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THE VEGETATION OF THE BEACH AREA IN NORTHEASTERN ILLINOIS AND SOUTHEASTERN WISCONSIN

BY

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ERRATA AND ADDENDA

Page 54, lines 3 and 2 from bottom, and elsewhere in Article III, for *Cassia chamaechrista* read *Cassia chamaecrista*.
Page 62, between lines 4 and 5 from bottom of table insert *Erigeron annuus*.
Page 101, table, after *Croton glandulosus* read var. *septentrionalis;* and for *Equisetum laevigatum* read *Equisetum hyemale* var. *intermedium*.
Page 131, line 3, for *coerulea* read *caerulea*.
Page 138, last line, for *Ziza* read *Zizia*.
Page 141, line 21 from bottom, dele *Diodia teres*.
Page 169, between lines 3 and 4, insert as follows:
Erigeron annuus (L.) Pers. An interstitial in the bunch-grass association in the Hanover area.
Page 177, line 5, for *eastward* read *westward*.
Page 209, line 3 from bottom, for *copalina* read *copallina*.
Page 210, line 13 from bottom, for *Diospyrus* read *Diaspyros*.
Page 211, line 5, for *Foresteria* read *Forestiera*.
Page 256, line 3 of table, for Dr. H. *M*. Pepoon read H. *S*. Pepoon.
Page 278, line 16, the fifth word should be in Roman type.
Page 286, line 6 (second column), page 295, list of secondary species (second column), and page 353, line 8 from bottom, for *hiemalis* or *hiemale* read *hyemale*.
Page 313, line 4 from bottom (first column), for *pedicularis* read *pedicularia*.
Page 315, line 10, second column, for *Apocynum* read *Apocynum*.
Page 323, line 3 from bottom, for *Cyperus* read *Scirpus*.
Page 330, line 14, for *virginianum* read *virginicum*.
Page 336, lines 3 and 2 from bottom, for *virginicum* read *virginianum*.
Page 337, line 2 from bottom, for *philadelphicum* read *philadelphicus*.
Page 339, in first list of invading species, for *Rhus hirta* read *Rhus typhina*.
Page 351, line 4 from bottom, for *xerophtic* read *xerophytic*.
Page 355, above line 6 from bottom, insert *Scirpus heterochaetus* Chase.
Page 356, line 14 from bottom, for *Symlocarpus* read *Symplocarpus*.
Page 360, line 14, for *Pirus* read *Pyrus*.
Page 362, after line 7, insert *Acer saccharinum* L.
Page 363, line 2 from bottom, for *quadiflorum* read *quadriflorum*.
Page 365, line 14, for *thapus* read *thopsus*.
Page 369, last line, for *Tanecetum* read *Tanacetum*.
Page 417, line 1, dele *the*.
Page 497, line 9 from bottom, for *neglible* read *negligible*, and in foot-note, for *Austalt* read *Anstalt*.
Page 498, line 4 from bottom, for *Lockport* read *Chillicothe*.
Page 500, line 13 from bottom, after *up* insert *in*.
Page 501, line 2 from bottom, for *dissolving* read *dissolved*.
Page 504, line 23, for *gryina* read *gyrina;* line 17, for *dentata* read *knickerbockeri*.
Page 506, line 11, for *vernata* read *ternata*.
Page 507, line 3 from bottom, for *Mazon* read *wagon*.
Page 513, line 19, for *Nepa* read *Zaitha;* line 18, and page 517, line 13 from bottom, page 520, line 12 from bottom, and page 532, line 4, read *naid* or *naids* for *naiid* or *naiids*.
Page 517, line 6 from bottom, for *pondweed* read *pickerel-weed*.

Page 519, for first sentence of last paragraph read as follows:

We have no exactly comparable chemical data for July; but analyses for August give percentages of saturation for Morris and Marseilles as follows: 20.4 per cent. at Morris on the 11th and 11 per cent. at Marseilles on the 12th; 16.35 per cent. at Morris on the 22d and 23d and 7.4 per cent. at Marseilles on the 24th and 25th.

Page 521, line 6 from bottom, and page 529, line 9, for *chrysoleucas* read *crysoleucas.*

Page 525, line 22, and page 536, lines 21 and 24, for *Ekmann* read *Ekman.*

Page 532, line 1, for *Ancyclus* read *Ancylus.*

Page 551, line 7, for *00* read *512.*

Page 615, second line above foot-note, for *106* read 94.

Page 616, line 1, for the second *Bündeln* read *Bündel;* line 2, for *Bündeln* read *Bündels;* line 3, for *aussern* read *ausseren;* line 6, for *zwcierlie* read *zweierlei.*

Page 629, line 12, for *kein* read *keinen.*

Page 634, line 9, for *unternommen* read *unternommenen;* and in line 14 from bottom, after *575* insert *13 fig.*

Plate III, Fig. 1, after the word *mixed* in legend insert *consocies of the.*

Plate IX, Fig. 2, dele the legend and read instead: Root-system of *Tephrosia virginiana,* exposed by blowing of the sand.

Plate X, Fig. 2, dele the legend and read instead: A blowout almost stabilized by bunch-grasses, especially *Leptoloma cognatum.*

Plate XXXIX, for *Calamogrostis* read *Calamagrostis.*

Plate LIV, exchange places of cuts, but not the legends.

Plate LXXXV, for *7* read *7c.*

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LIST OF ILLUSTRATIONS

ARTICLE V.—*The Vegetation of the Beach Area in Northeastern Illinois and Southeastern Wisconsin.* BY FRANK CALEB GATES.*

INTRODUCTION

During the university year of 1909-1910 at the University of Illinois, the results of the two previous summers' work on the area between Waukegan, Illinois, and Kenosha, Wiconsin, were presented in a bachelor's thesis, entitled "The Plant Associations of the Recent and Fossil Beaches of Lake Michigan between Kenosha, Wisconsin, and Waukegan, Illinois." The first half of the present article is taken bodily from that thesis, with whatsoever additions and omissions seemed most advisable.

The original article was written under the immediate supervision of Dr. H. A. Gleason, now of the University of Michigan. To him I am under the greatest obligations for innumerable suggestions both in interpreting the data and in putting them in written form. To Dr. H. S. Pepoon, of the Lake View High School, Chicago, to Dr. C. C. Adams, of the University of Illinois, and to Prof. L. M. Umbach, of Northwestern College, Naperville, Illinois, I am indebted for suggestions and other helpful features. The data for plotting the climatic factors were obtained through the courtesy of the Chicago and Milwaukee offices of the United States Weather Bureau; and the data for the levels of Lake Michigan, from the City Engineer's office, in Chicago.

The nomenclature used, is that of the seventh edition of Gray's Manual, since that is the latest taxonomic work.

The region under consideration is located near the northern limit of the type of vegetation known as the Deciduous Forest Province† and not very far from the eastern limit of an arm of the Prairie Province.‡ At the same time it is near the southern limit of the Northeastern Conifer Province§ and has within its area associations that are relics of that province.

*Submitted with spelling in accordance with the rules and recommendations of the Simplified Spelling Board.

†Deciduous Dicotylous Forest. WARMING, 1909:329 et seq. Deciduous Forest Province. GLEASON, 1910:43.

‡Prairie Province. POUND and CLEMENTS, 1898. Grass-steppe (Prairie). WARMING, 1909:285-86. Prairie Province. GLEASON, 1910:43.

§Evergreen Coniferous Forest. WARMING, 1909:315. Northeastern Conifer Province. GLEASON, 1910:43.

The aim of the work was to obtain a clear idea of the extent and floristic composition of the associations of the region to serve as a foundation for further work upon the successional relationships between the competing associations of the three provinces which are represented in the area.

Although the region had been visited for collecting purposes during some of the four years previous to 1908, work upon a strictly ecological basis was pursued only during the seasons of 1908, 1909, and 1910. A summary of the trips taken is here presented in tabular form.

Date.	Plants Collected.	Persons Accompanying Author.
June 8, 1908	Nos. 2448-2526	
June 29, 1908	2743-2779	Mr. N. L. Partridge and Mr. J. Sanford.
July 1, 1908	2780-2827	Dr. H. M. Pepoon, Prof. L. M. Umbach, and Mr. N. L. Partridge.
July 10, 1908	2828-2864	Mr. Carl Durand.
July 27, 1908	2865-2875	Dr. H. A. Gleason.
Aug. 3, 1908	2876-2907	
Aug. 7, 1908	2908-2924	Mr. Carl Durand.
Aug. 14, 1908	2925-2946	
Aug. 21, 1908	2947-2975	
Aug. 28, 1908	2976-2993	
Oct. 31, 1908	2995-2997	
Dec. 25, 1908		Mr. N. L. Partridge.
Jan. 1, 1909		Mr. R. R. Sleeper.
June 16, 1909	3014-3040	
June 22, 1909	3041-3065	
July 12, 1909	3078-3126	
July 19, 1909	3127-3163	
July 28, 1909	3164-3182	
Aug. 17, 1909	3201-3207	Mr. N. L. Partridge.
Aug. 24, 1909	3208-3221	
Aug. 30, 1909	3223-3259	
Sept. 4, 1909	3260-3278	
Sept. 11, 1909	3279-3284	
Oct. 17, 1909	3285-3292	
Nov. 24, 1909		
Dec. 25, 1909		
Mar. 24, 1910		
Aug. 13, 1910		Mr. A. G. Vestal.
Sept. 9, 1910		

Three nearly complete sets of the plants of the region were collected. One of these has been deposited in the Herbarium of the University of Illinois, another is in the author's private collection, while the third is in the Field Museum of Natural History, at Chicago, Illinois.

Location and Physiography

Geographically, this area is located along Lake Michigan, extending from Waukegan, Lake County, Illinois, to Kenosha, Kenosha

County, Wisconsin, lying between 42° 21′ and 42° 35′ north latitude and between 87° 48′ and 87° 49′ west longitude. The western boundary of the region under consideration, is the Glenwood ridge, which was the upper limit of glacial Lake Chicago, a brief discussion of which will presently follow. The region is entirely covered by the Racine (Wisconsin) and the Waukegan (Illinois-Wisconsin) quadrangles of the United States Geological Survey. The latter is by far the more detailed sheet and covers the greater part of the area. Parts of these two sheets have been used directly in making up Plates XXXVII and XXXVIII. Differences in elevation are very slight. The highest elevation on the Beach region proper is but nine meters, while virtually all of the area, with the exception of a few of the ridges, is less than five meters above the level of Lake Michigan. The Glenwood ridge, which forms the western boundary, is about seventeen meters above the Lake Michigan level.

Geologically the region consists of a sand and gravel beach superimposed upon glacial clay. In but one place, so far as was discovered, is the clay exposed. The sand is arranged in long ridges not quite parallel to the present shore-line. Between the ridges are swales, only a few of which are able to drain directly into Lake Michigan. Drainage is largely accomplished by seepage of the water through the sand and finally into the lake. In the vicinity of Waukegan, as indicated on the map (Pl. XXXVII), are two bodies of water located at practically lake level. These drain into the lake only during periods of rather heavy rainfall and during the spring thaws.

Physiographical History

The western boundary (Glenwood ridge) of the region under consideration was formed by Lake Chicago, the body of water that occupied the southern end of the Lake Michigan basin during the retreat of the Late Wisconsin Glacier. This glacial lake had a southwestern outlet into the Illinois River. By erosion of the outlet the lake level was reduced to 16.8 meters (55 ft.) above the present Lake Michigan. The process known as "stopping" caused a rather sudden transition from the Glenwood level to the Calumet level, which was about 10.6 meters (35 ft.) above the present one. During this period the ice-sheet retreated into the north until a low pass to the northeast was uncovered, which caused a lowering of the lake below the present level. A re-advance of the ice-sheet raised the water to approximately the 7.6 meter level which is known as the Tolleston stage. At this time Lake Maumee, which occupied the upper Erie and lower Huron basins, emptied into Lake Chicago through the Grand River,

which flowed across the present state of Michigan. Withdrawal of the ice-sheet uncovered an opening in the Mohawk Valley through which was drained Lake Warren, formed by the coalescing of the lakes in the Huron, Erie, Ontario, and Saginaw basins. Contemporaneous with this new outlet was the abandonment of the Grand River outlet into Lake Chicago. As the ice withdrew further, the lakes in the Michigan and Huron basins coalesced through the Straits of Mackinac, and the dismemberment of Lake Warren followed. With the uncovering of the Superior basin the lakes of that region together with those of the Michigan and Huron basins formed Lake Algonquin, which at first had a discharge through Port Huron and, at times of high water, through the Chicago outlet also. It seems possible that there may have been, in addition, an outlet to Lake Iroquois through the Trent Valley in Ontario. The land in the northeast began to rise when relieved of the weight of the glacier, and both Chicago and Port Huron outlets were in use until the Port Huron outlet was lowered, when this received all the drainage.

The next step was the opening of a pass near North Bay, Ontario, which resulted in what are termed the Nipissing Great Lakes. These were at a low stage and discharged through the northeastern outlet. Warping of the land there, however, finally brought the water up to the Port Huron level, and when the land in the northeast continued to rise the Port Huron outlet was resumed. From that time to the present, such changes in level as have occurred, are due to the widening and deepening of the Port Huron channel and to the fluctuations incident to variations in rainfall. Detailed accounts of the history of the lakes since the glacial epoch can be found in nearly any work dealing with the geology or physiography of the Upper Lakes region. The three following have been consulted especially:

Goldthwait, J. W. The Abandoned Shore-Lines of Eastern Wisconsin. Wisconsin Geological and Natural History Survey, Bulletin 17:2-9. 1907.

Goldthwait, J. W. The Records of the Extinct Lakes. Illinois State Geological Survey, Bulletin 7:54-68. 1908.

Leverett, Frank. Outline of the History of the Great Lakes. Twelfth Report of the Michigan Academy of Science, pp. 19-42. 1910.

The Beach area itself consists merely of sand-bars which were formed during the Tolleston stage, at which time the water was cutting into the Calumet ridge. The sudden drop in level which ended the Tolleston stage left these sand-bars emerged. Formerly this ter-

race extended along the whole border of the lake, but with the elevation of the water during the Nipissing stages the greater part of the terrace was washed away except in the Chicago district and in the area north of Waukegan. This interpretation, which signifies that the ridges are of about equal age, is substantiated by observations upon the plant associations. Jennings, in his work on Presque Isle (1909: 294-305), under "historical development," says that the ridges were formed at different dates, and that a line of plant successions could be traced which confirmed the physiographic interpretation. In the Beach area, however, evidence goes to show that, with the exception of the fringing dune from Zion City down to Waukegan, the ridges were formed at one time. The fringing dune, as it now exists, is undoubtedly a product of historic times. Since the building of the piers to protect the harbor at Waukegan, considerable sand has accumulated north of it, and the formation of a new dunal ridge a little north of the pest-house is now (1910) beginning to show. North of Zion City, particularly between Winthrop Harbor and Kenosha, the shore-line is being washed away a noticeable distance every year. These ridges are all oblique to the present shore-line but they are parallel, or very nearly so, to the shore-line that existed at the time of their formation, namely, the Calumet ridge. The work of erosion, which bid fair to allow the lake access to the Glenwood ridge south, as well as north, of Kenosha, has been to a considerable degree, checked by piers at Kenosha and by breakwaters, behind which the lake is being artificially filled.

Climate

As there are no weather bureau stations in the region having records of long duration, the records of the stations at Milwaukee and Chicago, situated at equal distances north and south of the area, are used. It is fairly safe to assume that the records for this region in very similar sort of country may be obtained by interpolating those given. It is recognized that these data do not actually give the conditions under which the plants live, but only a general indication of the climate. The records are given in curves to facilitate interpretation (Pl. XL-XLII). As climatic factors do not usually have edaphic influence, they are of value only in determining the general character of the vegetation that will occupy a given area.

Edaphic Factors

Far more important than the climatic factors in determining the floristic composition within an area are the edaphic factors. Of

these, the most important in itself is probably water. This region is abundantly supplied with precipitation quite uniformly distributed throughout the year. In addition, it lies in the immediate proximity of the water-table level of Lake Michigan, which makes it to a large degree independent of precipitation. The sandy soil is quite favorable for furnishing the plants with water, which the particles of sand hold as capillary films. The physiological supply is probably about 95 per cent. of the physical supply.

What seems the second factor in importance is the food material in the soil. Sandy soil is notably deficient in soluble food material. The relatively rapid eremacausis* characteristic of sandy soils, caused by ready admission of atmospheric oxygen, accounts for the destruction of much of what would have been available plant food under other environmental conditions. Furthermore, soluble materials, and even insoluble ones, are gradually leached out of the soil as the rain percolates through it instead of running off as it does in most soils.

With respect to light, plants of the sandy soils thrive best with a maximum, and this partially explains the lack of density in the vegetation under trees on the sand. Wind has a marked influence upon the vegetation of the dune regions, although for the most part its action is upon the environment directly and upon the plants only more or less indirectly. Wind increases the evaporation of water from the plants, but many of those which are modified to reduce transpiration have an abundant supply of water, so, at least to a certain extent, such modification is inherent in the species and is not provoked by the direct effect of the environment.

Influence of Lake Michigan

Lake Michigan exercises a leveling influence upon the region in so far as temperature is concerned. The most evident influence is, of course, upon the shore itself, which in places is built out and in others is torn down. This has had a very marked effect upon the beach associations, which will be discussed in the proper place. The fluctuations of the lake within the last sixty years are shown in Plate XLIII. Tidal waves are of rare occurrence (May 12, 1905, and April 29, 1909). They may violently modify the vegetation, but they do not occur sufficiently often nor are they sufficiently powerful to permanently modify it. Such waves are seldom over 1.5 meters

*The state of affairs in which humus-forming matter is so rapidly oxidized that no humus is formed.

high, and they are so short in their duration that the fringing dune has practically always been able to protect the land behind it. Once the average lake level is such that the water is at the foot of the ridges and prairies, as at Kenosha, no vegetation can prevent the steady cutting which gradually eats away the ridges, prairies, and marshes. Piers are built to combat this erosive action, but as a rule they merely retard it and do not stop it.

General Description of the Region

The region lying between the Glenwood ridge on the west, Lake Michigan on the east, Kenosha on the north, and Waukegan on the south is very shallowly crescent-shaped. Its northern and southern boundaries are marked by the extensions of the Glenwood ridge into the lake as cusps. The length of the area is about 25 kilometers with a width of from 0.4 to 1.6 kilometers. The elevation above Lake Michigan level varies from 0.8 to 9.0 meters. The soil is sandy throughout.

As seen from the Chicago and North Western railway, which skirts the western edge, the different parts of the region give the following general impressions: From Waukegan to a kilometer north of the Lake County pest-house the land is characterized by marshy swales separated from one another by very low sandy ridges. In no place are these ridges two meters above the level of Lake Michigan. The vegetation is essentially prairie-like. It is very monotonous in appearance, except during July, when the lilies are in bloom, and during September, when it is covered with blazing stars. The swales are uniformly occupied with swamp grasses and sedges, all of which appear very much alike from the train. There are, at very long intervals, scraggy trees which hardly break the monotony.

North of this area is another which, though of the same physiographic character, gives an entirely different impression because of the groves of pines that occupy the ridges. In consequence this portion is termed the area of the pines. It is bounded on the west and north by arms of the Dead Lake. Formerly the extent of this area was much greater both north, south, and west; but upon those sides it is being reduced by cutting, burning, and by natural successions, while the fringing dune and the lake form its eastern boundary.

From the Dead Lake north to Kenosha is the area of greatest extent. It is wooded, but in this case the trees are oak instead of pine. There are many blowouts, those towards the north being larger and slightly more numerous than those in the southern part. The interridgial depressions, which are not so low as those towards

the south, are, for the most part, wider, and are occupied by prairie rather than by marsh plants. At the Illinois-Wisconsin state line the innermost oak ridge has been cut away, leaving an area of level sandy ground, one kilometer in width, from the lake to the bluff, in which the highest elevation above Lake Michigan is scarcely 0.5 meter.

Nearer Kenosha occurs the last oak ridge (Pl. XLIV, Fig. 1), which is quite wide and has several large blowouts in its sandy soil. The end of this ridge is about a kilometer south of Kenosha. It is being rather rapidly cut into by Lake Michigan. A little north of the end of this ridge, and protected by it on the south and west, occurs the only traveling dune of this area. It is very small in comparison with those at the head of Lake Michigan. The part between the oak ridge and the railway track is a sodded, sandy plain.

Just south of Kenosha measures have been taken to prevent the rapid cutting away of the shore that had been going on. Consequently the natural conditions have been destroyed. A little north of Kenosha the Glenwood ridge has been cut into by the lake, and there the region under consideration terminates.

Associations: General Consideration

In the naming of the ecological units there is still a confusion of terms. In this article the name "association" is used to designate these units; and by an association is meant a group of living forms whose epharmony (ability to live with other forms in a given environment) enables them to live together as a uniform or homogeneous area of definite biotic composition.

Although animals are not given consideration in this article, it must not be forgotten that they are an essential part of the association, especially the smaller animals. Their ecological relationships and correlations have, in general, not been sufficiently worked out to accord them their proper consideration.

The term *association* rather than *formation* has been used for the name of the ecological unit because of its priority* and its natural fitness. The term *formation,* as originally proposed by Grisebach,† was clearly intended to connote a broader group than the simple ecological units which he mentions but to which he does not apply a name directly. To use the term formation as the name of the

*Humboldt, 1807. Essai sur la Géographie des Plantes, p. 17.

†Grisebach, 1838. Über den Einfluss des Klimas auf die Begrenzung der Natürlichen Floren. Linnaea, 12:159-200.

ecological unit, as several modern writers have done, is clearly a misinterpretation of Grisebach's statement. Warming (1909) definitely uses the word *association*, which he explicitly states is not synonymous with Grisebach's "formation" but is included under it.*

Approaching the question from an analytical standpoint, Warming (1909: 140-145) defines a *formation* as "an expression of certain defined conditions of life" which "is not concerned with floristic differences," and an *association* as "a community of *definite floristic composition* within a formation"; to which he adds: "it is, so to speak, *a floristic species of a formation which is an ecological genus*". The ecological unit (association) is equivalent to the taxonomic unit (species). Just as species are grouped to form a genus and genera are grouped to form a family, so are associations grouped to form a formation and formations grouped to form a province. If necessary, an association may be divided into consocies, in like manner as species are divided into subspecies.

Of the apparent properties that ecological associations and taxonomic species have in common, Harper (1906: 33-34) gives the following very pithy statement: "There are many analogies between habitat-groups and taxonomic groups, such as species, though the latter are mutually exclusive categories and the former often are not. For instance, both are able to be discovered, described, named, and associated with certain type-localities. Records of both may be preserved by descriptions, photographs, measurements, and other means. Both have their diagnostic characters, with more or less variation and intergradation. Both have passed through processes of evolution, are self-perpetuating, and are liable to disappear through geological or climatic changes or the works of man. New ones may also originate, suddenly or gradually. Both have more or less definite geographical distributions and regions of best development. Both are capable of being subdivided, combined, or relegated to synonymy, with the increase of our knowledge concerning them. Habitat-groups, like species, can also be aggregated into larger categories analogous to genera and families".

Just as genera and species present difficulties of delimitation, so do formations and associations. The difficulties of ecological classification show many points of similarity, and require fully as much

*For a detailed discussion of the questions involved the reader is referred to the following articles:

Smith, Robert. On the Study of Plant Associations. Nat. Sci., Vol. 14. 1899.

Warming, E. Oecology of Plants, p. 139-148. 1909.

Moss, C. E. The Fundamental Units of Vegetation. New Phytologist 9:18-53, 1910.

study and experience for solution as do those of taxonomic classification. The criteria that have been used in delimiting and classifying associations have been almost as various as writers upon the subject.

Jaccard (1902:350) says, "Im allgemeinen ist der Bestand bestimmt durch die dominirende Art oder Arten". He was the first to set up a mathematical criterion for distinguishing associations. The association- or community-coefficient (Gemeinschaftscoefficient) is obtained by dividing the number of common species, in the two areas under consideration, by the total number of species in them. For example, area A has 100 species, area B has 120 species, 60 of which are common to the two areas. Then $\frac{60}{100 + 120 - 60} = 37{\cdot}5$ per cent. the community coefficient. For areas which are in the same association and in the same locality this coefficient ought to be fairly high. That even this method has its limitations Jaccard recognized when he said, "Sie entsprechen zwar gewissen Differenzen in den ökologischen Bedingungen der verglichenen Territorien, aber es besteht zwischen dem absoluten Werth dieser Differenzen und dem der Gemeinschaftscoefficienten keine mathematische Proportionalität." The same method was independently arrived at by Professor S. A. Forbes in a statistical study of Illinois Fishes.*

Besides the floristic composition told by mathematical methods, associations are usually appreciated by any or all of the following characteristics: (1) the presence of one or more dominating species, (2) the presence of tension lines at their boundaries, (3) the presence of evidence of dynamic succession, usually shown at or near the tension line, (4) the presence of a uniform environment, (5) the inability of species of different associations to mix, and (6) the presence of similar vegetative forms and environmental adaptations.

The association itself is composed of one or more principal or dominating species, termed the *dominant species*, which give the fundamental character to the association. In some associations the dominant species may be the only species, but more usually the interstices between the plants of the dominant species are occupied by what are termed *secondary species*. Frequently secondary species by their showiness give the color tone to the association. Where this varies from season to season, these different appearances are termed the seasonal *aspects*. *Succession* occurs when, in a given area, one association displaces another. Successions trend toward a definite cli-

*On the Local Distribution of Certain Illinois Fishes: An Essay in Statistical Ecology. Volume VII of this series, Article 8.

matic association which, if conditions were ideal and sufficient time were allowed, would occupy the whole of the given area. The series of associations which succeeded one another from bare ground to the climatic type is known as a *genetic series*. It is not necessary, however, that successions in a given area should proceed according to the normal genetic series. Mishaps of various kinds are continually occurring to prevent this. Successions are recognized primarily by the presence of pioneer or relic species within a given association. A *pioneer* species, as its name implies, is a species of a given association that can invade a genetically lower association, and a *relic* species is a species of a preceding association which remains after a successful invasion, thereby giving a clue to the situation. From this it follows that a complete association—if one may be allowed to use that term in this connection—consists of dominant species, secondary species, whose varying seasonal dominance produces seasonal aspects, invaders or pioneer species of a succeeding association, relics of a former association, together with such ubiquitous species, which seem to have little or no restriction placed upon their distribution, as may occur there.*

Successions form the most satisfactory approach to the ecological study of a region, and for this reason it may be well to give the subject brief consideration. As mentioned above, successions are often easily recognized in an association by the presence of pioneer or relic species. When associations within one formation are concerned, succession usually takes place by the invasion of the secondary species of the invading association, and the succession may be said to be completed when the dominant species have made their appearance. In the case of the invasion of an association of one formation into an area occupied by an association of another formation, invasion is effected by the dominant species, with the subsequent appearance of the secondary species. As one would naturally expect, invasion of one formation into another takes place through the pioneer association, which is characterized by a paucity of species, relatively speaking, and, consequently, in such an area the vegetation consists of the dominant species of the invading association with such of the species of the invaded one as can live under the new conditions. These secondary species are existing there as relics, yet they comprise virtually all of the secondary vegetation. This same principle holds also

*For further discussion of the association consult:

Clements, F. E. Research Methods in Ecology. 1905.

Cowles, H. C. The Causes of Vegetative Cycles. Bot. Gaz. 51 :161-183, Mar., 1911.

for the invasion of one province by another; that is to say, the dominant species of the invading association are the pioneer species in the invasion. Many other general principles concerning succession might be given, but as Adams has summed up "Some Principles of Succession" the reader is referred to "An Ecological Survey of Isle Royal, Lake Superior," pages 146 to 149, (1909) for their statement. A relic species exists in a given association because it occupies ground which as yet is not tenantable by any of the species of the succeeding association, rather than because the succeeding association can not displace the relic. An invader occupies more nearly its optimum habitat, but the relic lives where the other plants seem not to be able to develop. The disappearance of the relic usually takes place with the death of the individuals, whereupon the bit of ground which it occupied may be taken up almost immediately; or again —and many instances are at hand—the spot may remain bare for some time to come. Some relics modify the structure of their vegetative parts and continue for a long time after the invasion has been completed. Junipers and *Rhus canadensis illinoensis* (sumac) are two very good examples of this class of plants.

The naming of the associations has been approached from many different view points, but the most natural course seems to be to use the name of one or more predominating species, and, accordingly, that method is adopted in this article. In cases where another investigator has found associations clearly the same as those of the Beach area, the name that he used will be given first consideration, priority being regarded in so far as the fitness of the subject will permit.

The Lower and Middle Beach Associations

As the waters of Lake Michigan receded, a sand beach was exposed. This furnishes the starting point of a genetic series of associations which is known as the beach succession. Bare sand and the water of the streams and lakes are the two initial points of primary successions in this area.

The Chlamydomonas association

The classification of lake beaches has usually been founded upon a physiographic basis, in which the features distinguished are lower, middle, and upper beaches. The "lower beach" of Lake Michigan has been defined by Cowles (1899:113) as "that zone which is situated between the water level and the line reached by the waves of common summer storms." He gives an alternate definition on page 114: "It

might almost be defined as that portion of the beach which is devoid of vegetation." The lower beach of the Beach area physiographically speaking, exists in two modifications, one consisting of a very gradual slope, which may be concave, and the other of a relatively steep slope. Beaches of the first type are but very little elevated above the average level of Lake Michigan. The sand is damp, either to the very surface or, at least, to within one or two millimeters of it. Just at the edge of the lake is a little ridge which permits water to be retained beyond it. This water forms what is termed a beach pool. Being almost at the level of the lake, drainage back into the lake is very slow. In rainy seasons or at times of frequent north to southeast winds the beach pools may remain for a long time. During the ordinary growing season the sand is never sufficiently dry to be blown about in the wind. In beaches of the second type, the slope is much greater and the water from each wave drains away very rapidly. As a result, two to three centimeters of dry sand form the surface. This sand is, of course, easily blown about in the wind.

Neither of these two types of the lower beach bears vegetation of a permanent nature. In beaches of the first type, the one-celled, motil alga, *Chlamydomonas*, together with *Oscillatoria*, may occur in such numbers as to cause the wet sand to appear green. This constitutes the *Chlamydomonas* association. These algae occur also in the waters of the lake, but their optimum habitat seems to be the beach pools which occur near the outlets of sewers or near the mouths of creeks bearing sewage. (See Plate XLIV, Fig. 2.) The sand around the pool is mushy and rather greenish in color. The ridgelet between the beach pool and the lake is very low (10 cm. at most) and very narrow. Every north to southeast wind will cause the waves to run over the ridge and flood the pool with sewage-laden water from the nearby sewer. This constant flooding, together with the rather frequent rains, resulted in a permanent pool during the season of 1909. Small snails appeared, and upon them as well as upon other living forms the sanderlings shown in the figure are feeding.

Aside from the algae, vegetation upon the lower beach is purely accidental. One such case is that of a large willow log which was broken in three pieces and washed up to the edge of the lower beach by the tidal wave of April 29, 1909. The original source of this log is not known, for nowhere in the Beach area are there willows of such size. The logs lie just within the reach of every ordinary wave. Succeeding storms have partially covered the logs with sand, which is constantly kept moist by the waves. From the logs themselves,

shoots have grown up six decimeters. Whether these logs will withstand the winter storms and, together with some wreckage near by, originate another ridge remains to be seen.

Another case of accidental vegetation on the lower beach is very temporary in duration and extent. It occurs south of Kenosha, where Lake Michigan is cutting into the prairie. Some prairie plants, notably loosestrife (*Lythrum alatum*), are carried bodily from the prairie and are occasionally left stranded with their root systems in the damp sand of the lower beach. They remain living until washed away altogether by a succeeding storm.

The part of the lower beach which is devoid of plants comes next into consideration. The area is bare because plants can not obtain a footing there—and not because they will not grow there. The reasons which are given briefly by Cowles (1899:114) and more fully by Jennings (1909:310) are as follows: the alternate washing by storm waves and the severe drying out under the sun, combined with the washing about of the sand when submerged and its blowing about when dry, prevent the establishment of any plants whose seeds actually do germinate. After a rainy spell of two or three days' duration, such as August 13-15, 1909, it is not at all a difficult task to find, scattered over the slightly damp sand, seeds which have begun to germinate. With the reappearance of the sun and the drying of the surface sand, these partially germinated seeds dry up and are blown about by the wind. That living forms, however, can maintain themselves on this area is clearly shown by the industry of the turnstone (*Arenaria interpres*), which, during its brief sojourn in this region in the spring and fall migrations, is continually occupied in ferreting out the small insects and other animals which are found under the pebbles.

The junction of this area with the portion of the beach continually washed by the waves is the location of the willow log and wreckage previously mentioned. One piece of wreckage, a little over a meter in length, projects somewhat over a decimeter into the air. The ordinary waves just fall short of its lakeward side. On the landward side, stretching southwestward, is a miniature dune of sand in which are growing the following plants: *Juniperus horizontalis*—a single healthy shoot, 3 cm. in length, growing next to the wreckage; *Prunus pumila* (sand cherry)—a sprawling shrub; *Poa compressa* (English blue-grass)—a few plants; *Potentilla anserina*—one plant with five radiating runners; *Equisetum arvense*—a few plants; a composite which was so depauperate as to be unrecognizable; and a convolvulaceous plant, together with the exposed roots of *Calamovilfa longifolia*. A wagon track through the dune explains the planting of

the *Potentilla,* the composite, the *Equisetum,* and the convolvulaceous plant, for they were growing in the bottom of it. The nearest source for the *Juniperus* was about a hundred meters away, from which the seed may have been carried by the gulls which are abundant on the beach and occasionally are seen in the heath. Close to the lee (southwest) side of another piece of embedded wreckage in this same vicinity was a straggling plant of *Xanthium commune* (cocklebur).

Taking all these facts into consideration, it seems evident that a new ridge is being thrown up. The pieces of wreckage were probably lodged there during the violent storm and tidal wave of May 12, 1905. The juniper came in in the backwash of that storm or by some other agency, as suggested above, in 1906, as it appeared to be three or four years of age (1909). The storm and tidal wave of April 29, 1909, did not dislodge the wreckage nor the juniper. It added material that can assist in the formation of a ridge. Progress towards that end, however, is very slow.

The *Chlamydomonas* association is entirely identical with the *Chlamydomonas* formation of Jennings at Cedar Point (1908:313) and at Presque Isle (1909:310). Occasional presence of the alga was reported by Cowles near Porter, Indiana, (1899:114). This association, together with the plantless area, composes what MacMillan termed the "front strand."

The Cakile-Xanthium Association

From the upper limits of the open sand of the middle beach, and therefore out of reach of the ordinary storm-waves, an area of sparsely vegetated sand stretches inland. This is the location of the *Cakile-Xanthium* association. The landward boundary of this area is usually the fringing dune.

Physical Environment.—The physiographic characteristics of this association are fully discussed by Cowles (1899:115-117) and by Jennings (1909:311). The middle beach, as Cowles designated it, lies "between the upper limits of the summer and winter waves." It is dry in summer, and differs from the lower beach only in that it is not subject to the mechanical violence of the waves during the growing season. The soil is, for the most part, sand whose grains vary between 0.2 and 1.0 mm. in diameter. It is exposed to the full force of wind and sun, and consequently it is very dry nearly all of the time. During the daytime the sand may become very hot (60° C.), but it cools off rapidly during the evening. Although the upper few centimeters are so very dry, the sand beneath is always moist and may even be wet.

Ecological Characteristics.—The plants that persist in this association possess certain general characteristics: (1) they are annuals, because perennials are uprooted during the winter storms; (2) their disseminules are comparatively heavy, so that altho they are blown about they are not blown away; (3) their seeds have sufficient vitality for sending their tap-roots through 4-10 cm. of dry sand to the moist sand below; and (4) their aerial parts are low, radiately branching or bushy, narrow-leaved, and frequently succulent. In other words, the plants of this association are subjected to the severest kind of xerophytism. Such a habitat, hydrophytic beneath the surface of the ground and xeropyhtic above ground, is termed dissophytic by Clements.

Development.—In the Beach area the middle beach, to use Cowles' term, exists in two modifications. Towards the southern end, it is highest at the boundary line separating it from the lower beach, from which it slopes very gradually down to the fringing dune—a slope of but a few centimeters at most. Towards the north the narrow middle beach slopes upwards and abruptly gives way to the much higher (2-4 meters) fringing dune. Here the middle beach is subject to continual removal of its sand by the prevailing westerly winds. As the winds are in the westerly half of the compass much more than half of the time, the formation of extensive or high dunes is impossible on account of the lack of sand. The replenishment of the sand of the middle beach takes place during the easterly storms, of which there are but a few each year. Such storms, as a rule, are accompanied by precipitation, which further retards their power of bringing up sand from the lake. One may judge of the amount of sand that such a storm may pile up by the effects of the storm of July 30-31, 1908, in which the wind was east for a day and a half. A ridge some 20 meters wide and 0.4 meters high was piled up in front of the mouth of the Dead River, completely closing the channel—6 meters wide and 0.5 meters deep—which that river had had the day previous. And this does not begin to compare with the amounts blown up on the southern and eastern shores of Lake Michigan. Some sand is blown up during the winter unless the shore is ice bound. At that season there is a noticeable transfer of sand from the northern parts, where it is held by the season's vegetation, towards the southern parts, where north of the Waukegan piers it is building the shore out into the lake.

The southern part is more wind-swept because protected on the landward side by only a very low (at most 0.2 meters) fringing dune. It is characterized by extreme openness of vegetation. The

plants that occur, always at very widely separated intervals, are seaside spurge (*Euphorbia polygonifolia*), cocklebur (*Xanthium commune*), and sea rocket (*Cakile edentula*), in abundance as named. Each of these plants has to contend with a continual exposure of its root system by the removal of sand. *Euphorbia polygonifolia* usually escapes this by living in depressions. If growing on the level, however, it forms a dense mat which holds the sand within its compass, building up a miniature dune about two centimeters in hight and sometimes twenty centimeters in diameter. (See Plate XLV, Figure 1.) If the blowing is too vigorous, the plants will succumb, and it is not unusual to find dead, curled-up plants of this species rolling about in the wind. There is apparently no adaptation in *Cakile* for the protection of its root system, but *Xanthium* is adapted by growing procumbent with only the apical four to seven centimeters projecting into the air. The spread of leaves around the stem aids in the formation of a small, temporary dune which protects the root system from exposure. Even then plants have been found in which there was a distance of 6-10 cm. from the exposed bur, from which the plant had germinated, to the point at which the root was covered with sand. This indicates that considerable sand had been removed.

Pieces of driftwood on the beach are often the starting points for small, temporary dunes. Occasionally a plant of *Xanthium commune* will fix such a dune for a season. In the vicinity of Beach, where the middle beach is very narrow and protected by the fringing dune, the characteristic plant is *Euphorbia polygonifolia*. This plant is most abundant where there are pebbles to afford it protection from the wind. *Cakile edentula* occurs only at rare intervals, while *Xanthium* is virtually absent.

During the season of 1910, which was characterized by the extreme duration of a protracted drought, the water-level of Lake Michigan was very noticeably lowered. This made the wave action on the ground occupied by this association virtually nil. In addition to a normal abundance of the usual dominant species, there were the following secondary plants, whose growing habits were somewhat similar to those of the dominant species: *Cycloloma atriplicifolium*, Russian thistle (*Salsola kali tenuifolia*); bug-seed (*Corispermum hyssopifolium*), cottonwood (*Populus deltoides*), and *Salix syrticola*. All of these plants were characterized by the extreme length of their secondary roots. These spread radially from the small bushy plants, giving the plant command of the water supply from an area eight to fourteen feet in diameter. The roots were quite strong and could be easily pulled up in lengths of four to six feet. The plants themselves

seemed to be smaller and more succulent than usual, but the stems were thicker, and in the case of plants which are more or less pubescent when young the pubescence was retained and frequently developed into villousness. All of these modifications were direct results of the dryness of the summer.

LIST OF THE SPECIES OF THE CAKILE-XANTHIUM ASSOCIATION

Dominant Species

Cakile edentula	*Xanthium commune*
Euphorbia polygonifolia	

Secondary Species

Corispermum hyssopifolium	*Cycloloma atriplicifolium*

Invading species (all of which are relatively scarce and are not met with every year)

Salsola kali tenuifolia	*Salix syrticola*
Populus deltoides	*Potentilla anserina*

On the normal middle beach, only the first three of the dominant species, mentioned above, are present. North of Winthrop Harbor, however, where the ridges and swales are being washed away by the waves, several other species are found on the middle beach. Their presence is both accidental and temporary. The more frequent of such plants are blue vervain (*Verbena hastata*), mullen (*Verbascum thapsus*), sandbur (*Cenchrus carolinianus*), strawberry (*Fragaria virginiana*), white clover (*Trifolium repens*), smartweed (*Polygonum persicaria*), *Potentilla anserina, Polygonum acre, Panicum capillare, Acnida tuberculata submuda, Polygonum lapathifolium,* horsetail (*Equisetum arvense*), and sand-bar willow (*Salix longifolia*). In other places were the following additional species: blue grass (*Poa pratensis*), *Juncus tenuis,* Canada thistle (*Cirsium arvense*), *Lythrum alatum, Radicula palustris,* and red clover (*Trifolium pratense*). Although these plants occur within the limits of the *Cakile-Xanthium* association, they do not properly belong to it for the following reasons. Surrounding their roots, there is always more or less prairie humus, which is sometimes only about the individual plants. In some places there is a strip of prairie which, when undermined by the waves, slides down on the middle beach, carrying with it whatever plants are growing in it. Later, these strips are buried by a few centimeters of drifted sand. The plants usually persist through the one season but do not grow the next year. The burying process may keep up dur-

ing the season. In general this is liable to kill prairie plants within the summer, but, in a few cases, *Panicum capillare, Acnida tuberculata subnuda, Trifolium repens,* and *Salix longifolia* will keep pace with the incoming sand.

Since these species which constitute the derived element of the association can under no circumstances commence to grow on the middle beach, and since their presence there is to be accounted for solely by physical displacement of the soil upon which they were growing and has absolutely no successional value, one can not say that they are a real part of the association.

The Middle-Beach Pool Associations

In describing the middle beach (see under *Development*, page 270) it was mentioned that in the southern part of the area its slope from the lower beach was downward toward the lake-level. Just a little north of the docks at Waukegan, the beach has reached the level of sand which is permanently moist clear to the surface. Standing water is not usually present throughout the season, and so the beach pool is not permanent. This is the situation to which three groups of plants give such a definite floristic character that they must be termed associations, small in area and isolated though they are. In genetic order these are the *Juncus alpinus insignis,* the *Triglochin palustris,* and the *Carex oederi pumila - Cyperus rivularis* associations. These groups of plants are not of frequent occurrence in this region. Although they usually occur isolated from one another, they show sufficient successional relationships to indicate that they are three associations, rather than consocies of one association as Jennings (1909: 352) treated them.

The Juncus alpinus insignis association

The lowest of these associations, the *Juncus alpinus insignis,* has been found in typical form only in exceptionally dry years, such as 1908 and 1910, when it occupied the dried-up bottoms of beach pools. This *Juncus* grows in small tufts, thoroughly dominating the association. With it are seldom any secondary species, and when they do occur they are of very minor importance.

List of the species of the Juncus alpinus insignis association

Dominant Species	Secondary Species
Juncus alpinus insignis	*Bidens vulgata*

Invading Species	
Scirpus americanus	*Triglochin palustris*

THE TRIGLOCHIN PALUSTRIS ASSOCIATION

This association is present every year. It normally occurs along the margins of the beach pools or in moist sand in other depressions. The individual plants of the *Triglochin,* which comprise about 70 per cent. of the area, grow close together in small tufts. The tufts themselves are separated by intervals of two to three to ten centimeters. Toward the landward side, where the tufts are still farther apart, the secondary species of this association occur. They are pioneers of succeeding associations, the most important of which is the *Juncus balticus littoralis,* which grows in higher ground than does the *Triglochin.*

LIST OF THE SPECIES OF THE TRIGLOCHIN PALUSTRIS ASSOCIATION

Dominant Species	Relic Species
Triglochin palustris	*Juncus alpinus insignis*
Invading Species	
Juncus balticus littoralis	*Juncus torreyi*
Potentilla anserina	*Scirpus americanus*
Populus deltoides (a few small seedlings under 12 cm. high)	*Cyperus rivularis*

THE CAREX OEDERI PUMILA - CYPERUS RIVULARIS ASSOCIATION

This association occupies a still higher position on the beach than the preceding one. It occurs around beach pools, but is more likely to be found in swales between the ridges than on the lake beach itself. Wherever it occurs, it is characteristic of moist rather than wet sand. It is usually submerged for a time in spring, but the ground becomes dry by the beginning of summer. This association is characterized during the different seasons by well-developed aspects. Throughout the aspects, plants belonging to the sedge family are the dominant species; *Carex oederi pumila* in late spring and early summer, *Rynchospora capillacea leviseta* during the serotinal season, and *Cyperus rivularis* during the fall. Secondary species are somewhat more numerous in point of numbers than in the two previous associations. Most of them are invaders of the different associations that may follow this one.

LIST OF THE SPECIES OF THE CAREX OEDERI PUMILA-CYPERUS RIVULARIS ASSOCIATION

Dominant Species

Carex oederi pumila
Rynchospora capillacea leviseta
Fimbristylis castanea
Ranunculus sceleratus
Cyperus rivularis
Carex aurea
Eleocharis acuminata

Relic Species

Triglochin palustris

Invading Species

Potentilla anserina
Juncus balticus littoralis
Linum virginianum
Salix syrticola (small plants)
Lobelia kalmii
Utricularia cornuta

THE SABATIA-LINUM ASSOCIATION

Immediately above the preceding association and sending out many invaders into it, is the *Sabatia-Linum* association, which is almost the exact counterpart of that found by Jennings (1909:355) on Presque Isle. One of the dominant species of this association, *Sabatia angularis,* occurs in the general region around the head of Lake Michigan, but is locally absent in the Beach region. The presence of this association is usually an indication that a given area of ground will be occupied by prairie rather than by forest associations.

LIST OF THE SPECIES OF THE SABATIA-LINUM ASSOCIATION

Dominant Species

Linum virginianum

Secondary Species

Lobelia kalmii
Utricularia cornuta
Aster ptarmicoides
Carex crawei
Gentiana procera (small plants)
Campanula aparinoides
Spiranthes cernua
Gerardia paupercula
Liparis loeselii

Relic Species

Eleocharis acuminata
Rynchospora capillacea leviseta
Carex oederi pumila
Carex aurea

Invading Species (of relatively frequent occurrence)
Juncus balticus littoralis

Invading Species (of rather rare occurrence)

Salix longifolia	*Panicum* sp.
Salix glaucophylla	*Arctostaphylos uva-ursi*
Salix syrticola	*Petalostemum purpureum*

THE JUNCUS BALTICUS LITTORALIS ASSOCIATION

One of the first indications of the first type of upper beach, as Cowles (1899:167 et seq.) terms that part of the beach which is entirely without wave action throughout the year, is the presence of the rush *Juncus balticus littoralis*. It grows from straight rhizomes which may be over three meters in length. The lines of plants cross and recross each other in every direction. Expansion on the landward side is ecologically impossible because of the closed association behind it. Progress out on to the middle beach is limited only by the action of the waves in winter and by the winds which keep uncovering the outermost rootstalks. As the lines grow outward the shifting sand is retained around the bases of the plants. It may even form embryonic dunes to the hight of a few centimeters. This work, however, is nearly always destroyed when the westerly winter winds, with nothing to impede them, carry the sand back into the lake. The *Juncus* itself does not seem to be able to fix the dunes, but it is a pioneer that enables dune-fixing plants to gain a foothold on a low and level beach like that which, in the southern part of this area, extends from Beach to Waukegan. There is no *Juncus* where the slope of the shore is 15° or more. The lakeward side of this association is composed of just the one species, *Juncus balticus littoralis*. In the middle and in the landward side other plants appear. The most abundant of these is silverweed (*Potentilla anserina*), of which more will be said in connection with the following association. Small straggling plants of *Salix syrticola* occur at intervals, but as a component part of this association they are not well developed. Occasionally a dwarfed, small-leaved plant of cottonwood, *Populus deltoides*, may be seen. Because of the deficiency of nutriment in the soil the cottonwoods grow very slowly—sometimes not more than a couple of centimeters in a season. *Scirpus americanus* occurs here more frequently than in the *Triglochin palustris* association, but still is not abundant. It has a remarkable tendency to grow in a spiral form when it grows in the sand.

The *Juncus balticus littoralis* itself possesses this tendency, but to a less marked degree. The presence of the *Scirpus* is conclusive proof that wet sand is close to the surface.

LIST OF THE SPECIES OF THE JUNCUS BALTICUS LITTORALIS ASSOCIATION

Dominant Species

Juncus balticus littoralis

Relic Species

Triglochin palustris
Cakile edentula
Cycloloma atriplicifolium

Invading Species

Potentilla anserina
Salix syrticola
Populus deltoides
Elymus canadensis
Scirpus americanus

In addition to the part that the *Juncus* plays in building up the beach, it has an important rôle in retarding the storm waves in their attack on the shore-line between Kenosha and Winthrop Harbor. Its efforts are only partially successful as Figure 1, Plate XLVI, illustrates. The relic dune* (A) in the center of the figure and the two at the left, mark the limits of the grassy sand plain in 1905. This plain is usually separated from the lake by a very dense growth of *Juncus balticus littoralis*. The width of this *Juncus* association is from one to three meters. It is separated from the grassy plain by a narrow tension zone of *Potentilla anserina*. The interwoven mass of rhizomes of the *Juncus* protects the sand from sliding. As a result there is normally a perpendicular bluff of 1.0 to 1.4 meters' elevation at the lake. Repeated buffetings of the lake wear through the *Juncus* in spots. This affords an opening to the grassy plain behind, with which violent waves make short work. The limit of the wave action is due to the loss of power to move sand after the waves have proceeded over a stretch of beach. The retreating waves carry back with them sand from the rear of the *Juncus*. After about four years of such action the beach line has the appearance shown in Figure 1, Plate XLVI. In the center of the figure is a relic dune. Its elevation above the water is the same as that of the grassy plain in the foreground. This is illustrated by Figure 2, Plate XLV. The sides of these relic dunes

*Gates, F. C. Relic Dunes, A Life History. Trans. Ill. Acad. Sci., Vol. III, 1910, pp. 110-116.

are coated with a dense mat of exposed rhizomes of *Juncus*. At "C" in the figure is a *Juncus* dune in one of the stages of obliteration.

The flora of these interesting relics is very uniform. *Juncus balticus littoralis* is the characteristic species and occupies 95 to 99 per cent. of the area of the caps in Figure 1, Plate XLVI. The following are infrequent in their occurrence and irregular in their distribution: evening primrose (*Oenothera rhombipetala*), Russian thistle (*Salsola kali tenuifolia*), sandbur (*Cenchrus carolinianus*), silverweed (*Potentilla anserina*), *Sporobolus cryptandrus,* dogwood (*Cornus stolonifera*), and *Calamovilfa longifolia.*

Proceeding southward from the portion shown in Figure 1, Plate XLVI, the shore-line begins to curve somewhat to the west and is not subject to so much wave action. The rifts in the *Juncus* association become less frequent and of less and less importance as the shore dips away from the direct attack of the waves. The sand is piled at the base of the *Juncus rhizomes* so that the bluff is concave. The association still contains over 90 per cent. of *Juncus balticus littoralis,* but secondary species are a little commoner and more sandbur (*Cenchrus carolinianus*), *Cornus stolonifera, Ptelea trifolia,* Canada thistle (*Cirsium arvense*), *Oenothera rhombipetala,* and balm of Gilead (*Populus candicans*) are present.

Besides characterizing an association, *Juncus balticus littoralis* grows in a majority of the other associations of the Beach region. It will be given consideration accordingly under them. Notwithstanding its apparent disregard for habitat it rarely shows any modifications in form in the habitats in which it is evidently a relic.

THE POTENTILLA ANSERINA ASSOCIATION

From the *Juncus balticus littoralis* association the sand slopes up gradually to the *Salix syrticola* or fringing-dune association. This slope is characterized by a rather dense growth of low plants of which silverweed (*Potentilla anserina*) constitutes from 70 to 90 per cent. It may be termed a tension-line association, and separates very distinctly the fringing dune from the *Juncus* association. *Potentilla anserina* grows in each of the three associations, but it shows its maximum development in the *Potentilla* association. In the bordering associations the size of the individuals varies to a minimum and their number to zero.

Potentilla anserina spreads very rapidly by means of runners which radiate from the parent plants. At quite regular intervals of from one to two decimeters each runner sends out roots and leaves.

The new growth decreases in size with increasing distance from the center. Any accident received by the runners causes separation into independent plants, from which new runners may extend. *Potentilla* can not contend with the wind. It is rather easily killed, either by sand being blown away from its roots or by being buried in drifting sand. In the spring, before there is a carpet of vegetation over the ground, the young plants are to some extent protected from the wind by the bushes of *Salix syrticola* and the dead stems of *Juncus balticus littoralis*. Once a carpet is formed, there is little danger of damage from the wind.

If protected from wind and still connected with the parent plant, runners may proceed through rifts in the *Juncus*, out upon the middle beach, where they may develop roots and leaves in the usual way but of smaller dimensions. During the season of 1908, when there was an unusually small number of heavy winds, many long runners developed in this way. A number of them were severed, resulting in the gradual starvation of the young plants, thus isolated upon the middle beach. This was probably due to the deficiency of food material there—a fact which has often been commented upon. The season of 1909, with its heavy surf and strong wind storms, prevented any such development of runners.

The secondary species of this association are not many in either number of species or of individuals. Without exception they are obviously under the usual size. This also is due to the lack of nourishment in the sand. The commonest of these species is *Juncus balticus littoralis*. A few *J. alpinus insignis* occur as relics where the *Potentilla* has successfully invaded the *Triglochin palustris* association. The *Triglochin* may also remain as a relic but it is less liable to persist.

LIST OF THE SPECIES OF THE POTENTILLA ANSERINA ASSOCIATION

Dominant Species

Potentilla anserina

Secondary Species

Juncus balticus littoralis (which is also a relic)

Relic Species

Juncus alpinus insignis
Triglochin palustris

Invading Species

Salix syrticola
Calamovilfa longifolia
Panicum virgatum
Populus deltoides (1-2 dm. high)
Salix longifolia

In beaches which are being destroyed, such as the region between Winthrop Harbor and Kenosha, a narrow tension association of *Potentilla anserina* separates the grassy plain (*Poa compressa* association) from the very low ridge of a very dense growth of *Juncus balticus littoralis*. In the course of the destruction of the shore, as has been mentioned above, there is exposed an area of open sand between the sand-plain and the relic dunes. (See Fig. 1, Plate XLVI.) For the most part, this area is devoid of plants but in slightly sheltered places, *Potentilla* comes in and spreads out radially, forming mats a few meters in width and several meters in length. The leaves are usually half buried and the runners can scarcely keep above the sand. It may be for this reason that here the internodes of the runners are so short. With it are seldom any secondary species. At the edge of the grass on the sand-plain (Fig. 1, Plate XLVI) is a well-developed association of *Potentilla,* and mixed with it are *Sporobolus cryptandrus* and sandbur (*Cenchrus carolinianus*). This makes a denser vegetation during the growing season than the grassy sand-plain itself shows, and effectually prevents any blowing during that period, thus protecting the grassy plain. During the winter, when the sand is rendered mobile with the drying of the *Potentilla,* a general southward movement of the sand takes place in sufficient quantities to be noticed from year to year.

The Dune Formation

Landward from the beach formation occurs the dune formation. This has been so frequently and so well described, (e.g., Cowles, 1899), that only a brief summary of the characteristics need be given before dealing with the associations. The essential conditions for dunes are wind, dry mobile sand, and a nucleus to allow the sand to accumulate (cf. Warming, 1909:263).

Ecological Characteristics.—(Cf. Cowles, 1899:106-111). The sand-dune is a very xerophytic habitat because of the agencies that increase transpiration and at the same time keep down the water supply, such as intense light and heat and strong winds. The water supply for sand-dune plants is deficient because water passes through sand very readily and but a small amount is retained in it. To this may be added the low nutritive value of the sand. On account of the insolubility of the sand grains and the easy access of air, organic matter which otherwise would form humus is rapidly oxidized. Water continually passing through the sand washes away even the less soluble food constituents (Livingston, 1903:14). A sand-dune, how-

ever, is not dry throughout. The sand to within a few centimeters of the surface is moist. The layer of dry sand which acts as a very good non-conductor of heat prevents the entire desiccation of a dune. Because of this, vegetation there is possible.

Adaptations of the Vegetation.—The characteristic adaptation of sand-dune plants is found in the extreme development of the root system in comparison with the aerial parts. To meet the constant shifting of the sand, which may uncover the roots, they are capable of producing adventitious shoots. Because of this, the plant can sometimes move a considerable distance in keeping pace with the sand. Sand-dune plants usually cover quite a little ground, and thus protect themselves from exposure of their roots because of the blowing sand. The grasses that inhabit the dunes are perennials, and they are frequently tufted. The mere presence of some of these grasses on the upper beach may often be the starting-point of a dune.

The aerial parts are clearly developed in response to the extremely xerophytic habitat. The leaves are firm in texture, with stomata well protected by the position of the leaves or by a protecting covering of hairs. Often the leaves are long and narrow and curled or folded to reduce transpiration. The inflorescence is frequently protected in the upper sheaths until it is virtually fully ready for pollination.

Plants as Dune Builders.—(Cf. Cowles, 1899:175 et seq.) Plants may live on a dune and yet add nothing to the life of a dune. They will accumulate sand during a season and form miniature or embryonic dunes, but as soon as the plants die down in autumn the sand is again mobile. Such dunes very seldom last during the winter, although many of them are formed during the growing season. They are the "annual dunes" of Cowles (1899:177). To endure from season to season a dune must be fixed by perennials, particularly of the group known as sand-binders. It is well known that owing to the persistence of the vegetative parts in winter such plants have considerable ability to prevent sand from shifting. For a dune to grow larger the sand-binder must be able to respond easily to changing conditions; and it must not be killed by exposure of its root system nor by the burial of its stem. To make the dune more extensive it must be able to spread radially by rhizome development, thus developing the dune in expanse at the same time that the upward growth of the stems is developing it in altitude.

Location in the Beach Area.—The sand-dunes occur a little beyond the limit of winter wave-action. They are more general in occurrence and better developed in constructive beaches. Nowhere in

this region are sand-dunes well developed. This is because the prevailing winds are westerly, while the lake, from which the sand must come, is to the eastward of the beach. The largest dunes are about four meters high. They are protected from westerly winds by woods of pine or oak. Towards the northern and southern parts of the area, where there is no protection from winds, the dunes are seldom more than four decimeters in hight. All but one of the dunes in the area are fixed dunes, either permanently or for a season only. Traveling dunes, such as occur along the southern and eastern sides of Lake Michigan, are absent because the prevailing westerly winds merely take away any loose sand and carry it back into the lake. The one traveling dune is nine meters high, and is protected from westerly winds by oak woods. In order to have any permanent dunes whatsoever the sand must be fixed by vegetation.

The Dune Associations

The different dune-forming plants give a more or less characteristic apearance to the dunes on which they occur. The dune-former is the all-important plant in the dune associations. Only a very few other species are capable of withstanding such a severe habitat, and as a consequence the dune associations are poor in species. As soon as the pioneer species begin to accumulate humus, invaders appear and assume possession, while the pioneers advance onward, in general, towards the lake. The process is, however, very slow, and is greatly hindered by severe wind storms and tidal waves.

Dune associations are usually independent of one another, and the dune complexes are built up in part by the growth of individual dunes. When this occurs, succession takes place which leads to the formation of the climax dune vegetation, as the juniper dunes may be designated.

The Calamovilfa Dune Association

The sand-binding grass, *Calamovilfa longifolia,* plays the most important part in initiating new dunes on the upper beaches. This grass is a most efficient sand-binder, and it will commence its growth under more adverse conditions in this region than will any of the others. The root system is extensive and forms a very dense tangle, as shown in Figure 1, Plate XLVIII. This plant always grows in tufts, and as soon as the leaves appear sand begins to be caught around the stems and lower leaves. The dune soon takes the shape shown in Figure 2, Plate XLVII. From the windward side the dune

slopes quite gradually up to the highest point in the center of the clump, from which the slope is more gradual down to the leeward. After severe wind storms the leeward trail may be over a meter in length. A change of wind, however, soon changes its position.

During the winter the dead standing stems with their leaves protect the dune in a measure from ordinary winds and storms. On the more open upper beach this protection is inadequate, and the return of the growing season finds the sand level with some exposed roots to show the former location of the *Calamovilfa* dune. But a short time is needed to reconstruct the dune when the growing season is once commenced. In less exposed situations the dunes persist over winter.

The *Calamovilfa* dunes are a conspicuous feature of the vegetation of the lake shore in the central part of the region, yet the dunes are never large in size. They spread radially quite easily but they do not grow very much in hight. A *Calamovilfa* dune a meter high is uncommon. The usual altitude is from three to six decimeters. Higher dunes are formed by plants whose ecesis can be accomplished in a *Calamovilfa* dune but could not have been on the normal upper beach.

The outcome of the growth of these dunes is usually the formation of a ridge running parallel with the line of wave action. As additional ridges are built up nearer the lake, the *Calamovilfa* remains as a relic along the crest of the ridge. In such places it sometimes exhibits the growth form known as fairy rings. Succeeding associations, however, finally bring about its disappearance. The secondary species of this association are very few in number and, in general, unimportant in value.

LIST OF THE SPECIES OF THE CALAMOVILFA DUNE ASSOCIATION

Dominant Species

Calamovilfa longifolia

Invading Species

Andropogon scoparius
Prunus pumila
Elymus canadensis
Salix glaucophylla
Populus candicans
Petalostemum purpureum f. *arenarium*
Quercus velutina (rarely)
Vitis vulpina (one plant, 3.5 meters long)

THE AMMOPHILA ARENARIA DUNE ASSOCIATION

Because there is so little sand carried from the lake, this association of dune plants is very scarce in this region. *Ammophila arenaria*

is a plant that grows best where there is an abundance of blowing sand. In such situations it builds dunes to a hight of several meters. In this region the *Ammophila* dunes are in no case more than a meter high. The dune has a very gradual slope, which is steeper on the landward side. The plant spreads in lines and does not form clumps as *Calamovilfa* does. *Ammophila* exceeds all other sand-binding grasses in the ability to grow upwards with the accumulation of the sand. At the same time the aggregation is so open that, in this region, it permits the sand to be carried back into the lake almost as fast as it is accumulated by the plant. This is the exact reverse of conditions prevailing in the *Calamovilfa* dunes, where the close bunching of the grass and the usually persistent dead leaves at the base of the stem permit a more prominent heaping up of the sand.

Ammophila dunes are pioneers of upper beach vegetation, but they will not commence so near the drift beach as will the *Calamovilfa*. On the other hand, *Calamovilfa* can capture the *Ammophila* dunes and replace the plants by which they were formed.

The *Ammophila* dune association is so poorly developed in this area that an adequate description of it is not possible from the data at hand. An extended description is given in a paper by Cowles (1899:179-181). The secondary species that occur have scarcely anything to do with the growth of the dune. They merely represent beach species whose seeds have lodged among the *Ammophila* stems. *Lathyrus maritimus*, the beach pea, is the most abundant and best developed. Its procumbent stems trail in and out between the *Ammophila* stems for several decimeters. Like the other secondary species, it occurs just over the crest, as viewed from the lake. The main part of Figure 2, Plate XLVIII, is occupied by an *Ammophila* dune.

LIST OF THE SPECIES OF THE AMMOPHILA DUNE ASSOCIATION

Dominant Species

Ammophila arenaria

Secondary Species

Calamovilfa longifolia
Lathyrus maritimus
Potentilla anserina

Relic Species

Euphorbia polygonifolia
Xanthium commune

Invading Species

Calamovilfa longifolia
Prunus pumila
Salix longifolia
Solidago graminifolia

THE SALIX SYRTICOLA DUNE ASSOCIATION

In the southern part of the region occur the low fringing dunes which are tenanted by the willow, *Salix syrticola*. They are low flat dunes, just a little out of the reach of the winter storms. They tend to grow in width rather than in hight, and consequently this association is one of the first to make a permanent vegetation on the beach.

The plant itself grows as a straggly bush, sufficiently dense, apparently, to cover the ground with vegetation but not to prevent a strong wind from carrying away sand that may have accumulated at the bases of the stems. Because of this the hight of these dunes depends upon the amount of protection that they have from the westerly winds. From Waukegan to the area of the pines, where there is no such protection, the *Salix syrticola* dunes are from two to four decimeters in hight. When protection is afforded by the pines the dune will keep pace with the blowing sand to a hight of about three meters. Only a few plants of this willow, however, are able to continue their growth upward with the accumulating sand, and the ridge is broken up into a dune-complex in which only a few of the dunes belong to this association.

At the southern end of the area, where the beach is low and very level, seeds of this willow germinate in the *Juncus balticus littoralis* association. The plants are larger in the *Potentilla* association, and reach their average development in size on the low ridge just back from it. This ridge is the typically developed *Salix syrticola* dune. In this part of the region occur the majority of the secondary species, virtually all of which are relics or invaders.

A little farther north where the beach is still level, although sloping upward all the way from the lake, the *Salix syrticola* dune, composed of the dominant species only, occupies the lakeward front. There is more blowing sand there and each plant is partly buried. The plants continue their advance lakeward as fast as they are permitted by means of their underground stems.

LIST OF THE SPECIES OF THE SALIX SYRTICOLA DUNE ASSOCIATION

Dominant Species

Salix syrticola

Secondary Species

Elymus canadensis
Salix longifolia
Populus deltoides (1 m. high)
Lathyrus maritimus (rare)
Salix glaucophylla

Relic Species

Potentilla anserina
Juncus balticus littoralis
Xanthium commune
Calamovilfa longifolia (not common; it usually occurs as a little hill, built up 1-2 dm. above its surroundings)

Invading Species

Andropogon scoparius
Solidago graminifolia
Potentilla fruticosa
Equisetum hiemalis

THE PRUNUS PUMILA DUNE ASSOCIATION

Entering into the composition of the dune-complex to the eastward of the pines are several steep mounds surrounded and capped by sand cherry (*Prunus pumila*). This plant is a very efficient dune-holder, but no examples of stages in dune formation by it were found. The occasional presence of a *Calamovilfa* at the summit indicates that, in this region at least, *Prunus pumila* dunes are formed by the replacement of a dune-originator. The fruit of the *Prunus* is eaten by a few species of birds among which are two, the song sparrow and the tree sparrow, which occasionally frequent the clumps of *Calamovilfa*. Once the *Prunus* is started, sand can be easily held by its dense growth. This is too dense for secondary species, but where there is a break, a young *Populus candicans* may be present. Occasionally on one of these dunes there is alongside of the *Prunus pumila* a bush of dogwood (*Cornus stolonifera*), which has much the same habits as the *Prunus*. The presence of the *Cornus* is due directly to birds, as this species is avevectant. The robin seems to be the most probable agent, as it has been observed eating the drupelets, and has been seen on the *Prunus* bushes while drying after a bath in the lake. The distance traversed by the dogwood amounts to nearly a kilometer.

On account of the dense growth of the dominant species, a *Prunus pumila* dune remains an isolated unit in the dune-complex. In case of the death of the *Prunus* the sand which it has held is again mobile, and a few wind storms will effect its removal.

LIST OF THE SPECIES OF THE PRUNUS PUMILA DUNE ASSOCIATION

Dominant Species

Prunus pumila
Cornus stolonifera (infrequent)

Secondary Species

Populus candicans

Relic Species

Calamovilfa longifolia (not common)

THE POPULUS CANDICANS DUNE ASSOCIATION

In a restricted area between Beach and Zion City occur the dunes of maximum hight. They are surmounted by narrow groves of balm of Gilead (*Populus candicans*). The tree trunks show no evidence of being buried. On the other hand, at the ends of the association there is every evidence to show that sand is being blown lakeward, and, to a slight degree, landward, upon an adjoining prairie or heath, as the case may be.

Populus candicans is a plant which facilitates the growth of dunes but it does not originate them. The plants of the dunes are all trees of average size. The young plants, when present on dunes at all, occur among other species, especially with *Prunus pumila*. By far the greater number of the young plants occur in the heath and the *Liatris scariosa* associations. There they grow, and by their shade the density of the ground flora is reduced. As this disappears sand is set free to the wind, and may then form a ridge dune. These dunes are quite similar to those found by Jennings (1909:338) on Presque Isle. There, however, it is cottonwood (*Populus deltoides*) that is the dune nucleus. *Populus deltoides* occurs in the Beach region along the margins of either permanent or temporary lagoons but the individuals are separated and do not show a tendency to become dune-formers. A *Populus candicans* dune is shown in the background of Figure 2, Plate XLVIII.

LIST OF THE SPECIES OF THE POPULUS CANDICANS DUNE ASSOCIATION

Dominant Species	Secondary Species
Populus candicans	*Prunus pumila*

THE ELYMUS CANADENSIS DUNE ASSOCIATION

Dunes of this type are infrequent and of little importance in this region. They are low (3 dm.) with a rather steep front towards the lake and a very gradual slope away from the lake. The crest is occupied by wild rye (*Elymus canadensis*) and the slope by that species mixed in with *Sporobolus cryptandrus* and *Artemisia caudata*. Westward of these dunes is an open area from which sand has been removed by man to the lake-level. The *Elymus* dunes keep the lake from flooding the area and the spring rains from running directly into the lake.

LIST OF THE SPECIES OF THE ELYMUS CANADENSIS DUNE ASSOCIATION

Dominant Species

Elymus canadensis

Secondary Species

Sporobolus cryptandrus
Euphorbia polygonifolia
Euphorbia corollata
Rhus toxicodendron
Artemisia caudata
Salix longifolia
Cycloloma atriplicifolium
Asclepias syriaca
Panicum virgatum

Relic Species

Cakile edentula

THE JUNIPERUS DUNES ASSOCIATION

When a small dune has been formed by some of the sand-binding plants, such as *Calamovilfa, Prunus pumila,* or, less frequently, *Andropogon scoparius,* either one or both of two species of *Juniperus* may come in and replace them, forming what is called the juniper dune. Bearberry (*Arctostaphylos uva-ursi*), a heath plant, may be present, but in this region it shows a preference for the sides rather than the crests of dunes. These plants, *Arctostaphylos* and the two species of *Juniperus,* seldom intermingle but form adjoining families in the same association. There seems to be no evidence as to which juniper appears on a dune first. *Juniperus horizontalis,* however, is by far the more abundant on the dunes, although *Juniperus communis depressa* is just as well developed. It is characteristic of juniper dunes to have the sides as well as the crest densely matted with vegetation. *Juniperus horizontalis* is especially adapted for this (see Pl. XLIX, Fig. 1). Its prostrate stems form a dense matwork of vegetation in both winter and summer, which retains considerable sand. The junipers themselves easily keep pace with the infiltration of sand, and by growing outwards permit the dune to grow radially at the same time that it is growing in hight. This figure shows a place where the wind is demolishing the dune. The *Calamovilfa* which appears midway at the left was carried there when the crest gave way to undermining. These dunes reach an altitude of three to four meters. Higher growth is difficult because most of the sand-blowing winds are parallel to rather than at right angles with the axes of the dunes.

Juniperus communis depressa dunes are less frequent and more gently sloping than those of *Juniperus horizontalis.* Their sides are

much more frequently blown away by the wind. In view of this, unless the sides are fixed with *Juniperus horizontalis* or *Arctostaphylos*, a *Juniperus communis depressa* dune is liable to be blown away, thus forming a break in the line of dunes through which the wind carries sand on to the heath behind them. At the same time, adjoining dunes of *Juniperus horizontalis* are undermined until the exposed side becomes covered with vegetation.

The junipers are the most efficient dune-builders in this region, but they can build dunes only where their westward side is protected from the prevailing winds. Normally the junipers are mat-formers in the heath association, which will be considered later, but in the presence of blowing sand they meet the change of condition by becoming dune-builders. These dunes must be closed associations, since any open place on them would be seized upon by the wind and the removal of the dune effected. The vegetation being dense and completely covering the ground, secondary species, with the exception of relics on the crests, do not occur. Of these relics, which were the nuclei about which the dune originated, *Calamovilfa* is the most frequent, with *Prunus pumila* second, and a very few plants of *Andropogon scoparius* and a single one of *Cornus stolonifera*.

LIST OF THE SPECIES OF THE JUNIPERUS DUNES ASSOCIATION

Dominant Species	Relic Species
Juniperus horizontalis	*Calamovilfa longifolia*
Juniperus communis depressa	*Prunus pumila*
Arctostaphylos uva-ursi	*Andropogon scoparius*
	Cornus stolonifera

Miscellaneous Dunes

In addition to the associations given above, which occupy about 97 per cent. of the dune areas, there are isolated dunes, each one of which is characterized by a rather definite association of plants. In each case the plants are more typical of other associations, but they grow within the range of blowing sand and consequently dunes may be formed around them.

THE POPULUS-SALIX DUNE ASSOCIATION

But two well-marked examples of this dune association, which has been described from Presque Isle by Jennings (1909), occur in the region. In both cases the dunes are low and are formed on the east-

ern border of the bunch-grass prairie, to be described later. One of these dunes was occupied by the following species: cottonwood (*Populus deltoides*) (2 meters in hight), *Salix glaucophylla, Salix syrticola* (a relic), *Calamovilfa longifolia,* and *Potentilla fruticosa.* The other example had the following plants: *Salix syrticola, Juncus balticus littoralis, Elymus canadensis, Salix longifolia, Populus deltoides,* and *Potentilla anserina.*

Once in a while a well developed *Salix glaucophylla* or *Salix longifolia* will form miniature dunes. The branches bend down to the ground, and beneath their shelter sand and debris gradually accumulate. In the debris are seeds of various plants, notably the winged ones of species of *Populus* and *Salix.* In rifts where sufficient light may be had, a number of plants which could not obtain a foothold on the open sand may get a start. The following species were observed: strawberry (*Fragaria virginiana*), rock cress (*Arabis lyrata*), fleabane (*Erigeron philadelphicus*), silverweed (*Potentilla anserina*). *Panicum virgatum, Artemisia caudata, Zizia aurea,* touch-me-not (*Impatiens biflora*), dandelion (*Taraxacum erythrospermum*), and sweet clover (*Melilotus alba*). Seedling *Populus deltoides* were also present, which indicates that a *Populus-Salix* dune is being formed. *Populus deltoides* itself when growing on sand in this region does not form dunes. Species of *Salix,* which afford a ground protection to retain sand, at the same time serve to catch *Populus* seeds. Normally a thicket should be formed, but as yet the ground is too poor in food materials to support the mesophytic species of the thicket association.

THE SALIX GLAUCOPHYLLA DUNE ASSOCIATION

A few dunes formed entirely by this plant were observed near Kenosha, one of which is shown in Figure 2, Plate XLIX. The dunes are low and elliptical in shape, while the major axis, which runs north-northwest, is about twice as long as the minor axis.

THE PANICUM VIRGATUM DUNE ASSOCIATION

During the growing season a small dune may be built up around a tuft of *Panicum virgatum,* but such dunes are temporary, as they do not withstand the winter. As a rule these dunes have no other species than the *Panicum* upon them, but occasionally *Arabis lyrata, Salix syrticola, Poa compressa* and *Poa pratensis* occur around the edges of the tuft of *Panicum.*

THE ANDROPOGON SCOPARIUS DUNE ASSOCIATION

This grass normally grows on level ground, but it may come in on the sides of dunes originated by sand-binders such as *Calamovilfa*. With the death of the *Calamovilfa, Andropogon scoparius* is left in full possession. It is efficient in holding the dune, but further growth of the dune ceases. Such dunes are at most five decimeters high.

Near Waukegan, in a place where sand has been freed from gravel, there was left a gravel mound about two meters high. The summit and nearly all of the sides are tenanted by *Andropogan scoparius* stools, in the interstices of which are several sand plants, as, for example, *Arabis lyrata, Petalostemum purpureum* f. *arenarium, Lithospermum gmelini,* etc. It has the general appearance of a developed dune, such as Jennings has described from Presque Isle, but the manner of its origin was evident.

THE POPULUS-SALIX-CORNUS THICKET DUNE ASSOCIATION

This dunelike condition exists near the state line where the lake is attacking the shore. It is not a developed dune, but the result of sand being blown in upon the *Populus-Salix-Cornus* thicket which is being cut into by the lake. The thicket reacts to the inblowing sand, however, by becoming a dense mass of liana-entwined vegetation with an advance-guard of *Salix longifolia* to check the advancing sand. Such thickets are well nigh impassable on account of the network of lianas, which in this area are wild grape (*Vitis vulpina*) and Virginia creeper (*Psedera quinquefolia*). Sand-bar willow (*Salix longifolia*) easily keeps pace with the blowing sand, but succumbs to the violence of wave action as the shore is gradually washed away. With the *Salix longifolia* are associated a few prairie plants, the roots of which are in sod buried beneath the sand. A few of the commonest are loosestrife (*Lythrum alatum*), *Panicum capillare,* white clover (*Trifolium repens*), blue vervain (*Verbena hastata*), mullen (*Verbascum thapsus*), *Polygonum lapathifolium,* sandbur (*Cenchrus caroliniannus*), and Canada thistle (*Cirsium arvense*), which in this and other places forms small dunes five to six centimeters in hight.

THE BETULA ALBA PAPYRIFERA DUNE ASSOCIATION

But two examples of this kind of a dune occur in this area. The sides are very steep and are effectually protected by a small grove of seedling trees of white birch.

RELIC DUNES*

Dunes form one of the typical stages in the construction of beaches and they may also be one of the stages in the destruction of a vegetated beach, when they may be termed "relic dunes." (See group of dunes, Pl. XLVI, Fig. 1.) The vegetation north of Winthrop Harbor is bordered on the lakeward side by a low ridge which supports a very dense growth of *Juncus balticus littoralis.* When the lake begins to cut into the beach it washes away sand from the *Juncus,* leaving an exposed bluff of densely intertangled roots. In weak spots the waves are able to wash their way entirely through the ridge of *Juncus* to the grassy plain beyond, which is easily destroyed as far as the waves have power. In places the *Juncus* is left as a mound with its sides perpendicular and densely coated with exposed roots. This is an early stage of a relic dune. (For such dune, shown in detail, see Pl. XLVI, Fig. 2.) As wave action continues, the onwash and the backwash of the waves, in combination with the wind, reduces the dune from the appearance of "A" (Fig. 1, Pl. XLVI) to that of "C," in which the sides are sloping. These summer secondary stages look very much like ordinary dunes except that they are more or less coated with exposed roots. In course of time the dune is entirely washed away. During winter the disruptive power of freezing water is an important agent in the breaking up of the dunes. The effect of a severe frost immediately following a heavy rain upon one of these dunes is shown in Figure 1, Plate XLVII.

These dunes are prominent features of the vegetation of the beach from the state line to Kenosha. With the *Juncus* are associated a few plants of relatively little importance, such as *Sporobolus cryptandrus,* Russian thistle (*Salsola kali tenuifolia*) and dogwood (*Cornus stolonifera*). Besides the *Juncus* relic dunes, there is also a single example of a relic dune formed by *Juniperus communis depressa* (see "D," Fig. 1, Pl. XLVI). Its sides are not so steep as those of the *Juncus,* and most of the vegetation is on the lakeward side. The sand that accumulates somewhat in the rear of the dune is not washed away rapidly because the dune is so near the limit of wave power. During the course of the next few decades there will be eight or ten of these *Juniperus* relic dunes, formed by both *Juniperus communis depressa* and *J. horizontalis.*

THE MAN-MADE DUNE

In order to protect the golf grounds at the southern edge of Kenosha from blowing sand, a long dune about two meters high has

*See p. 277.

been constructed and fixed by planting willows upon it. For the most part it is tenanted by species of willow, especially *Salix longifolia* and *S. glaucophylla*. The bushes form a fairly dense tangle about 1.4 meters high, and mixed with them are individuals of wild rye (*Elymus canadensis*), horsemint (*Monarda punctata*), butter and eggs (*Linaria vulgaris*), wormwood (*Artemisia caudata*) and yarrow (*Achillea millefolium*). In a few places the dune is fronted by *Juncus balticus littoralis*. Upon the west side of the dune the sodded ground extends to its base. The south end is not sufficiently well protected, and consequently the wind is undermining the willows to some extent.

THE TRAVELING DUNE

For reasons given before, this kind of a dune is not a feature of the region; in fact there is but one present in the area. Its hight above the lake-level is nine meters, and a few oaks have been partially covered by it.

The Upper Beach Associations

THE ARTEMISIA-PANICUM ASSOCIATION

This association, which is so wide-spread on Presque Isle and is of general occurrence along the shores of Lake Michigan, is but poorly represented in this region. A majority of the species mentioned by Cowles (1899:168 et seq.) occur upon it, but from 40 to 60 per cent. of the area is taken up by invading plants of the bunch-grass association, which borders and is extending rapidly into it.

Location and Physical Characteristics.—The area which stretches back from the fringing dunes, is largely composed of sand whose grains are about 0.5 mm. in diameter. The relative amount of sand decreases in going away from the lake. At the same time the relative amount of gravel increases. The change is uniform, though gradual. The *Artemisia-Panicum* association occupies the sandier parts of the upper beach, and thins out quite rapidly as the amount of gravel increases. The reverse of this is true with respect to the bunch-grass association. The sand is somewhat mobile, but not much so because of protection by the fringing dune and by the vegetation of the bunch-grass association. Water is near the surface and is easily available, but food materials dissolved in it are low in amount. The aeration of the sand, aided by the relatively large spaces between the grains and the sudden changes of temperature, is very thorough, which leads to rapid eremacausis and consequent absence of humus.

Ecological Characteristics.—Except for the absence of wave ac-

tion there is very little difference ecologically between this area and the middle beach. The habitat is dissophytic, because the underground parts of the plants are in mesophytic to hydrophytic condition according to the water content of the soil, while the upper parts are subjected to rather severe xerophytism. The desiccating effect of the wind and sun are met by adjustments in the plant structure (cf. Kearny 1900:276-280).

The Association.—The association is an open one, in which about 30 to 40 per cent. of the area is vegetated. From 30 to 50 per cent. of the vegetation is occupied by the dominant species, wormwood (*Artemisia caudata*), which gives a grayish tone to the soil. Cowles (1899:168) says that the most characteristic plants are *Artemisia caudata* and *A. canadensis*. In the Beach region, only the *A. caudata* is present. In a similar area near Rogers Park, Chicago, a few miles south, both species occur. Another dominant species, *Panicum virgatum*, which Jennings found at Cedar Point and Presque Isle, is of relatively little importance in this association in this region, although it occurs not infrequently. Its place is taken by *Sporobolus cryptandrus*, which grows in clumps somewhat like a bunch-grass. Its growth habit is illustrated by Figure 1, Plate L. This plant, however, is usually more characteristic of blowouts.

These three character species occupy about 95 per cent. of this area in typical situations of this association. Typical examples are, however, rather rare in this area. The best developed of them is about a kilometer north of the Lake County pest-house. There, this association is eight to ten meters in width and approximately twenty meters in length. Usually the invader, *Andropogon scoparius*, gives a decided character to the appearance of this association, in which it grows at intervals of two to three meters.

Of the other species which Cowles has listed as characteristic of this association, only four specimens of Pitcher's thistle (*Cirsium pitcheri*) have been found. A very few plants of beach pea (*Lathyrus maritimus*) occur here, although it is commoner on the lee slopes of the *Ammophila* dunes. A spurge (*Euphorbia polygonifolia*) is fairly abundant, although it can not be so characteristic as on the middle beach. Evening primrose, *Oenothera biennis*, does not occur in this association, and a grass (*Agropyron dasystachyum*) does not grow in the region.

Secondary species occur more or less throughout the association, but are most abundant near to the margins, where the prairie element has commenced to invade. They are not usually numerous, but frequently, because of their bright-colored flowers, seem to be nearly

dominant floristically. Such plants characterize the seasonal aspects of the association. The late-vernal and estival aspects are given by the orange flowers of puccoon (*Lithospermum gmelini*). This plant has a very long (3 or more meters), bulky tap-root, from the crown of which grow many spreading stems. It does not occur so frequently in the typical parts of the association as it does in the tension line, which the bunch-grass is rapidly pushing outwards. The serotinal aspect is characterized by the blooming of the yellow flowers of a goldenrod (*Solidago nemoralis*). This plant also is much more characteristic of the bunch-grass sand areas. The autumnal aspect is given by the blooming of *Sporobolus cryptandrus* and of *Artemisia caudata*.

In addition to those secondary species that give character to the different seasonal aspects, there are a few other species, typical of different associations, that are of importance in showing the past stages and in indicating the future successions.

LIST OF THE SPECIES OF THE ARTEMISIA-PANICUM ASSOCIATION

Dominant Species

Artemisia caudata
Panicum virgatum
Sporobolus cryptandrus

Secondary Species

Cirsium pitcheri
Lathyrus maritimus
Euphorbia polygonifolia
Lithospermum gmelini
Arenaria stricta
Cycloloma atriplicifolium
Equisetum hiemale
Arabis lyrata
Petalostemum purpureum f. *arenarium*

Relic Species

Euphorbia polygonifolia
Prunus pumila
Calamovilfa longifolia

Invading Species

Andropogon scoparius (at intervals of 2-3 meters)
Lithospermum gmelini
Arenaria stricta
Solidago nemoralis
Liatris scariosa (few)
Potentilla fruticosa
Poa compressa
Aster dumosus
Arctostaphylos uva-ursi (few)
Juniperus horizontalis (a few patches)

THE BUNCH-GRASS ASSOCIATION

The Andropogon scoparius Consocies

Location and Physical Characteristics.—Immediately westward of

the usually poorly developed *Artemisia-Panicum* association lies a more or less gravelly or pebbly area, whose vegetative appearance is characterized by the stools of *Andropogon scoparius*. The physiographic appearance gives every indication that the area was at one time part of the beach. Later it was covered with drifting sand, and it is now being gradually uncovered by the very slow movement of the fringing dune towards the lake. Because of its past history it is given the name, "fossil beach," in allusion to the corresponding geological term. The pebbles and the gravel of which its surface is composed are all well-rounded and flattened, clearly indicating the former presence of surf. The largest of these pebbles are about 15 cm. in diameter and 2-3 cm. in thickness. Almost all of them are made up of granites, quartz, and, less frequently, shales and sandstones. From between them the wind has gradually removed the mobile sand, which is taken to the lakeward side of the fringing dune. So much sand has been removed that now the pebbles are very frequently perched upon little hills a few millimeters in hight. Investigation has shown that the sand in these little "tees," to use a golfing term, is virtually damp clear to the surface. The pebble itself affords the tee protection from the drying effects of the direct rays of the sun. In the protection thus afforded, spiders as well as some small insects spend the hotter part of the day. Rain drains very rapidly through this soil.

Ecological Characteristics.—What has been said of the ecological characteristics of the *Artemisia-Panicum* association will apply here also. The habitat is dissophytic, but the above-ground part is not quite so xerophytic as in the other association. Humification—rather than eremacausis, which is the rule in the *Artemisia-Panicum* association—is beginning to take place. Lack of sufficient food material seemed to be the most potent cause for the openness of the vegetation.

The Association.—The bunch-grass association is a typical prairie one, and, of course, is better represented in areas farther west. The bunch-grass association of the prairie vegetation is the pioneer both of the prairie and the forest type of vegetation. It can maintain itself on fossil beaches and readily invades the upper beach. Meanwhile it adds humus to the soil and prepares the way for successions to a more advanced type of prairie or to a heath or to a forest. Which succeeds, depends upon several factors, among which are proximity, means of dispersal of the invaders, and the ability of the invaders to effect ecesis. The association itself has for its dominant species a grass which grows in tufts or bunches. According to the specific identity of the bunch-grass, the association is divided into

consocies. Some of these have been described for southeastern South Dakota by Harvey (1908) and for the Illinois sand areas by Gleason (1910). Of these consocies only one appears as a definite part of the region in this area. That is the *Andropogon scoparius* consocies, which has been described as a pioneer of prairie vegetation by Harvey (1908:287). There are, however, clear indications that other consocies have been represented which are now succeeded by forest associations. Some of the bunch-grasses, which were once dominant species, are now relics, living as secondary species in the *Quercus velutina* woods.

The association itself is open, since but 25 to 40 per cent. of the area is vegetated. Approximately 90 per cent. of the vegetated area is occupied by the dominant species, *Andropogon scoparius*. The secondary species may be more numerous, but they are interstitials that occupy very little surface. Figure 2, Plate L, shows the general appearance of the association throughout the year, and exhibits the manner of growth of the dominant species.

Andropogon scoparius.—As shown in Figure 2, Plate L, this grass is a typical bunch-grass. The dead leaves remain over winter and until the new leaves grow. They do not seem to be capable of retaining blowing sand, and so this grass is not a dune-former. It can fix dunes, however, but not until the dune has been built up by some regular dune-former. The plant spreads radially, but very slowly as it has no runners. The spreading continues until the diameter of the stool, or bunch, is from 3.0 to 3.5 decimeters. It does not often grow larger than this. Occasionally bunches are to be found in which the central part is dead, the circle of stems around it forming a small fairy ring. Other plants become established in the center, and tend to lead to the gradual replacement of the bunch-grass. *Arabis lyrata* and shrubby cinquefoil (*Potentilla fruticosa*), an invader, are most frequent in this rôle. Others that have been found so situated are *Arenaria stricta, Oenothera rhombipetala,* blue-eyed grass (*Sisyrinchium* sp.?), and *Artemisia caudata*. In this area the bunches themselves are always separated, usually by about eight to nine decimeters The more pebbly the area, the greater the tendency for the bunches to be nearer together, but seldom closer than five decimeters. The bunches which are invading the *Artemisia-Panicum* are developed just as well as those in the bunch-grass itself.

The area between the bunches is occupied by interstitials, which, however, are not sufficiently abundant to prevent the sand from giving the general color-tone. In point of numbers rock cress (*Arabis lyrata*) is most abundant. When it is well in bloom, in May, the

white flowers considerably lighten the general dull gray tone of the dead leaves of the *Andropogon*. This is the vernal aspect. Next to secure color prominence is *Lithospermum gmelini*, which blooms during June and July. This plant is not actually abundant in the typical part of the association, but its manner of growing and the abundance of its brilliant orange flowers are easily misleading in determining the importance of the species in the association. It is most abundant near the tension line, towards the outside of the association. Although this plant has neither dune-forming nor dune-fixing abilities, it seems most at home where this association is invading the lower parts of the dune-complex near Beach. There it occurs at frequent intervals, without apparent discrimination between the lower places and the sides of the dunes. Occasionally it is present on the tops of some of the smaller dunes. Seedlings of this species can be found in various situations, although they are most frequent in depressions. The root system of *Lithospermum gmelini* can withstand a moderate amount of either burying or uncovering, so that the plant can easily tenant the dune-complexes of the region which are protected from the westerly winds by the area of the pines. It seems to fulfill the position of pioneer to the *Andropogon scoparius* consocies of the bunch-grass association. *Cycloloma atriplicifolium*, *Petalostemum purpureum* f. *arenarium*, and *Arenaria stricta* play the same rôle, but to a less marked degree.

The estival aspect of this consocies is characterized by the blooming of the *Andropogon scoparius* itself, and of the interstitial *Petalostemum purpureum* f. *arenarium* (sand-prairie clover). The latter species, which is typically a prairie plant, exhibits marked xerophytic adaptations in several particulars—so much so that a detailed description is necessary, and it is here given in the form of a table.*

PETALOSTEMUM PURPUREUM f. arenarium FORMA NOVA.

	Petalostemum purpureum (Prairie plant)	*Petalostemum purpureum* f. arenarium (Sand-prairie plant)
Root	tap root	larger and more bulky tap root
Crown	composed of a few upright stems	composed of many (20-38) radiating stems
Stems	stout and upright	shorter, wiry, divaricate, *i. e.*, standing at an angle of less than 45° with the earth from the commencement of growth. When growing on little hillocks the stems project below the horizontal
Leaves	divaricate, lancolate-trifoliolate	appressed, linear-trifoliolate
Heads	cylindrical, larger	cylindrical, smaller relatively
Flowers and Fruit	no appreciable differences	

*This table is taken from the original description of this new form, in Torreya, 11:125-128, June, 1911.

The appearance of the sand form is very different from that of the prairie type, but the differences are due to the edaphic xerophytic conditions under which it grows. In places where this association has been succeeded by trees which have induced milder xerophytic conditions the *Petalostemum,* although still growing in nearly pure sand, is about normal in appearance. Figure 1, Plate LI shows a plant of this form in which the stems form an angle of from 5° to 15° with the sand level. In some cases sand and debris have been piled up above the crown, while sand beyond the protection of the stems has been blown away. In such places the *Petalostemum,* when growing prone, makes a negative angle with the general level. In general the individual plants grow apart, but on the gravel, where there is almost no exposed sand, they grow so close together that the heads overlap and form a tangled layer about a decimeter above the gravel level. Such situations are frequent hiding-places for savanna and song sparrows. The heads of the *Petalostemum* seem usually to be infested with a small green caterpillar, and the leaves with tent-weaving larvæ.

In the serotinal aspect, *Petalostemum* continues to dominate the more gravelly parts, but in other places a goldenrod (*Solidago nemoralis*) comes into prominence. The bright white pappus of the fruits of both *Andropogon scoparius* and *Solidago nemoralis* are characteristic of the autumnal aspect. Neither of these plants loses its seeds until after the sharp winter frosts. With the return of winter the association assumes a dull gray color of dead leaves which resembles in some particulars the arid brush-lands of the West.

List of the Species of the Andropogon scoparius Consocies of the Bunch-grass Association

Dominant Species

Andropogon scoparius

Secondary Species

Arabis lyrata
Arenaria stricta
Oenothera rhombipetala
Lithospermum gmelini
Petalostemum purpureum f. *arenarium*
Solidago nemoralis
Euphorbia corollata
Aster sericeus
Elymus canadensis
Cycloloma atriplicifolium
Hypericum kalmianum
Oenothera biennis (very few)
Prunus pumila
Aster multiflorus
Mosses (unidentified)

Relic Species

Artemisia caudata
Salix syrticola
Salix glaucophylla (not common)
Juncus balticus littoralis (not common)
Calamovilfa longifolia (as individuals rather than in bunches)
Sporobolus cryptandrus

Invading Species

Potentilla fruticosa
Sisyrinchium sp.?
Populus deltoides (small)
Salix longifolia
Juniperus communis depressa (few)
Juniperus horizontalis (few)

The Sporobolus heterolepis-Sorghastrum nutans Consocies

This consocies, which has been more widely extended in the past than it is at present, is quite similar to ordinary prairie. For the most part the consocies has been succeeded by *Quercus velutina,* but in a few places between the oak ridges there still remain small characteristic areas of it. Four bunch-grasses are its dominant species. The two after which it is named are most abundant. The others are *Andropogon scoparius* and *A. furcatus.* The largest and most conspicuous of the bunch-grasses is *Sorghastrum nutans,* which grows in tufts rather than bunches. It is, perhaps, the most persistent as a relic in the association that has followed. *Sporobolus heterolepis* itself grows in rather good-sized bunches which are usually ringlike, the open area in the center being a flat mound of blackish dirt. The stems and leaves are thin and wiry, and the plant as a whole has a rather delicate appearance. In parts of this region this grass may occupy 60 per cent. of the area. *Andropogon furcatus,* which grows in small bunches, aids in giving a general character to the area, but it is the least important of the four bunch-grasses mentioned. It seldom occupies more than 10 per cent. of the area, but it will persist under the oaks almost as well as the *Sorghastrum. Andropogon scoparius,* whose bunches have already been described, occupies from 30 to 50 per cent. of the area. It is smaller in size and does not give so much character to the vegetation. It grows out in the open parts of the association and, while it does persist in the *Quercus velutina* association, it does so only in the open places. In the autumnal aspect these four bunch-grasses occupy about 97 per cent. of the area, the remaining 3 per cent. being secondary species. Some of the latter are interstitials, as *Arenaria stricta*; others are grasses, as *Spartina michauxiana* and *Poa compressa*; and still others are invaders from

nearby prairies and forest, as *Potentilla fruticosa* and small plants of *Quercus velutina*. *Solidago rigida* and *S. nemoralis* occur, but not in sufficient numbers to produce the usual color-dominance. Other prairie plants occur, but very little sod is being formed. *Quercus velutina* seedlings develop readily.

List of the Species of the Sporobolus heterolepis-Sorghastrum nutans Consocies of the Bunch-grass Association

(Of the typical portion only)

Dominant Species

Sporobolus heterolepis
Sorghastrum nutans
Andropogon scoparius
Andropogon furcatus

Secondary Species

Panicum virgatum
Solidago rigida
Solidago nemoralis
Spartina michauxiana
Koeleria cristata
Aster ptarmicoides
Polygonum tenue
Amorpha canescens
Euphorbia corollata
Solidago speciosa angustata

Relic Species

Sporobolus cryptandrus

Invading Species

Quercus velutina
Liatris scariosa
Potentilla fruticosa
Lobelia spicata
Potentilla arguta
Comandra umbellata

THE LIATRIS SCARIOSA ASSOCIATION

Following the *Artemisia-Panicum* association or either of the consocies of the bunch-grass association, is another association of xerophytic plants, the *Liatris scariosa* association.

Location.—This association is found particularly upon the sand ridges farther inland than the fringing dune. It is best developed toward the southern part of the region, where it dominates the ridges of nearly pure sand. Toward the northern parts of the region the black oak has obtained dominance on the sand ridges, although the *Liatris scariosa* association may remain coexistent with it, but occupying the open spaces between the trees.

Physical Characteristics.—The soil occupied by this association is essentially sand to which a little humus has been added, though not

in sufficient quantity to change the color. The ground is protected from the lake by the fringing dune. The ridges, which parallel the bluff, are low (1-5 dm.) and usually free from blowing, but occasionally small blowouts are developed.

Ecological Characteristics.—The vegetation is essentially open, and consists mostly of upright plants half a meter or more high. Toward the sides of the ridges, where the soil contains more humus, are invaders of more typical prairie associations. The plants of this association need a maximum of light and consequently do not long withstand the shade of invading oaks. Yet the vegetation is relatively so open that the *Liatris scariosa* association forms one of the important pathways for the spreading of the oak woods. The stations of its best development are separated from the main body of the oaks by the area of the pines. The latter has acted as a partial barrier in retarding the development of the black oaks on the ridges between Waukegan and Beach.

The Association.—This association has been named from its most imposing species, blazing star (*Liatris scariosa*). This plant, with its large purplish spikes, is thoroughly dominant in the serotinal and autumnal aspects. During the estival and early serotinal seasons the white blossoms of flowering spurge (*Euphorbia corollata*) are almost equally conspicuous. A few other species of less importance are typically charcteristic of the association, such as *Castilleja sessiliflora, Liatris cylindracea,* lead plant (*Amorpha canescens*), bush clover (*Lespedeza capitata*), and black-eyed Susan (*Rudbeckia hirta*). In addition to these, almost any sand-preferring plant may be found in greater or less abundance in this association. The lines of succession leading from this association may proceed to any of the three provinces represented in this region. In the northern part of the region the succeeding association is usually the oak forest; in the vicinity of Beach it may be the heath or, to a much smaller extent, the pine woods; and near Waukegan it is usually the prairie associations, such as the *Liatris spicata,* each one of which will be described later.

LIST OF THE SPECIES OF THE LIATRIS SCARIOSA ASSOCIATION

Dominant Species

Liatris scariosa
Castilleja sessiliflora
Euphorbia corollata
Oenothera rhombipetala
Lespedeza capitata

Secondary Species

Amorpha canescens
Acerates viridiflora
Aster multiflorus
Andropogon furcatus

Aster azureus
Rudbeckia hirta
Solidago nemoralis
Panicum huachucae (in blowing sand)
Tradescantia reflexa
Liatris cylindracea
Carex umbellata
Potentilla arguta
Asclepias amplexicaulis
Silene antirrhina
Polygonum tenue

Relic Species

Koeleria cristata
Lithospermum gmelini
Panicum virgatum
Calamovilfa longifolia
Salix glaucophylla
Juncus balticus littoralis
Cycloloma atriplicifolium
Andropogon scoparius

Relic species persisting in places in which this association develops after oaks have been cleared off

Anemone cylindrica
Helianthus occidentalis
Lupinus perennis
Smilacina stellata
Hieracium canadense

Invading Species

Arctostaphylos uva-ursi
Juniperus horizontalis
Betula alba papyrifera
Potentilla fruticosa
Lobelia spicata
Linum virginianum
Aster ptarmicoides
Petalostemum candidum
Petalostemum purpureum
Comandra umbellata
Silphium integrifolium
Quercus velutina
Rhus toxicodendron
Fragaria virginiana
Asparagus officinalis (avevectant under very small *Q. velutina*)
Poa compressa

THE POA COMPRESSA ASSOCIATION

The sand-plain which stretches inland from the limit of storm wave-action, particularly from the state line to Kenosha, is characterized by a light sod of English blue grass (*Poa compressa*) rather than by blazing star (*Liatris scariosa*) or black oak. Farther inland this association may also occur on ridges from which the black oaks have been removed.

Physical Characteristics.—The ground on which this association occurs is quite pure sand, made more or less yellowish by the admixture of a substance which tends to cement the sand grains together. Occasionally there are deposits of what appears to be guano, al-

though this region is no longer a breeding place for gulls. The sand-plain is very flat, and slopes down away from the lake rather than towards it. Ordinarily the sand is fixed; but when storm waves are able to effect entrance, the sand is released and is usually blown into the lake.

Ecological Characteristics.—A comparatively thin growth of grass sufficiently dense to prevent blowing but not sufficiently dense to obscure the yellowish color of the sand, is the prevailing feature of this association. Secondary species occur here and there but are nowhere of much importance, since they occur as scattered individuals among the grass plants, which form about 90 per cent. of the area. Near the lake the grass plants are separated two to three centimeters (see foreground, Fig. 1, Pl. XLVI). On the ridges nearer the western boundary, however, the grass plants grow much closer together and form a true sod, which is usually effective in preventing further succession.

The Association.—The grass, *Poa compressa,* is the dominant species and thoroughly characterizes the association. The secondary species are, for the most part, merely sand plants which happen to become established. Some of them are relics of the *Quercus velutina* association in places where oaks have been removed, others are normal beach-plants, and several are weeds that grow readily in sandy ground. Ecesis (establishment) is not difficult for the weeds, since the ground is so open. A few species are indicative of successions. Near the lake the presence of small plants of *Juniperus horizontalis* and *J. communis depressa* look toward a heath, but in some other places the dense growth of this grass has been responsible for the dying out of the junipers. On the ridges farther inland the occasional presence of seedling trees indicates the approaching development of a forest.

LIST OF THE SPECIES OF THE POA COMPRESSA ASSOCIATION

Dominant Species

Poa compressa

The most important secondary species near the lake shore

Monarda punctata — *Cenchrus carolinianus*
Sporobolus cryptandrus

Other secondary species near the lake shore

Verbena hastata — *Achillea millefolium*
Erigeron canadensis — *Anaphalis margaritacea*

Verbascum thapsus
Cacalia tuberosa
Panicum sp.?
Erigeron divaricatus
Poa pratensis
Rumex acetosella
Draba caroliniana
Oxalis stricta (very small plants)
Scutellaria parvula
Hypericum kalmianum
Potentilla arguta
Euphorbia corollata

Invading species living near the lake shore

Pycnanthemum virginianum
Juniperus horizontalis
Juniperus communis depressa
Lobelia spicata
Isanthus brachiatus

Secondary species in the inland areas

Rudbeckia hirta
Oenothera biennis
Euphorbia corollata
Koeleria cristata
Verbascum thapsus
Achillea millefolium
Erigeron annuus
Erigeron canadensis
Erigeron ramosus
Cyperus filiculmis macilentus
Poa pratensis
Plantago major
Rumex acetosella
Lepidium apetalum
Rosa humilis
Ambrosia artemisiaefolia
Aster dumosus
Helianthemum majus
Juncus tenuis
Oxalis stricta (dwarfed plants)
Trifolium repens
Panicum scribnerianum
Rumex crispus
Solidago serotina
Euphorbia maculata
Fragaria virginiana
Cirsium arvense
Digitaria sanguinalis
Desmodium illinoense

Relic species in the inland areas

Juncus balticus littoralis
Lithospermum gmelini
Juniperus communis depressa
Juniperus horizontalis

Invading species living in the inland areas

Lobelia spicata
Potentilla arguta
Verbena hastata
Solidago graminifolia
Allium cernuum (rare)
Aster azureus
Helianthus grosseserratus
Prunella vulgaris (much dwarfed)
Monarda mollis
Vitis vulpina
Sambucus canadensis (small)
Salix spp. (seedlings)
Quercus velutina (seedlings)
Juglans nigra (seedlings)
Carya ovata (a few seedlings)
Crataegus punctata (a few seedlings)

THE ARCTOSTAPHYLOS-JUNIPERUS HEATH ASSOCIATION

Following Warming, a heath may be defined as an area of low, evergreen vegetation. In Europe the heaths are composed mainly of ericaceous plants. In this area, the vegetative structure is similar, but the ericaceous plants play more of a secondary part.

Location.—The heath is best developed in the part of the region near Beach, where it covers what has been a dune-complex. It is becoming well developed on the present dune-complex, which is sheltered by the pine forest. Thence the heath extends south behind the bunch-grass until it disappears a little north of Waukegan. Towards the south its development is mostly in patches rather than a general condition. North of Zion City the heath exists as relic patches, of which there are but a few.

Physical Characteristics.—The heath usually appears as sandy ground almost entirely carpeted with low, shrubby, evergreen plants, such as are in the foreground of Figure 1, Plate LII. The color tone is dark green, especially in the winter. The sand is somewhat darker in color on account of the admixture with debris and humus materials.

Ecological Characteristics.—Invading heath plants are in epharmony (close accord) with the ecological conditions which they encounter. Once they become established, however, they bring about radical changes, the most important of which is the institution of humification rather than eremacausis. Blowing sand, leaves, and debris are caught and held between the branches of the heaths. For this reason, if nothing interferes, a heath is usually growing upward in hight. Although the ground is carpeted, there is still sufficient room for interstitials.

The Association.—In this area three species characterize the heath. *Juniperus horizontalis* and bearberry (*Arctostaphylos uva-ursi*) are of prime importance, while *Juniperus communis depressa* is less so. The first two are essentially mat-formers, while the *J. communis depressa* usually forms a table, elevated two to four decimeters above the surroundings. *J. horizontalis* forms large mats by growing radially. The runners, as the branches may be termed, take root at intervals. This results in a gradual movement of the whole plant. In the larger mats the central area is dead, and in some instances has given rise to blowouts. Often, however, the center may be occupied by a normally developed plant of *Juniperus communis depressa*. It is evident that this came in last because of the dead stems of the *J. horizontalis* which remain under it. A well-developed *J. communis depressa* so excludes the light that no plants will germinate or grow under it. The runners of the *J. horizontalis* send up twigs

which bear the leaves. The leaves of the season are more or less coated with a bloom which gives them a somewhat whitish appearance. The tips of the runners project into the air at an angle of about 25° to 30°. Should blowing sand encounter them a small ridge is built. Between these runners debris accumulates fairly rapidly, and as it is not blown away during the winter it contributes to the enrichment of the soil. Many seeds also are retained, and when proper conditions are attained they grow. Some of them may replace the heath altogether. This juniper, as well as the other two heath plants, has seeds which are eaten by birds, although the birds seem to prefer the bright red berries of *Arctostaphylos*. The latter plant, known as the bearberry, is of second importance. What has been said about *Juniperus horizontalis* applies here almost equally well. The development of the runners is not so noticeable, however, and a greater amount of debris is retained in its denser network of branches.

The development of *Juniperus communis depressa* reminds one very strongly of the development of conifers near the tree line in Lapland (Kihlman, 1890). The truncated top of this plant is characteristic of all the individuals wherever they are growing. Some of these tables are a little over a meter in diameter. They vary in hight from about two decimeters up to nearly a meter. The explanation which Kihlman found to solve the problem in Lapland has no bearing in this case, however, for it seldom happens that there is sufficient snow in winter to cover even the lowest of these tables. The explanation lies more probably in the fact that this growth is a germ character of the species, for, in so far as evidence is at hand, edaphic factors merely change the amount of growth and not its manner.

For northern Michigan, where the heath is much better represented than in this region, Whitford (1901:298) lists the character plants as follows: *Juniperus communis, J. horizontalis, Arctostaphylos uva-ursi,* bracken (*Pteris aquilina*), *Zygadenus chloranthus, Solidago nemoralis,* bluebell (*Campanula rotundifolia*), and *Comandra umbellata.* Of the eight species, five occur in the Beach area, and four of these are important members of the heath association.

Secondary species in this association are not very numerous and very few of them are typical of the association. They are either relics of past associations or invaders of succeeding ones. In no case do they add to the general character of the vegetation, although they may greatly change the appearance of individual parts.

The health plants come in on *Calamovilfa* or *Prunus pumila* dunes, which they work over into *Juniperus* dunes. In the meantime the plants spread from the dune over the interdunal spaces. When these

become covered or nearly so, the dune-complex has been changed into a heath. Blowouts occurring in the heath are, in general, revegetated with heath plants rather than with invaders. This will be discussed later, under the general topic of blowouts.

This association is a transitory one of northern affinities, and all the evidence goes to show that it is very gradually being driven entirely from the region. In the northern part of this area it has disappeared already. In the central part north of Dead Lake the *Quercus velutina* association is taking its place. For a little ways south of Dead Lake it is being slowly replaced by pine trees. The only places where the heath is reproducing itself are still farther south, although at the same time the prairie is coming in from the westward more rapidly to take its place.

LIST OF THE SPECIES OF THE HEATH ASSOCIATION

Dominant Species

Juniperus horizontalis
Arctostaphylos uva-ursi
Juniperus communis depressa
Juniperus virginiana (one plant)

Secondary Species

Solidago nemoralis
Petalostemum purpureum f. *arenarium*

Relic Species

Andropogon scoparius
Calamovilfa longifolia
Salix glaucophylla
Koeleria cristata
Salix syrticola
Prunus pumila
Artemisia caudata
Juncus balticus littoralis
Sorghastrum nutans

Invading Species

Ceanothus americanus
Populus deltoides (1.5 m. high)
Quercus velutina
Potentilla fruticosa
Aster ptarmicoides
Panicum virgatum
Populus candicans (0.6 m. high)
Liatris scariosa
Pinus strobus
Pinus laricio
Pinus silvestris
Poa compressa
Hypericum kalmianum
Aster azureus
Tilia americana (one plant 0.5 m. high)

THE PINE FOREST ASSOCIATION

General Location and *History*.—South of the Dead Lake there is approximately a square mile of ground forested by coniferous trees,

forming the pine association. Its present extent is much less than formerly. This is due to cutting, burning, erosion by the lake, and to natural successions. Of the three species of conifers that form the greater part of the association, only one is native to the region. This species, *Pinus strobus,* was formerly relatively common, but is now represented only by a few rather old trees in isolated situations. From the taxonomic nature of the other three species, *Pinus laricio* and *Pinus silvestris* and *Pinus* sp.? it is evident that they have, at some past time, been planted there by man. It has been difficult to secure accurate evidence as to the date, but it was probably sixty or seventy years ago. As long as the groves were taken care of the pines flourished; but with neglect and succession they are slowly disappearing.

Physical and Ecological Characteristics.—The pine association occurs on sandy soil and especially on the ridges of sand. Here, for the first time, there is a definite differentiation between the soil and the subsoil. Where the pines are densest there is a carpet of pine needles, which are gradually being converted into humus. The trees afford plenty of protection for ground plants, but at the same time cut off so much light that ground plants can only occur in the interstices between the trees and in places where a tree has been removed or cut, thus permitting more light to reach the ground. As a result of the ground-covering, water is easily retained and conditions in general are less xerophytic than those on the heath.

The Association.—This association is a representative of the boreal element which has remained as a relic of the postglacial coniferous forests which at one time were dominant in this region. In places where the pines are dense, the association is more typical of its appearance in the northern regions. There are usually few or no secondary species in such situations. The exceptions are false Solomon's seal (*Smilacina stellata*), *Anemone cylindrica,* and *Poa compressa.* The ground is carpeted with needles and pine cones. In places where this association is more open, as along the ridges, there is an abundance of secondary species, all of which represent succeeding associations. Which association does follow, is, of course, determined by the number and nature of the secondary species. In the ridges towards the southward, where the soil is more xerophytic, prairie plants surround the pine trees and often occupy the ground clear up to the trunk of the trees. (Pl. LVI, Fig. 2.) In such places it is impossible for the pine to reproduce itself, as the seeds can not get down to the ground on account of the tangle of prairie grass, debris, etc. As long as the pine trees live, they give the character to the area; when they die, the prairie dominates entirely. Toward the northward, although

there are many prairie species around the trees, there are plenty of young oaks, *Quercus velutina,* in all stages of development. They grow quite easily and are able to replace the pine—not merely to dominate the region with the dying of the pines as is the case with the prairie plants. In the openings in the denser parts of the pine area, the pioneer species that come in are forerunners of both the prairie and the oak forest. Seedling oaks are rather plentiful and occur at various distances from the parent trees, from which acorns were probably carried and stored by birds, especially crows and blue jays. If the oaks are present in any number they determine which succession is to take place.

Pinus strobus occurs rather commonly throughout the association, but it is rather more abundant in the more xerophytic and less fertile soils. It acts as a pioneer for this association, and even now is very gradually reproducing itself on the edges of the prairie and marshes or in broken places in the prairie. This, however, is taking place much more slowly than the occupation of the pine land by oaks. The densest growth of pine is formed largely of *Pinus laricio* and *Pinus silvestris,* growing in separate groves.

LIST OF THE SPECIES OF THE PINE FOREST ASSOCIATION

Dominant Species

Pinus strobus
Pinus laricio
Pinus silvestris
Pinus sp.?
Larix decidua

Secondary Species

Smilacina stellata
Oenothera rhombipetala
Anemone cylindrica
Polygonatum commutatum
Aster azureus

Relic species which are very abundant

Juniperus communis depressa
Juniperus horizontalis
Arctostaphylos uva-ursi
Solidago nemoralis
Euphorbia corollata
Lithospermum gmelini

Relic species which are not abundant

Elymus canadensis
Aster dumosus
Prunus pumila
Salix glaucophylla
Juncus balticus littoralis
Panicum virgatum
Artemisia caudata
Salix syrticola
Arabis lyrata
Sorghastrum nutans
Calamovilfa longifolia
Koeleria cristata

Invading species from the prairie and prairie-like associations

Liatris scariosa
Potentilla fruticosa
Poa compressa
Poa pratensis
Trifolium hybridum
Plantago major
Pycnanthemum virginianum
Taraxacum erythrospermum
Lobelia spicata
Saturcja glabra
Zizia aurea
Hypoxis hirsuta
Sisyrinchium sp.?
Phlox pilosa
Castilleja sessiliflora
Tradescantia reflexa
Comandra umbellata
Ceanothus ovatus
Epilobium densum
Equisetum laevigatum

Invading species from the oak forest

Helianthemum majus
Fragaria virginiana
Rubus occidentalis
Verbascum thapsus
Rumex acetosella
Quercus velutina
Salix spp.
Asparagus officinalis
Solidago serotina
Lonicera dioica
Vitis vulpina
Maianthemum canadense
Luzula campestris multiflora
Helianthus occidentalis f. *illinoensis*
Ceanothus americanus
Geranium carolinianum
Lactuca canadensis
Rosa humilis
Pedicularis canadensis

THE QUERCUS VELUTINA ASSOCIATION

As the climax stage of the successions on the ridges of the sand-plain, this forest association exists. The association obtains its start in either of the prairie or coniferous types of vegetation, quite often in broken places in them. It can obtain a slight foothold upon open sand, but more usually the young oaks obtain their foothold in the humus of the prairie or the pines. Development then is quite certain. It is rather more rapid in the prairie situations. As development proceeds the prairie gives way. After a time the ground begins to be more open as the ground-carpet disintegrates to a greater or less extent. Thereupon eremacausis, at least with respect to the upper layers of ground, begins again to be the usual state of affairs. This, coupled with the winds of the more violent storms, causes the surface to reassume a sandy appearance. The sand itself is more or less easily blown, especially where the removal of any of the trees permits a more open exposure. Such blowing results in the formation of what are known as blowouts. While the upper layers may be sandy and the secondary vegetation that of true sand ridges, in which there has

been no intervening prairie stage, the subsoil in which the oaks are rooted is distinctly humic in nature. The secondary species, however, consist of both prairie and sand plants, some of the latter of which, as *Juncus balticus littoralis,* may have persisted through the prairie stage. The same thing happens with respect to the heath. As soon as the oak becomes dominant, by its foliage, light is cut off from the heath plants, and consequently the heath is gradually replaced. With the disappearance of the heath plants the sand is left exposed to blowing. In such situations blowouts are very common. The invasion of the pines takes place much slower because that necessitates the dying of the old pine trees. The oaks can not drive these out as they can the herbaceous vegetation. The young pines can not germinate or develop under the shade of the oaks, which results in the extinction of the pines by the dying of the old trees. As soon as a pine dies, young oaks spring up in its place. They could not do this before on account of the great shade from the pine. Once sufficient light is allowed, the oaks very rapidly replace the spot with trees, against which invasion, in this region, the pines can do nothing.

The *Liatris scariosa* association may develop contemporaneously with the *Quercus velutina,* but usually *Liatris scariosa* develops first, and as it is a fairly open association the *Quercus velutina* quite readily invades it. It retains nearly all of its identity, however, even after invasion, because there is not as yet sufficient food material to support a dense growth of oak. As soon as the oak does become dense, the *Liatris scariosa* gives way.

In its primary stages the *Quercus velutina* association occupies stable sandy soil where humification is the rule. The humus, however, is not abundant, and consequently a luxuriant undergrowth is not developed. Protection against wind and sun is afforded, resulting in a flora somewhat mesophytic in tendency, but the succession of this association to a distinctly mesophytic one requires a space of very many years. In the mature stages of the development of this association humification is very slow and may be absent. The oaks themselves are well developed but their shade keeps out sand plants which would make a dense ground covering, while there is not sufficient food material in the soil to permit the growth of mesophytic forms which require the amount of shade that the oaks furnish. For these reasons eremacausis again takes hold and very materially increases the length of time between this association and the one that will finally succeed it.

Because of its great diversity of environments this association has a large number of secondary species, many of which belong more properly to the associations which the black oak has displaced. The

association is characterized by the black oak, *Quercus velutina,* which is the only dominant species of this association in this region. Other trees are virtually never present. Occasionally a few *Pinus strobus* do remain as relics, and a few trees of *Quercus macrocarpa* and *Q. alba* occupy a mound north of Winthrop Harbor.

The *Quercus velutina* association, as it is found in the Beach region, accords in all essential particulars with Jennings's associations of the same name on Cedar Point, Ohio, and Presque Isle, Pennsylvania (1908 and 1909). The same association occurs throughout Illinois and southern Wisconsin in glaciated land which is xerophytic in nature. In different parts of its range other species of oak also may become dominant, as, for example, *Quercus marilandica* in Mason County, but *Quercus velutina* usually predominates.

LIST OF THE SPECIES OF THE QUERCUS VELUTINA ASSOCIATION

Dominant Species

Quercus velutina

Secondary species which are most characteristic

Achillea millefolium
Amorpha canescens
Anemone cylindrica
Aralia nudicaulis
Arabis lyrata
Asclepias tuberosa
Asparagus officinalis
Aster azureus
Aster sericeus
Baptisia leucantha
Ceanothus americanus
Celastrus scandens
Coreopsis lanceolata
Coreopsis palmata
Desmodium illinoense
Erigeron ramosus
Euphorbia corollata
Fragaria virginiana
Gerardia grandiflora
Gerardia pedicularis
Helianthemum majus
Helianthus divaricatus
Helianthus occidentalis
Lechea leggettii
Lupinus perennis
Lepachys pinnata
Luzula campestris multiflora
Monarda fistulosa
Monarda sp.?
Mosses (unidentified)
Panicum scribnerianum
Pedicularis canadensis
Physalis virginiana
Polygonatum commutatum
Potentilla arguta
Rhus toxicodendron
Rosa humilis
Rudbeckia hirta
Scrophularia leporella
Scutellaria parvula
Silene antirrhina
Silene stellata
Smilacina stellata
Solidago arguta
Solidago serotina
Taraxacum erythrospermum

Helianthus occidentalis f. *illinoensis*
Helianthus strumosus
Heuchera hispida
Lactuca canadensis
Tradescantia reflexa
Maianthemum canadense
Verbascum thapsus
Vitis vulpina
Zizia aurea

Relic species which are most abundant

Arctostaphylos uva-ursi
Juniperus communis depressa
Juniperus horizontalis
Kocleria cristata
Lespedeza capitata
Liatris scariosa
Lithospermum gmelini
Oenothera rhombipetala
Panicum virgatum
Panicum spp.
Poa compressa
Solidago nemoralis

Secondary species which are less characteristic

Antennaria sp.?
Arenaria stricta
Asclepias syriaca
Aster novae-angliae
Carex bebbii
Chenopodium album
Convolvulus sepium
Equisetum arvense
Erigeron canadensis
Hypericum sp.?
Plantago major
Poa pratensis
Polygala sanguinea
Polygala verticillata
Prenanthes alba
Pteris aquilina (rare)
Rosa blanda
Sambucus canadensis
Silphium integrifolium
Sisymbrium officinale leiocarpum
Smilax hispida
Solanum nigrum
Solidago canadensis
Stipa spartea
Trifolium repens
Viburnum lentago

Relic species which are less abundant

Acerates viridiflora
Andropogon furcatus
Andropogon scoparius
Artemisia caudata
Asclepias incarnata
Aster dumosus
Aster ptarmicoides
Betula alba papyrifera
Calamovilfa longifolia
Carex muhlenbergii
Ceanothus ovatus
Comandra umbellata
Eryngium yuccifolium
Lobelia spicata
Oxypolis rigidior
Petalostemum candidum
Petalostemum purpureum
Pinus strobus
Populus deltoides
Populus tremuloides
Prunus serotina
Pycnanthemum virginianum
Rynchospora capillacea leviseta
Salix glaucophylla
Salix longifolia
Salix pedicellaris

Eupatorium purpureum maculatum
Hypericum kalmianum
Juncus balticus littoralis
Liatris spicata
Salix spp.
Scleria triglomerata
Solidago graminifolia
Spiraea salicifolia

Invading species, none of which are abundant

Allium cernuum
Amphicarpa monoica
Aster macrophyllus
Geranium carolinianum
Nepeta cataria
Polygonum persicaria
Prunella vulgaris
Quercus alba (very few)
Quercus macrocarpa (few)
Rudbeckia subtomentosa
Smilax ecirrhata
Sanicula marilandica

In burns:

Apocynum androsaemifolium
Epilobium angustifolium
Helianthus grosseserratus
Populus deltoides
Populus tremuloides

Species whose occurrence is accidental

Apios tuberosa
Catalpa speciosa (planted)
Cirsium arvense
Cyperus rivularis
Krigia amplexicaulis

THE BLOWOUT ASSOCIATIONS

Blowouts are open sandy places evacuated by the wind. They may occur in almost any of the associations that inhabit sandy ground. They are usually started during the winter when the ground is not well protected by vegetation. Once begun, however, any wind with sufficient power to move sand may effect their greater development. As a rule, in this region vegetation is more than able to keep pace with any blowing that may take place, and so there is but little blowout development during the growing season. Blowouts are especially liable to occur in the sand ridges, no matter whether these are tenanted by the heath, the *Liatris scariosa,* or the *Quercus velutina* association. The blowouts of greatest extent occur in the *Quercus velutina* association, more especially where trees have been removed. This is because the shade from the oaks has reduced the density of the vegetation underneath them and left more ground exposed to the wind.

In general, the blowouts are elliptic to oval in shape with their major axis north-northeast or north-northwest. Occasionally a circular blowout may be found and less frequently crescent-shaped ones. Winds from all directions of the compass are responsible for blowouts of greater or less extent, but the largest ones are formed by

either the northwest or the southwest winds, either one of which is quite likely to be strong.

In some regions the flora of even quite widely separated blowouts is remarkably uniform, but this can hardly be said to be true of this region. The blowout is in some measure dependent upon the surrounding associations for most of its species, but there are a few characteristic blowout species which do not occur in associations immediately adjoining the blowout; as, for example, green milkweed (*Acerates viridiflora lanceolata*), flowering spurge (*Euphorbia corollata*), *Cyperus filiculmis macilentus, Sporobolus cryptandrus, Oenothera rhombipetala, Cyperus schweinitzii, Corispermum hyssopifolium,* and horsemint (*Monarda punctata*).Though blowouts occur in several associations, the association that succeeds the blowout need not be the same as the one in which it started. Blowouts occurring in the *Quercus velutina* association sooner or later give place to *Quercus velutina,* often by passing through a heath stage. Blowouts occurring in the heaths may become tenanted by one of several associations: the *Quercus velutina*, a thicket, the *Liatris scariosa*, or the *L. spicata* association. Blowouts in *L. scariosa* may become occupied by *Quercus velutina,* but more frequently by *Liatris spicata*; or, occasionally, by some of the marsh associations, if the blowing should continue during the winter until the bottom of the blowout is below the water-table level. Typical blowouts do not occur in *Liatris spicata,* but occasionally, where the surface-covering of vegetation has been removed by man, blowing ensues. Such blowing does not last long because the sandy bottom is usually damp, and an association such as the *Carex ocderi pumila* soon obtains dominance and finally reverts to *Liatris spicata.* Some of these different types of blowouts are shown in Figure 2, Plate LI, Figure 2, Plate LII, and Figure 1, Plate LIII.

Physically a blowout may be divided into four parts. The low central part, or basin, is occupied by the basin association of deep-rooted perennials, such as *Acerates viridiflora lanceolata.* The windward slope, located on the side from which the sand is being blown, is, with very few exceptions, occupied by the plants of the association in which the blowout occurs. In the prairie blowouts, the windward slope association is characterized by a species of *Panicum, P. huachucae,* a feature which is markedly characteristic of the blowouts at Hanover Station, Jo Daviess County, Illinois (Gleason 1910:79). There, however, a different species, *Panicum pseudopubescens,* is involved. The lee slope, which is directly across from the windward slope, consists of constantly shifting sand, in which the blowsand association of annuals usually dominates. The lee slope usually ter-

minates in a small dunelike ridge, termed the lee deposits, consisting of the sand blown out from the basin. The dunelike form is maintained by sand-binding perennials, many of which are the dune-formers on the lake beach.

Normally very little blowing occurs during the summer, and most of the blowouts show various stages of stabilization. This is most frequently indicated by bush clover (*Lespedeza capitata*), evening primrose (*Oenothera rhombipetala*), and *Panicum virgatum*, although in any single blowout several other species may play the same rôle. With the dying down of the vegetation in the fall, much sand is left exposed to the winter winds, whose blowing power is not usually much hampered by the protection of a snow covering.

LIST OF THE SPECIES OF THE BLOWOUT ASSOCIATIONS

I. Species characteristic of the basin association

Acerates viridiflora lanceolata
Sporobolus cryptandrus
Euphorbia corollata
Lithospermum angustifolium
Lithospermum gmelini
Rhus toxicodendron

II. Other species found in the basin

Cyperus filiculmis macilentus
Oenothera rhombipetala
Koeleria cristata
Carex muhlenbergii
Quercus velutina (seedlings)
Solidago nemoralis
Arctostaphylos uva-ursi
Smilacina stellata
Silene antirrhina
Andropogon scoparius
Scutellaria parvula
Liatris scariosa
Tradescantia reflexa
Juncus balticus littoralis
Rosa humilis
Juniperus horizontalis
Juniperus communis depressa
Opuntia rafinesquii
Amorpha canescens
Juncus torreyi
Rudbeckia hirta
Hypericum kalmianum
Salix glaucophylla
Aster ptarmicoides
Liatris spicata
Eleocharis intermedia
Lobelia kalmii
Potentilla fruticosa
Polytrichum juniperinum
Verbascum thapsus

III. Species characteristic of the windward slope

Panicum huachucae

The other windward slope species are the normal species of the associations in which the blowouts occur, and consequently are not listed.

IV. Species characteristic of the lee slope (blowsand association)

Cyperus filiculmis macilentus
Cyperus schweinitzii
Corispermum hyssopifolium
Monarda punctata
Artemisia caudata
Cenchrus carolinianus
Cakile edentula
Festuca octoflora
Euphorbia polygonifolia
Sporobolus cryptandrus
Cycloloma atriplicifolium

V. Species characteristic of the lee deposits

Panicum virgatum
Oenothera rhombipetala
Lespedeza capitata
*Arctostaphylos uva-ursi**
Tradescantia reflexa
*Juniperus horizontalis**
*Juniperus communis depressa**
Populus deltoides
Asclepias tuberosa
Poa compressa
Prunus pumila
Calamovilfa longifolia
Elymus canadensis
Euphorbia corollata

VI. Miscellaneous species occasionally occurring in blowouts

Chenopodium album
Solidago serotina
Arenaria stricta
Melilotus alba
Hieracium canadense
Aspidium thelypteris
Rynchospora capillacea leviseta
Linum sp.?
Satureja glabra
Aster azureus
Pycnanthemum virginianum
Trifolium repens
Solidago ohioensis
Orobanche fasciculata (parasitic on *Artemisia*)

The Associations of the Marsh Habitats

In the low ground back of the fringing dune and south of Beach are two small bodies of water known as the Dead River and the Little Dead River. The former expands in width as it nears Lake Michigan and becomes what is know as Dead Lake. The small drainage area commanded by these rivers is very level, and consequently there is very little flow of water. For the greater part of the year the outlets into Lake Michigan are closed by a ridge of sand. The surplus water, at these times, is partly evaporated away, partly sinks through the sand to the lake-level, and is partly taken up by the plants which grow along the shores. In general physical charac-

*The asterisk denotes that the species spreads in from surrounding areas by vegetative growth.

teristics these situations are quite similar to lake beaches. The important difference is the slow movement of the water in the rivers, which are not sufficiently extensive to permit the wind to raise waves which could destroy the vegetation along the shores. The bottom of these rivers is seldom more than one or two meters below the level of Lake Michigan.

The associations which occur in these localities are characterized by the great abundance of a very few species. The associations are restricted to narrow bands which spread out horizontally for many meters. This gives rise to zones of associations around the ponds and along the streams. The associations may alternate to a limited extent. They are, however, sharply separated from one another by definite tension lines, which are sharpest between the associations farthest out in the water. Landward the tension lines are occupied by species of both of the bordering associations and in many cases by small plants which occur there only.

THE PLANKTON ASSOCIATION

The free-swimming *protozoans* and algae which enter into the plankton were not investigated, owing to lack of proper facilities for such work.

THE CHARA ASSOCIATION

The bottom of the deeper parts of lakes and ponds in northern Illinois and Indiana is usually covered with an alga, *Chara*, constituting the *Chara* association. There are no secondary species with the *Chara*, as it normally occurs in this area. In streams with visibly running water there is no *Chara*. The accumulation of *Chara* furnishes a lodging place for the seeds of *Potamogeton*, giving rise to the following association.

THE POTAMOGETON ASSOCIATION

This association occurs in both quiet and running water, although usually with different dominant species in the two cases. The association consists mainly of plants that are entirely submerged, although some of them may mature their flowers and fruit at the surface of the water. This association frequently starts near the edge of the *Chara*, or it just as frequently has its beginning in ponds in which there is no *Chara*. In the main part of Dead Lake the association is characterized by a single species, *Potamogeton natans*. In some of the ponds, where the water is not so deep, it may have

associated with it *Myriophyllum verticillatum*. In little streams of running water the dominant species is usually *Potamogeton foliosus niagarensis*, and associated with it are *Myriophyllum verticillatum* and *Elodea canadensis*. In one such little stream *Myriophyllum* and *Elodea* occur almost to the exclusion of the *Potamogeton*. This association is developed to such a limited extent that in a description of this region no adequate idea can be given of it. A more detailed account may be found in Jennings (1909).

THE CASTALIA-NYMPHAEA ASSOCIATION

In shallower water than that occupied by the Potamogetons is the *Castalia-Nymphaea* association. The water is quiet and a layer of mud covers the bottom. The plants of this association are essentially submerged, but they frequently have their leaves at or above the surface of the water. They may mature their flowers and fruits under water, at the surface, or above the water. This association is very effective in accumulating matter which builds up the bottom. This work is furthered not only by the petioles of the water-lilies, which serve to catch materials, but also by the semi-floating secondary species when they occur. The large leaves of the water-lilies, spreading out on the surface, serve to keep the water calm, and this permits a deposition of the matter brought there in suspension. The very noticeable accumulation of organic matter on the bottom is correlated with slow subaqueous oxidation.

The Association.—This association is not well represented in the area. In only one pond do both the species which give the name to the association occur. When this happens, the white water-lily (*Castalia tuberosa*) appears to prefer deeper water than the yellow water-lily (*Nymphaea advena*). *Castalia* is not usually emersed, while *Nymphaea* frequently grows above the water. In this particular pond, associated with the water-lilies are *Ceratophyllum demersum*, *Chara*, *Potamogeton* sp.?, and *Elodea canadensis*. In all the other places in this region where this association occurs, it is represented by the dominant species, *Nymphaea advena*, and there are seldom any secondary species with it. (See Pl. LIII, Fig. 2.) Not only does *Nymphaea* occur along the ponds in the swales, but it also grows in a good many of the ditches and holes that have been dug in the right of way of the Chicago and North Western railway. Only one case is at hand to give an idea of how long it takes for the *Nymphaea* to appear in a ditch after it has been dug. In an excavation made during the summer of 1906 *Nymphaea* appeared in

the permanently standing water during the season of 1909. Its nearest possible source was about forty meters away, and the probable agent in dispersal was a marsh bird. Occurring with *Nymphaea* in some of these artificial situations, as well as in natural ones, were *Polygonum amphibium hartwrightii* and *Sparganium eurycarpum,* which more properly belong to other associations. In areas in the western part of Lake County, Illinois, this association is often dominated during the fall by the tall stems of *Pontederia cordata,* but until three examples of it were found during the summer of 1910, this plant was what Harper (1906:329) has termed a "notable absentee."

LIST OF THE SPECIES OF THE CASTALIA-NYMPHAEA ASSOCIATION

Dominant Species

Castalia tuberosa — *Nymphaea advena*

Secondary Species

Pontederia cordata — *Potamogeton* spp.
Ceratophyllum demersum — *Elodea canadensis*
Potamogeton natans

Relic Species

Chara sp.

Species of accidental occurrence

Polygonum amphibium hartwrightii — *Sparganium eurycarpum*

THE RANUNCULUS AQUATILIS CAPILLACEUS ASSOCIATION

After the establishment of the *Nymphaea* association around the margin of many of these ditch pools, plants of *Ranunculus aquatilis capillaceus* appear at the lower (inner) edge of the *Nymphaea.* Thence they spread out, and in time usually cover the surface of the open water. The vegetation floats out towards the center of the water, while the roots remain in the *Nymphaea.* The mass of *Ranunculus* becomes so dense in some of the smaller pools that it can support the weight of marsh birds. The flowers of this plant are borne two or three centimeters above the water on slender hollow stems. While the plant is in bloom the pool appears almost white. With the *R. aquatilis capillaceus* are occasionally a few plants of *R. delphinifolius,* and mixed in with the leaves are colonies of *Lemna minor.* This association is one of the many small associations of waterplants which are rather local in their distribution even in a given area. Ultimately it will be displaced by the *Castalia-Nymphaea* association.

THE LEMNA-RICCIA ASSOCIATION

An alternating association with the one just described is the *Lemna-Riccia* association. It shows a tendency to inhabit the longer, narrower pools, where there is less chance of the wind disturbing the water. The plants differ from those of the *Ranunculus* association in that they are free-floating. They mass together, however, in great mats which cover the surface of the water with vegetation. *Lemna* seems to prefer the more open water, while *Riccia* shows a tendency to remain nearer the border association of *Nymphaea* or *Typha*. The *Lemna* and the *Riccia* are, however, so intermingled with one another that they have essentially the same ecological conditions to meet, and so are parts of the same association. This association can only exist as such in quiet water, for in streams the plants are washed away. On this account it is more conspicuous in the small pools, although careful search usually revealed its plants, especially the *Lemna*, among the grasses or sedges that form the bordering amphibious vegetation of the rivers. Numerous small animal forms are associated with these plants, but no other species of plants have been observed with it in this region.

THE MENYANTHES-SAGITTARIA ASSOCIATION

In fairly wide and shallow (2-4 dm.) sloughs the *Castalia-Nymphaea* association occupies the central part, where there is a little running water, especially during the spring floods. Bordering it on either side is the expanse of the *Menyanthes-Sagittaria* association, which reaches to the sedges. As it occurs in a few of the situations it is a typical bog, like those so much more common farther north. The bottom is very level and somewhat peaty. The plants of this association have their root systems entirely submerged, while the leaves and the flowers are usually above the surface of the water. The vegetation is very dense, as shown in the center of Figure 2, Plate LIII.

Arrowleaf (*Sagittaria latifolia*) is always one of the dominant species in the bogs that occur in this region. It occurs along streams of running water as well, and associated with it are many of the same secondary species that accompany it in the typical bog situation. This association is boreal in distribution. Here, near its southern limit, as shown in Transeau's map of the distribution of bog plants (1903:406), it is not typically developed. The species that is most abundant in this association in this region, *Sagittaria latifolia*, is not listed by Transeau as a bog plant because it is not characteristically

of this habitat and its range is much wider than that of bogs. Nevertheless, in all the bogs of this region it is one of the dominant species and occupies from thirty to sixty per cent. of the area of the association. The two species that complete the list of the dominant species are given in Transeau's list of the plants characteristic of bogs across northern North America (1903:405). Of the two, buckbean (*Menyanthes trifoliata*) is the more abundant, and may form as much as fifty per cent. of the vegetation in some of the bogs, while *Potentilla palustris* is relatively infrequent. Secondary species are not common because the *Sagittaria* and the *Menyanthes* so occupy the area that very little interstitial room remains. Those that occur most abundantly are bladderwort (*Utricularia vulgaris americana*), *Polygonum amphibium hartwrightii, Lysimachia thyrsiflora, Acorus calamus,* and *Proserpinaca palustris.* Towards the edge, an invader of the sedge association, *Carex lanuginosa*, may be within the limits of the association. In less typical situations, especially those near the railway, where the drainage has been interfered with, there are mixtures of this association with species of others near by, the result of which is vegetation of the following composition: *Menyanthes trifoliata, Sagittaria latifolia, Utricularia vulgaris americana, Scutellaria galericulata, Hypericum virginicum, Bidens trichosperma tenuiloba, Iris versicolor, Lysimachia thyrsiflora* and *Polygonum muhlenbergii.* In other situations, differing from these, were *Acorus calamus, Alisma plantago-aquatica, Oxypolis rigidior, Asclepias incarnata, Polygonum hydropiperoides,* and *Ludvigia palustris* in addition to the dominant species.

Along some of the ditches in the right of way of the Chicago and North Western railway this association is appearing. In most of them the first member to appear is *Menyanthes.* With it are associated *Utricularia vulgaris americana* and *Proserpinaca palustris.* In one case *Menyanthes* and *Proserpinaca* were giving way to *Spartina* and *Cephalanthus*, which is worthy of mention because the two bushes of buttonbush that occur in this station are the only individuals in this region of a species so characteristic of similar situations in other places. *Sagittaria* will not as a rule come into these ditches until they are larger in size, and not even then unless there is some movement in the water.

Along the little streams that lead from the bluff towards Lake Michigan, the *Menyanthes-Sagittaria* association is usually represented by *Sagittaria* alone. With it may occur a few secondary species, as *Oxypolis rigidior, Cyperus fluviatilis, Alisma plantago-aquatica, Proserpinaca palustris, Veronica anagallis-aquatica, Ranunculus delphinifolius, Scirpus atrovirens* and *Penthorum sedoides.*

The dense growth of this association aids very materially in building up the sloughs, after which it is replaced by other associations that would otherwise have been unable to develop.

LIST OF THE SPECIES OF THE MENYANTHES-SAGITTARIA ASSOCIATION

Dominant Species

Menyanthes trifoliata
Sagittaria latifolia
Potentilla palustris

Secondary Species

Utricularia vulgaris americana
Polygonum amphibium hartwrightii
Lysimachia thyrsiflora
Acorus calamus
Proserpinaca palustris
Polygonum muhlenbergii
Scutellaria galericulata
Alisma plantago-aquatica
Oxypolis rigidior
Polygonum hydropiperoides
Ludvigia palustris
Sagittaria heterophylla rigida
Veronica anagallis-aquatica

Relic Species

Nymphaea advena
Ranunculus delphinifolius

Invading species

Carex lanuginosa
Hypericum virginicum
Bidens trichosperma tenuiloba
Iris versicolor
Asclepias incarnata
Scirpus fluviatilis
Scirpus atrovirens
Spartina michauxiana
Cephalanthus occidentalis
Penthorum sedoides

THE CAREX ASSOCIATION

In the bogs, above the *Menyanthes-Sagittaria* association, occurs a sedge association composed almost entirely of species of *Carex*. The sedges grow quite densely, and while above the surface of the water the culms seem to be regularly distributed, beneath the surface they are found to be grouped together in bunches or hummocks. If the water-level is lowered, this gives rise to the hummocks, which are so characteristic of boggy shores. The bottom is decidedly muddy, and the water is shallower than in the two preceding associations. The sedges afford good hiding places for several of the marsh birds and other animals.

There are seldom any secondary species with the sedges. In the bogs, *Utricularia vulgaris americana* and *Iris versicolor* have

been found as secondary species in several stations, and, in addition cardinal-flower (*Lobelia cardinalis*) in a single station. In a few of the ditches along the railway, where this association has found its way, *Spartina michauxiana, Lobelia cardinalis,* and a few plants of *Iris versicolor* take the part of secondary species. *Dulichium arundinaceum,* a typical bog plant, is present in this region in only two very small boggy places in the midst of a succeeding *Populus-Salix-Cornus* thicket, where it was accompanied by *Carex* sp.

Along the shores of Dead Lake, except for a few places where the *Castalia-Nymphaea* association exists, this association of sedges forms the outermost zone of vegetation visible above the water. At the outer edge it is formed solely of two species of *Carex—Carex lanuginosa,* and the other was probably *Carex filiformis,* although none of its flowering culms were obtained. Nearer the shore are invaders of associations occupying shallower water. Among these invaders is *Scirpus validus,* which may, in other lakes, grow in much deeper water than the *Carex* does in the Dead Lake. This leads to the conclusion that, although most of the aquatic and semiaquatic plants are closely restricted within certain depths of water, their position in any given locality is determined by competition of associations rather than by the different physical requirements of the plants. The same relative arrangement is maintained within the limits of the requirements of the individual plants in different localities, even though the absolute conditions may vary greatly.

LIST OF THE SPECIES OF THE CAREX ASSOCIATION

Dominant Species

Carex filiformis
Carex lanuginosa
Carex stricta
Carex comosa
Carex riparia
Carex stipata
Carex buxbaumii
Carex spp.
Dulichium arundinaceum

Secondary Species

Utricularia vulgaris americana
Lobelia cardinalis
Spartina michauxiana
Acorus calamus
Echinochloa crusgalli

Invading Species

Iris versicolor
Scirpus validus
Typha latifolia

THE PHRAGMITES-TYPHA ASSOCIATION

In shallower water than the *Carex* association is the *Phragmites-Typha* association. Ecological conditions seem to be much the same as for the *Carex* except that the water is shallower. The plants of this association are rooted in muddy soil a few decimeters below the water-level and have their vegetative parts comparatively high in the air, where they are exposed to the drying effects of the wind and sun. The cattail (*Typha*) is, in a small measure, adapted to these conditions by having its broad leaves edgewise with the noonday sun. Adaptation would seem hardly necessary since the plants can obtain water as fast as it is evaporated. Even on the hottest and driest days, *Typha* never appears wilted, but *Phragmites* may be quite noticeably wilted. Each of the dominant species dominates the situations in which it is located. Very dense plant families are formed on account of the close method of vegetative reproduction. Although these two species seldom intermingle, they conform exactly to the limits of water-depth in which either will grow. For these reasons, either may be farther out or nearer the shore, or a family of one may be between two families of the other, and this without change of water-depth. There is very little room for secondary species, and the few that do occur are relics or invaders of other associations. When this association appears in the ditches along the railway, the dominant species is usually *Typha* on account of the much greater production of its seeds. In two pools *Typha angustifolia* alternates with *T. latifolia*. Hybrids between these two species occasionally occur, and there is a form having two completely separated spikes of pistillate flowers in addition to the staminate spike.

LIST OF THE SPECIES OF THE PHRAGMITES-TYPHA ASSOCIATION

Dominant Species

Typha latifolia
Typha angustifolia
Phragmites communis

Secondary Species

Acorus calamus (a very little)
Oxypolis rigidior
Utricularia vulgaris americana
Scirpus atrovirens
Scirpus rubrotinctus

Relic Species

Carex lanuginosa (a little)
Proserpinaca palustris

Invading Species

Scirpus validus

The following floating plants are frequently present:

Riccia fluitans *Lemna minor*

THE SCIRPUS VALIDUS ASSOCIATION

In still shallower water than the preceding association occurs the *Scirpus validus* association. It is characterized by the bulrush, *Scirpus validus,* and the very closely related species, *S. heterochaetus* and *S. occidentalis.* The former species grows in water which varies in depth from one to ten decimeters. In this area, and in general in the lake region in northeastern Illinois and southeastern Wisconsin, the *Scirpus validus* association grows in deeper water only when there are no other associations of emersed plants between it and the open water. This association is one of the commonest aquatic pioneers, and will grow either in still water or in a moderate current. Although this association agrees with the *Phragmites-Typha* association and the *Scirpus americanus* association in having the roots in saturated soil and the tops of the plants in the air, they can hardly be grouped into a single association, as Jennings (1909:354) has pointed out, because of the definite arrangement they always exhibit with respect to one another. This differentiation is most evident in the relations of the plants to the varying depths of water. The *Phragmites-Typha* association grows in deeper water than the *Scirpus validus,* while *Scirpus americanus* grows in shallower water and will persist out of the water as a relic. Where *Typha* or *Phragmites* have been found surrounded by *Scirpus validus,* or vice versa, investigation has always shown a difference in level. *Scirpus validus* grows in soil which contains rather more humus than that in which *Typha* grows. Both associations have few secondary species, which for the most part are unimportant. Taken as a whole, the secondary species constitute less than 3 per cent. of the association, the remaining 97 per cent. being the dominant species. Neither *Phragmites* nor *Typha* have more than a very slight ability to persist among *Scirpus validus* as relics, but the *Scirpus* itself is, to a limited extent, capable of being an invader in the *Phragmites-Typha,* and to a greater extent possesses the power of growing as a relic in the *Scirpus americanus* association. The color tone of the *Scripus validus* during the growing season is dark green, which very decidedly separates it from the light green of the *Scirpus americanus.* The two latter associations are shown in Figure 1, Plate LIV, where *Scirpus americanus* occupies the left half and the lower part of the right half of the figure, while *Scirpus validus,* appearing darker in color, is in the upper part of the right half of the figure.

LIST OF THE SPECIES OF THE SCIRPUS VALIDUS ASSOCIATION

Dominant Species

Scirpus validus

Secondary Species

Utricularia vulgaris americana
Acorus calamus (a very little on the lower border)
Spartina michauxiana (dwarfed and but little of it)
Rumex britannica

Relic Species

Nymphaea advena (scarce)
Typha latifolia (only on the lower border and scarce)

Invading Species

Scirpus americanus (on the upper border)

THE SCIRPUS AMERICANUS ASSOCIATION

As has been mentioned, the *Scirpus americanus* association occupies shallower water than the *Scirpus validus* association. The accumulation of humus is greater, and it is sometimes peaty in nature. This association does not occupy ground that is permanently out of water, although sometimes during dry seasons it may be a decimeter or two above the water-level. In such cases, however, the ground is still, as a rule, thoroughly soaked by means of capillary attraction or other agency. If this is not so, the *Scirpus* stems will become dry and brown, but upon restoration of the water to its former level they usually become green again. These light green stems give the characteristic color-tone to the association. When growing in nearly pure damp sand, the *Scirpus* stems are often spirally twisted—a modification exhibited also by *Juncus balticus littoralis,* as mentioned on page 277.

LIST OF THE SPECIES OF THE SCIRPUS AMERICANUS ASSOCIATION

Dominant Species

Scirpus americanus

Secondary Species

Triglochin maritima
Salix candida
Bidens trichosperma tenuiloba
Eleocharis acuminata
Eriophorum angustifolium
Rynchospora capillacea leviseta

Relic Species

Alisma plantago-aquatica
Scirpus validus (scarce)

Invading Species

Solidago graminifolia	*Juncus canadensis*
Iris versicolor	*Hypericum virginicum*
Aspidium thelypteris	*Salix longifolia*
Steironema quadriflorum	*Asclepias incarnata*
Lythrum alatum	

This association is the last of the strictly aquatic associations, whose dominant species compose from 85 to 100 per cent. of their area. The following are land associations in which the dominant species are usually more numerous and more openly distributed in the area. Secondary species are much more numerous, and lead in determining the different seasonal aspects of the associations. The marsh group of associations is transitional to either prairie or forest.

THE CLADIUM MARISCOIDES ASSOCIATION

Developing on mucky soil just back of the *Scirpus americanus,* a little above the hight of standing water but not sufficiently high for the surface to become dry, is the *Cladium* association, about 98 per cent. of whose plants are the sedge, *Cladium mariscoides.* In the youngest swales the *Cladium* and *Scirpus americanus* are adjacent, while in the middle-aged swales they are often separated by the development of the *Calamagrostis canadensis* association on the tension line between them. In the oldest swales the *Cladium* is entirely absent. There is seldom any mingling of these associations, even on their border lines. The vegetation is so dense in the main part of this association that secondary species can obtain a foothold only on the tension line between this and other associations. In level places this association will spread out to a width of 15 or 20 meters, with a uniform structure throughout. More usually, however, it occurs as a zone around ponds or as a belt along swales, seldom attaining a width of one meter, but exhibiting the same uniformity of vegetational structure. During the growing season the color tone of this association is dark green—the color of the stems and leaves. About the first of August the plants come into bloom and the color tone is changed to brown, which makes the association stand out very sharply from the surrounding ones. This is especially the case during years of drought, as 1908 and 1910, when every plant of *Cladium* blooms. During normal seasons, as 1909, when Figure 2, Plate LIV, was taken, scarcely half of the plants bloom. Usually *Cladium* persists from season to season by the growth of the root stalks. The

abundant production of seeds in a dry season is a xerophytic adaptation.

The *Cladium* association may be displaced by a thicket, but in nearly every case it is succeeded by the blazing star (*Liatris spicata*) prairie. This latter succession takes place more easily when the *Cladium* is not restricted to a narrow belt. The species that invades first are usually *Lythrum alatum, Solidago graminifolia, Pycnanthemum virginianum, Oxypolis rigidior, Gerardia paupercula, Epilobium densum,* and *Liatris spicata.*

LIST OF THE SPECIES OF THE CLADIUM MARISCOIDES ASSOCIATION

Dominant Species

Cladium mariscoides

Secondary Species

Hypericum virginianum (scarce) *Spartina michauxiana* (scarce)

Relic Species

Eriophorum angustifolium
Scirpus americanus
Utricularia cornuta
Aspidium thelypteris

Invading species, nowhere abundant in this association

Lythrum alatum
Solidago graminifolia
Pycnanthemum virginianum
Oxypolis rigidior
Gerardia paupercula
Epilobium densum
Potentilla fruticosa
Solidago ohioensis
Eupatorium perfoliatum
Steironema quadriflorum
Liatris spicata
Lycopus americanus
Lycopus sp.?
Osmunda regalis
Iris versicolor (uncommon)
Habenaria psycodes (two individuals)

THE CALAMAGROSTIS CANADENSIS ASSOCIATION

When swales have reached a sufficiently advanced stage of development, *Calamagrostis canadensis* appears on the tension line between the *Cladium* and *Scirpus americanus* associations and ultimately entirely replaces the *Cladium.* The *Calamagrostis* association occupies somewhat mucky soil in which, a little above standing water but not sufficiently high for the surface to become dry, an abundance of *Marchantia polymorpha* may occasionally be found. It is not usually subject to inundation. From 98 to 99 per cent. of the area of this association is occupied by the marsh grass, *Calama-*

grostis canadensis, whose stems grow so closely as virtually to prohibit the development of secondary species. The association varies in width from a meter or two where the slope is evident to thirty to fifty meters or more where there is no evident slope. In all cases the dense growth of *Calamagrostis* completely dominates, and the small number of secondary species, which are usually either relics or invaders, are notably more slender, broader-leaved, and taller than individuals of the same species in their normal associations. This is clearly a response to the diminution of the amount of light which they receive, as this effect is often observed where these plants persist under the shade of trees. The foreground of Figure 1, Plate LV, shows a typically developed *Calamagrostis* swale.

When this association obtains dominance successions are very nearly at a standstill, since the seedlings of invaders have considerable difficulty in obtaining a foothold, and they must also be able to withstand a great deal of shade. Normally the *Liatris spicata* prairie is the association which should succeed. Near Zion City, however, where the swales are occasionally burned over, the thicket association obtains a foothold and is rapidly followed by aspens and willows.

LIST OF THE SPECIES OF THE CALAMAGROSTIS CANADENSIS ASSOCIATION

Dominant Species

Calamagrostis canadensis

(All of the following species are very poorly represented in number of individuals)

Secondary Species

Spartina michauxiana
Campanula aparinoides
Aster ericoides

Relic Species

Scirpus validus
Scirpus americanus
Oxypolis rigidior
Asclepias incarnata
Polygonum amphibium hartwrightii
Dulichium arundinaceum (very rare)

Invading Species

Lythrum alatum
Spiraea salicifolia
Salix candida
Salix longifolia
Iris versicolor
Mentha arvensis canadensis
Eupatorium perfoliatum

THE IRIS VERSICOLOR ASSOCIATION

With the draining of the stations of *Carex* by the lowering of the water-level, or otherwise, the hummocks are exposed. This is usually followed by a marked increase in the number of plants of *Iris versicolor* and a reduction in the amount of *Carex*. Grasses, especially *Poa compressa* and *Poa pratensis,* spread over the hummocks, while *Iris* and the secondary plants for the most part occupy the spaces between the hummocks.

Most of the stations of this association are in the stage characterized above. A few in more advanced stages indicate that if the water-table is further lowered, the *Iris* association will ultimately be replaced either by grass or by the *Liatris spicata* prairie association. In other situations, especially near the foot of the bluff south of Beach, where the ground is more boggy, the *Iris* occupies a tension zone between the carices and the thickets, persisting as a relic in case of succession by the latter association. It is very frequently present as a transition zone between the swale associations and the ridge associations, between which there are usually no successions although they may grow in direct contact with one another.

The association is characterized by plants that prefer a somewhat boggy soil which is always moist yet rarely inundated. The vegetation is very compact and invasion into it is rather slow. This association presents conspicuous aspects during the different seasons. The blooming of the dominant species itself characterizes the spring aspect. During the summer the abundant yellow flowers of *Steironema quadriflorum* again make this association conspicuous. Vervain (*Verbena hastata*), smartweed (*Polygonum punctatum*), *Solidago graminifolia,* and boneset (*Eupatorium perfoliatum*) combine to produce the serotional aspect, while several species, most important of which are ladies' tresses (*Spiranthes cernua*), closed gentian (*Gentiana andrewsii*), *Gerardia paupercula, Gerardia tenuifolia,* and a few asters, make up the fall aspect. Very small, single-flowered plants of *Gentiana procera* continue blooming late in the fall, until finally killed by the severe frosts towards the end of October.

LIST OF THE SPECIES OF THE IRIS VERSICOLOR ASSOCIATION

Dominant Species

Iris versicolor	*Eleocharis intermedia*

Secondary species which are most abundant

Lycopus americanus	*Verbena hastata*
Steironema quadriflorum	*Prunella vulgaris*

Eupatorium perfoliatum
Epilobium densum
Solidago graminifolia
Spiranthes cernua
Gentiana procera
Aspidium thelypteris
Lobelia siphilitica
Gerardia paupercula
Aster paniculatus
Aster salicifolius
Aster spp.
Carex hystericina
Lobelia kalmii
Parnassia caroliniana
Habenaria dilatata
Habenaria hyperborea

Secondary species which are not abundant

Lycopus sp.
Hypericum virginicum
Comandra umbellata
Gentiana andrewsii
Chelone glabra
Polygonum acre
Gerardia skinneriana
Gerardia tenuifolia
Satureja glabra
Cyperus rivularis
Penthorum sedoides
Isanthus brachiatus
Aster spp.
Leersia oryzoides
Rumex crispus
Juncus canadensis
Cicuta bulbifera
Cicuta maculata
Aster novae-angliae
Ranunculus pennsylvanicus
Eupatorium purpureum maculatum
Apocynum cannabinum hypericifolium
Cirsium muticum
Habenaria clavellata
Habenaria leucophaea
Osmunda regalis
Tofieldia glutinosa
Polygala sanguinea
Drosera rotundifolia
Galium boreale
Pogonia ophioglossoides
Symplocarpus foetidus
Cypripedium hirsutum
Pedicularis lanceolata

Relic Species

Calamagrostis canadensis (few)
Spartina michauxiana
Alisma plantago-aquatica
Potentilla palustris
Lysimachia thyrsiflora

Invading Species

Rudbeckia hirta
Pycnanthemum virginianum
Lythrum alatum
Galium trifidum
Salix candida
Spiraea salicifolia
Betula pumila

THE OSMUNDA ASSOCIATION

A few patches of *Osmunda regalis* which occur on the border of the *Calamagrostis* association are all that remain to indicate a big as-

sociation which has been driven from the region. Usually the *Osmunda* is between the *Calamagrostis* and the prairie, but it is also between the *Quercus velutina* and the *Calamagrostis,* and less frequently is preserved as a relic in the midst of willow thickets which have been developed in boggy ground. *Osmunda cinnamomea* is a very characteristic species of this association, but it is entirely absent from the Beach region. The only associates that have been noted with the *Osmunda regalis* are *Geranium maculatum, Fragaria virginiana, Polytrichum* sp., and *Zizia aurea.*

THE POTENTILLA FRUTICOSA ASSOCIATION

This northern association occurs on sandy soil which is usually moist, although only exceptionally flooded. The association typically follows the destruction of the pines in a soil which can support an association genetically higher than bunch-grass prairie, but not yet sufficiently mesophytic for the blazing star (*Liatris spicata*) prairie. It often occupies the lower ground between the ridges on which the pines are growing.

The Association.—The wide-spread growth of the dominant species, *Potentilla fruticosa,* a low bushy plant, is the characteristic feature of the association. Few or no characteristic secondary species occur, since this association is a boreal relic. Other species that may occur are usually relics or invaders of former or succeeding associations. The composition of the invaders depends almost entirely upon the proximity of the associations likely to succeed. In the southern part of the region, especially towards Waukegan, this association is so intermingled with the *Liatris spicata* prairie that it is difficult to separate them. Throughout most of the year this association presents a dull, monotonous color-tone, but in the late summer it is relieved by the bright yellow flowers of the *Potentilla,* which occur in profusion.

Successional Relationships.—Shrubby cinquefoil (*Potentilla fruticosa*) has more ability to invade and take possession of bunch-grass prairie than *Liatris spicata* prairie, but in turn the *Potentilla* is almost immediately followed by *Liatris spicata.* Near the pines *Potentilla fruticosa* easily invades the heath and prepares it for subsequent prairie invasion. *Potentilla fruiticosa* readily takes possession of the moister places where pines have been removed, while the heath is characteristic of the drier places. Seedling pines (*Pinus strobus*) occasionally obtain a foothold in the *Potentilla fruticosa,* while seedling oaks (*Quercus velutina*) are less liable to do so. In general, however, oaks will obtain dominance quicker in cut-over pine land

which is not subsequently occupied by *Potentilla fruticosa*. In other words, ground that is covered with a good stand of *Potentilla fruticosa* is more easily invaded by prairie than by oak.

LIST OF THE SPECIES OF THE POTENTILLA FRUTICOSA ASSOCIATION

Dominant Species

Potentilla fruticosa
Hypericum kalmianum

Secondary Species

Senecio balsamitae
Habenaria dilatata
Habenaria hyperborea
Sisyrinchium sp.
Solidago graminifolia
Cladonia spp.
Mosses

Relic Species

Euphorbia corollata
Rudbeckia hirta
Smilacina stellata
Anemone cylindrica
Lithospermum gmelini
Solidago nemoralis
Pinus strobus (by cutting)
Arabis lyrata
Potentilla anserina
Elymus canadensis
Artemisia caudata
Juniperus horizontalis
Arctostaphylos uva-ursi
Arenaria stricta
Ceanothus americanus
Calamovilfa longifolia
Tradescantia reflexa
Pteris aquilina
Osmunda regalis

Invading Species

Pycnanthemum virginianum
Krigia amplexicaulis
Liatris spicata
Pinus strobus (few)
Erigeron ramosus
Petalostemum candidum
Lobelia spicata
Prunella vulgaris
Spiraea salicifolia
Fragaria virginiana
Poa compressa
Salix spp.
Bromus kalmii

THE LIATRIS SPICATA PRAIRIE ASSOCIATION

Spread over the low ridges of the southern part of the Beach area occurs the best development of the southwestern or prairie element of the flora of this region. In the forested parts of the region the prairie associations occupy belts or zones between the swale assocations and those of the forest. The area between the Dead Lake and the Chicago and North Western railway, which was

formerly dominated by swamp associations, is now very largely being replaced by the prairie association, which in turn is slowly giving way to the oak forest.

Physical and Ecological Characteristics.—The area covered by the prairie has an ample precipitation, distributed quite equally throughout the year. In addition the ground is but very little elevated above the surface of Lake Michigan. According to Schimper (1903) this ought to mean that the ground is forest-covered. At the present time this is not the case, but all indications look toward that succession ultimately. In former years, at which time the lake level was higher, this region was swampy and was occupied by swamp associations, relics of which are easily found in the prairie at the present time. The swamp associations formed a layer of black soil on the sand, upon which the prairie plants spread quite rapidly as soon as they obtained a foothold. Lowering of the Lake Michigan level has led to a partial draining of much of this land. Many of the swamp plants can still live under the new conditions, with prairie species, but they are gradually being displaced. As the land is drained, more and more prairie plants have the ability to effect ecesis even in the dense growths of swamp plants. Under normal conditions oaks do not possess this ability. They can reproduce under such conditions if the acorns are actually planted, but in the dense coating of vegetation in swamps and prairies this rarely happens except accidentally. This explains why prairies rather than forests came to occupy the swamp areas.

The Association.—This prairie association is made up of herbaceous plants, nearly all of which die down to the ground each year. The association is characterized by the great abundance of individuals of a few typical species together with scattering plants of many secondary species. The season is separated into several well-marked aspects by the changes due to the blooming of the different important species. The vernal aspect is characterized by phlox (*Phlox pilosa*), painted cup (*Castilleja coccinea*), shooting star (*Dodecatheon meadia*) and lobelia (*Lobelia spicata*). *Phlox glaberrima* is dominant in the estival aspect. (See Fig. 2, Pl. LV.) Between the estival and the serotinal aspects occurs the blooming of *Calopogon pulchellus* and *Lilium philadelphicum andinum*, which for a short time produces another aspect. The serotinal aspect results from the great abundance of blazing star (*Liatris spicata*), as shown in Figure 1, Plate LVI, and by a lesser abundance of *Pycnanthemum virginicum*, *Lythrum alatum*, *Petalostemum purpureum*, and *Eryngium yuccifolium*. During the fall the blooming of goldenrods and asters,

but particularly *Solidago ohioensis,* characterizes the association. The dead standing stems of many of these plants remain over winter.

Successional Relationships.—This association is preeminently an association inhabiting low ridges which have a coating of black soil. Accordingly it is usually able to succeed any association which forms black soil. This is especially true in the case of the genetically highest swamp associations, which, in spite of their density, the *Liatris spicata* prairie is able to invade and replace as long as the water-content factor of the soil is not prohibitive to its development. In the more sandy swales between the ridges of pine near the lake, shrubby plants of *Potentilla fruticosa* frequently obtain dominance, with nearly the same set of secondary species. *Liatris spicata* is rather scarce at present in such areas, but shows every indication of ultimately replacing them with prairie. As has been shown before, a dense prairie sod prevents the invasion of oaks, but wherever it may be broken, or near its margins, oaks can obtain a foothold. It can readily be seen, therefore, that under the present climatic conditions the final outcome of the prairie areas of this region is, or will be, an oak forest.

LIST OF THE SPECIES OF THE LIATRIS SPICATA PRAIRIE ASSOCIATION

Dominant Species

Liatris spicata
Phlox pilosa
Phlox glaberrima
Castilleja coccinea
Dodecatheon meadia
Lilium philadelphicum andinum
Pycnanthemum virginianum
Lythrum alatum
Solidago ohioensis
Solidago riddellii
Rudbeckia hirta
Senecio balsamitae
Sorghastrum nutans
Andropogon furcatus
Allium cernuum
Petalostemum purpureum

Secondary Species

Aletris farinosa
Apocynum cannabinum hypericifolium
Aster novae-angliae
Aster ptarmicoides
Aster spp.
Calopogon pulchellus
Erigeron ramosus
Erigeron philadelphicum
Eryngium yuccifolium
Anemone virginiana
Aster dumosus
Astragalus canadensis
Bromus kalmii
Comandra umbellata
Desmodium illinoense
Coreopsis lanceolata villosa
Coreopsis palmata
Eupatorium perfoliatum (abundant)

Euphorbia corollata (abundant)
Fragaria virginiana
Helenium autumnale
Heuchera hispida
Hierochloe odorata
Hypoxis hirsuta
Lactuca canadensis
Lespedeza capitata
Liatris cylindracea
Lobelia siphilitica
Lobelia spicata
Poa compressa
Poa pratensis
Potentilla arguta
Rumex crispus
Sisyrinchium sp.
Solidago graminifolia
Solidago serotina
Solidago speciosa
Solidago speciosa angustata
Vicia americana
Valeriana edulis
Zizia aurea
Eupatorium purpureum
. maculatum
Glyceria nervata
Helianthus grosseserratus
Helianthus occidentalis
Helianthus maximiliani
Krigia amplexicaulis
Lathyrus palustris myrtifolius
Lepachys pinnata
Lilium canadense
Pedicularis lanceolata
Petalostemum candidum
Polygala polygama
Polygala verticillata
Prenanthes racemosa
Satureja glabra
Silphium integrifolium
Silphium terebinthinaceum
Tofieldia glutinosa
Tradescantia reflexa
Vernonia fasciculata
Viola papilionacea
Viola sagittata
Scleria verticillata

Relic species in normal genetic succession

Accrates viridiflora
Amorpha canescens
Arabis lyrata
Arctostaphylos uva-ursi
Juniperus communis depressa
Juniperus horizontalis
Aspidium thelypteris
Aster azureus
Calamovilfa longifolia (rarely)
Elymus canadensis
Euphorbia corollata
Gerardia tenuifolia
Gerardia paupercula
Gerardia skinneriana
Hypericum kalmianum
Koeleria cristata
Betula alba papyrifera
Achillea millefolium
Andropogon scoparius
Arenaria stricta
Artemisia caudata
Asclepias incarnata
Asclepias purpurascens
Asclepias syriaca
Asclepias tuberosa
Carex oederi pumila
Carex spp.
Eupatorium perfoliatum
Habenaria clavellata
Habenaria dilatata
Habenaria leucophaea (3 plants)
Iris versicolor
*Liatris scariosa**
Campanula aparinoides

Betula pumila
Juncus balticus littoralis
Juncus canadensis
*Juncus torreyi**
Osmunda regalis
Oxypolis rigidior
Parnassia caroliniana
Polygonum hydropiperoides
Potentilla anserina
Potentilla fruticosa
Rynchospora capillacea leviseta
Scirpus americanus
Scirpus atrovirens
Scirpus lineatus
Solidago nemoralis (scarce)
Steironema quadriflorum
Linum virginianum
Lithospermum gmelini (scarce)
Lobelia cardinalis
Lycopus americanus
Panicum virgatum
Pinus strobus
Pinus laricio
Pinus silvestris
Rhus toxicodendron
Salix candida
Salix glaucophylla
Salix syrticola
Scleria triglomerata
Spartina michauxiana
Alisma plantago-aquatica

Relic species remaining after the removal of oak groves

Anemone cylindrica
Heracleum lanatum
Pedicularis canadensis
Prunella vulgaris
Smilacina stellata
Ceanothus americanus
Monarda mollis
Podophyllum peltatum
Pteris aquilina
Smilax cirrhata

Invading species of the thicket associations

Cirsium muticum
Populus deltoides
Populus tremuloides
Sambucus canadensis
Spiraea salicifolia
Salix spp.
Cornus stolonifera
Rhus hirta
Salix cordata
Salix discolor
Salix pedicellaris

Invading species of the woods

Quercus velutina
Carya ovata (a few seedlings)
Vitis vulpina
Sanicula marilandica
Geum canadense
Agrimonia gryposepala

Species of accidental occurrence

Ambrosia artemisiaefolia
Convolvulus sepium
Trifolium repens
Bromus tectorum
Salsola kali tenuifolia

*The two species marked with an asterisk also play the rôle of invaders where the water-table is being lowered beyond the requirements of the *Liatris spicata* prairie.

THE JUNCUS TORREYI ASSOCIATION

This small association, composed virtually of only the dominant species, occupies very definitely the tension line between the blazing star (*Liatris spicata*) and the *Liatris scariosa* associations. It may extend slightly into both of them, but in such cases is evidently acting as an invader in one and a relic in the other. This depends upon which *Liatris* association is succeeding the other, since that succession is reversible and bears a seemingly definite relation to elevation or depression of the water-table. The large dark green to brown heads of the dominant species make this association stand out very distinctly from each of its neighbors. The usual width of the association is five to twenty-five centimeters, though it may be greater or less according to the slope of the land. In blowouts where neither *Liatris* is present, this *Juncus* occupies very definitely the median position between the sets of plants which represent those two associations.

LIST OF THE SPECIES OF THE JUNCUS TORREYI ASSOCIATION

Dominant Species

Juncus torreyi

Relic or Invading Species (depending on the direction of succession)

Rynchospora capillacea laeviscta *Steironema quadriflorum*

THE THICKET ASSOCIATIONS

THE POPULUS-SALIX-CORNUS THICKET ASSOCIATION

This association is one of the usual steps in the succession from marsh to oak forest. It is quite general in its distribution throughout the central part of the Beach area. It may invade almost any association, but it is most successful in the *Liatris spicata, Calamagrostis canadensis, Iris versicolor,* and blowout associations.

Physical and Ecological Characteristics.—This association grows in soil varying from sandy loam to the black soil of the prairie. The water supply is always ample on account of the proximity of the water-table level of Lake Michigan. The growth of the thickets is very dense, and in the protection thus afforded considerable humus may be formed.

The Association.—The association is composed of any one of the dominant species or of different combinations of them. Dogwood (*Cornus stolonifera*) and the species of willow (*Salix*) are each much more abundant than the species of *Populus.* There seems to

be no particular arrangement of the dominant species when they occur together, except in the more pronounced ridges. Here *Populus* occupies the crest and *Salix* and *Cornus* the slopes. With them are a number of secondary species, many of which are either invaders of the forest type of vegetation or relics of the prairie.

Successional Relationships.—On sandy ground this association is very frequently introduced by the invasion of cottonwood (*Populus deltoides*), followed by species of *Salix* and *Cornus*. In black soil, species of *Salix* or *Cornus* are more usually the pioneer invaders. Succession is accomplished by the cutting-off of the light supply from the vegetation below as soon as the shrubs attain sufficient size. In due course of time some of the species of *Salix* and *Populus* become trees, with almost the same assemblage of secondary species, but ultimately the thickets occurring on the beach plain will be replaced by the *Quercus velutina* association, while those near the base of the bluffs will be replaced by the oak-hickory woods.

LIST OF THE SPECIES OF THE POPULUS-SALIX-CORNUS THICKET ASSOCIATION

Dominant Species

Cornus stolonifera
Populus tremuloides
Populus deltoides
Rosa carolina
Salix amygdaloides
Salix cordata
Salix discolor
Salix longifolia
Salix lucida
Salix pedicillaris
Salix serissima

Secondary Species

Aster umbellatus
Aster novae-angliae
Betula alba papyrifera
Betula pumila
Bromus incanus (1 plant)
Dioscorea paniculata
Equisetum arvense
Helianthus occidentalis f. *illinoensis*
Helianthus grosseserratus
Lactuca canadensis
Lechea leggettii
Lechea villosa
Lonicera dioica
Prunus serotina
Ribes sp.?
Rhus toxicodendron
Rhamnus alnifolia
Rubus occidentalis
Spiraea salicifolia
Solidago canadensis
Solidago serotina
Sambucus canadensis
Silphium integrifolium

Relic Species

Achillea millefolium
Lespedeza capitata

Agrostis alba
Amorpha canescens
Andropogon furcatus
Asclepias incarnata
Asclepias syriaca
Asclepias tuberosa
Aspidium thelypteris
Aster azureus
Aster dumosus
Betula alba papyrifera
Betula pumila
Calopogon pulchellus
Desmodium illinoense
Erigeron ramosus
Eupatorium purpureum maculatum
Euphorbia corollata
Habenaria psycodes
Juncus balticus littoralis
Koeleria cristata
Krigia amplexicaulis
Lathyrus palustris myrtifolius
Liatris spicata
Lobelia spicata
Lythrum alatum
Oxypolis rigidior
Panicum virgatum
Parnassia caroliniana
Pedicularis lanceolata
Petalostemum candidum
Potentilla fruticosa
Prenanthes racemosa
Prunus pumila
Pycnanthemum virginianum
Rynchospora capillacea leviseta
Rudbeckia hirta
Salix glaucophylla
Salix syrticola
Silene antirrhina
Solidago ohiocnsis
Solidago graminifolia
Sorghastrum nutans
Tradescantia reflexa
Zizia aurea

Invading Species

Acer negundo
Acer saccharinum
Aralia nudicaulis
Echinocystis lobata
Geranium maculatum
Maianthemum canadense
Carya ovata
Monarda fistulosa
Polygonatum commutatum
Quercus velutina
Smilacina stellata
Smilax hispida
Vitis vulpina
Juglans nigra

THE PRUNUS THICKET ASSOCIATION

While over 90 per cent. of the thickets of this region belong to the *Populus-Salix-Cornus* thicket association, there are, along the north bank of the Dead Lake, a few thickets which belong to a different association. Their position and composition are about the same as the sand river-bank thickets occurring along the Mississippi River in the vicinity of Hanover, Illinois, described by Gleason (1910:142). The bushes form the dominant part, but mixed in with them are lianas, which in places make the vegetation difficult to penetrate. The ground is sandy at the surface, although below it may be somewhat

loamy. These thickets grow in and around the borders of the pines, effectually cutting off their chances of reproduction. The central parts of the thickets are too dense for the ecesis of oaks, but towards the edge, where it is more open, black oak, *Quercus velutina,* quite readily obtains a foothold and in time replaces the thicket.

The marked differences between these two kinds of thickets are the possession of lianas and the sandy-appearing soil in the *Prunus* thickets, while the *Populus-Salix-Cornus* thicket, with virtually no exceptions, is free from lianas and has somewhat loamy or mucky soil.

LIST OF THE SPECIES OF THE PRUNUS THICKET ASSOCIATION

Dominant Species

Prunus pumila
Prunus serotina
Prunus virginiana
Sambucus canadensis

Secondary Species

Lianas:

Vitis vulpina
Celastrus scandens
Rhus toxicodendron radicans

Herbaceous plants:

Anemone canadensis
Asparagus officinalis
Aster spp.
Fragaria virginiana
Lathyrus venosus
Veronica virginica
Melilotus alba
Rosa humilis

Relic Species

Calamovilfa longifolia
Euphorbia corollata
Oenothera rhombipetala
Phlox pilosa
Poa compressa
Potentilla fruticosa
Solidago nemoralis
Artemisia caudata (few)
Juncus balticus littoralis
Koeleria cristata
Petalostemum purpureum
Salix glaucophylla
Polygonatum biflorum (where oaks have been cut)

Invading Species

Quercus velutina

Up to the present point, the discussion of associations has been limited to those of the sand-plain. The bluffs which constitute its western boundary are tenanted by arboreal associations which show an inclination to invade the prairie, although, up to the present

time, very little has been accomplished. The most widely distributed is the oak-hickory association, in which the following species are the most important: bur oak (*Quercus macrocarpa*), red oak (*Quercus rubra*), white oak (*Quercus alba*), shell-bark hickory (*Carya ovata*), *Carya cordiformis*, and *Juglans nigra*, together with many secondary species. It is an association of essentially loamy or clayey soil, and does not readily invade the sandy areas. On moister ground occurs a more mesophytic association of trees, the *Ulmus-Acer* association, whose characteristic species are elm (*Ulmus americana*), soft maple (*Acer saccharinum*), basswood (*Tilia americana*), and white ash (*Fraxinus americana*). This in turn is succeeded by the climax association of this region, the sugar maple (*Acer saccharum*) association, which at the present time is in the infancy of its development in northeastern Illinois.

The following cross-sections, or transects, taken in the southern part of the region, will aid in the understanding of the region. The sections were obtained by listing the changes in the associations, while walking across the area from east to west.

SECTION OF THE ASSOCIATIONS OF THE BEACH AREA MADE ALONG THE LINE OF THE WAUKEGAN SEWER, AUGUST, 1909

1. Lake Michigan.
2. Open sand of lower beach.
3. Beach pool with *Chlamydomonas* and *Oscillatoria*.
4. Open sand.
5. *Cakile-Xanthium* association on the middle beach.
6. *Salix syrticola* dune.
7. *Potentilla anserina* association.
8. *Salix syrticola* dune with a little *Calamovilfa*.
9. *Andropogon scoparius* bunch-grass prairie.
10. *Populus-Salix* dune, 0.1 to 0.4 meter high.
11. *Calamovilfa* growing on the edge of bunch-grass prairie.
12. *Andropogon scoparius* bunch-grass prairie.
13. *Calamovilfa* ridge.
14. Bunch-grass prairie with a few very low *Calamovilfa* ridges.
15. *Potentilla fruticosa* association.
16. A thicket of *Salix*.
17. A swale.
18. *Populus-Salix* ridge.
19. Heath.
20. Heath with blowouts and a little *Calamovilfa*.
21. *Scirpus americanus* association.

22. *Scirpus validus* association.
23. *Typha latifolia.*
24. *Castalia-Nymphaea* association.
25. *Potamogeton natans* association.
26. Little Dead River.
27. *Nymphaea advena.*
28. *Typha latifolia.*
29. *Scirpus validus* association.
30. *Scirpus americanus* association.
31. *Liatris spicata* prairie.
32. *Scirpus americanus* association.
33. *Panicum virgatum* ridge.
34. *Juncus torreyi* association.
35. *Liatris spicata* prairie.
36. *Juncus torreyi* association.
37. *Scirpus validus* association.
38. *Typha latifolia.*
39. *Scirpus americanus* association.
40. Elgin, Joliet and Eastern railway.
41. Swale, whose structure was exceedingly complex.
42. A ridge which had been cleared and was covered with weeds, including especially *Polygonum orientale* and *Helianthus annuus.*
43. *Liatris spicata* prairie.
44. *Phragmites-Typha* swamp, eighty feet wide.
45. *Scirpus validus* association.
46. *Scirpus americanus* association.
47. Chicago and North Western railway.
48. Cultivated land.
49. *Ulmus-Acer* association at the foot of the bluff.
50. Bluff covered for the most part with oak-hickory woods.

SECTION MADE ALONG THE LINE OF THE PEST-HOUSE ROAD BETWEEN WAUKEGAN AND BEACH, AUGUST, 1909

1. Lake Michigan.
2. Lower beach, devoid of plants.
3. Middle beach, bare except for an occasional *Xanthium.*
4. *Salix syrticola* fringing dune.
5. Depression.
6. Small *Populus-Salix* dunes.
7. *Andropogon scoparius* bunch-grass prairie.
8. *Calamovilfa* dune.

9. Bunch-grass prairie.
10. Heath represented by *Arctostaphylos.*
11. Bunch-grass prairie.
12. Heath of *Arctostaphylos.*
13. *Calamovilfa* dune.
14. Bunch-grass prairie.
15. Heath of *Arctostaphylos* and *Juniperus.*
16. *Potentilla fruticosa* association.
17. *Juncus torreyi* association.
18. *Cladium mariscoides* swale.
19. *Calamovilfa* dune, mostly supplanted by heath.
20. A suggestion of *Liatris spicata* prairie by *Tofieldia.*
21. Heath.
22. *Juncus torreyi.*
23. *Cladium* swale.
24. *Liatris spicata* prairie.
25. *Juncus torreyi* association.
26. *Cladium* swale.
27. *Liatris spicata* prairie.
28. *Scirpus americanus* association.
29. *Potamogeton* association.
30. *Juncus torreyi* association.
31. *Liatris spicata* prairie.
32. *Juncus torreyi* association.
33. *Scirpus americanus* association.
34. *Cladium mariscoides* association.
35. *Scirpus americanus* association.
36. *Scirpus validus* association.
37. *Nymphaea advena.*
38. Open water.
39. *Scirpus validus* association.
40. *Scirpus americanus* association.
41. *Liatris spicata* prairie.
42. *Cladium* swale.
43. *Liatris scariosa* association with blowouts.
44. *Scirpus americanus* association.
45. *Cladium* swale.
46. *Liatris spicata* prairie.
47. *Cladium* swale.
48. *Liatris scariosa* ridge with a few relic pines.
49. *Calamagrostis canadensis* association.

50. A ridge with *Calamovilfa, Betula alba papyrifera,* and *Juniperus.*
51. *Cladium* swale of considerable width.
52. *Scirpus americanus* association.
53. *Scirpus validus* association.
54. *Sagittaria latifolia.*
55. *Liatris spicata* prairie.
56. *Scirpus validus* association.
57. *Typha latifolia* association.
58. *Sagittaria latifolia.*
59. *Liatris spicata* prairie giving way to thicket.
60. *Scirpus validus* association.
61. *Typha latifolia.*
62. *Scirpus validus* association.
63. *Liatris spicata* prairie with a few relic pines.
64. *Scirpus validus* swale.
65. *Liatris spicata* prairie on a ridge.
66. *Scirpus validus* association.
67. *Liatris spicata* prairie.
68. *Scirpus validus* association.
69. Chicago and North Western railway.
70. *Typha latifolia.*
71. *Calamagrostis canadensis* association.
72. *Salix* thicket.
73. *Calamagrostis* association.
74. *Salix* thicket which has followed *Liatris spicata.*
75. *Scirpus validus* association.
76. *Phragmites-Typha* association.
77. *Scirpus validus* association.
78. *Salix* thicket.
79. *Scirpus fluviatilis.*
80. *Populus-Salix* thicket.
81. Bluff woods, of oaks and hickories for the most part.

A section taken north of Beach would show, behind the dune-complex, ridges of *Quercus velutina* alternating with thickets and with prairie for a distance of about 0.8 km. from the lake. Between the last ridge of oaks and the railway, areas of prairie alternate with areas of swamp. Sections taken farther north become simpler, and contain fewer and fewer associations until, near Kenosha, the bluff is cut into by the lake.

General Conclusions

Consideration of the foregoing data makes evident the successional relations of the three floral provinces represented in the Beach area. And what holds good for this area is applicable to northeastern Illinois and southeastern Wisconsin in general, as might naturally be expected. Over the greater part of this general region there is a greater extent of prairie than of forest, but in the Beach area, forests occupy about half the ground. The larger part of the forest is the deciduous forest of the southeastern center of dispersal.

Successions clearly show that there have been times in the past when each one of these provinces was more widely extended than is now the case. This is particularly true of the prairie and the conifer forest, for they are gradually being reduced in extent through natural causes which at the same time favor the increase of the deciduous forest. Aside from wave action the factors that tend toward the destruction of the deciduous forest are all connected with the inroads of man.

Before going further into detail, a recapitulation of the pertinent characteristics of the vegetation of the different floral provinces is in order.

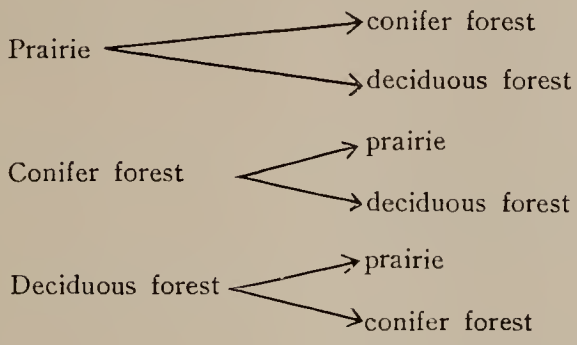
Prairie Province.—The vegetation is less than two meters, usually about one meter, in hight, consisting of grasses and herbs usually assembled very closely together, often forming sod. The plants will stand a considerable variation in the moisture content of the soil but require virtually the maximum amount of light.

Deciduous Forest Province.—The dominant plants are deciduous trees, in the more xerophytic associations, such as are represented in this region, rather openly assembled, giving all variation in shade, usually with little or no sod. The ground vegetation is open, and often consists of a number of plants whose showy flowers constitute the seasonal aspects. The seedlings are rather intolerant of shade, but otherwise develop very readily. Once established on this sandy soil, associations of this province are usually permanent.

Northeastern Conifer Forest Province.—The plants are evergreen trees or prostrate evergreen shrubs, growing in sandy soil in more or less closed assemblages. The denser assemblages of trees cast so much shade that all undergrowth is prohibited and the ground is carpeted with pine needles. Where the assemblages are more open, there are numerous herbaceous plants. With the exception of a very few local stations, the pines of this region are not reproducing themselves. On the other hand, the heath plants reproduce readily, by

seeds as well as through vegetative means, on the more xerophytic soils.

With these characteristics in mind, consideration can now be given to the different lines of succession that are theoretically possible between the associations of the three provinces. The possible successions are indicated below, and will be taken up in corresponding order.



As this region is nominally placed in the prairie on maps of vegetation (by Pound and Clements, Engler, Transeau, Sargent, and others), the successional relationships of the prairie will be taken up first. In this region the prairie should not be replaced by the conifer forest, as it is south of the natural range of that province. Locally, where the prairie sod has been accidentally broken, young pines are occasionally found, but as the occurrence is so plainly accidental, and taking into consideration other facts of the region, it is perfectly justifiable to say that in this region the prairie will never be succeeded by conifer forest.

In the case of the deciduous forest, matters are different. Prairie and deciduous forest are everywhere in juxtaposition, which results in the shading of the edges of the prairie. This occasions the gradual breaking up of the normally dense prairie growth, permitting the occurrence of open places in which the deciduous forest can readily take hold. Such succession is very slow. Occasionally an oak will effect ecesis in the body of the prairie itself—the result of accidental planting, probably by crows or jays. Once started, nothing but accident prevents the development of mature trees, which by their increasing shade modify the prairie radially and serve as a nucleus for the spread of the forest. As long as the prairie sod remains intact, however, this succession can not take place. Yet, notwithstanding the fact that things are changing slowly, it is apparent that, under

present climatic conditions, the prairie of this region will ultimately give place to the deciduous forest.

In dealing with the conifer forest province it must be kept in mind that the area is several (130) kilometers south of the southern limit of the province in eastern Wisconsin, and virtually no invasion by it into other provinces could be expected. The question is whether or not it can hold its own. In the case of the prairie this question is usually decided in the affirmative, as the prairie can not exist in the dense shade of the conifers. It spreads into the pines only when some of their number die. Then it takes possession of the open spaces and prevents reproduction of the pines, so that with the dying of the old trees the prairie is left supreme. (Fig. 2, Pl. LVI.)

Seedlings of the oak *Quercus velutina,* are present almost throughout the area of the pines, with the exception of the very densest parts. While usually only the oaks in the open places develop, the continual presence of seedling oaks under the pines means that whenever a pine dies, in a short time its place is occupied by a number of oak trees, under whose shade the seedling pines—few in number at best—can not develop. It is therefore clearly evident that in this region the remaining representatives of the conifer forest province will ultimately be replaced by trees, representative of the deciduous forest province.

These same general statements, slightly modified, hold true for the heath association, a member of the conifer forest province. The typical heath plants are somewhat more lenient in their ecological demands than the coniferous trees, which signifies, however, only that a much greater length of time will be necessary to effect their elimination from the region. As long as the prairie growth is fairly open, the heath and prairie plants thrive together, but a dense prairie growth is very efficient in choking out the heath. Heath plants are only fairly tolerant of shade; but as long as the open black oak woods prevail, the heath can readily persist in the open places. Greater shading eliminates bearberry (*Arctostaphylos*), but *Juniperus horizontalis* and especially *J. communis depressa* can exist even in the much denser shading of a bur oak (*Quercus macrocarpa*) woods. Here, however, they are etiolated in response to the diminution of light, and show the other characteristic modifications induced by shade, namely, broader, flatter leaves which spread more, making a looser and weaker growth.

The deciduous forest—now occupying nearly half of the Beach area—is the natural climatic floral province to be expected in this region with the present conditions of climate. In all natural suc-

cessions this province maintains its dominance. The prairie can not naturally supersede it because the climatic conditions are suitable for the development of forests, and the prairie, as a unit, can not make headway under shade. Conifers can not succeed the deciduous forest because they can not reproduce themselves in it.

In view of these facts, it is plainly evident that, under the present conditions of climate, the deciduous forest province is the dominant one in this region, and if left to itself in nature would ultimately occupy the entire region.

Summary

1. The Beach area is a strip of low sandy land bordering Lake Michigan in northeastern Illinois and southeastern Wisconsin. Its length is about 14 miles and its extreme width is a little over a mile. Its maximum elevation above Lake Michigan is less than 30 feet.

2. This region lies a little way south of the southern limits of the Northeastern Conifer Province, within an area of competition between the Prairie and Deciduous Forest provinces, in a climate which is favorable to tree growth.

3. During postglacial times the entire region was submerged, and within the past eighty years the region has at times been virtually inundated.

4. The region contains 55 plant associations, representing three plant provinces: Northeastern Conifer, Prairie, and Deciduous Forest.

5. A study of the successions between the different plant associations gives a very satisfactory understanding of plant dynamics.

6. The two fundamental starting-points for genetic series are the open water of Lake Michigan and of the streams that flow into it. The lines of succession commence with open water and proceed through stages of progressively increasing dryness, which culminates, in the Beach area proper, in the black oak association. The intermediate steps group themselves along several genetic lines.

7. Commencing with Lake Michigan, one genetic line extends from aquatic algae through associations inhabiting progressively drier soil in the depressions and swales between the ridges. Another line begins with the plants that inhabit the open beach, where they are exposed to extreme xerophtic conditions, because of a continual addition to the food in the soil, and advances to associations of an increasing number of species and a higher type of vegetative development. A third line commences in the streams with plants which are wholly

submerged, and proceeds through associations of plants which are progressively less hydrophytic to those which are mesophytic.

8. A change in the water-table level—whether brought about by special factors, as local erosion, blowing away or piling up of sand, or general factors, as periodical fluctuations in the level of Lake Michigan—very materially aids the plant dynamics in bringing about these successions.

9. The establishment of a genetic series may be initiated by nearly any of its lower members, while the advanced stages are dependent upon preceding associations for a foothold.

10. Favorable chances for invasion are usually readily taken advantage of, while the unfavorable periods of the lesser climatic cycles tend to produce adaptations to those conditions rather than a reversal of the normal line of succession.

11. Aquatic associations have a relatively greater number of individuals of a much smaller number of species than land associations.

12. Associations in the middle of a true genetic series are composed of a larger number of species than the associations towards the beginning or towards the end of the series.

13. Although most of the aquatic and semiaquatic plants are closely restricted within certain depths of water, their position in any given locality is determined by competition of associations rather than by the different physical requirements of the plants. The same relative arrangement is maintained within the limits of the requirements of the individual plants in different localities, even though the absolute conditions may vary greatly.

14. When associations within one formation are concerned, succession usually begins by the invasion of the secondary species of the invading association, and the succession may be said to be completed when the dominant species have made their appearance.

15. In the case of the invasion of an association of one formation into an area occupied by an association of another formation, invasion is effected by the dominant species with the subsequent appearance of the secondary species. Invasion of one formation into another takes place through the genetically lower, or pioneer associations.

16. In the Beach area, either the black oak or the prairie may displace the conifers; the prairie also gives way to the deciduous forest. Associations of the marsh habitats usually go through a prairie stage before becoming forested by deciduous trees.

List of the Species of Plants Growing on the Beach Area

This list is arranged in systematic order, with the collection numbers of those collected. The nomenclature is that of Gray's Manual, 7th edition. Synonyms are given in parentheses.

THALLOPHYTA

Chlamydomonas sp.?
Oscillatoria sp.?
Chara sp.? (3202)
(No other genera of algae were determined)

BRYOPHYTA

Riccia fluitans L. (3217)
Marchantia polymorpha L. (3151) Liverwort
Polytrichum juniperinum Willd. (2744) Moss
(No other species were determined)

PTERIDOPHYTA

Polypodiaceae. Fern Family.

Pteris aquilina L. Bracken Fern
Aspidium thelypteris (L.) Sw. (2501, 2801, 2929) Marsh Fern

Osmundaceae. Flowering Fern Family.

Osmunda regalis L. (O. spectabilis Willd.) (1652, 2765) Royal Fern

Equisetaceae. Horsetail Family.

Equisetum arvense L. Horsetail
Equisetum laevigatum A. Br. Scouring rush
Equisetum hiemale L. (3041) Scouring rush

SPERMATOPHYTA

Pinaceae. Pine Family.

Pinus strobus L. (2483, 2809, 2905) White Pine
Pinus laricio Poir. (2841, 2903) Austrian Pine
Pinus silvestris L. (3165, 3205) Scotch Pine
Pinus sp.
Larix decidua Mill. (2460, 2842) Tamarack

Juniperus communis depressa Pursh. (1659, 2843, 2907) Juniper
Juniperus horizontalis Moench. (1658) Procumbent Juniper
Juniperus virginiana L. (2910) Red Cedar

Typhaceae. Cattail Family.

Typha latifolia L. (3091) Cattail
Typha angustifolia L. (2824) Narrow-leaved Cattail
Typha latifolia x angustifolia (2915)

Sparganiaceae. Bur-reed Family.

Sparganium eurycarpum Engelm. (2831) Bur-reed

Naiadaceae. Pondweed Family.

Potamogeton natans L. Pondweed
Potamogeton foliosus niagarensis (Tuckerm.) Morong. (3246) Pondweed

Juncaginaceae. Arrow Grass Family.

Triglochin maritima L. (2515) Arrow Grass
Triglochin palustris L. (2867)

Alismaceae. Water-plantain Family.

Sagittaria latifolia Willd. (2908) Arrowleaf
Sagittaria heterophylla rigida (Pursh) Engelm. Arrowleaf
Alisma plantago-aquatica L. (2902) Water-plantain

Hydrocharitaceae. Frog's Bit Family.

Elodea canadensis Michaux. Water-weed

(Gramineae) Poaceae. Grass Family.

Andropogon scoparius Michx. (2921) Beard Grass
Andropogon furcatus Muhl. (2940) Beard Grass
Sorghastrum nutans (L.) Nash. (2966)
Digitaria sanguinalis (L.) Scop. (3257) Finger Grass, Crab Grass
Panicum capillare L. (3232) Witch Grass, Old-witch Grass
Panicum virgatum L. (2938) Switch Grass
Panicum huachucae Ashe. (3224)
Panicum scribnerianum Nash. (3065)
Echinochloa crusgalli (L.) Beauv. (3209) Barnyard Grass
Cenchrus carolinianus Walt. (2980) Sandbur
Leersia oryzoides (L.) Sw. (2985) Rice Cut-grass

Hierochloe odorata (L.) Wahlenb. Vanilla Grass
Stipa spartea Trin. (2464) Porcupine Grass
Aristida purpurascens Poir. (3260)
Phleum pratense L. (3064) Timothy
Sporobolus cryptandrus (Torr.) A. Gray. (3255) Drop-seed
Sporobolus heterolepis A. Gray. (3223)
Agrostis alba L. Red Top.
Calamovilfa longifolia (Hook.) Hack. (2920)
Calamagrostis canadensis (Michx.) Beauv. (2823) Reed Grass, Blue-joint Grass
Ammophila arenaria (L.) Link. (3201, 3281) Beach Grass
Koeleria cristata (L.) Pers. (2467, 2763)
Spartina michauxiana Hitchc. (2913) Slough Grass
Phragmites communis Trin. (3166) Reed
Poa compressa L. (2860) English Blue Grass
Poa pratensis L. (3037) Blue Grass, June Grass, Spear Grass, Kentucky Blue Grass
Glyceria nervata (Willd.) Trin. (2810)
Festuca octoflora Walt. (2468) Fescue Grass
Bromus tectorum L.
Bromus incanus (Shear) Hitchc. (3173)
Bromus kalmii Gray. (2762, 2795) Wild Chess
Elymus canadensis L. (2879, 2880) Wild Rye

Cyperaceae. Sedge Family.

Cyperus rivularis Kunth. (2986) Sedge
Cyperus schweinitzii Torr. (3149)
Cyperus filiculmis macilentus Fernald. (3147)
Dulichium arundinaceum (L.) Britton. (3261)
Eleocharis acuminata (Muhl.) Nees. Spike Rush
Eleocharis intermedia (Muhl.) Schultes. (2926)
Fimbristylis castanea (Michx.) Vahl. (2814, 2863)
Scirpus americanus Pers. (2508, 2856.) 3-angle Bulrush
Scirpus validus Vahl. (2862, 2865) Great Bulrush
Scirpus occidentalis (Wats.) Chase. (Collected by Dr. H. A. Gleason and determined by Mrs. Chase.)
Scirpus fluviatilis (Torr.) Gray. (2785) River Bulrush
Scirpus rubrotinctus Fernald. (3059)
Scirpus atrovirens Muhl. (2770)
Scirpus lineatus Michx. (2836)
Eriophorum angustifolium Roth. (E. polystachion L. in part) (1669, 2523) Cotton Grass

Rynchospora alba (L.) Vahl. (Collected by L. M. Umbach, July 31, 1909.)
Rynchospora capillacea leviseta E. J. Hill. (2851, 2925) Beak Rush
Cladium mariscoides (Muhl.) Torr. (2857, 2868, 2916) Twig Rush
Scleria triglomerata Michx. (2772) Nut Rush
Scleria verticillata Muhl. (3210)
Carex bebbii Olney. Sedge
Carex aurea Nutt. (2503)
Carex buxbaumii Wahl. (2504)
Carex comosa Boott. (2917)
Carex crawei Dewey. (2502, 2821)
Carex filiformis L.
Carex hystericina Muhl. (2787)
Carex lanuginosa Michx. (3027)
Carex muhlenbergii Schk. (2465, 3163)
Carex oederi pumila (Cosson & Germain) Fernald. (C. viridula Michx.) (2509, 2517)
Carex riparia W. Curtis. (2786)
Carex stipata Muhl. (3052)
Carex stricta Lam. (2498)
Carex trisperma Dewey. (Collected by Dr. H. A. Gleason)
Carex umbellata Schk. (2474)

Araceae. Arum Family.

Symlocarpus foetidus (L.) Nutt. (3062) Skunk Cabbage
Acorus calamus L. (2766, 2897) Sweet Flag

Lemnaceae. Duckweed Family.

Lemna minor L. (3218) Duckweed

Commelinaceae. Spiderwort Family.

Tradescantia reflexa Raf. (3022) Spiderwort

Pontederiaceae. Pickerel-weed Family.

Pontederia cordata L. Pickerel-weed

Juncaceae. Rush Family.

Juncus bufonius L. (2782) Rush
Juncus tenuis Willd.
Juncus balticus littoralis Engelm. (2882, 2923, 3250)
Juncus canadensis J. Gay. (2848, 2850)
Juncus torreyi Coville. (2869, 2909)

Juncus alpinus insignis Fries.
Luzula campestris multiflora (Ehrh.) Celak. (3046) Wood Rush

Liliaceae. Lily Family.

Tofieldia glutinosa (Michx.) Pers. (2789, 2846, 2912) False Asphodel
Allium cernuum Roth. (2895) Nodding Onion
Lilium canadense L. (2828) Wild Yellow Lily
Lilium philadelphicum andinum (Nutt.) Ker. (2764, 2777, 2793, 2807, 2947, 2933) Wood Lily
Asparagus officinalis L. (3023) Asparagus
Smilacina stellata (L.) Desf. (2492) False Solomon's Seal
Maianthemum canadense Desf. (2484, 2488) One-leaved Solomon's Seal
Polygonatum biflorum (Walt.) Ell. Small Solomon's Seal
Polygonatum commutatum (R. & S.) Dietr. (3025) Great Solomon's Seal
Aletris farinosa L. (2748, 2835) Colic Root
Smilax ecirrhata (Engelm.) Watson. Carrion Flower
Smilax hispida Muhl. Green Brier

Dioscoreaceae. Yam Family.

Dioscorea paniculata Michx. (3113) Yam

Amaryllidaceae. Amaryllis Family.

Hypoxis hirsuta (L.) Coville. (2519) Star Grass

Iridaceae. Iris Family.

Iris versicolor L. (2521) Iris
Sisyrinchium sp.? (2485, 2514, 2855, 3018) Blue-eyed Grass

Orchidaceae. Orchid Family.

Cypripedium hirsutum Mill. (C. reginae Walt.) (2961) Showy Lady's Slipper
Habenaria hyperborea (L.) R. Br.
Habenaria dilatata (Pursh) A. Gray. (2753, 2797)
Habenaria clavellata (Michx.) Spreng. (2884)
Habenaria leucophaea (Nutt.) A. Gray. (2800, 2840) White Fringed Orchid
Habenaria psycodes (L.) Sw. (3176, 3182) Purple Fringed Orchid
Pogonia ophioglossoides (L.) Ker. (2754, 2804)
Calopogon pulchellus (Sw.) R. Br. (2747)

Spiranthes cernua (L.) Richard. (2992, 2971) Ladies' Tresses
Liparis loeselii (L.) Richard. (2507) Twayblade

Salicaceae. Willow Family.

Salix amygdaloides Anders. (3172, 3175) Peach-leaved Willow
Salix lucida Muhl. (2900, 3060, 3170) Shining Willow
Salix serissima (Bailey) Fernald. (2995) Autumn Willow
Salix longifolia Muhl. (3080) Sand-bar Willow
Salix cordata Muhl.
Salix glaucophylla Bebb. (3033, 3036)
Salix syrticola Fernald. (2459, 3156)
Salix pedicellaris Pursh. (3174)
Salix discolor Muhl. Pussy Willow
Salix candida Fluegge. (2758) Hoary Willow
Populus tremuloides Michaux. (3104) Trembling Aspen
Populus candicans Aiton. (2780, 3155) Balm of Gilead
Populus deltoides Marsh. (3035) Cottonwood

Juglandaceae. Walnut Family.

Juglans nigra L. (3117) Black Walnut
Carya ovata (Mill.) K. Koch. (3120) Shag-bark Hickory

Betulaceae. Birch Family.

Betula alba papyrifera (Marsh.) Spach. (3097) White Birch
Betula pumila L. (2493, 2500, 2813) Swamp Birch

Fagaceae. Beech Family.

Quercus alba L. (3125) White Oak
Quercus macrocarpa Michaux. (3119) Bur Oak
Quercus velutina Lam. (2981) Black Oak

Santalaceae. Sandalwood Family.

Comandra umbellata (L.) Nutt. (2790) Bastard Toad-flax

Polygonaceae. Buckwheat Family.

Rumex britannica L. (3231) Great Water Dock
Rumex acetosella L. (3063) Sheep Sorrel
Rumex crispus L. (3095) Curled Dock
Polygonum tenue Michaux. (3206) Smartweed
Polygonum lapathifolium L. (=P. incarnatum Ell.) (3227)
Polygonum amphibium hartwrightii (A. Gray) Bissell. (3179)
Polygonum muhlenbergii (Meisn.) Wats. (3247)

Polygonum pennsylvanicum L. (3238)
Polygonum acre HBK. (3241)
Polgonum persicaria L. (3253) Lady's Thumb
Polygonum hydropiperoides Michaux. Mild Water Pepper

Chenopodiaceae. Goosefoot Family.

Cycloloma atriplicifolium (Spreng.) Coulter. (2975) Winged Pigweed
Chenopodium album L. Lamb's Quarters
Corispermum hyssopifolium L. (3226) Bug-seed
Salsola kali tenuifolia G. F. W. Mey. (2974) Russian Thistle

Amaranthaceae. Amaranth Family.

Acnida tuberculata subnuda Wats. Water Hemp

Caryophyllaceae. Pink Family.

Arenaria stricta Michaux. (2510) Sandwort
Silene antirrhina L. (2449) Sleepy Catchfly
Silene stellata (L.) Aiton f. (3267) Starry Campion

Ceratophyllaceae. Hornwort Family.

Ceratophyllum demersum L. (Collected by Dr. H. A. Gleason.)

Nymphaeaceae. Water Lily Family.

Nymphaea advena Aiton. (3015) Yellow Water Lily
Castalia tuberosa (Paine) Greene. (3204) White Water Lily

Ranunculaceae. Crowfoot Family.

Ranunculus aquatilis capillaceus DC. (Batrachium trichophyllum Bosch) (3014) White Water Crowfoot
Ranunculus delphinifolius Torrey. Yellow Water Crowfoot
Ranunculus sceleratus L. Cursed Crowfoot
Ranunculus pennsylvanicus L. f. (3244) Bristly Crowfoot
Anemone cylindrica A. Gray. (2761) Anemone
Anemone virginiana L. (3140)
Anemone canadensis L. (3029)

Berberidaceae. Barberry Family.

Podophyllum peltatum L. (3056) May Apple

(Cruciferae) Brassicaceae. Mustard Family.

Draba caroliniana Walt. (2477)
Lepidium apetalum Willd. (3101) Peppergrass

Cakile edentula (Bigel.) Hook. (2976) Sea Rocket
Sisymbrium officinale leiocarpum DC. (3251) Hedge Mustard
Radicula palustris (L.) Moench. Water Cress
Arabis lyrata L. (2511) Rock Cress

Droseraceae. Sundew Family.

Drosera rotundifolia L. (2803) Sundew

Crassulaceae. Orpine Family.

Penthorum sedoides L. (3248) Ditch Stonecrop

Saxifragaceae. Saxifrage Family.

Heuchera hispida Pursh. (1663, 2451) Alum Root
Parnassia caroliniana Michaux. (2959) Grass of Parnassus

Rosaceae. Rose Family.

Spiraea salicifolia L. (2888) Spiraea
Pirus malus L. (Malus malus (L.) Britton) Apple
Crataegus punctata Jacq. (3110) Thorn Apple
Fragaria virginiana Duchesne. (2455, 2480, 2773) Strawberry
Potentilla arguta Pursh. (2829)
Potentilla palustris (L.) Scop. (Comarum palustre L.) (3178) Marsh Five-finger
Potentilla fruticosa L. (Dasiphora fruticosa (L.) Rydb.) (2853, 2973) Shrubby Cinquefoil
Potentilla anserina L. (Argentina anserina (L.) Rydb.) (2518, 2924 Silver Weed
Geum canadense Jacq. (3107) Avens
Rubus occidentalis L. Black Raspberry
Agrimonia gryposepala Wallr. (3278) Agrimony
Rosa blanda Aiton. (3262) Smooth Wild Rose
Rosa carolina L. Swamp Wild Rose
Rosa humilis Marsh. (3167)
Prunus serotina Ehrh. (3028) Black Cherry
Prunus virginiana L. (3024) Choke Cherry
Prunus pumila L. (2458, 2745) Sand Cherry

Leguminosae. Pulse Family.

Baptisia leucantha Torr. & Gray. (2750) False Indigo
Lupinus perennis L. (2452) Wild Lupine
Trifolium pratense L. Red Clover
Trifolium repens L. White Clover

Trifolium hybridum L. Alsike Clover
Melilotus alba Desr. White Sweet Clover
Amorpha canescens Pursh. (2894) Lead Plant
Petalostemum purpureum (Vent.) Rydb. (2872) Purple Prairie Clover
Petalostemum purpureum f. arenarium Gates, forma nova (2922) Sand-Prairie Clover
Petalostemum candidum Michaux. (2832, 2871) White Prairie Clover
Astragalus canadensis L. (3042) Milk Vetch
Desmodium illinoense A. Gray. Tick Trefoil
Lespedeza capitata Michaux. (2962) Bush Clover
Vicia americana Muhl. Vetch
Lathyrus palustris myrtifolius (Muhl.) A. Gray. (2822) Vetchling
Lathyrus maritimus (L.) Bigel. (3157) Beach Pea
Lathyrus venosus Muhl. (3016)
Apios tuberosa Moench. (2946) Wild Bean
Amphicarpa monoica (L.) Ell. Hog Peanut

Linaceae. Flax Family.

Linum virginianum L. (2833, 2845) Flax
Linum sp.

Oxalidaceae. Wood Sorrel Family.

Oxalis stricta L. (3230) Wood Sorrel

Geraniaceae. Geranium Family.

Geranium maculatum L. (3044) Wild Geranium
Geranium carolinianum L. (3152)

Rutaceae. Rue Family.

Ptelea trifoliata L. (3229) Hop Tree

Polygalaceae. Milkwort Family.

Polygala polygama Walt. (2768) Milkwort
Polygala sanguinea L. (2948)
Polygala verticillata L. (2883)

Euphorbiaceae. Spurge Family.

Euphorbia polgygonifolia L. (2967) Seaside Spurge
Euphorbia maculata L. (3258) Milk Purslane
Euphorbia corollata L. (2852, 2892) Flowering Spurge

Anacardiaceae. Cashew Family.

Rhus typhina L. Staghorn Sumac
Rhus toxicodendron L. (2506, 2805) Poison Ivy
Rhus toxicodendron radicans (L.) Torrey. Climbing Poison Ivy

Celastraceae. Staff Tree Family.

Celastrus scandens L. Bittersweet

Aceraceae. Maple Family.

Acer negundo L. Box Elder

Balsaminaceae. Touch-me-not Family.

Impatiens biflora Walt. (2968) Spotted Touch-me-not

Rhamnaceae. Buckthorn Family.

Rhamnus alnifolia L'Her. (2486) Buckthorn
Ceanothus americanus L. (3162) New Jersey Tea
Ceanothus ovatus Desf. (1656, 2470, 2812) Red-root

Vitaceae. Vine Family.

Psedera quinquefolia (L.) Greene. Virginia Creeper
Vitis vulpina L. (2930) River-bank Grape

Tiliaceae. Linden Family.

Tilia americana L. (3098) Basswood

Hypericaceae. St. John's-wort Family.

Hypericum kalmianum L. (2462, 2844) Kalm's St. John's-wort
Hypericum sp.
Hypericum virginicum L. (Triadenum virginicum (L.) Raf.) (2963) Marsh St. John's-wort

Cistaceae. Rockrose Family.

Helianthemum majus BSP (2752) Frostweed
Lechea villosa Ell. (2956) Pinweed
Lechea leggettii Britton & Hollick. (2889, 2932, 2955)

Violaceae. Violet Family.

Viola papilionacea Pursh. (2448) Violet
Viola sagittata Aiton (=V. subsagittata Greene). (2481, 2839, 3161) Violet

Cactaceae. Cactus Family.

Opuntia rafinesquii Engelm. (2802) Prickly Pear

Lythraceae. Loosestrife Family.

Lythrum alatum Pursh. (3159) Loosestrife

Onagraceae. Evening Primrose Family.

Ludvigia palustris (L.) Ell. (Isnardia palustris L.) (2898) Water Purslane
Epilobium angustifolium L. (2759) Fireweed
Epilobium densum Raf. (2989, 3236) Willow-herb
Oenothera biennis L. Evening Primrose
Oenothera rhombipetala Nutt. (3158)

Haloragidaceae. Water Milfoil Family.

Myriophyllum verticillatum L. Water Milfoil
Proserpinaca palustris L. (3215) Mermaid-weed

Araliaceae. Ginseng Family.

Aralia nudicaulis L. Wild Sarsaparilla

Umbelliferae. Parsley Family.

Eryngium yuccifolium Michaux. (2886) Rattlesnake Master
Sanicula marilandica L. (3021) Black Snakeroot
Cicuta bulbifera L. (3234). Bulbiferous Water Hemlock
Cicuta maculata L. (3111) Water Hemlock
Zizia aurea (L.) Koch. (2476) Golden Alexanders
Heracleum lanatum Michaux. (3123) Cow Parsnip
Oxypolis rigidior (L.) Coulter & Rose. (2934) Cowbane

Cornaceae. Dogwood Family.

Cornus stolonifera Michaux. (2505, 2757, 3032) Red-osier Dogwood

Ericaceae. Heath Family.

Arctostaphylos uva-ursi (L.) Spreng. (2491) Bearberry

Primulaceae. Primrose Family.

Lysimachia thyrsiflora L. (Naumburgia thyrsiflora (L.) Duby) (2520) Tufted Loosestrife
Steironema quadiflorum (Sims) Hitchcock. (2873)
Dodecatheon meadia L. (2450) Shooting Star

Gentianaceae. Gentian Family.

Gentiana crinita Froel. Fringed Gentian
Gentiana procera Holm. (2977, 2997, 3284, 3287) Small Fringed Gentian
Gentiana andrewsii Griseb. (3271) Closed Gentian
Menyanthes trifoliata L. (3177) Buckbean

Apocynaceae. Dogbane Family.

Apocynum androsaemifolium L. (3114) Spreading Dogbane
Apocynum cannabinum hypericifolium (Ait.) A. Gray. Indian Hemp

Asclepiadaceae. Milkweed Family.

Asclepias tuberosa L. (2781) Butterfly-weed
Asclepias purpurascens L. (2779) Purple Milkweed
Asclepias incarnata L. (2896) Swamp Milkweed
Ascelpias syriaca L. (3088) Common Milkweed
Ascelpias amplexicaulis Sm. (2746)
Acerates viridiflora Ell. Green Milkweed
Acerates viridiflora lanceolata (Ives) A. Gray. (2806, 2808) Sand Green Milkweed

Convolvulaceae. Convolvulus Family.

Convolvulus sepium L. (3150) Hedge Bindweed

Polemoniaceae. Polemonium Family.

Phlox glaberrima L. (2791, 2837, 2991) Phlox
Phlox pilosa L. (2456) Phlox

Boraginaceae. Borage Family.

Lithospermum gmelini (Michx.) Hitchc. (2490, 2776) Puccoon
Lithospermum angustifolium Michaux. (1655, 3017) Puccoon

Verbenaceae. Vervain Family.

Verbena hastata L. (3211) Blue Vervain

Labiatae. Mint Family.

Isanthus brachiatus (L.) BSP. (3242) False Pennyroyal
Scutellaria galericulata L. (2756) Skullcap
Scutellaria parvula Michaux. (2461) Small Skullcap
Nepeta cataria L. (3136) Catnip
Prunella vulgaris L. Self-heal

Monarda fistulosa L. (3168) Wild Bergamot
Monarda mollis L.
Monarda punctata L. (2939) Horse Mint
Satureja glabra (Nutt.) Fernald. (2788, 2861) Calamint
Pycnanthemum virginianum (L.) Durand & Jackson. (2874) Mountain Mint
Lycopus sp.? (3243)
Lycopus americanus Muhl. (2899, 2935) Water Horehound
Mentha arvensis canadensis (L.) Briquet. Mint

Solanaceae. Nightshade Family.

Solanum nigrum L. Common Nightshade
Physalis virginiana Mill. (2463) Ground Cherry

Scrophulariaceae. Figwort Family.

Verbascum thapus L. (3259) Mullen
Linaria vulgaris Hill. Butter and Eggs
Scrophularia leporella Bicknell. (3092) Figwort
Chelone glabra L. (3269) Turtlehead
Veronica virginica L. (2927) Culver's-root
Veronica anagallis-aquatica L. (3239) Water Speedwell
Gerardia pedicularia L. Gerardia
Gerardia grandiflora Benth.
Gerardia paupercula (A. Gray) Britton. (2970)
Gerardia skinneriana Wood. (2942, 2964)
Gerardia tenuifolia Vahl. (3212) Slender Gerardia
Castilleja coccinea (L.) Spreng. (2479) Scarlet Painted Cup
Castilleja sessiliflora Pursh. (2466, 2751, 2811) Painted Cup
Pedicularis canadensis L. (2496) Common Lousewort
Pedicularis lanceolata Michaux. (3235) Lousewort

Lentibulariaceae. Bladderwort Family.

Utricularia vulgaris americana A. Gray. (3180) Bladderwort
Utricularia cornuta Michaux. (2847)

Orobanchaceae. Broom-rape Family.

Orobanche fasciculata Nutt. (2482, 2487) Broom-rape

Bignoniaceae. Bignonia Family.

Catalpa speciosa Warder. (3169) Catalpa

Plantaginaceae. Plantain Family.

Plantago major L. Common Plantain
Plantago rugelii Dcne.

Rubiaceae. Madder Family.

Galium boreale L. (2767) Northern Bedstraw
Galium trifidum L. (3237) Bedstraw
Cephalanthus occidentalis L. Buttonbush

Caprifoliaceae. Honeysuckle Family.

Lonicera dioica L. (2453) Honeysuckle
Viburnum lentago L. (3094) Sweet Viburnum
Sambucus canadensis L. (3116) Elder

Valerianaceae. Valerian Family.

Valeriana edulis Nutt. (1666) Valerian

Cucurbitaceae. Gourd Family.

Echinocystis lobata (Michx.) Torr. & Gray. Wild Cucumber

Campanulaceae. Bluebell Family.

Campanula aparinoides Pursh. (2885) Marsh Bluebell

Lobeliaceae. Lobelia Family.

Lobelia cardinalis L. (3214) Cardinal-flower
Lobelia siphilitica L. (2993) Great Lobelia
Lobelia spicata Lam. (2818) Spiked Lobelia
Lobelia kalmii L. (2919) Kalm's Lobelia

Compositae. Composite Family.

Vernonia fasciculata Michaux. (3213) Ironweed
Eupatorium purpureum maculatum (L.) Darl. (2950) Jo-Pye Weed
Eupatorium perfoliatum L. (2951) Boneset
Liatris cylindracea Michaux. (2943) Blazing Star
Liatris scariosa Willd. (2958) Blazing Star
Liatris spicata (L.) Willd. (2937, 2928) Blazing Star
Solidago speciosa Nutt. Goldenrod
Solidago speciosa angustata T. & G. (3265) Goldenrod
Solidago arguta Aiton. Goldenrod
Solidago nemoralis Aiton. (3273) Goldenrod
Solidago canadensis L. Goldenrod

Solidago serotina Ait. (2983, 3153)
Solidago rigida L.
Solidago ohioensis Riddell. (2988)
Solidago riddellii Frank.
Solidago graminifolia (L.) Salisb. (Euthamia graminifolia (L.) Nutt.) (3233)
Solidago spp.
Aster macrophyllus L. (3128) Aster
Aster novae-angliae L. (3263)
Aster sericeus Vent. (3154)
Aster azureus Lindl. (3268)
Aster ericoides L.
Aster multiflorus Ait. (3164)
Aster dumosus L. (3208, 3221)
Aster paniculatus Lam.
Aster salicifolius Ait.
Aster umbellatus Mill. (Doellingeria umbellata (Mill.) Nees) (2949)
Aster ptarmicoides T. & G. (2944, 2957)
Aster spp.
Erigeron philadelphicus L. (3020) Fleabane
Erigeron annuus (L.) Persoon. Daisy Fleabane
Erigeron ramosus (Walt.) BSP. (3090) Daisy Fleabane
Erigeron canadensis L. (Leptilon canadense (L.) Britton) (3256) Horse-weed
Erigeron divaricatus Michx. (Leptilon divaricatum Raf.) (3254)
Antennaria sp. Everlasting
Anaphalis margaritacea (L.) B. & H. (2990) Pearly Everlasting
Silphium terebinthinaceum Jacq. (3216) Prairie Rosin-weed
Silphium integrifolium Michaux. (2893) Rosin-weed
Ambrosia artemisiaefolia L. (3274) Ragweed
Xanthium commune Britton. (3228) Cocklebur
Rudbeckia subtomentosa Pursh. (2890) Cone-flower
Rudbeckia hirta L. (2830) Black-eyed Susan
Lepachys pinnata (Vent.) T. & G. (2891) Cone-flower
Helianthus occidentalis Riddell. (2965) Sunflower
Helianthus occidentalis illinoensis (Gleason) Gates. (2774, 2887, 2936)
Helianthus grosseserratus Martens
Helianthus maximiliani Schrad. (3282)
Helianthus divaricatus L. (2954)
Helianthus strumosus L.
Helianthus spp.

Coreopsis lanceolata L. (2478) Tickseed
Coreopsis lanceolata villosa Michaux. (2817)
Coreopsis palmata Nuttall. (3148)
Bidens vulgata Greene. Stick-tight
Bidens trichosperma tenuiloba (A. Gray) Britton. (2982) Tickseed Sunflower
Helenium autumnale L. (2984) Sneezeweed
Achillea millefolium L. (2760) Yarrow
Artemisia caudata Michaux. (2972) Wormwood
Cacalia tuberosa Nutt. (3249) Indian Plantain
Senecio balsamitae Muhl. (2512, 3031) Ragwort
Cirsium pitcheri (Torr.) T. & G. (2866) Pitcher's Thistle
Cirsium muticum Michaux. (2953) Swamp Thistle
Cirsium arvense (L.) Scop. (3245) Canada Thistle
Krigia amplexicaulis Nutt. (2499) False Dandelion
Taraxacum erythrospermum Andrz. Red-seeded Dandelion
Lactuca canadensis L. Wild Lettuce
Prenanthes racemosa Michaux. (3283) Rattlesnake-root
Prenanthes alba L. White Rattlesnake-root
Hieracium canadense Michaux. (2945) Hawkweed
Hieracium aurantiacum L. (2826) Orange Hawkweed. Though not occurring on the beach proper, but in the oak woods back of the Glenwood ridge, this is inserted here on account of the extension of its westward limit.

The following additional plants, although they were found within the limits of the region, were limited in distribution to the dump heaps and railway ballast.

Abutilon theophrasti Medic. Velvet Leaf
Agropyron repens (L.) Beauv. Couch Grass
Amaranthus retroflexus L. Pigweed
Ambrosia psilostachya DC. Ragweed
Anthemis cotula L. Dog Fennel
Arctium minus Bernh. Burdock
Brassica arvensis (L.) Ktze. Mustard
Capsella bursa-pastoris (L.) Medic. Shepherd's Purse
Eragrostis purshii Schrad.
Erechtites hieracifolia (L.) Raf. Fireweed
Helianthus annuus L. Sunflower
Helianthus atrorubens L. (3219) Sunflower
Hordeum jubatum L. (3040) Squirrel-tail Grass
Lactuca pulchella (Pursh) DC. (3220) Blue Lettuce

Lactuca scariola L. Prickly Lettuce
Lithospermum officinale L. (2784) Puccoon
Melilotus officinalis (L.) Lam. Yellow Sweet Clover
Panicum miliaceum L. (3207) Millet
Polanisia graveolens Raf.
Polygonum orientale L. (3279) Prince's Feather
Polygonum aviculare L. Knotweed
Setaria glauca (L.) Beauv. Yellow Foxtail Grass
Setaria viridis (L.) Beauv. Green Foxtail Grass
Sisymbrium officinale (L.) Scop. (2819) Hedge Mustard
Solanum dulcamara L. (3086) Bittersweet
Sonchus oleraceus L. Sow Thistle
Stellaria aquatica (L.) Scop. (2820) Water Chickweed
Tanecetum vulgare L. Tansy

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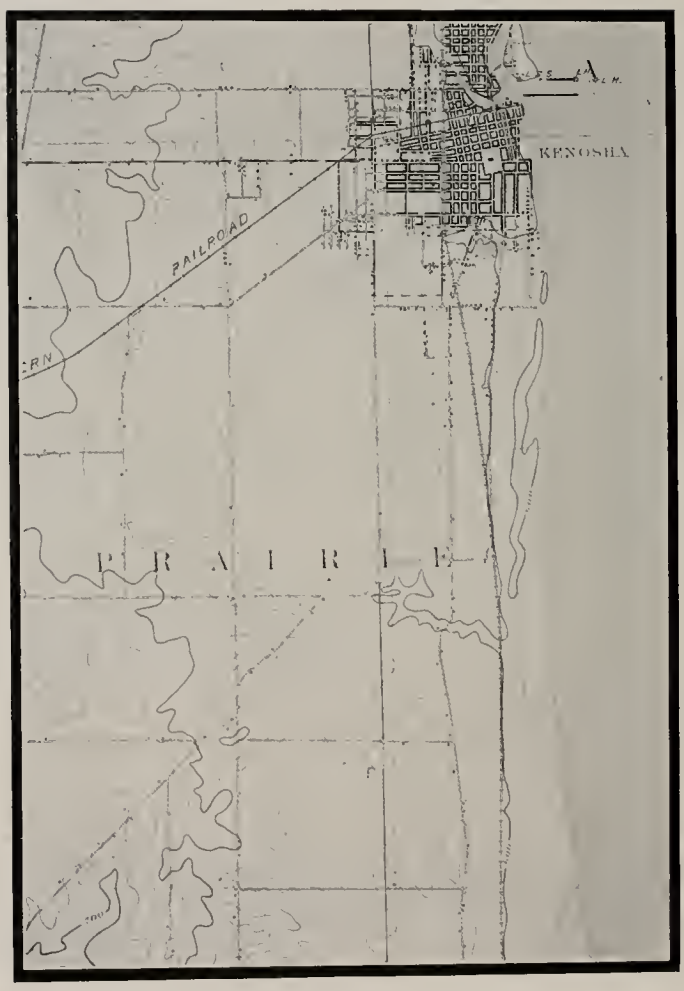
ERRATA

Page 256, line 3 of table, for Dr. H. *M.* Pepoon read Dr. H. *S.* Pepoon.
Page 278, line 16, rhizomes should be in Roman type.
Page 315, line 10, for *Apocynum* read *Apocynum*.
Page 351, line 4 from bottom, for *xerophitic* read *xerophytic*.
Page 356, line 14 from bottom, for *Symlocarpus* read *Symplocarpus*.
Page 365, line 14, for *thapus* read *thapsus*.
Plate XXXIX, for *Calamogrostis* read *Calamagrostis*.
Plate LIV, exchange places of cuts, but not the legends.

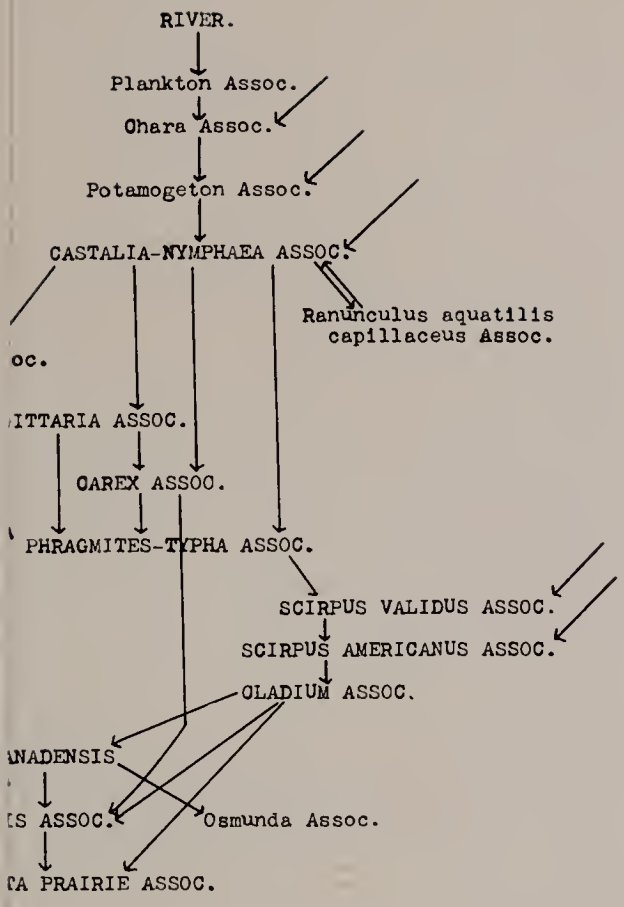
Plate XXXVII.

General map of the southern part of the Beach area.

Plate XXXVIII.



General map of the northern part of the Beach area.



n showing the successions exhibited between
associations in the Beach Area, Illinois.
primary successions.
secondary successions due to clearing,
burning or other disturbing factors.
letters denote the important associations.

FCA

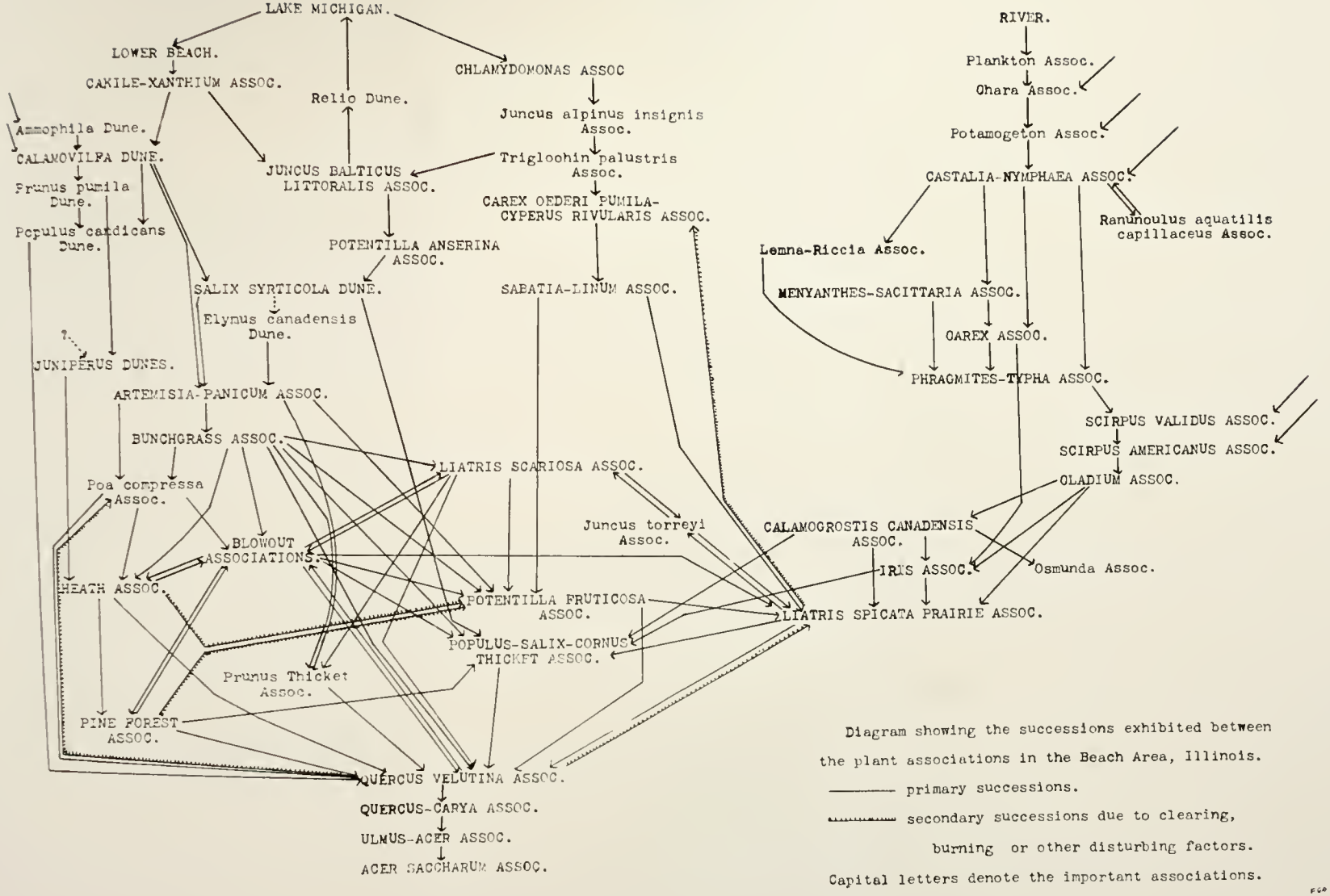


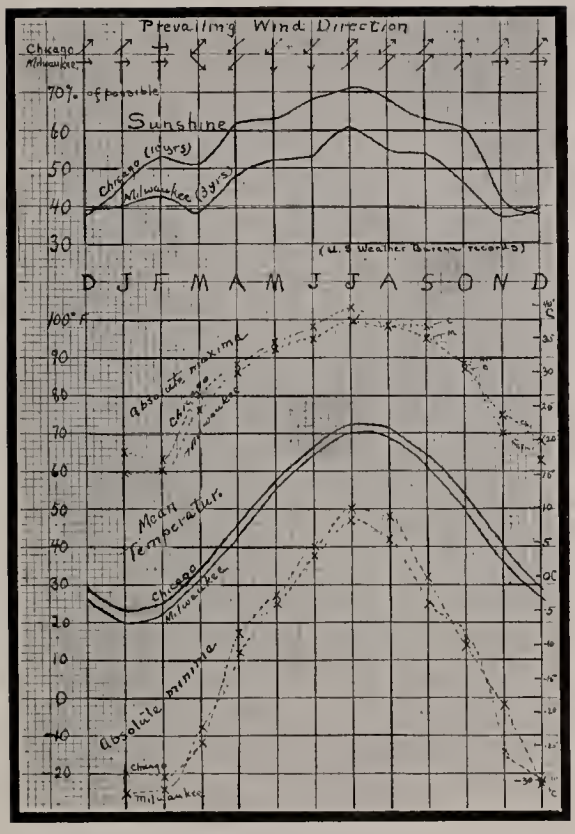
Diagram showing the successions exhibited between the plant associations in the Beach Area, Illinois.

——— primary successions.

..... secondary successions due to clearing, burning or other disturbing factors.

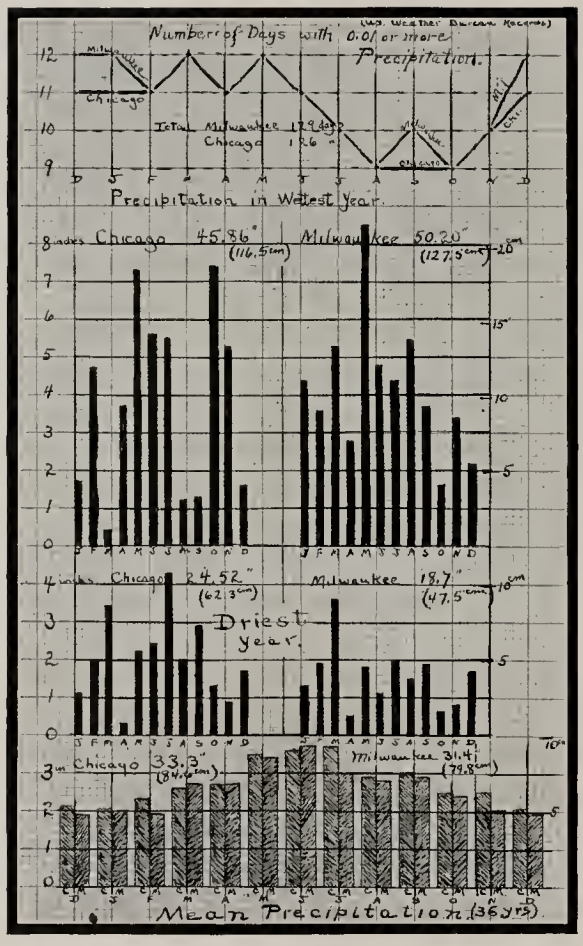
Capital letters denote the important associations.

PLATE XL.



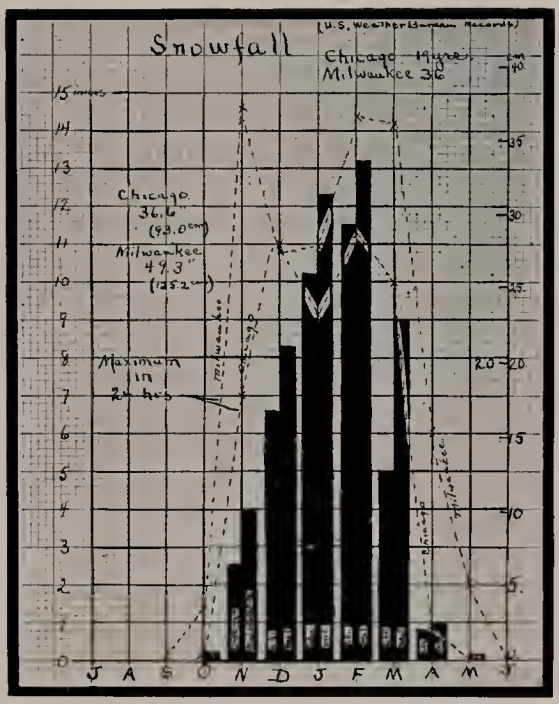
Wind direction; sunshine and temperature curves for Chicago and Milwaukee.

Plate XLI.

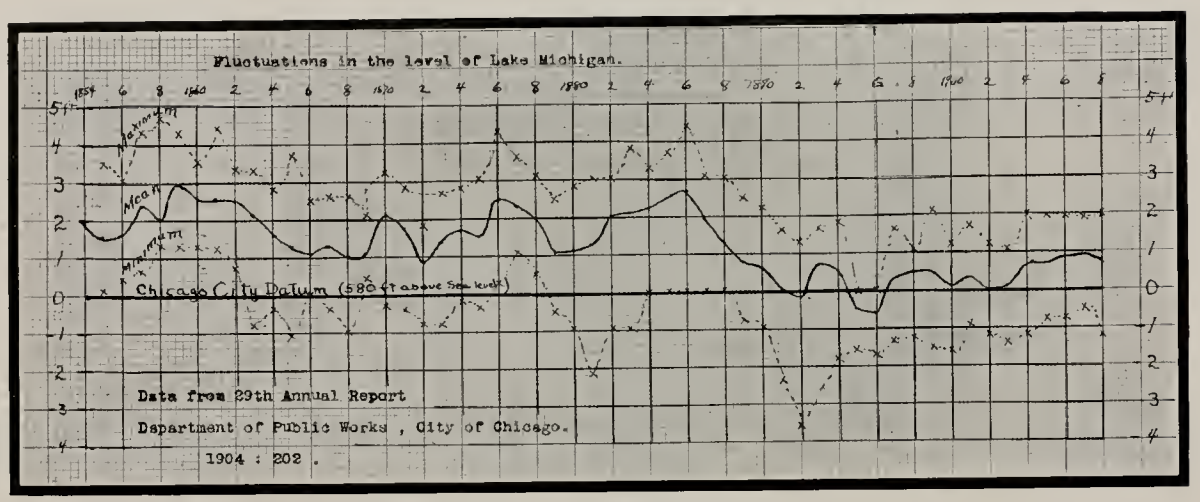


Mean precipitation for Chicago and Milwaukee, by months, for thirty-six years.

PLATE XLII.



Mean snowfall, by months, for Chicago (19 years) and Milwaukee (36 years).



Fluctuations in the level of Lake Michigan from 1854 to 1908.

PLATE XLIII.

Plate XLIV.

Fig. 1. An oak ridge near Kenosha, Wis., which is being washed away by Lake Michigan. November 23, 1909.

Fig. 2. Beach pool near Waukegan, Illinois, showing sanderlings feeding. August 17, 1909.

Plate XLV.

Fig. 1. Little dunes formed by seaside spurge (*Euphorbia polygonifolia*). Beach, Illinois. August 30, 1909.

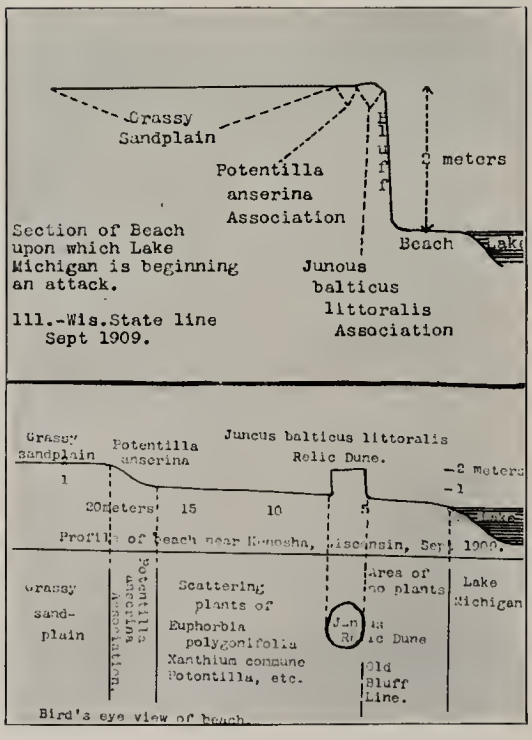


Fig. 2. Diagrams illustrating the character of the shore south of Kenosha, Wisconsin. September, 1909.

Fig. 1 Relic dunes along the shore of Lake Michigan near Kenosha, Wisconsin. A closer view of "A" is shown in Fig. 2. "C" is a nearly extinct relic dune, and "D" is a *Juniperus* relic dune. With the exception of "D" the relic dunes shown are formed by *Juncus balticus littoralis*. August 30, 1909.

Fig. 2. *Juncus balticus littoralis* relic dune, near Kenosha, Wisconsin. November 23, 1909.

Fig. 1. A relic dune near Kenosha, Wisconsin, showing the disruptive power of freezing water. November 23, 1909.

Fig. 2. *Calamovilfa longifolia* dune at Beach, Illinois. July 19, 1909.

Fig. 1. Bluff at Camp Logan, Illinois, being cut by Lake Michigan, showing exposed roots of *Calamovilfa longifolia* on the left, and of red-osier dogwood (*Cornus stolonifera*) on the right. September 4, 1909.

Fig. 2. Part of the beach near Beach, Illinois, showing an *Ammophila* dune in the foreground, a *Salix glaucophylla* dune on the right, and, in the center of the background, a *Populus candicans* dune. September 11, 1909.

Fig. 1. Section of a *Juniperus horizontalis* dune, Beach, Illinois. July 19, 1909.

Fig. 2. A willow (*Salix glaucophylla*) dune, 0.7 meter high, near Kenosha, Wisconsin. November 23, 1909.

Fig 1. *Sporobolus cryptandrus*, illustrating growth habit. Winthrop Harbor, Illinois. August 30, 1909.

Fig. 2. *Andropogon scoparius* bunch-grass prairie near Beach, Illinois. August 17, 1909.

Fig. 1. Growth habit of *Petalostemum purpureum* f. *arenarium* in the bunch-grass prairie, Waukegan, Illinois. August 13, 1910.

Fig. 2. Blowout in the oak (*Quercus velutina*) association near Beach, Illinois. Revegetation consists largely of heath plants, but scattered throughout are oak seedlings. July 19, 1909.

Fig. 1. Heath near Beach, Illinois. *Juniperus horizontalis* in the foreground. Back of a strip of sand is bearberry (*Arctostaphylos uva-ursi*) In the background is a tree of white pine (*Pinus strobus*) and a grove of black oak (*Quercus velutina*). August 24, 1909.

Fig. 2. Blowout in the heath, Zion City, Illinois. Revegetation mainly by heath plants. September 4, 1909.

Fig. 1. Blowout on the edge of the oak (*Quercus velutina*) near Beach, Illinois. Revegetation by prairie, marsh, and thicket plants. September 11, 1909.

Fig. 2. Marsh associations in the Dead River near Beach, Illinois. Yellow water-lily (*Nymphaea advena*), arrowleaf (*Sagittaria latifolia*), cattail (*Typha latifolia*), and reed (*Phragmites communis*). August 13, 1910.

Fig. 1. *Scirpus americanus* (3-angled bulrush) association toward the left hand side. *Scirpus validus* (giant bulrush) association at the right of the center. Beach, Illinois. August 24, 1909.

Fig. 2. Swale south of Beach, Illinois, dominated by *Cladium mariscoides* Pines in the background. September 11, 1909.

Fig. 1. A swale near Zion City, Illinois, showing the *Calamagrostis canadensis* association in the foreground and an aspen-willow grove in the background, separated by a narrow zone of shrubs. September 4, 1909.

Fig. 2. *Phlox glaberrima* consocies of the blazing star (*Liatris spicata*) prairie. Beach, Illinois. July 19, 1909.

Plate LVI.

Fig. 1. Blazing star (*Liatris spicata*) prairie, Zion City, Illinois Balm of Gilead (*Populus candicans*) in the background. September 4, 1909.

Fig. 2 The prairie invading the pines. One of the last stages, showing old trees scarcely alive while no seedlings are present. Beach, Illinois. June 22, 1909.