following is a list of the principal algæ found in Great Lake:

Anabaena flosaquae (Bg.) Kg.
Bulbochaete sp.
Chantransia sp.
Hapalosiphon brebissonii Bg.
Lyngbia sp.
Oedogonium sp.
Scenedesmus caudatus Corda.
Sirosiphon sp.
Spirogyra sp.
Ulothrix sp.

LITTLE LAKE.

Little Lake lies to the north of Lake Ellis and is the smallest of the group. It is nearly round, with a diameter of a little over a mile and a half and an area of about 400 acres. The outlet is through a swamp which extends to Bear Branch, this flowing into Slocums Creek and this, in turn, into Neuse River.

The physical features of Little Lake are like those described as belonging to Great Lake. It has the same kind of bottom and shore and the same character and depth of water. In the center the bottom is muddy, while nearer the shore it is sandy. The water is dark-colored and in the center is about 8 feet deep.

The only vegetation found in the lake consisted of a small clump of *Xyris caroliniana* growing on an old log. The vegetation on the shore resembles very closely that of the shore of Great Lake except that there is here less low pocosin, and *Chamaecyparis thyoides* takes the place of *Taxodium distichum*, which is not found on the shore of Little Lake or in the lake itself.

LONG LAKE.

Long Lake lies to the northwest of Little Lake. It is a little over 3 miles long and nearly 2 wide in the widest part, with an area of about 1,286 acres.

This lake was visited but not thoroughly examined. The physical conditions and flora seemed to resemble very closely those of Little Lake.

THEORETICAL DISCUSSION.

ZONATION.

The relation of soils to aquatic vegetation has been very little studied. It is generally believed that the value of a soil depends largely on its ability to retain moisture. This, however, can hardly be true for submerged soil which is always saturated with water. Pieters (1901), in his work on Lake Erie, has shown that there is probably a relation between the soil and aquatic vegetation. He says that his soil samples were not numerous enough to make general deductions possible, but he indicates the direction in which they seem to point. To quote: "As a rule the soils on which plants occurred in abundance were composed largely of firm sand and contained relatively little silt, fine silt, and clay, while the soils on which few or no plants occurred, although the depth of water and other physical conditions were favorable, were composed largely of silt, fine silt, and clay, and were poor in fine sand and very fine sand." And again: "The water in sandy soils is undoubtedly better aerated than that in clay soils, though both are under water, because in the former case the water passes through the soil more rapidly than it does in the latter, and it would seem that even the roots of aquatics are unable to thrive in a soil so poor in oxygen as the saturated heavy clays." This explanation can not account for the zonation in Lake Ellis, for here we have no clay and the poorest soil is a coarse sand.

Pond (1903) as the result of experiments concluded that Philotria, Myriophyllum, and a number of other plants grew better when rooted in a good soil than when anchored over a soil or rooted in clean washed sand. The writer repeated these experiments with *Philotria canadensis* in the greenhouse of the Johns Hopkins University during the winter and spring of 1910. In these experiments, which will be described more fully in a later paper, as in those performed by Pond, the plants rooted in a good soil grew better than those anchored over the same soil. In the latter case, however, the soil soon became covered by a dense growth of algæ. When the same algæ were transferred to a jar with rooted plants the algæ failed to make any appreciable growth. This suggested that the slight growth of the anchored plants of Philotria was due to the use by the algæ of some substance which came from the soil and which, in the case of the rooted plants, could be used by them, since they were nearer the soil than the anchored ones. Further experiments seemed to show that this substance was CO_2, derived from the organic matter in the soil. Plants were grown under a number of different conditions but in no case did they make a normal growth unless some CO_2 other than that obtained by the water from the air was supplied them. When a soil which contained little or no organic matter, even though it were rich in mineral substances, was used the plants made no better growth when rooted than when floating free in the water. This was true both when CO_2 was and was not supplied artificially. These experiments seem to show that the CO_2 derived from the organic matter of the soil may be an important element in the growth of submerged plants and may be a factor in the distribution of the submerged plants of Lake Ellis. This is, however, probably not the only factor concerned, as this conclusion can hardly apply to the emergent forms and it is probable that the soil factors which determine the distribution of the emergent forms also affect the submerged ones.

Why the nature of the soil should determine the distribution of the emergent plants in Lake Ellis is not clear. When we remember that soils have the property of withdrawing salts from solution and that plants can concentrate salts from very dilute solutions it does not seem probable that anywhere in Lake Ellis there are not enough salts to support the plants of the marginal zone.

The physical nature of the soil, on the other hand, may be a very important factor in determining the zonation. Most of the plants of the two outer zones grow rapidly and have large and rapidly growing roots. The hard-packed condition of the sand would probably offer considerable resistance to the large rhizomes and roots, while the sharp edges of the coarse grains might possibly injure them as they were being pushed through the packed soil. The mud, however, would offer little resistance or injury to the large, soft, and rapidly growing roots and rhizomes.

PRODUCTION OF PHYTOPLANKTON.

Kofoid (1903) after making careful quantitative determinations of the plankton in a number of lakes concluded that "The amount of plankton produced by bodies of fresh water is, other things being equal, in some inverse ratio proportional to the amount of its gross aquatic vegetation of the submerged sort." He attributes the scarcity of plankton in lakes containing submerged vegetation to a number of causes, but chiefly to the removal from the water, by the larger aquatics, of a great part of the available food material.

Pond (1903), as mentioned above, found that a number of aquatics grew better when rooted in a good soil than when anchored over the same soil. From these and other experiments he concluded that these plants "are dependent upon their rooting in the soil for optimum growth," and that "the roots of these plants are organs of absorption as well as of attachment." He says further that these conclusions are probably applicable to all aquatic plants which grow rooted in a soil substratum.

In a discussion of Pond's experiments by Reighard and Pond (Pond, 1903), these authors conclude that, if Pond's observations are correct, submerged aquatics when rooted not only act as a mechanical support for algæ, but also play an important nutritive rôle by taking mineral food from the soil and organizing it into vegetable matter. "Upon the decay of the vegetable matter this food material is believed to pass into solution in the water. It should there nourish the plankton algæ." Reighard and Pond ascribe Kofoid's results to the fact that the vegetation with which he was dealing was largely Ceratophyllum, and therefore not rooted.

In the experiments mentioned above in which *Philotria canadensis* grew as well when floating free in the water as when rooted in the soil, root hairs were not developed by the floating plants. This suggests that Philotria draws a large part of its nutriment through its leaves and may therefore compete with the plankton algæ for mineral salts, as well as for CO_2.

We have already seen that plants of Philotria grow better when some CO_2, other than that obtained by the water from the air, is supplied them. The same thing is true of many algæ. A large number of these were tried in different solutions, both with and without the artificial addition of CO_2. In every case they made a much better growth when CO_2 was added to the solution, and in a number of cases in which they would not grow in a solution without the addition of CO_2 they made a vigorous growth when this was added. The need of an abundant supply of CO_2, which is shown by both Philotria and many algæ, would suggest that there may be a sharp competition for CO_2 between these forms, and that the growth of such plants as Philotria would be detrimental to the production of phytoplankton. In a large number of cases in which various algæ were grown in jars with and without Philotria, it was found that in every case, the algæ grew much better when there was no Philotria present. This was true in all of the solutions tried, both when the Philotria was and was not rooted. It is evident, therefore, that the presence of such a plant as Philotria is in some way harmful to phytoplankton, and since variations in the amount of CO_2 control the growth of the plankton algæ to a great extent it is not unlikely that the effect of Philotria on the algæ is due in large part to the use of CO_2 by Philotria. It is also probable that the amount of CO_2 present in a fresh-water lake will be a more important factor than the amount of mineral matter in determining the quantity of phytoplankton produced.

It has been shown that Great Lake with little submerged vegetation has a very scanty phytoplankton, while Lake Ellis, with a great quantity of submerged vegetation, had an abundant phytoplankton. These results appear at first to be contrary to the conclusions drawn from the experiments; but in Lake Ellis the shallow water, allowing the use of sunlight by the plants, is probably more favorable to both phanerogams and algæ than is the deeper water of Great Lake. The phanerogams, by giving mechanical support to the algæ, may also place these in a more advantageous position in relation to the sunlight and thus counterbalance to some extent the harmful effect due to their competition.

SUMMARY.

The whole of the bottom of Lake Ellis is covered with vegetation. There are three distinct zones or successions occurring in the same depth of water, but on different soils. The central zone, found on the sandiest soil, is characterized by *Eriocaulon compressum, Eleocharis robbinsii,* and Myriophyllum. The intermediate zone, on muddier soil, is characterized by *Philotria minor,* Sphagnum, *Eleocharis interstincta, Panicum hemitomon, Nymphaea advena,* and *Castalia odorata*. The marginal zone, found on the muddiest soil, is composed mostly of grasses and sedges, the chief component being *Sacciolepis striata.*

The disposition of the three zones seems to be determined by the character of the soil. The plants of the intermediate zone invade the territory of the central as it becomes muddier by the depositing of débris, while the plants of the marginal zone in turn invade the territory of the intermediate. As this invasion continues the grasses and sedges will occupy more and more of the lake and probably will finally drive out the plants of the other zones. The vegetation in the lake is of recent origin and the invasion seems to be going on rapidly. A few small plants of *Pinus serotina, Acer rubrum,* and *Liquidambar styraciflua* are found when the soil comes near the surface of the water.

Pinus serotina and *Liquidambar styraciflua* are invading the growth of grasses and sedges from the outer edge.

The emergent vegetation growing in Great Lake consists of *Taxodium distichum, Nymphaea advena, Panicum hemitomon,* and *Xyris caroliniana.* The aquatic vegetation is very scanty. In the shallow water this is probably due to the hard, shifting sand which forms the bottom, while in the deeper parts of the lake where the bottom is muddy, the dark color of the water probably excludes too much sunlight to allow the growth of plants.

The shore of the eastern half of the lake is covered with large trees under which there is a dense undergrowth. The shore of the western half is covered with low bushes and briers and a few small pine trees. The scarcity of trees here seems to be due to forest fires, which sweep over this part of the shore, whereas the other half is protected by swamps.

The algal flora of Lake Ellis is rich in both species and individuals. The green algæ are abundant but not in good condition in the summer season, while the blue green algæ are more abundant and more vigorous. The blue green seem to endure the high and changeable temperature better then the green algæ.

The algal flora of Great Lake is very scanty and this is associated with an absence of supporting plants, the darkness of the water, and the presence of great quantities of bacteria.

The phanerogams in Lake Ellis compete with the algæ for CO_2 and possibly also for mineral matter, and thus probably tend to decrease the amount of phytoplankton, although the mechanical support which they afford the algæ may counterbalance the effect of the competition to some extent.

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LIST OF PLANTS COLLECTED BY W. H. BROWN IN NORTH CAROLINA.

Of the following list the Juncaceae were determined by Mr. Frederick V. Coville, the Pteridophyta by Mr. William R. Maxon, and the remainder by Mr. Paul C. Standley. The numbers following the names are the collection numbers.

Osmunda regalis L. 33.
Anchistea virginica (L.) Presl. 105.
Lorinseria areolata (L.) Presl. 30.
Polypodium polypodioides (L.) Hitchc. 113.
Lycopodium adpressum (Chapm.) Lloyd & Underw. 14.
Lycopodium alopecuroides L. 41.
Chamaecyparis thyoides (L.) B. S. P. 115.
Pinus serotina Michx. 65, 103.
Taxodium distichum (L.) Rich. 10.
Typha latifolia L. 112.
Sagittaria teres S. Wats. 31.
Philotria minor (Engelm.) Small. 4.
Arundinaria tecta (Walt.) Muhl. 108.
Panicum hemitomon Schult. 42.
Panicum lucidum Ashe. 83.
Panicum scabriusculum Ell. 52.
Sacciolepis striata (L.) Nash. 43.
Carex macrokolea Steud. 17.
Cyperus haspan L. 34.
Dulichium arundinaceum (L.) Britton. 46.
Fuirena hispida Ell. 53.
Eleocharis interstincta (Vahl) Roem. & Schult. 18.
Eleocharis mutata (L.) Roem. & Schult. 74, 75.
Eleocharis prolifera Torr. 63.

Eleocharis quadrangulata (Michx.) Roem. & Schult. 76.
Eleocharis robbinsii Oakes. 26.
Eleocharis tuberculosa (Michx.) Roem. & Schult. 24.
Eriophorum virginicum L. 67.
Rynchospora axillaris (Lam.) Britton. 8, 61.
Rynchospora distans Nutt. 40.
Rynchospora inexpansa (Michx.) Vahl. 11.
Rynchospora macrostachya Torr. 13, 15, 62.
Rynchospora torreyana A. Gray. 39.
Scirpus americanus Vahl. 7.
Scirpus eriophorum Michx. 48.
Scirpus occidentalis (S. Wats.) Chase. 47.
Xyris caroliniana Walt. 1.
Xyris fimbriata Ell. 50.
Eriocaulon compressum Lam. 66.
Eriocaulon decangulare L. 49.
Pontederia cordata L. 70.
Dendropogon usneoides (L.) Raf. 110.
Juncus acuminatus Michx. 45.
Juncus aristulatus Michx. 68, 69.
Juncus canadensis J. Gay. 38.
Juncus effusus L. 9.
Smilax laurifolia L. 54.
Blephariglottis cristata (Michx.) Raf. 16.
Limodorum tuberosum L. 27.
Morella cerifera (L.) Small. 100.
Salix longipes Shuttlew. 20.
Quercus nigra L. 93.
Phoradendron flavescens (Pursh) Nutt. 114.
Persicaria hydropiperoides (Michx.) Small. 44.
Magnolia virginiana L. 78.
Nelumbo lutea (Willd.) Pers. 71, 73.
Castalia odorata (Dryand.) Woodr. & Wood. 6.
Nymphaea advena Ait. 72.
Drosera intermedia Hayne. 22.
Sarracenia purpurea L. 23.
Decumaria barbara L. 97.
Itea virginica L. 59.
Liquidambar styraciflua L. 21.
Rosa carolina L. 109.
Apios apios (L.) MacM. 89.
Polygala cymosa Walt. 3.
Cyrilla racemiflora L. 92.
Ilex glabra L. 55.
Ilex lucida (Ait.) Torr. & Gr. 82.
Ilex opaca Ait. 90.
Acer drummondii Hook. & Arn. 101.
Acer rubrum L. 12.
Vitis rotundifolia Michx. 94, 95.
Ascyrum hypericoides L. 91.
Hypericum maculatum Walt. 81.
Hypericum subpetiolatum Bickn.? 99.
Gordonia lasiantha (L.) Ellis. 56.
Persea borbonia (L.) Spreng. 51.
Persea pubescens (Pursh) Sarg. 2
Rhexia mariana L. 19.
Decodon verticillatus (L.) Ell. 64.
Myriophyllum pinnatum (Walt.) B. S. P. 5.
Nyssa biflora Walt. 57.
Hydrocotyle umbellata L. 28, 35.
Clethra alnifolia L. 77.
Azalea viscosa L. 87.
Chamaedaphne calyculata (L.) Moench. 371.
Leucothoe elongata Small. 102.
Pieris nitida (Bartr.) Benth. & Hook. 88.
Symplocos tinctoria (L.) L'Her. 86.
Utricularia purpurea Walt. 25.
Bignonia crucigera L. 79.
Lonicera japonica Thunb. 98.
Viburnum nudum L. 36.
Eupatorium hyssopifolium L. 107.
Eupatorium maculatum L. 96.
Pluchea foetida (L.) B. S. P. 58.