

THE VEGETATIONAL HISTORY OF A RIVER DUNE.*

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Sand regions and dunes have long been a popular field for the plant ecologist, and studies of them have been of great importance in developing and widening our ideas of plant ecology. Of the many interesting features of the Illinois sand areas, the single physiographic structure, the river dune, has been chosen for description, since it illustrates in a striking manner the action of water and wind, the role of vegetation in sand-binding, and some important phases of succession.

Three of the chief sand areas of Illinois lie along the east bank of a river; the Havana area parallels the Illinois River for many miles south of Pekin, the Hanover area extends along the Mississippi River in Jo Daviess and Carroll counties, and the Oquawka area borders the same river in Mercer and Henderson counties. In each of these the river dune is developed to some degree, but it is especially prominent in the last two, which are the only ones referred to in this article.

The sand deposits constitute the so-called second bottom, which extends from the swampy, alluvial first bottom, the modern flood-plain of the river, inland usually to the bluffs. While they are always more or less undulating, their general level is fairly constant. This level in the Hanover area is approximately twenty feet above high-water mark in the river. The river meanders over its modern flood-plain from one side to the other, and when it flows at the eastern margin, directly against the deposits of sand, the conditions are such that a river dune may be formed. Erosion by the river carries away the sand from below, and that portion of the sand above the river action stands at a steep slope, the angle

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depending upon the wind and the rapidity of erosion. The surface sand on this slope is exposed to the full sun and keeps loose and dry. The wind, which in Illinois is prevailing from a westerly direction, carries a part of the loose sand up the slope and piles it up in a long dune parallel with the river and higher than the general level of the sand plain. The whole dune consists therefore of two divisions, the lower of sand now being uncovered by the wind and erosion and removed by wind, and the upper of sand deposited by the action of the wind.

In spite of general current opinion regarding the relation of wind to the formation of dunes, the general effect of wind alone on sand is to reduce the elevations, fill up the depressions, and make the general surface more nearly level. While wind furnishes the actual force in piling up sand into dunes, the sand does not remain so indefinitely unless it is held by some efficient means, usually by the action of plants. So, in the region under discussion, the river dune is initiated by the wind, but perpetuated by sand-binding plants upon its crest. Most notable among these are the redroot, *Ceanothus ovatus* Desf., switch grass, *Panicum virgatum* L., and, most important of all, sumach, *Rhus canadensis* Marsh. var. *illinoensis* (Greene) Fernald. The latter grows in dense thickets, and possesses the ability to grow up indefinitely, keeping the tips of its twigs always at least six inches or a foot above the surface of the sand. The sand beneath these thickets is effectually protected from wind action, while more may be added with every wind storm. Aided by these three species and some others of less importance the wind builds up the river dune to a height which may reach eighty feet above the general level, or one hundred feet above the river. The amount of sand thus exposed offers a considerable surface for colonization by plants, and is occupied in turn by several distinct associations.

Contemporaneous with the sand-binders there appears on the riverward side of the ridge a group of herbaceous plants which may be called the blowsand association. It consists primarily of annuals, such as the partridge-pea, *Cassia*

Chamaechrista L., and button-weed, *Diodia teres* Walt., or sometimes also of deep-rooted perennials as bush clover, *Lespedeza capitata* Michx., puccoon, *Lithospermum Gmelini* (Michx.) Hitchc., and spurge, *Euphorbia corollata* L. The density of the plant-covering depends primarily upon the rapidity of movement of the sand, and partly upon the portion of the slope occupied. The area below the general level, which is being freshly exposed, is much more thinly covered than the upper portion, composed of deposited sand. The same type of vegetation is also found on the lee side of the dune.

The upper margin of the lower part of the slope, which indicates the former level of the region before the formation of the dune, is usually marked by a thin layer of dark-colored sand. This is caused by organic matter deposited by past generations of plants which occupied this surface before the dune was formed, or at least before it had migrated so far inland. The outcrop of this old soil layer along the river front affords better conditions for plant life than the sterile sand above and below it, and is usually marked by a line of wild rye, *Elymus canadensis* L.

The next group of plants to appear may be termed the thicket association, and is composed of several species of plants aggregated into dense thickets. Green ash, *Fraxinus pennsylvanica* Marsh. var. *lanceolata* (Borkh.) Sarg., is the first of the group to appear, its seeds being blown in by the wind from the neighboring bottom-land forests. Honey-locust, *Gleditsia triacanthos* L., appears at an early stage, although the way in which its pods are scattered is not known. These young trees attract a bird population, which in turn are instrumental in the dissemination of various plants with edible fruits. The mature thicket is composed of an impenetrable tangle of green ash, honey-locust, crab, *Pyrus ioensis* (Wood) Bailey, plum, *Prunus* sp., and choke cherry, *Prunus virginiana* L., with some admixture of other species. It is covered with a luxuriant growth of tangled vines of wild grape, *Vitis vulpina* L., moonseed, *Menispermum canadense* L., poison ivy, *Rhus Toxicodendron* L., Virginia creeper, *Psedera quinquefolia* (L.)

Greene, green brier *Smilax hispida* Muhl., carrion flower *Smilax herbacea* L., and bittersweet, *Celastrus scandens* L. These thickets extend most rapidly down the lee side of the dune, but also encroach gradually on the riverward side as well. The later fate of these thickets is not known.

During these two early stages in the history of the dune the wind sometimes breaks down the defense of the sand-binders at the crest and excavates a trough-shaped hollow perpendicular to the river. These hollows are known as blow-outs. The sand is removed from the windward end and from the bottom and is poured out in a steep incline on the landward side. The sides of the blowouts are held by thickets or by clumps of sand-binders, and if the movement is not too rapid the lee deposits are also soon covered with plants.

A third stage in the history of the dune is characterized by an oak forest, which in the Hanover area consists of black oak, *Quercus velutina* Lam., and in the Oquawka area of black oak and blackjack oak, *Quercus marilandica* Muench., together. This is the oldest* stage represented in the Hanover area and the youngest in the Oquawka area, so that the latter serves to complete the history and to indicate the fate of the Hanover dune. The blowing of the sand is effectually prevented by the forest cover, and if the river is not eroding its banks too rapidly the forest soon extends down to the water's edge.

This forest is composed of gnarled, crooked trees with short trunks. They are not close together and the underbrush, if any, consists almost entirely of young trees of the same species. The herbaceous vegetation is somewhat different from that of the preceding stages in its specific composition. One particularly characteristic species is *Synthyris Bullii* (Eaton) Heller. The poisonous fly-mushroom, *Amanita muscaria*, and an earth-star, *Geaster* sp., are quite abundant. The trees produce a bountiful

*The meaning of the terms old and young, as applied in ecology, is sometimes confusing. "Old" signifies that the particular area has passed through a greater number of physiographic or ecological stages than those designated as "young." In the case in point, the oak forest in the Hanover area is itself relatively young in age (i. e., of recent development), but the portion of the dune so occupied has passed through one or more previous stages. This is in contrast to the blowsand association, which may be considered as occupying new ground: it is therefore the first ecological stage in the vegetation, and is designated as young.

crop of acorns, but comparatively few of them germinate. This association is not peculiar to the river dune, but is widely distributed over all the sand deposits of the state.

The presence of these trees, together with certain of their life processes, makes a gradual change in the environmental conditions for the plant. Chief among these is the annual leaf-fall, covering the sand with a thick layer of vegetable material rich in organic matter. This, and the shade of the trees during the summer and autumn, also tend to check the evaporation of water from the sand and to aid in retaining water in the superficial layers. Naturally the shade also tends to reduce the transpiration from the herbs and shrubs beneath the trees. By the combined and long-continued action of these two agents, shade and ground cover, the association is prepared for invasion by moisture-loving species; or, in other words, it changes from xerophytic to mesophytic. Moreover, their effect is cumulative and proceeds with ever increasing rapidity, so that while the first mesophytes appear only after a long period, the remainder follow them at shorter intervals.

A hillside north of Oquawka shows the order of appearance of the mesophytes very clearly. The river dune here has a maximum height of about one hundred feet, indicating a very strong and continued wind action at some time in the past. Now it is covered with trees to the very base and the upper layers of sand are well mixed with organic matter. Just off shore lies a series of wooded islands, which serve to shelter the dune from erosion by wind or water. At the north end the forest is composed exclusively of black oak and blackjack oak, which are found over the whole length of the dune. Farther towards the south, trees of scarlet oak, *Quercus coccinea* Muench., are soon noticed near the base of the hill not far above water-level; farther down they extend higher, and soon appear even at the very crest of the dune. The black walnut, *Juglans nigra* L., next appears near the base, and in the same way climbs towards the top. It is usually accompanied by the redbud, *Cercis canadensis* L. In a similar way there appear in order the river birch, *Betula nigra* L., American elm, *Ulmus americana*

L., green ash, and finally the soft maple, *Acer saccharinum* L. It will be noticed that each of these species is more moisture-loving than its predecessors, until as a climax there appears the soft maple, a characteristic tree of the river-bottom swamps.

These changes in the arborescent vegetation are by no means the only ones which occur. Even before the scarlet oak appears, various species of lianas invade the association. The Virginia creeper is one of the most abundant, but several other species may be found with it. These climb up the trunks of the oak trees or, more generally, trail along the ground.

There is also a profound change in the herbaceous vegetation corresponding with the gradual increase in moisture. Horse-mint, *Monarda mollis* L., starry campion, *Silene stellata* (L.) Ait.f., and columbine, *Aquilegia canadensis* L., are among the early additions. At a later stage alum root, *Heuchera hispida* Pursh, comes in, the ground has some dense carpets of moss and foliaceous lichens, and at the last a fern, *Woodsia obtusa* (Spreng.) Torr., and anemone, *Anemone canadensis* L., appear. Both of these species appear singularly out-of-place when growing in sand on a hillside, possibly at the base of a tree of blackjack oak. The anemone among the herbaceous plants corresponds to the maple among the trees; like the latter it grows normally in river-bottoms subject to overflow. The presence of these two semi-hydrophytes indicates how great has been the environmental change from the original xerophytic oak forest.

It must not be assumed that this development could continue in the same direction indefinitely, leading to the ultimate establishment of a hydrophytic plant association. The climax or final stage of ecological successions in this region seems to be a mesophytic forest characterized by sugar maple, *Acer saccharum* Marsh., basswood, *Tilia americana* L., and other species. There is no indication in this latest stage of the river dune of the appearance of this climax association, yet on the other hand there is no reason to doubt that it would eventually come in.

The frequent changes in the channel of the Mississippi have

long been well known, and are very characteristic of the restless energy of that immense river. Near the south end of the river dune just described, the river is even now operating to destroy the product of many years of plant activity. Below the islands already mentioned the current sets across from the Iowa side, and striking the base of this river dune veers off to the south along the Illinois shore. The current has broken down the barrier of leaf-mold and intertangled roots and is rapidly eroding the sand. This erosion begins at the base of the dune, exposing the bare sand. As more and more of the sand is carried away, the upper portion of the dune is undermined and begins to settle down toward the river. It is now seen that the principal mass of roots has extended only one to one and a half feet below the surface, forming a coherent stratum resting on the loose sand beneath. The loose sand rests at as steep an angle as possible, and irregular detached blocks of the coherent surface layer slide slowly down the incline toward the river. Their motion is of course very slow, and partially dependent upon the rate of erosion. But that they are loose is at once demonstrated by stepping on one, which then immediately starts down and in ten seconds to a minute, depending upon the distance, comes to rest on the flat beach at the base of the dune. That the plant population is a relic of the former mesophytic conditions is shown by the species, which are largely perennials found also on the mesophytic slope. Prominent among them are bush clover, spiderwort, *Tradescantia reflexa* Raf., horsemint, goldenrod, *Solidago nemoralis* Ait., and wormwood, *Artemisia caudata* Michx. Naturally such species as the anemone or the fern could not be expected to persist under such conditions. The flora of the sliding masses stands in sharp contrast with the meager vegetation of the general slope, composed mainly of partridge-pea and a few other annuals. These plants constitute the blowsand association, identical with the first association of the river dune.

At the top of this interesting slope the trees are being undermined also, and such a mesophytic species as river birch ap-

pears singularly out-of-place above a steep hillside of almost bare sand.

Just as the conversion from a xerophytic to a mesophytic association proceeded from south to north, so is the reversion proceeding in the same direction. At the south end the hillside is already bare to the top, while farther north the erosion has extended but little above the high-water mark.

The general effect of the vegetation on the river dune, from its beginning on, may be summarized as tending toward stabilization, and, as elsewhere also, toward a mesophytic environment. The accompanying physical factors may hasten or retard or even destroy the effect of the vegetation. It is interesting to note that on the crest of the newly destroyed dune the thickets of bunch-grass and sumach of a new cycle of successions have already appeared.*

*In this popular discussion of the subject no attempt has been made to give full lists of plants, or to correlate the associations and successions mentioned with similar conditions elsewhere. A fuller treatment is now in preparation. The reader who desires further information on the plant successions in sand is referred to the following articles, in which many of the ecological features treated in the present paper are described in detail:

Cowles, H. C. The ecological relations of the vegetation of the sand dunes of Lake Michigan. *Bot. Gaz.* 27:95-117, 167-202, 281-308, 361-391. 1899.

Gleason, H. A. A botanical survey of the Illinois river valley sand region. *Bull. Ill. State Lab. Nat. Hist.* 7:149-194. 1907.

Jennings, O. E. An ecological classification of the vegetation of Cedar Point. *Ohio Naturalist* 8:291-340. 1908.

Jennings, O. E. A botanical survey of Presque Isle, Erie County, Pennsylvania. *Annals Carnegie Museum* 5:289-421, pls. 22-51. 1909.