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SOME NOTES ON THE ECOLOGY OF THE DELA-
WARE COAST.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY.
XL.

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(WITH MAP AND TEN FIGURES)

IN July and August of 1901 the observations here recorded were made at Rehoboth Beach, Delaware, as a small addition to the increasing collection of data from the Atlantic seacoast. In sequence and nomenclature an attempt is made to harmonize these results with those obtained by Mr. Kearney¹ and Dr. Harshberger², on Ocracoke island and the New Jersey coast, respectively. The Britton and Brown nomenclature is used throughout, with the synonyms from Gray's *Manual*, where such occur, in parentheses. The list of plants does not claim to be complete, as the work was done during the summer months, and therefore the flowers of many species had disappeared, while other forms had not yet flowered, making identification difficult and at times impossible. Many forms were doubtless overlooked in the one or two visits which limited the opportunities for study in some parts of the field. The algae and fungi were not studied, while the lichens and mosses received the most superficial attention.

I. GEOGRAPHY.

The region studied extends from Cape Henlopen to a little over a mile south of Rehoboth, including a tract of land about six and a half miles long, by one-half to one mile in width, lying on the mainland, instead of on a fringing chain of islands, which is the usual condition along the Atlantic coast. The trend of the

¹ KEARNEY, T. H., The plant covering of Ocracoke island. Contrib. U. S. Nat. Herb. 5: 261-319. figs. 18. 1900.

² HARSHBERGER, J. W., An ecological study of the New Jersey strand flora. Proc. Acad. Philad. Oct. 1900.

coast line is almost due north and south, and the ocean currents come predominantly from the southeast.

II. PHYSIOGRAPHY.

A. Topography.—From the northeast end of Maine to the Florida peninsula the Atlantic coast is more or less fringed with islands, the shore lines of Delaware and Maryland being no

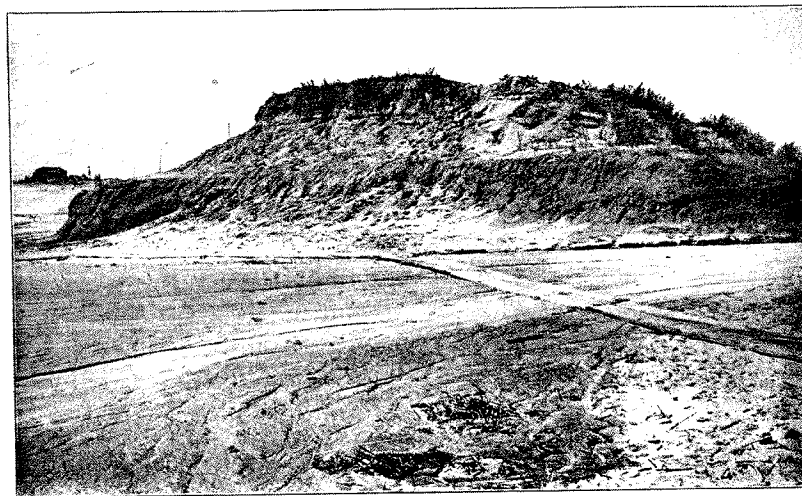


FIG. 1.—Shore south from Rehoboth, showing sandstone layer upon which is a dune; Douglas House at left, one mile to the south.

exception to the general rule. Here the bays and lagoons extend far into the mainland, usually surrounded by swampy tracts, broken up into sub-bays by low lying islands, and often connected by slowly flowing streams. In the course of time the lagoons and bays become filled up by sediment and plant remains. This process of filling up could be studied with great advantage in the Henlopen region, for all the stages from lakes through storm-flooded areas and swamps to the meadows are found, although the lagoon stage is past.

The sea beach is smooth and usually has a very gradual slope; the sand is fine and compact and is not easily drifted, therefore

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there is a tendency for low, more or less fixed dunes to form. Diagonally across the cape, however, is a large active dune, which by comparison with the 75-foot lighthouse seemed to be about 80-90 feet high. To the southwest of this are several smaller active dunes, becoming lower and more stable toward the south. A row of small dunes, somewhat fixed, edge the beach around the cape, enclosing a region of swamps, meadows, lakes, and low dunes. South along the beach extends a line of dunes, with a second series back from it, the distance between the two varying greatly at different places. Meadows, swamps, lakes, and small dunes occupy this space.

The second series extends in a very irregular line across the cape (see map), and since these dunes must have been blown in from the coast it is natural to suppose that the coast at one time was parallel to them (S.E.-N.W.), instead of projecting to the northeast as now. The supposition that Cape Henlopen has grown out from a S.E.-N.W. coast, and is still growing, is supported also by the formation of hooks on the western shore by the southeast ocean currents. Such cape and hook formation is described and figured by Gerhardt³ from the coast of Europe.

Back of the second series of dunes a plain slopes to the thicket and forest, broken in places by meadows and small dunes, and interrupted by fields. This plain, for want of a better name, I have called a "heath;" physiographically it corresponds with that type, although it is not characterized by the typical plants.

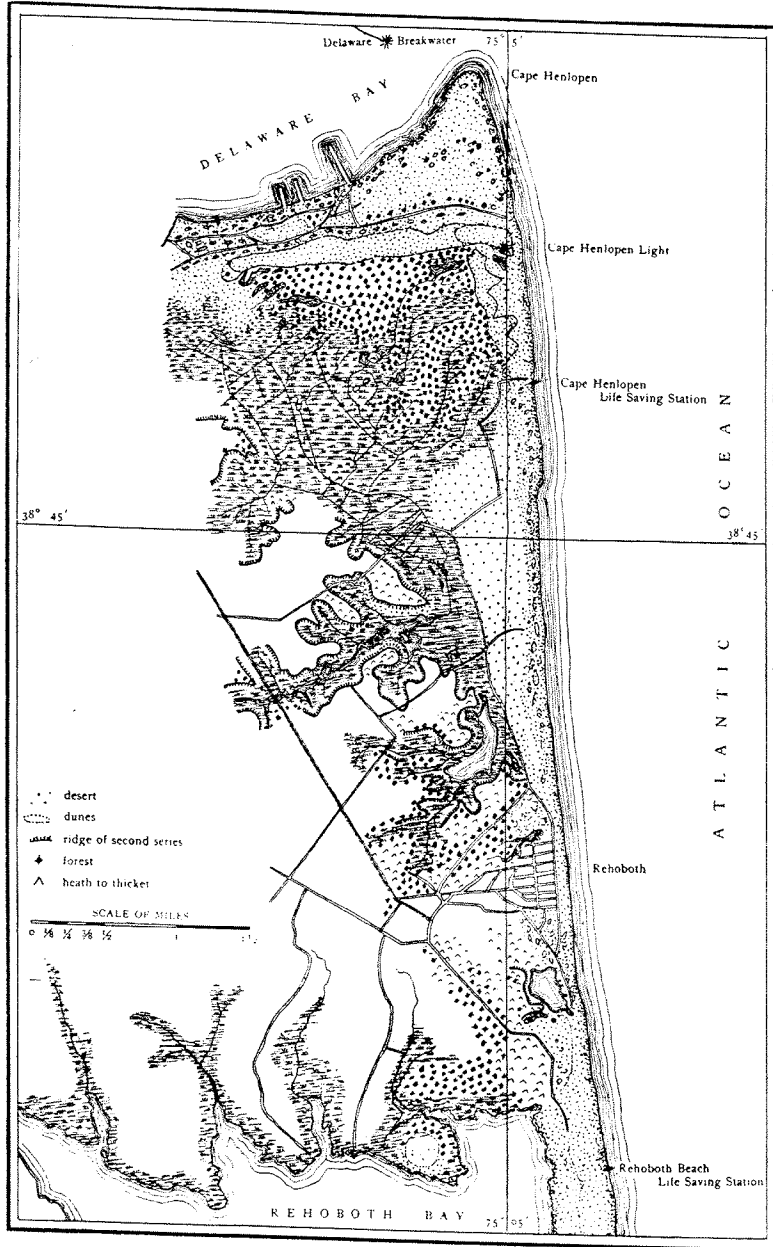
B. Soil. — I. CHARACTER. — The soil is predominantly sandy throughout, usually nearly to the surface, where a thin layer of humus appears in the moister regions. The beach is nearly pure sand, with a few patches of clay in hollows, where it is deposited by the wash of storms. From Rehoboth for about a mile south there crops out along the beach a deposit of sandstone. This being much more resistant than pure sand stands out in step-like structures, upon which dunes are usually superposed (*fig. 1*). In

³GERHARDT, PAUL, Handbuch d. Deutsch. Dunenbaues. Berlin. 1900. pp. 43-46, 61-63.

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Map of region from Cape Henlopen to Rehoboth bay. Adapted from Coast Chart no. 127, U. S. Coast and Geodetic survey.

several places, however, the dunes have either not formed there, or have passed back, leaving a golden brown slab of hard material. On the beach pieces of iron ore were found, washed from an undetermined source. Back in the dune region are tracts of land almost totally destitute of vegetation (*fig. 2*). These desert spaces are rain-washed in times of storm, and hold water for some little time, the water washing into the depression

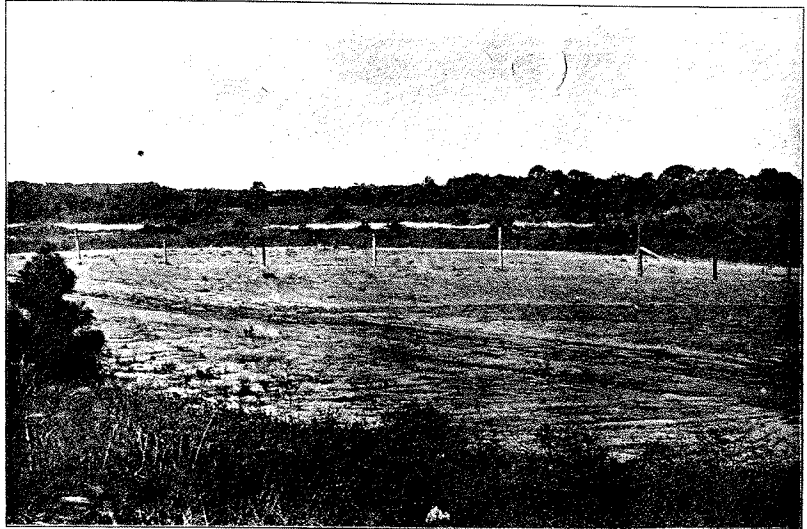


FIG. 2.—Bare space between dune series; second series immediately beyond, on crest of which a thicket is forming; forest beyond.

from a higher region, and then evaporating, covering the ground with a deposit of sand and clay, which becomes baked in the hot sun. The ground is so unfavorable for the existence of plants, that very little vegetation is found here. In the swamps and meadows a layer of humus covers the sand to a greater or less depth, according to the character of the vegetation, the exposure, and the length of time of deposition.

2. SOIL WATER.—Water level is very near the surface, in most places only a slight depression being needed for the development of a swamp. The water furnished by pumps in the vil-

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lage is strongly impregnated with iron, showing that a stratum of ferruginous material underlies at least part of the region.

III. CLIMATOLOGY.

A. Rainfall.—Besides lacking state geological and topographical surveys, Delaware has no Weather Bureau station, and therefore the statements concerning the climate must be very general. From the Rainfall Division of the U. S. Weather Bulletin, 1897, the following facts were obtained. The mean annual precipitation is 40–50 inches in the Middle Atlantic states. The distribution here is more uniform than in any other part of the country, 20–25 inches being the usual amount in the growing season (April–September), the least recorded for this period being 10–15 inches.

B. Heat and light.—During the two months spent at Rehoboth a very imperfect record of temperature and direction of the wind was kept, and in the absence of accurate reports the results will be used for comparison. The temperature figures for the New Jersey and North Carolina stations were kindly furnished by the U. S. Weather Bureau, the mean temperature for July and August, 1901, being as follows:

	July	August		July	August
Atlantic City, N. J.	- 75	74	Cape May, N. J.	- 75.6	73
Rehoboth, Del.	- 77.7	78.4	Cape Hatteras, N. C.	78.9	79.5

Even on cloudy days the light on the coast is more intense than inland, on account of the reflection from the sand surface, while on bright days it is almost blinding. The amount of heat radiated by the sand is considerable, and taken in connection with the reflected light must necessarily have great influence upon the flora, only those plants appearing that are able to adapt themselves to these severe conditions.

C. Wind.—The direction of the wind, as well as its force, is very important with reference to the shape and size of the dunes. For the two months during which these observations were made the prevailing wind was southwest, alternating with northeast during July, and becoming more variable in August. No observations being made during the other months, no conclusions as to

the prevailing wind for the year can be drawn. The oaks and cedars bend away from the shore, as is usual, their outer branches suffering from the salt-laden wind, while the more protected limbs grow fairly well, thus producing a one-sided plant. The prevailing wind is not necessarily the dune-forming wind. For that other factors must be considered: the strength of the wind, the sweep over an expanse of surface, the absence of obstacles in the path, and lastly the angle at which it meets the shore. At Cape Henlopen the northeast wind is probably the strongest, having a sweep over the mouth of Delaware bay, and meeting the shore at a large angle; hence the dune is moving across country southwest. Farther down the coast the northeast wind meets the shore at a small angle, while the lighter east wind strikes perpendicularly. In this case the dune movement depends upon which factor is the stronger. The dunes here have become practically fixed, but what little movement there is appears to be directly west.

IV. PLANT FORMATIONS.

As a matter of convenience in harmonizing the two regions, the order used by Dr. Harshberger is adopted here so far as possible. Although adjacent situations, the conditions differ somewhat, because the region from Henlopen to Rehoboth bay is at a higher stage of physiographic development than the New Jersey beaches.

A. Treeless open.—I. BEACH FORMATION.—(a) *Lower beach.*—For reasons pointed out by Dr. Cowles⁴ and Dr. Harshberger⁵, the lower beach is incapable of supporting vegetation. We find it composed of bare sand, extending back, usually in a gentle slope, to the line of summer driftwood.

(b) *Middle beach.*—(i) *Succulent zone.*—At Rehoboth and northward the summer tides wash up to a ridge of driftwood and débris, where the loose sand first gathers, seeds rest and

⁴COWLES, H. C., The ecological relations of the vegetation on the sand dunes of Lake Michigan. *BOT. GAZ.* 27:114-185. 1899.

⁵*Loc. cit.* 639.

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life-saving station (see map), the dunes have retreated quite a distance, and the place now occupied by active dunes was once a line of fixed pine dunes, for the active crest shows knolls still held by pines, and the dead trunks falling on the windward side. Coming from the beach over the waste of drifting sand, back of the life-saving station, and climbing to the crest of this active dune, one is startled by the contrast formed by the view towards the west with that on the windward side of the ridge. The dune is sweeping into a marshy meadow, apparently stretching for



FIG. 4.—Southwest from life-saving station dune; extreme right, rejuvenated face of old pine dune appearing again at center; active dunes to left; desert waste in middle distance showing a grass island.

miles to the southwest, and cut up towards the coast by ridges, upon which stand tall pines. One ridge is seen running nearly perpendicular to the active dune, and others at smaller angles. *Fig. 4* shows the rejuvenated face of one of these ridges. Between this rejuvenated dune and the shore just south of the life-saving station lies an active dune complex, containing meadows and swamps. Further to the south the complex spreads out and borders a broad level desert reach (seen in the distance in *fig. 4*, partially covered by water), the outer line of dunes following the shore, the inner ridge swinging off to the southwest. As the outer series north of Rehoboth is the frontal ridge, it has the sloping sea face sparsely covered with *Ammophila*, as is the case

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(a) Lower beach.— Dr. Harshberger⁵, getation. We find usually in a gentle

At Rehoboth and ridge of driftwood ers, seeds rest and ion on the sand dunes of

germinate, and such plants as *Cakile* sp., *Salsola Kali*, *Xanthium* sp., and *Atriplex arenaria* are found. Here also we find tufts of *Ammophila arenaria* (*A. arundinacea*), although it is not a character plant. This succulent zone is in some places confined to the ridge of débris around the bases of the low dunes, in others it extends much further back. It may reach many feet inland, to the foot of the higher dunes, or may even form channels by which the sea enters inland lakes in times of storm. The name of the zone indicates the structure of two of the characteristic species, *Cakile* and *Salsola*, and of the rarer *Atriplex*.

(ii) Low *Ammophila* dune zone.—From the line of summer driftwood to that of winter driftwood has been called by Dr. Cowles⁶ "middle beach," while above the winter drift line the "upper beach" extends to the foot of the dunes. Here conditions are different. The winter drift line usually lies at the foot of the higher dunes, although logs are sometimes found on the low dunes. Hence there is no "upper beach" corresponding to that on the Lake Michigan strand, but what corresponds to the "middle beach" is more or less distinctly divided into two zones, which are designated here as "succulent zone" and "low *Ammophila*-dune zone." As the name indicates, the upper belt is characterized by low dunes held by *Ammophila arenaria*, in association with *Panicum amarum* and *Cenchrus tribuloides*, while scattered mats of *Euphorbia polygonifolia* and bunches of *Oenothera humifusa* occur. *Xanthium* comes up from the lower zone in places, and *Leptilon canadense* (*Erigeron canadensis*) wanders to some extent from the higher dunes. From the fact that the winter drift line lies back of these dunes, it seems probable that they are of annual formation. This question was not settled definitely, but in July they appeared to be rather large and firm for spring planting. North of Rehoboth the succulent zone is very narrow or entirely wanting. The beach is wide and bare and slopes to the first ridge of dunes, the low *Ammophila*-dune zone being omitted, or no distinction appearing between it and the next belt. At the Cape the same conditions obtain, the

⁶ *Loc. cit.* 115.

lighthouse dune coming down, a bare, loose slope, to the beach. South of this is a hollow, formed by active dunes, and in which lies a swamp. Just in front of this swamp are the remains of the only low *Ammophila* dunes in this part of the region.

2. DUNES.—(a) *Outer series*.—South of Rehoboth this outer series is practically fixed. The sea face is exposed to storms from the sea, and is sharply eroded. North of Rehoboth this series is more active, being formed of loose sand partially held by *Ammophila*, the activity increasing until the lighthouse dune

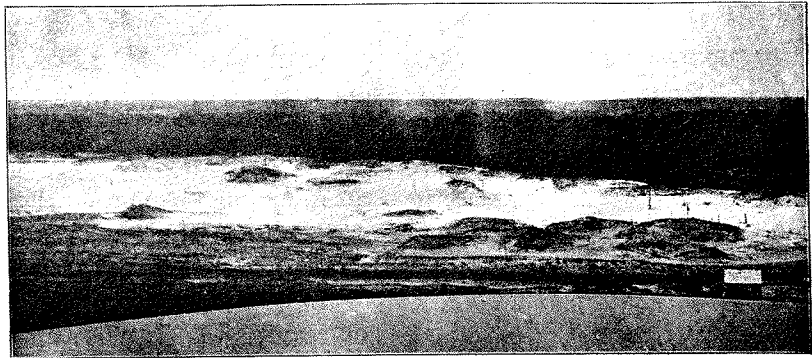


FIG. 3.—Southwest from lighthouse; lighthouse dune in foreground; swampy hollow at center; active dunes ("pine graveyards"), beyond which is a pine forest.

forms the climax. In this region they have a rounded form due to their activity. For most of the distance from Rehoboth to the Cape this series varies in height from 6–10 feet, getting higher to the north, where it culminates in the 80–90 feet lighthouse dune. In places it slopes from its crest into a heath, although it is usually followed by a dune complex or swampy meadow. Just south of the lighthouse dune lies the previously mentioned semicircle of active dunes enclosing a swamp. Other dunes stretch in a S.E.-N.W. direction, showing a northeast wind action. On the windward slopes of these dunes are several "pine graveyards"⁷ (*fig. 3*), the remains of the forest over which the dunes are now passing. A little further south, at the

⁷ COWLES, *loc. cit.* 298.

with the low frontal dunes south of the village. South, however, the face of the first series of higher dunes is eroded, more probably on account of the fixed condition of the dunes than from any protection which the frontal line offers. This eroded surface has very little vegetation, some few plants from the top having fallen and taken root. In places where the erosion is not so great, this slope is characterized by *Ammophila*, *Euphorbia polygonifolia*, and *Leptilon canadense*. Over the edge, on the more protected slope also appear *Cassia nictitans*, *Oenothera humifusa*, *Strophostyles helvola* (*S. angulosa*), *Panicum amarum*, *Ionactis linariifolius* (*Aster linariifolius*), *Rumex* sp., etc., grading into heath forms, as *Lechea minor* (*L. thymifolia*), *Baptisia tinctoria*, *Myrica cerifera*, *Baccharis halmifolia*, *Rhus copallina*, *Diospyros virginiana*, followed by clumps of *Pinus rigida*, *Juniperus virginiana*, and *Quercus digitata* (*Q. falcata*). This first series borders the cape in a practically complete line, openings allowing the sea in times of storm to wash into the depressed area within. This region is covered mostly by swampy meadows (the dominant form being apparently *Spartina patens*) with open water in places. In this extended swampy area rise small rounded or elongated dunes, the higher ones topped by pines (*Pinus rigida*). In one clump of pines, occupying a depression surrounded by dunes, an undergrowth of *Myrica cerifera* and cranberry indicated a pine swamp flora. Such swamps doubtless occupy similar situations in the depressed area.

(b) *Hudsonia complex*.—Back of the protecting ridge of the first series lies a region of general depression in which at certain places low dunes extend in all directions, forming a complex, and held mainly by *Hudsonia tomentosa*. In places the formation is almost pure, in others various forms appear. These dunes are rounded in form, and about a foot or two in height, corresponding to the habit of the plant holding them. Swamps and meadows extend among these dunes, produced in most cases by the flooding in of the sea during winter storms, the ground remaining wet for most of the year. This complex is best seen south of Rehoboth, between the sea and Silver lake.

(c) *Swamps and meadows.*—The swamps found between the two series of dunes are undrained for at least part of the year, the history of Silver lake being a good example of what probably takes place in the majority of lakes and swamps of this region. During winter storms the sea comes in through openings in the outer ridge and floods the lake until its boundaries extend around the low dunes in its vicinity. During the summer months the lake margin retreats, leaving wet soil, and sometimes water standing in the depressions. This drying process nearly converts Silver lake itself into a swamp, very little open water being visible, an increase only occurring at times of unusually high storm tides and during showers. The first event occurs but rarely, and the amount contributed by the second method is not sufficient to supply the loss occasioned by evaporation during the hot dry days.

Around the edge of Silver lake grows *Scirpus americanus* (*S. pungens*), the growth being much more luxuriant at the north end, where the water is fresh. In places also occur *Cyperus ferox*, *C. diandrus elongatus*, and *C. Nuttallii*. At the south end of the lake, where the main entrance from the sea lies, were found such strand forms as *Polygonum maritimum*, *Dondia americana* (*Suaeda linearis*), and *Atriplex hastata* (*A. patulum hastatum*); while at the northern end the formations show a tendency toward fresh-water forms, passing from a swamp to a wet meadow and thence to drier conditions. Here we find such forms as *Scirpus americanus*, *Hydrocotyle umbellata*, *Hypericum canadense*, *Cassia nictitans*, *Pluchea camphorata*, *Linum virginianum*, *Linaria canadensis*, *Fuirena squarrosa*, *Xyris flexuosa*, becoming gradually replaced by *Spartina patens* (*S. juncea*), *Ambrosia artemisiaefolia*, *Solidago sempervirens*, *Erechtites hieracifolia*, *Gnaphalium purpureum*, *Erigeron ramosus* (*E. strigosus*), *Carex silicea* (*C. straminea moniliformis*), *Juncus tenuis*, *Fimbristylis castanea*, and *Scirpus subterminalis terrestris*. *Xanthium* sp., *Mollugo verticillata*, and other more xerophytic forms appear on low elevations and toward the dunes.

West of the lake lies a small meadow worthy of mention because it holds a plant assemblage not seen elsewhere, although

some forms present are the usual meadow species. Following the belt of *Scirpus americanus* and *Spartina patens* which borders the water of a small lily pond west of Silver lake is an association of *Strophostyles umbellata* (*S. peduncularis*), *Diodia virginiana*, and *Cyperus cylindricus*. Higher up appear *Hieracium Gronovii*, *Asclepias incarnata*, *Galium pilosum*, *Gnaphalium purpureum*, *Solidago sempervirens*, *Festuca rubra*, *Panicum amarum*, *P. sphaerocarpon*, and *Sieglingia seslerioides* (*Triodia cuprea*), out of which assemblage rise the stalks of *Kosteletzkya virginica*. One place a little more depressed supports *Iris* sp., *Achillea Millefolium*, *Daucus Carota*, *Rhexia Mariana*, *Lactuca canadensis*, *Prunella vulgaris* (*Brunella vulgaris*), *Salvia urticifolia*, and *Viola sagittata*. *Eupatorium hyssopifolium* and *Solidago canadensis* occur also, showing a tendency toward drier conditions.

That Silver lake extended in former years much beyond its present boundaries may be supposed from at least three things. First, by comparison with the chart of the Coast Survey no. 127, from which the map given has been copied, with what corrections appeared to be needed; second, from the presence around it of meadows, whose hydrophytic forms are being replaced by mesophytic species; and third, the presence of a clump of *Iris* on the east shore of the lake, but no longer in swamp conditions, being now on top of a flat dune.

The Hudsonia complex, back of the first line of dunes, and protected from the ocean winds, is subjected on its western edge to winds sweeping over the lake and the plain beyond. The dunes here show a windward slope covered with roots and débris of dead plants, uprooted and destroyed by the wind action (*fig. 5*). Toward the south end of the lake these dunes become low and are occupied chiefly by *Spartina patens*.

Across the lake, on its western border, rises the second series of dunes, bending round the meadow described above, and including in the bend a thicket of sumac (*Rhus copallina*), wax berry (*Myrica cerifera*), pines, cedars, oaks, and *Baccharis halmifolia*. Northward the depression between the two series is broad, and we find many mesophytic areas, probably the remains

of former swamps. Southward the depression narrows and for some distance is occupied by a road. Farther south it broadens out into a bare rain-washed area of hard baked soil with few plants, such as *Panicum sphaerocarpon*, *Antennaria plantaginifolia*, *Ionactis linariifolius*, *Diodia teres*, *Plantago aristata*, etc. This bare space passes seaward into a wet meadow which in turn slopes toward the dunes, *Spartina patens* replacing the meadow

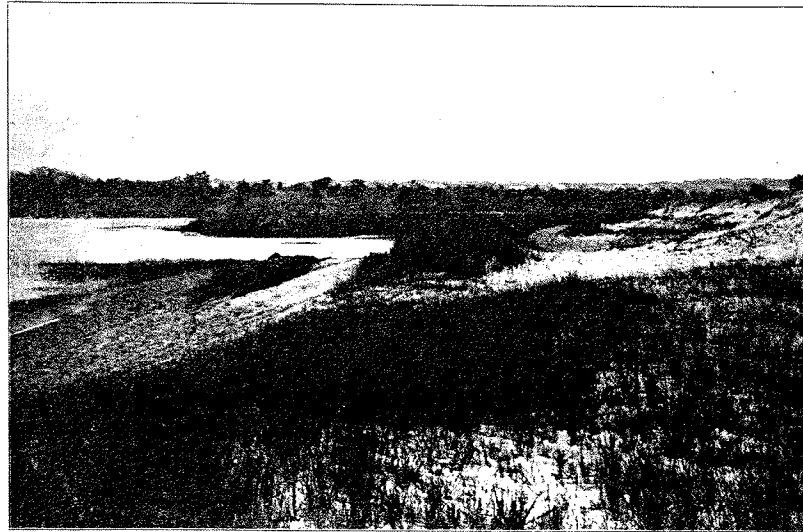


FIG. 5.—East shore of Silver lake, showing at extreme right windward faces of dunes moving eastward; the swampy character of shore of the meadow extending northward.

forms, among which may be mentioned *Senecio tomentosus*, *Hieracium Gronovii*, *Gnaphalium purpureum*, *Viola sagittata*, and giving place to *Ammophila* toward the crest of the dunes, which here slope directly to the beach, no low dunes being present.

North of Rehoboth the two series open out in a V, near the apex of which lie Hudsonia dunes and swamps, one of which is a pine swamp. In this was found the typical pine swamp flora, *Osmunda regalis*, *Dryopteris Thelypteris* (*Aspidium Thelypteris*), *Oxycoccus macrocarpus* (*Vaccinium macrocarpon*), with *Xyris flexu-*

osa, *Rhexia virginica*, *Myrica cerifera*, *Rhus copallina*, and *Smilax rotundifolia*. No *Sphagnum* was found, however, during the one visit paid to this swamp. In another swamp in this region appeared an association of *Polytrichum* sp. and *Lycopodium inundatum*; while in still another *Iris* sp., *Hibiscus Moscheutos*, *Senecio tomentosus*, and *Viola sagittata* were grouped together.

On the Hudsonia dunes between the two series we find,

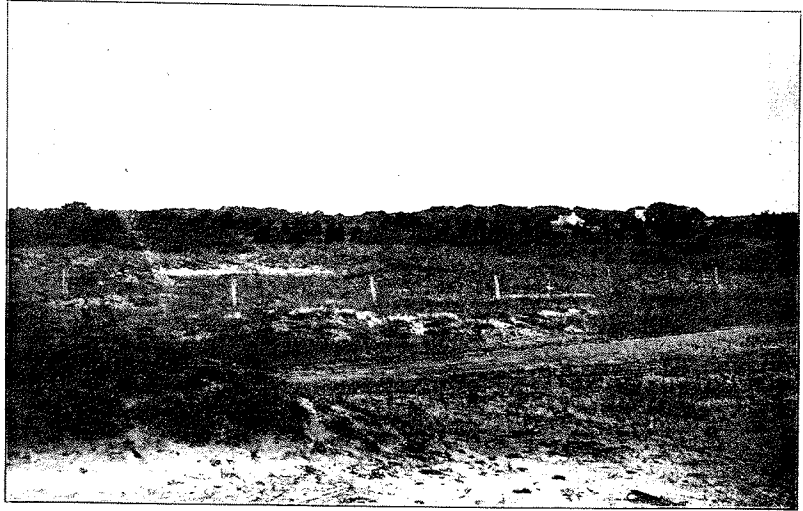


FIG. 6.—Hudsonia complex south of Rehoboth, a nearly pure formation; heath character is not developed; Hudsonia dune in left foreground.

besides *Hudsonia tomentosa*, *Lespedeza frutescens* (*L. reticulata*), *L. capitata*, *Meibomia obtusa* (*Desmodium ciliare*), *Cassia chamaecrista*, *Crotalaria sagittalis*, *Strophostyles helvola*, *Solidago canadensis*, *Euthamia caroliniana* (*Solidago tenuifolia*), *Myrica cerifera*, *Pinus rigida*, *P. virginiana* (*P. inops*), and *Juniperus virginiana*, which, with some bushes of *Gaylussacia resinosa*, *Vaccinium corymbosum*, *V. atrococcum* (*V. corymbosum atrococcum*), and *Oxycoccus erythrocarpus* (*V. erythrocarpon*) give the region a heath-like appearance (figs. 6, 7).

Farther north extends a low, flat meadow, swampy in places,

and containing lily ponds (fig. 8). Here were found such character plants as *Spartina patens*, *Hibiscus Moscheutos*, *Solidago sempervirens*, *Juncus scirpoides*, *J. tenuis*, *Sabbatia stellaris*, *Polygonum hydropiperoides*, *Xyris flexuosa*, etc., *Andropogon virginicus* and *Carex silicea* occupying a little higher ground. Some portions of this swampy meadow are undoubtedly under water during the winter

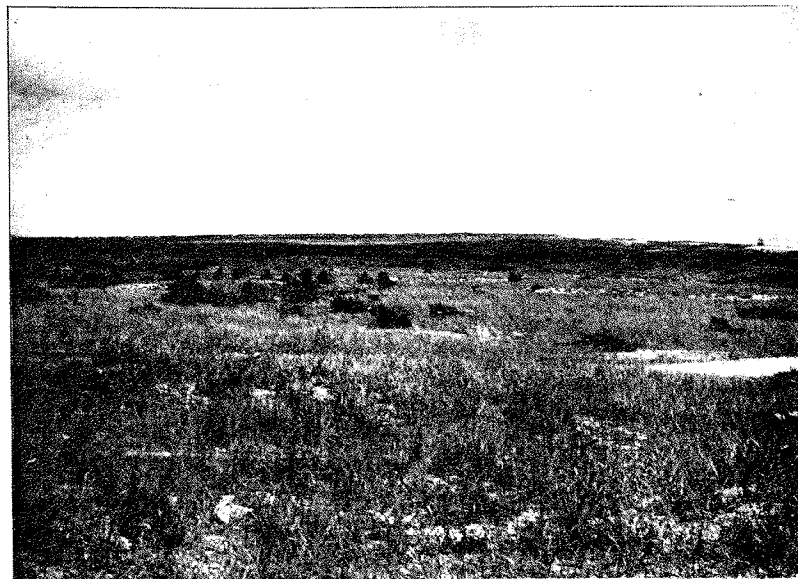


FIG. 7.—Hudsonia complex north of Rehoboth, with heath-like character somewhat developed; looking toward Henlopen light to northeast from the board walk; coast with first series of dunes shows in right background; clumps of Myrica, oaks, pines, with Hudsonia dunes in center background.

storms, the sea coming in through openings in the dunes of the first series.

This meadow area stops rather abruptly on its northern edge, at the desert-like expanse referred to above, which extends nearly two and a half miles north and south, by five-eighths of a mile at its widest point. Several inlets give an opportunity for the sea to flood this region during storms; in fact, the whole sandy area is reported to be covered with water "three foot deep" in winter,

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but during the summer a part of it at least was dry. The process of filling up and reclamation seems to be progressing from the meadow, where adventurous plants are creeping out over the waste. This end must be higher than the northern end, for during a part of the summer the water remained in the latter. Several low dunes lie scattered like islands on this desert, their

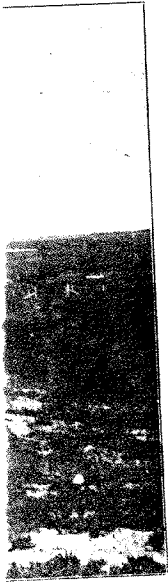


FIG. 8.—North from board walk on second series, a continuation to left of *fig. 7*; meadow showing in right background with a lake at left; the continuation of the second series at left.

flora, consisting apparently of grasses and sedges, making a weak attempt to spread over the sand. Why has not this region a swamp flora? Swamps are frequent in the inlets, therefore lack of water is apparently not the cause. Only two trips were taken over this desert; they were excursions, therefore careful investigation was impossible. It gave promise, however, of yielding more interesting results.

(*d*) *Second series*.—This series has been mentioned so frequently in the discussion of other regions that little needs be

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said here. *Ammophila* characterizes the crest, associating with heath forms as the plain slopes toward the west. Just north of Rehoboth is a good example of this condition. Here scant *Ammophila* growth is accompanied by *Lespedeza procumbens*, *Sarothra gentianoides* (*Hypericum nudicaule*), *Lespedeza capitata*, *Helianthemum canadense*, and *Pinus rigida* just over the crest; while four clumps of *Panicum virgatum* stand out on the windward side among the scant vegetation creeping up from the *Hudsonia* complex.

3. HEATH.—Although small portions of heath occur in many places on the lee side of the first series of dunes, the heath proper must be considered as starting from the second series and extending back to the forest. Its chief characteristic appears to be its large number of species of varied distribution, with very few that stand out as character forms, even the most common plants not being characteristic of all parts of the heath. Just south of Rehoboth occurs the most typical piece of this formation (fig. 9), being less interrupted by roads, cultivated fields, etc., than elsewhere, consequently most of the forms mentioned were collected in this region. It is a wilderness of *Baptisia tinctoria* and blackberries (*Rubus villosus*, *R. cuneifolius*, *R. canadensis*), with occasionally almost meadow-like growths of *Ammophila*. In clumps or singly rise cedars (*Juniperus virginiana*), persimmons (*Diospyros virginiana*), pines (*Pinus virginiana*, *P. rigida*), oaks (*Quercus digitata*), *Prunus maritima*, *P. pennsylvanica*, *Myrica cerifera*, *Rhus copallina*, and *Helianthemum canadense*, with an occasional *Sassafras sassafras* (*S. officinale*). A bush or two of *Rosa humilis* appeared at two points, and holly (*Ilex opaca*) at only one. Among the herbaceous dicotyledons from rare to frequent were observed *Solidago juncea*, *S. canadensis*, *Eupatorium album*, *E. hyssopifolium*, *Erigeron ramosus*, *Leptilon canadense*, *Aster ericoides*, *Gnaphalium obtusifolium* (*G. polycephalum*), *Achillea Millefolium*, *Lactuca canadensis*, *Hieracium Gronovii*, *Ascyrum hypericoides*, *Sarothra gentianoides*, *Asclepias tuberosa*, *Linaria canadensis*, *Trichostema dichotomum*, *Meibomia arenicola* (*Desmodium lineatum*), *M. obtusa* (*D. ciliare*), *Rumex* sp., and in

some places *Hudsonia tomentosa* forming small, almost pure formations. Of the monocotyledons, next in importance to *Ammophila* comes *Andropogon virginicus*, becoming more abundant as *Ammophila* decreases toward the west. With it are also associated in different places (besides various dicotyledons) *Agrostis alba*, *A. hyemalis* (*A. scabra*), *Eragrostis pectinacea*, *Pani-*

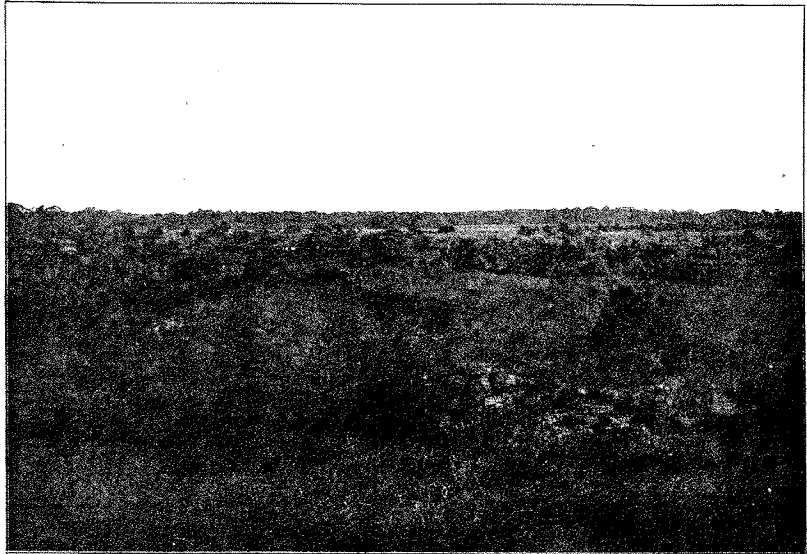


FIG. 9.—Heath south of Rehoboth, looking nearly due west.

cum sphaerocarpon, *P. viscidum* (*P. scoparium*), and *Poa compressa*; *Paspalum setaceum* occurring rarely. In many places there appeared a carpet of lichens and mosses, the most prominent of which were "reindeer moss" (*Cladonia rangiferina*) and *Ceratodon purpurea*, while Geasters occurred frequently in such situations. Lianas were almost entirely absent, *Parthenocissus quinquefolia* (*Ampelopsis quinquefolia*) being found at only three points, *Vitis aestivalis* on one dune summit, while *Smilax rotundifolia* occurred only in the pine swamp described.

At one point south of Rehoboth, a single dune rising from a bare space has developed upon its summit a heath flora, com-

posed of plants which occur elsewhere only rarely or not at all. Among a thicket of blackberries, indigo, and cedars was found the only plant of *Crataegus coccinea* (*C. pruinosa* Wendl.) appearing in the whole region. *Vitis aestivalis* and *Festuca octoflora* (*F. tenella*) were also found here only. Besides these, there appeared the usual heath forms: *Andropogon*, *Lechea*, *Meibomia obtusa*, *Lespedeza capitata*, *Hudsonia*, *Panicum sphaerocarpon*, with *Solidago sempervirens*, *Galium pilosum*, and *Poa pratensis*. By roadsides and near dwellings were found such plants as *Plantago lanceolata*, *Poa pratensis*, *Daucus Carota*, *Achillea Millefolium*, *Lepidium virginicum*, *Chrysanthemum Leucanthemum*, etc., while one clump of *Opuntia* sp. occurred back of a cottage at the extreme end of the village.

B. Wooded region.—1. THICKET FORMATION.—This formation was merely glanced at in one situation, therefore no general idea can be formed of its character. At this one point were found *Aronia arbutifolia* (*Pyrus arbutifolia*), *Malus malus* (*Pyrus malus*) from cultivation, *Seriocarpus astroides* (*S. conyzoides*), *Ilex glabra*, *I. opaca*, *Vaccinium corymbosum*, *V. arboreum*, *Juniperus virginiana*, and *Pinus rigida*. With these forms occur many heath species, for this formation grades on the one hand into the heath and on the other into the pine forest.

2. FOREST FORMATION.—About a mile west of the village the oak woods appear as a belt back of the pine region. Here appears *Quercus digitata*, which gives place to *Q. alba*, *Q. coccinea*, and *Q. nigra*, with an occasional *Hicoria ovata* (*Carya ovata*). In the oak woods a canal has been started towards Rehoboth bay, but it is now abandoned, forming a deep cut partly filled with water and supporting a swamp flora. The excavation has broken up the fixed condition of the soil, and just west of the canal, possibly composed of the excavated sand, rises a fair-sized dune (fig. 10). At this distance from the coast the northeast and southwest winds seem to be about equal, and the dune is "going both ways," a process resulting in a flattening of the crest. It is of rather loose sand, with very little vegetation; grasses and occasionally a composite or sedge were all that gave it character.

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Back in the country, pine and oak belts alternate for some distance, but no attempt to study this region was made.

V. CONCLUSIONS.

Dr. Harshberger⁸ and Mr. Kearney^{9, 10} have given sufficiently extended discussions of the geographical affinities of the floras of New Jersey, Ocracoke, and Virginia, to render any additional



FIG. 10.—Dune west of Rehoboth.

remarks unnecessary, only a few words being required to place these observations in line. The conditions on the Delaware strand are in general similar to the conditions on the whole Atlantic coast, the Gulf,^{11, 12} and Lake Michigan shores. The beach is characterized by a succulent zone, in which *Cakile* and

⁸ *Loc. cit.*, 658.

⁹ The plant covering of Ocracoke island, p. 312.

¹⁰ Report on a botanical survey of the Dismal Swamp region, p. 458. *Contrib. U. S. Nat. Herb.* 5: 321-585. 1901.

¹¹ LLOYD, F. E. and TRACY, S. M., The insular flora of Mississippi and Louisiana. *Bull. Torr. Bot. Club* 28: 61-101. *pls. 8-11*. 1901.

¹² WEBBER, H. J., Notes on the strand flora of Florida. *Science, N. S.* 8: 658. 1898.

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Salsola almost invariably occur, although their accompanying forms, *Xanthium* and *Atriplex*, are not so widely distributed. On the dunes the character plant, *Ammophila*, is of northern distribution, and is not found south of Chesapeake bay, but is abundant on the Michigan coast. Of its associates, *Euphorbia polygonifolia*, *Leptilon canadense*, and *Cenchrus tribuloides* are widely distributed, *Panicum amarum* is absent from the lake flora, and *Oenothera humifusa* extends along the Atlantic coast only to New Jersey.

Back of the first line of dunes, the combination of low dunes, swamps, and meadows offers a wide choice of habitat for plants, and we find many plants of wide range. The dune-holder *Hudsonia tomentosa* is a plant of northern distribution, Maryland being its southern limit, but it has a western range. Associated with *Hudsonia*, such forms as *Myrica cerifera* and *Baccharis halmifolia* are distributed along the Atlantic coast, but neither is found on Lake Michigan. Many grasses, sedges, and legumes are widely spread and need not be taken into consideration. *Strophostyles helvola*, very characteristic in Delaware, is mentioned only in the reports from New Jersey and Mississippi. *Spartina patens* shows a preference for salt conditions, appearing all along the sea and gulf strand, but not forming a part of the lake flora. Among the plants characteristic of the heath we find some widely distributed grasses and composites, although *Juniperus virginiana* stands out preeminently the most widely spread. *Quercus digitata* and *Diospyros virginiana* extend from Rhode Island and New York to the gulf; *Rhus copallina* is mentioned only in the New Jersey and Virginia floras; while the widely spread *Rhus radicans* (*R. Toxicodendron*) was found at Rehoboth in only one situation in the woods. Of the pines, *Pinus Taeda*, reaching (according to Britton and Brown) its northern limit in Delaware, was not found, although it is reported at Cape May, the peculiar conditions there obtaining accounting for its presence.¹³ *Pinus rigida* and *P. virginiana*, however, extend north and south of this region.

¹³ HARSHBERGER, 632.

A surprising lack of lianas was observed in the Delaware region, *Parthenocissus* occurring occasionally, and *Vitis aestivalis* and *Smilax rotundifolia* appearing in one situation, while "trumpet creeper" was collected in the surrounding country. This scarcity of climbers is in striking contrast to the condition described for other strand regions.

The pine swamp flora (*Osmunda*, *Dryopteris*, *Oxycoccus*, etc.) is composed of the usual undrained swamp forms, but no *Sphagnum* was found, and apparently the same is true of New Jersey, although one or two species are reported for Virginia.¹⁴

The similarity of strand conditions is therefore shown by the similarity of floras, for regardless of a wide difference in temperature there is a striking resemblance between the lists of forms found in New Jersey and Delaware and those reported for Mississippi, Louisiana, and Florida, while in spite of the fresh water condition on Lake Michigan the occurrence there of many genera and species which also inhabit the ocean strand bears evidence of common factors in the environment. These seem to be the excessive light and heat and strong wind-action of the sandy regions, the last being probably the most important element. In addition, the power of a large body of water in equalizing temperature explains in part the presence of many forms on the New Jersey, Delaware, and the Gulf coasts.

I wish here to express my thanks to Dr. C. F. Millspaugh of the Field Columbian Museum, Mrs. Agnes Chase of Chicago, Dr. J. N. Rose of the National Museum, and Dr. J. W. Harshberger of the University of Pennsylvania, for their kind assistance in identification; and I wish also to acknowledge my indebtedness to Dr. H. C. Cowles and Professor John M. Coulter for valuable criticism and suggestions.

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¹⁴ KEARNEY, Dismal Swamp 428