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NUMBER 7

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BY

PEHR OLSSON-SEFFER, Ph. D.

The Sand Strand Flora of Marine Coasts

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PUBLISHED
BY THE AUTHORITY OF THE BOARD OF DIRECTORS OF
AUGUSTANA COLLEGE AND THEOLOGICAL SEMINARY
ROCK ISLAND, ILLINOIS

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AUGUSTANA BOOK CONCERN, PRINTERS
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Pehr Olsson-Seffer, Ph. D.

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Genesis and Development of Sand Formations on Marine Coasts.

By Pehr Olsson-Seffer, Ph. D.

Since the year 1891 I have been studying the sand formations on marine coasts and their flora and vegetation. During the years 1891 to 1899 my investigations were confined to the coasts of the Baltic. The last mentioned year I also investigated the dunes on the Danish North Sea Coast, in Holland, and in certain parts of Scotland and France. In 1900—1901 observations were made in Southern Sweden, in various places in Denmark, on the South Coast of England, in Southern Italy, at Port Said, in Egypt, in Western Australia, and in Queensland.

Various coasts in Australia, from Central Queensland to Western Australia, through New South Wales, Victoria and South Australia, were visited and re-visited during 1902. In New Zealand only part of the North Cape was made subject to a brief and hurried visit and notes of the strand vegetation were taken during stays in various islands of the Pacific, such as the New Hebrides, Solomon Islands, Samoa and Hawaii.

On the Pacific coast of North America the dunes at San Francisco and Monterey Bay were studied in 1903—05. During 1905, I also visited the coastal sands at Santa Barbara and Santa Monica, in Southern California, as well as several sand dune districts on the Pacific coast of Mexico, such as Salina Cruz, in the innermost part of the Gulf of Tehuantepec, and San Benito, near the Guatemalan border. The extensive sand dunes near Vera Cruz, in Mexico, on the Gulf side, were investigated in August of the same year. In December, sand strands were studied at Mazatlan, a Mexican port on the eastern shore of the Gulf of California, as well as at San Blas in Mexico and Champerico in Guatemala.

The large field these observations cover have given me ample opportunity to make comparisons of the coastal sands in various climates and under the most different natural conditions. In the present paper I propose to deal briefly with some of the marine sand formations, their origin, development, and classification, so far as it is necessary to demonstrate the most fundamental facts of this subject and the principles on which they are based. I also give short comments upon the principal dune districts visited in the course of my studies.

To Professor Wm. R. Dudley of Leland Stanford Junior University I am greatly indebted for many favors in connection with my work, and I have also to express my acknowledgments to Dr. Johan Erikson, Karlskrona, Sweden, Dr. K. R. Kupffer, Riga, Russia, Dr. W. J. Smith, Leeds, England, B. H. Woodward, Esq., F. R. G. S., Perth, Western Australia, C. E. Benbow, Esq., C. E., Sidney, New South Wales, Dr. L. Cockayne, Christchurch, New Zealand, and various other persons, who have assisted me with information and photographs.

SAND FORMATIONS IN GENERAL.

When we consider the factors which have given rise to the formation of sand, the principal ones are the atmospheric and the aqueous agencies, which also are the most important in transportation and distribution of the material. It will therefore be convenient to distinguish between the following general classes of sand deposits:

1. Eolian sand formations.
2. Neptunian sand formations.

The term eolian in this connection was to my knowledge first used in 1835 by *R. J. Nelson*[1] and it signifies the agency of wind. Eolian deposits exhibit a different composition and structure from the neptunian, those sediments which have been built up by the water. The transporting power of water being considerably greater than that of wind, it necessarily follows that the material moved by aqueous agencies varies more in size than that which is carried by the wind. We will have ample opportunity to note this difference as we proceed in our inquiry.

No rational nomenclature for the different kinds of soil constituents, neither of inorganic nor of organogenetic origin, has yet been agreed upon, and it will thus be necessary to give here the designations which have been used during my observations in the field.

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1) Proceedings of Geological Society of London, Vol. II., p. 160.

	Diameter of grains in millimeters.
Fine dust or silt	0.02— 0.03
Medium dust or silt	0.03— 0.05
Coarse dust or silt	0.05— 0.1
Finest sand	0.1 — 0.2
Fine sand	0.2 — 0.3
Medium sand	0.3 — 0.5
Coarse sand	0.5 — 1
Grits	1 — 2
Gravel	2 — 4
Coarse gravel	4 — 6
Pebbles	6 — 10
Coarse pebbles	10 — 20
Shingle	20 — 50
Stones	50 —250
Boulders	250 —Upwards.

The limit of the coarseness of sand grains is here considered as 0.2—0.1 mm. When the grains are finer than 0.05 mm., the soil[1]) has lost the physical properties of sand. It does not feel gritty to the fingers, and if it is dropped on a level and hard surface the grains will not separate but congregate in small heaps. It needs several minutes to sink in water to the bottom of a test tube. When over 0.05 mm. the soil has, however, more of the characteristics of real sand. It is then gritty, when pulverized between the fingers. If scattered dry, it will separate into grains conspicuous to the naked eye. When mixed with water in the test tube, it sinks rapidly, usually in less than one minute, and it is to a noticeable degree conductive of water. It is difficult in practice to draw the lower limit for sand of a certain coarseness, because the soil is more or less mixed. On account of the difference in specific gravity of the grains many samples contain grains of different grades.

In the above table the measurements of diameter refer to the average sized grains in each class. The term sand has here been applied to soil, the grains of which are under 1 mm., while a coarseness of 1—2 mm. has entitled the soil to the name of grits. When the chief ingredient is particles larger than 2 mm. and below 6 mm. the soil has been designated as gravel.

Common sand is 2,100 times heavier than dry air, while only 2.5 to

1) The term soil is in this paper used in its broadest technical sense to designate the loose material constituting the disintegrated superficial layers of the earth's surface.

2.7 times heavier than water. A strong breeze is therefore required to raise the dust of a road for transportation by the wind, and a still stronger breeze to raise quartz sand; while large pebbles are seldom lifted from the ground. The winds are also extremely irregular in their movements and action. The trades over the ocean have a higher degree of uniformity than other winds, but the velocity is generally only 10 to 20 km. an hour. The winds that do the chief part of eolian geological work are those of storms, whose velocity per hour is from 50 to more than 100 km. Such winds are very unsteady in their action, blowing in gusts, in which there is a sudden increase to a maximum and a slower decline to a minimum. There is no constancy in force even for an hour, and no uniformity over large areas.

The transporting power of water, on the contrary, is very great; strong waves or torrents being able to move rocks weighing hundreds of tons. By experiments it has been found that a current moving at the rate of 25 cm. per second is able to carry fine sand, while a velocity of 50 cm. is sufficient to transport coarse gravel. The action of water is, moreover, very constant as a rule, and the waves on a long coast, for instance, exert their uniform influence over a considerable area.

We must not, however, confound the transporting power of these agencies, wind and water, with their erosive power. In one case it is the weight, in the other the cohesion, that offers the resistance. Neither wind nor water has any greater erosive power by itself. It is where mud or sand is carried by the wind or water, that a friction arises which removes the particles, loosened by decaying and other processes, from their original place.

Water is efficient in denudation by 1) dissolving of rocks, 2) transportation of the material which assists in the eroding work, and 3) carrying away the debris. The analogous functions of wind are: 1) transportation of the material which triturates and erodes all substances in its way, and 2) distribution.

A water current when overloaded with solids will deposit; when underloaded it will erode. A sandladen wind always both cuts and deposits. Dry sand, wind borne, is an unobtrusive agent, working silently but diligently on the task of paring away the surface. It leaves no monuments to show the magnitude of its results, as does denudation by water. River beds and sandbanks are examples of the excavating and building up through sedimentation by the water.

Water is a base leveler in the sense that it transfers material from higher places to lower; but where it erodes, it always works more rapidly along the lowest lines and leaves ridges and islands, by which its results can be measured. The water currents have, at any one spot, but a single direction, and the furrows and mouldings of the curved surface are grouped in a single system; but the wind may blow in many directions, and produces series of corresponding complexity.

It is a well known law in dynamical geology that all sedimentary deposits are stratified. This lamination is somewhat different when caused by eolian influence than when resulting from the action of water. The sorting power of water is more distinct than that of wind, because of the greater regularity of water currents.

As a consequence of the rapid variations to which the transporting power of the wind is subjected, eolian deposits are generally straticulate, finer and coarser laminae succeeding each other in indefinite alterations. But there is not the evenness of layer characterizing aqueous deposits, even when made over level surfaces. To make beds without straticulation would require winds without these irregularities,—little varying and long continuing,—such as few regions have, except those that have winds of too moderate velocity to carry any but the finest particles. The gusty winds also tend, by their denuding as well as transporting work, to make wavy rather than plane upper surfaces. Moreover, any barrier, as a projecting rock or a stump, or a tuft of grasses, causes a heaping of the sands around the obstacle, and makes curving surfaces in the heaps, owing to the eddies in the air.

We must here consider the following kinds of lamination:

1) horizontal
2) oblique
3) flow- and plunge
4) irregular.

Horizontal strata are developed in water only, especially in non-running water. Each lamination here represents different conditions of the water in which the sediment is deposited, and oblique lamination or cross-bed structure is a result of deposition by rapid shifting currents, carrying material of varying coarseness. While strictly horizontal lamination cannot be formed by winds, obliquely laminated layers occur in eolian deposits, indicating that somewhat regular winds have blown for some time.

This cross-bed structure of the sediments is characterized by a lamination in a plane, oblique to the horizon. It results from the pushing along of the sand by currents, causing at first a little elevation, and then the deposition of successive layers over the front slope of the elevation. If the currents are transient, alternating with conditions of still water, the obliquely laminated beds will alternate with others horizontally laminated. Such laminations may be due to changes of wind or tide, or to the periodical or occasional fluctuations in the volume of rivers.

The flow- and plunge structure has been caused by plunging waves accompanying the rapid flow of a current, through which action the oblique laminae have been broken up into short, wavelike parts. This lamination bears evidence of being the result of an agent less variable, and moving slower than that which has formed the irregular structure so characteristic of most eolian deposits.

THE DEVELOPMENT OF COASTAL SAND FORMATIONS.

The sand formations, which will come under discussion in connection with our present subject, all have their origin ultimately due to the action of the sea. We can conveniently divide these marine formations into following groups:

1. Submarine sand banks.
2. Sandy islands.
3. Sandy spits.
4. Sandy beaches.

1. The first class of formations or submarine sand banks are formed by the combined action of streams and the waves of the sea, or by the latter alone. Most of these accumulations contain more or less of river detritus, which is brought down to the sea during floods. The ocean's waves and currents meet it as the tide sets in, with a counter action, or one from the sea landward; between the two the waters, as they lose their velocity, drop the detritus over the bottom. Where the river is very large and the tides feeble, the banks and reefs extend far out to sea. Where the tide is strong, sand bars are formed, and the stronger the tide, the closer are the sand bars to the coast. Where the stream is small, the ocean may throw a sand bank quite across its mouth, so that there may be no egress to the river waters except by percolation through the sand; or, if a channel is left open, it may be only a shallow one.

In other cases the material constituting the sand banks is derived from the land through the erosion and transportation of waves and currents. This material consists usually of coarse or fine sand, but may include some beds of pebbles or stones when the currents are strong. The stratification is comparatively regular and nearly horizontal.

2. When the accumulations just spoken of increase under wave-action in shallow water, until they rise above low tide level, they form sandy islands.

3. Sandy spits are the lengthwise extensions of beaches formed through the waves throwing material on shoals at the turn of the shore. Their composition is similar to that of the above formations.

4. Sandy beaches are made by material thrown up on the shore by waves. This material is coarse where the waves break heavily, because, although trituration is going on at all times, the powerful wave action and the undertow carry off the finer material seaward into the offshore shallow waters, where it settles over the bottom or is distributed by currents. It is fine where the waves are gentle in movement, as in sheltered bays, or estuaries, the triturated material accumulating in such places near where it is made.

As soon as the accumulations of eroded material have increased so far as to rise above the surface of the water, the further growth is similar to that of the beaches, and from these latter other coastal sand formations such as dunes and sand fields are developed by the influence of wind. The development of these two kinds of eolian sand formations will be discussed in detail under separate headings.

It is a well known fact that the salts of seawater hasten the deposition of sediments, and consequently the shape and formation of sand banks and beaches on marine coasts is somewhat different from those of corresponding freshwater deposits. I have not been able to ascertain whether the seawater acts differently on siliceous material than on clay sediments. We usually find that deposits nearer the shore or the source of the material contain more silica than further out in the deep water, but this may depend on the usually large size and the greater weight of the siliceous fragments, which causes them to sink sooner.

In order to determine this, experiments were conducted in the laboratory. I tried ordinary seawater from the Baltic, of a salinity of 0.6% measured with areometer, and artificially prepared solutions of resp. 2.7% and 3% corresponding to the salt content of ocean water. Finely ground clay and beach sand were stirred in the water samples, and allowed to settle in vessels 25 cm., 50 cm., and 100 cm. deep, all being 42 cm. in diameter. The following results were obtained:

Depth of vessel.	No. of vessel.	Salinity of water pr cent.	Hours for settling.	
			Silica.	Clay.
25 cm.	1	fresh	29	38
	2	0.6	10	12
	3	2.7	2	2.5
	4	3.0	1.75	2.25
50 cm.	5	fresh	42	50
	6	0.6	14	16
	7	2.7	3	3.75
	8	3.0	2.50	3.25
100 cm.	9	fresh	68	84
	10	0.6	24	30
	11	2.7	5	6.25
	12	3.0	4.25	5.25

As will be seen from this table, silica in all cases both in salt and fresh water settled faster than clay. Whether this fact was merely a result of a greater weight of the siliceous particles, or whether other factors influenced the sedimentation, I was unable to decide. At all events it was evident that the salt produces a considerable flocculation in the water. The primary cause of the growth of the deposit in water is sedimentation, but in many cases the rising of the level of the coast-line has to be taken into consideration as a secondary factor. It is often difficult to determine to what extent the rate of growth of a deposit is due to one of these factors or the other. Especially is this the case on a low coast, where the growth always takes place more rapidly than on a steeper shore. The horizontal growth of the deposit is also much greater on coasts protected by islands than on open coasts with deep water, where the material is more easily carried away.

With regard to the position of the marine sediments it will be noticed that they are apparently horizontal, and the tendency is to level the beds through filling all depressions. The coarser sediments are always nearer the shore in comparatively narrow lines, parallel to the coast, whereas the finer sediments are spread over a larger area further off the shore. Banks and beaches are always sloping gently seawards, and they are, perhaps, somewhat steeper on marine coasts than on fresh water shores, general conditions being equal.

We have here also to consider the peculiar results of the wave-action of both water and wind, which are generally known by the name of ripple marks, a term introduced by *Lyell.*

The phenomena of rippling have in recent times had a careful observer in *Cornish,* and the following statements are principally based on his studies of this problem, although the laws and facts presented by him have been subjected to a detailed investigation in the field by the present writer, and I am able in a few instances to bring forward some evidence in support of *Cornish's* theories.

The same factor which causes the wave formation of water has a similar influence on the sand. The resulting wave-forms or ripples consist of alternate ridges and furrows made by the wash of the waters over a sand flat or beach, or over the bottom within soundings. They may also be made by the action of wind on a surface of sand. When the ripples are formed through the action of water we can distinguish between

1. wave formed ripples,
2. current made ripple marks, and
3. tidal sand ripples.

The parallel formations of wind made sand waves are

4. eolian sand ripples, and
5. dunes.

Comparing waves of water with those of a more solid medium, such as sand, we find that, while in the case of water two kinds of waves, oscillatory and wind driven, can be recognized, wave formation in sand is always connected with onward movement of the particles. In oscillatory waves the water particles on the crest are moving forward, but those in the trough backward with the same velocity and consequently the water body as such does not move in either direction. It is customary to express this motion by saying that the particles move in a circular orbit. When the waves are wind driven the forward velocity is greater than the backward, and a bodily movement of the water in the direction of the acting force is the result. The curve described by the water particles is still closed, having a trochoidal form. In the case of drifting sand the particles from the crest of the wave move in curves, which are open.

Wave-formed sand ripples have an unsymmetrical form, always facing with the waves. Current made ripple marks are similarly unsymmetrical in form, the sheltered side being steeper, and the front facing the current. Tidal sand ripples, first described by *Reynolds*[1] and later by *Cornish*[2] occur in estuaries and also on some shores where the sand is exposed to waves as well as currents. *Cornish* is of the opinion that they do not require for their formation any cooperation between flood and ebb currents. The size and form of these ripples is constantly changing with the variations in the tide. *Cornish* describes this in the following words:

"At neap tides the sands were nearly smooth, and as the tides increased the tidal sand ripples appeared, short and relatively steep. The amplitude increased steadily, the average wave-length also increased, apparently by elimination of some of the ridges. When the highest spring tide was passed the amplitude rapidly diminished, the wave-length remaining nearly, but not quite constant, and the mean sand level remaining practically unchanged."

Tidal sand ripples sometimes attain a considerable size, *Cornish* giving the wave length of from 1 to 6.7 m. I have often noticed a finer rippling of the proper tidal ripples, and in two instances, on the eastern coast of Australia, I observed the tidal sand ripples crossed by another set of large ripples. These were formed by a sudden change of the direction of the tide current through the overflow of a neighboring stream. Both these sets of wave formations were then beautifully rippled in the usual way by little current marks, facing almost transversely the second set of larger ripples. *Cornish* attributes the formation of current marks to the pulsation of the fluid rather than to the current itself.

In the formation of eolian sand ripples it is the heterogeneity of the material which is of the greatest importance. The sorting action of wind is remarkable, and it is evident at the first glance on a group of ripples that the heavier grains always constitute the crest, the lighter the trough. A moderate range of sizes of grains seems therefore most favorable to the formation of ripples.

Darwin[3] remarked the uniformity of pattern in the ripples formed by wind, which uniformity, as a rule, is absent from ripples made in

1) Reports of committee appointed to investigate the action of waves and currents on the beds and foreshores of estuaries by means of working models. — British Association for Advancement of Science, Reports '89, '90, '91.

2) The formation of wave surfaces in sand.— Scot. Geogr. Mag. 17: 1—11. 1901.

3) *G. H. Darwin:* On ripple mark. — Proceedings of Royal Society, London, vol. 36. 1883.

water. When the wind blows upon the sand, a winnowing process takes place, the finer particles being carried farther away than the coarser material, which then produces the ridges of heavier grains mentioned above. This uniformity of pattern connected with the fact that the wave length increases with the time during which the force of the wind is acting upon the sand led *Cornish* 1) to advance the following law for rippling by wind: *The rippling takes place when the eddy in the lee of the larger grains is of sufficient strength to lift the smaller.*

The systematically corrugated surface of loose sand can only be produced by a wind that is not too strong for the larger grains to remain on the ground. If the breeze is too strong no rippling whatever takes place as all the particles of sand then will be transported. If on the other hand the wind is too weak to make an eddy, the sand moves slowly, but does not form ripples.

The height of the waves and their distances from each other is larger the larger the grains are. The movement of the waves is of different rapidity and depends on the force of wind and the size of the grains. It is naturally more rapid when the wind is stronger and the sand fine. Following results were obtained by the author from a number of measurements of amplitude or height of ridge and wave-length of sand ripples made by wind on the coast of West Australia. All measurements are given in millimeters.

No.	Coarseness of grains.	Amplitude.	Wave length	Number of measure ments of which sample is average.
1.	0.7	8.6	36	34
2.	0.6	3.1	29	6
3.	0.4	3.7	34	3
4.	0.3	2.5	47	14
5.	0.8	6.2	40	8
6.	0.6	4.4	39	6
7.	0.7	8.7	51	25
8.	0.8	8.3	68	21
9.	0.6	14.6	82	19

These measurements serve to support the results obtained by *Cornish* and the law advanced by him, that *amplitude and wave-length increase*

1) On the formation of sand dunes. — Geographical Journal, vol. IX: 280.

in same proportion. His other conclusion that regular rippling has an amplitude of three grains from trough to crest, seems to me rather hasty. I have, however, not made any regular observations to test this statement, it being of minor importance in connection with my present inquiry.

For the study of wave forms, which as a legitimate subject for investigation has attracted the attention of several scientists since the time of *Newton, Cornish* has proposed[1] the term *Kumatology* (κῦμα -wave).

Accepting this name for the sake of convenience, the writer has to point out that the digressions here made into the domain of Kumatology have been necessary in order to arrive at a better understanding of the factors which control the movements of sand, the interpretation of which is in many respects still contradictory.

SANDY BEACHES.

The beach may be defined as that strip of the shore which is formed by the agency of waves. As a rule, it is situated between the lowest level of the water and the formations produced by other geological agents.

The method of beach formation has already been indicated. It was mentioned that the mechanical action of the sea is evidenced in the phenomena of erosion, transportation and sedimentation. The eroding action of the sea is especially prominent on steep rocky shores, and on places where the difference between low and high tide is great.

The material from the rocks eroded by the waves as well as the sand and silt carried down to the rivers, sinks to the bottom of the sea and is again transported by the waves and currents to the coast, there to be accumulated. Although the transporting power of the waves is immensely great, the distances to which rocks or even sand can be carried is limited. In sediments of a clastic nature a sifting takes place through the action of the waves against the shore, the finer material being carried farther away, while the coarser is left on the shore. On very steep shores, only larger pebbles and gravel are found, on lower fine sand, and on very low coasts, silt.

If we consider the movements of the sand on a low shore, we will

1) Geographical Journal, March 1897 and June 1898.

notice that the sand grains follow the movement of the waves, that is roll up and down. The deposit of sand takes place only when the returning current does not carry back all material brought forward by the wave. It follows that the velocity of the forward movement must be greater than that of the returning current which is possible only on very low strands, the sloping angle of which is not greater than five degrees. If the size of the grains is large, the angle naturally also changes. At the limit to which the wave reaches, an instantaneous absorption of the very thin strata of water takes place in the sand, so that the returning current does not begin at this limit, but at a place lower down. It is easy to determine the width of this belt in which the absorption takes place, as the sand surface first is shining by the water and then quickly turns dull. The width is always varying, and is in direct relation to the strength of the waves, and also to the sloping angle of the beach. During a strong gale and on a very low strand, this belt is from 2 m. upwards on the Baltic coast, and on the western coasts of Australia and the Pacific coast of America, where the mighty waves of the ocean strike the shore with all their force, this belt is still much broader. Secondly, deposits take place only on coasts, the sloping angle of which is not more than 5 to 10 degrees. This angle is about 5 degrees with a grain size of 0.5 to 1 mm. in diameter. With finer sand, under 0.5 mm., as is the case on many places on sheltered shores on the Baltic coasts, it sinks to between 1 and 2 degrees, while with larger grains, from 1 to 3 mm., an angle of 7 or even 8.5 degrees is formed. With a steeper slope, deposition does not take place, but a denudation is commenced.

Sandy beaches afford a certain protection of the coast line against the erosive action of waves and surf. During the constant landward urging of the sediments the coarser ingredients of the arenaceous material soon cease to roll, and come to rest, and as the deposits are augmented they will offer sufficient resistance to reduce the energy of the wave, and consequently the erosion is diminished.

That beach sands remain unworn depends to a great extent on the fact that the particles do not touch each other, as each one is surrounded by a film of water. The beating of the waves also compresses the interstitial water, and the solitary grains are thus not tossed about and therefore do not grind and wear.

The presence of a considerable amount of interstitial water in the beach sand washed by the waves is demonstrated when through the pressure of the foot on the sand this whitens because of the expulsion of water, while as soon as the foot is lifted the original dull color is quickly resumed.

Very fine sand is angular, and the rounding by water is produced only when the strength of the current is not sufficient to keep the grains suspended, but yet capable of moving them. The specific gravity of the volume of sand is always smaller than that of the solitary grains. The latter leave between each other spaces which are filled with air and water; if all the grains were of the same size and exactly spherical, the specific gravity of the volume of sand would be independent of the absolute size of the grains, but as soon as grains of different sizes are mixed, the small grains fill the spaces between the larger and hence increase the specific gravity. This latter is also, the mineral character of the grains being equal, higher the more dissimilar the grains are.

The texture of the sand in each locality depends entirely upon the nature of the rocks from which it was originally derived. Through having a comparatively large mixture of different sizes, and consisting of the most different minerals of different specific gravity, beach sands exhibit considerable differences in texture. On almost every non-rocky coast, however, some kind of accumulation of fine grained quartz sand can be noticed.

By quartz sand we understand a soil consisting mainly of white or yellowish quartz grains, among which only very seldom any organic matter is distributed. Being conspicuously free from foreign constituents, quartz sand is very uniform. It is generally believed that the pure quartz sand on marine shore is a special result of the action of the sea. This is, however, not the case. I have examined many samples of the littoral sediments on different coasts, but never found the clean white quartz sand of the beach occuring on the bottom of the sea. On the contrary, the sandy sediment under water is impure, mixed with organic matter, and highly colored. As soon as the sand is thrown ashore by the wave and current action, and left at the water level, it is picked up by the wind and carried inland. And if we observe the sand of the beach from the edge of the water landward, we will find that it becomes cleaner the further it is from the sea. This fact is mentioned by several authors; for instance, *Serres*,[1] who speaks of it in discussing the French Mediterranean coast. Beach formations are very irregular in stratification in their upper portions, where they are made by the toss

1) *Marcel de Serres:* Der Treib- und Flugsand des Mittelländischen Meeres. —Peterm. Mitth. V: 197—198. 1859.

of the waves combined with the drifting of the winds. But the sloping part swept by the waves below high-tide level is very evenly stratified parallel to the surface: This surface dips usually at an angle of 5° to 15°. Generally speaking the coarsest beaches have the steepest slopes. The sand of the beach is increased or decreased according to the weather and the seasons, it being thickest in summer and thinnest in winter, and sometimes the beach is almost stripped of sand after a series of gales. On the beach, there is formed a ridge of sand during offshore winds. The sand is readily raised by the breakers and usually an excavation or trough is found at the back of the ridge. This is similar to the excavation and elevation produced in ripples. When the wind goes down, a succession of low ridges are formed concave on the side toward the sea, but as soon as a wave reaches over the top of the ridge, the concavity is filled and an edge with uniformly sloping sides is formed. The height of this beach ridge is usually not very considerable on the Baltic coasts; seldom more than 1.5 m. over the general level of the beach, or 2.25 over the sea. On the Atlantic and Pacific coasts, the height is not much greater, although the ridge is formed by breakers of considerable strength.

When the breaker line has been stationary for some time, for instance during a high tide, an excavation is dredged out, and at ebb a lagoon is often left here. For our purposes the beach may be divided into the following belts: 1. *The submerged beach;* 2. *The front beach;* 3. *The middle beach;* and 4. *The upper beach.* The first belt includes that portion of the beach that lies below mean low tide, but which may be exposed by neap tides. It is normally covered with water, and is subjected to the constant beating of the waves, which carry the material ashore in their landward advance. Some of the detritus is deposited, while another part is returned seawards with the undertow. Where the carrying power of the surf is great, the beach is often built up by material containing a considerable amount of coarse gravel and pebbles. On such beaches there is always a residue of mud after a storm or an exceptionally high tide, while no such deposits occur on sand alone. The front beach is the belt between mean low tide and mean high tide, being alternately each day exposed to the air and submerged. It mostly passes without any marked break into the submerged belt. Situated on the border between the land and water the front beach offers very unfavorable conditions, not allowing the deposits to remain stable or resting, on account of the repeated washing of the waves and currents.

With the term middle beach we would designate that portion of the shore which is continuously moistened by the spray from the sea, and it may even occasionally become inundated. The sand of this formation which has been piled up by the waves, is picked up by the wind and carried inland. It is usually of a light color. The upper layers are rapidly drying up, but the ground water keeps at a high level, and moisture is usually found at a very slight depth.

The upper beach is limited on one side by the line of debris that marks the highest water. This debris, cast up by the sea, consists of lumber and other wooden articles, fruits and seeds, fragments of marine plants, and a quantity of animal remains, rapidly decaying. The upper beach is also characterized by a greater rise in elevation and contains more organic matter than any other part of the beach. The development of this formation is modified to a greater extent by the wind than by water, and it is especially on this strip of the shore, where the sands commence to drift, and where they usually form the first ridges of sand parallel to the coast, which we know as dunes.

The windmade embankments on the beach have a remarkable construction, somewhat different from the usual. When the shifting of the sand is very rapid, the littoral dunes do not reach any remarkable height, and their existence is then very precarious.

DUNES.

The etymology of the word dune is somewhat obscure. Generally it is presumed that it is derived from the Celtic word *dun,* hill. In Latin it is called *dunum,* in Greek δουνον, and hence the modern languages have acquired the use of the same term in more or less changed dress. According to *Grewingk,* not every ridge of sand parallel to the coast is a dune, as they can in some cases originally be sand-banks formed under water, which later have been lifted above the surface of the water through the elevation of the shore. Dunes are formed especially where the sands are almost purely siliceous, and hence incoherent, and little fit for any kind of vegetation. They reach their greatest height on projecting coasts that receive the winds from different directions.

The source of the dune sand is usually either diluvial sand, which has been laid bare, or sand which has been brought ashore by the sea.

On the Dutch and Danish west coasts almost all the sand which forms the dunes traces its origin from the sea. It is here thrown up on the beach by the waves, and as soon as it has been dried by the sun, the wind carries it further inland. On the coasts in question, the westerly winds are the prevailing, and therefore the sand wanders in an easterly direction.

Because of their extreme shiftiness of soil, the dunes do not attain any considerable elevation. The sand deposited by the wind on the summit of the hill is always in a state of unstable equilibrium. It has a constant tendency to be precipitated down the other side, and the higher the summit, the greater is this tendency, so that the dune arrives at last to a point when no further accumulation is possible. The dune, however, still continues to grow, extending its base and generally increasing in dimensions, but does not increase in elevation.

The size and the height of the dune depends on the distance from the sea and on the strength of the wind. In some cases it has been observed that during a strong wind a dune has decreased in height 5 cm., while other dunes have increased 25 cm. Every dune has one side placed against the prevailing wind. This front side has a lower grade than that on the lee side, which is always more abrupt. As long as the same wind prevails, and as long as the wind carries only so much sand as it is able to take away from the top of the dune, so long will the dune retain its position and form, just as a whirlpool in a river is constant, so long as the river maintains the same velocity and volume. Because the sand grains cannot be lifted to any greater height in the air, the dunes, when they have reached a certain elevation, would present to the sand grains an almost insurmountable obstacle, but they have very seldom time to cohere. The wind modifies its work incessantly and the height of the dune is very soon reduced by stronger winds.

The transporting power of the air is, as already mentioned, small compared with that of water, because of its lightness and want of cohesion. The size of the particles has, therefore, a great influence not only on the degree to which the sand is liable to drift, but also on the extent in which it may manifest properties relative to the texture of the soil, among others that of retaining moisture, which is so important to vegetation.

The amount of sand transportation is greatest, other things being equal, where there is no cover of vegetation to keep down the sands, and the deposits made are most extensive in the direction of the prevailing currents. The coarser dune sand particles are pushed along the ground, while the finer form clouds of dust in the air, and settle rapidly or slowly near to or remote from the source of supply according to the force of the wind and the size of the particles suspended.

The drifting of sand by wind takes place according to following principles: If the force of the wind is great, the grains do not move on the surface but are lifted by the wind to a certain height. The larger grains make jumps, and touch the ground from time to time, while the smaller grains often are carried forward in form of clouds at a considerable height from the ground. At a velocity of 4.5 m. in the second, grains of 0.25 mm. diameter slide on the ground, but at a velocity of 15 m., grains of 1 mm. diameter are lifted high in the air. As a corollary of this fact it follows that the movement of the grains depends on their volume. The greater part of the sand grains have an irregular flat form, and hence their movement is not rolling but sliding. That of the largest take place spasmodically and only during stronger gusts. According to *Sokoloff*, a wind of a velocity of 10—12 m. in a second cannot carry grains of 100—150 cubic mm. When the wind is not too strong, the grains slide along the surface, but when they are lifted up during the strong gusts, and fall down at a certain angle, they again rebound at the same angle. *Hagen* has proved that coarser sand grains are sometimes lifted up to 2 m. height, and in such a case they are carried up to 12 m. from their original place.

Ridges or rim formed ripples advance almost entirely by the sliding of the larger grains of the top layer of the crest, and *Cornish* estimates the progress of the ridges at one foot per hour. *Helmann* found in Chiwa that the ripples on the lee-side of the dunes move almost with the same rapidity as on the windward side, and he was not able to interpret this phenomenon. It has been ascertained that the movement of the dunes landward goes on at the average rate of 4.30 m. a year, and that the quantity of sand thus transported is about 75 cubic m. to the running m. of the length of the dune.

The winds have a greater power at a higher elevation than near the surface, and consequently more sand is removed from the summit than the wind is able to lift from the ground. This difference in the strength of wind exercises a modifying influence on the development of the dunes. The effect of the wind is to diminish the maximum slope, but as the formation of dunes is mainly regulated by the supply of sand, the varying angle of the windward slope depends upon the varying density of the sand shower pushed forth toward the summit. In cases where the supply of sand has become scarce or exhausted, the front slope of the dune soon will be almost as steep as the lee side, that is, approach the natural limit of the angle of rest.

The leeward slope of the dune varies but slightly, provided a reverse of the dominant wind does not take place. It is the gravity which here exercises its force and reduces to the angle of rest any steeper slope caused by the air currents or other factors. The development of a dune is similar to that of a ripple, although it takes place on a larger scale. In lee of the dune crest there is an eddy, the upward motion of which lifts the fine sand particles, and in cooperation with the wind sends them flying from the summit. Gravity acts upon these particles, causing the fall across the stream lines of the air. The coarser sand falls more steeply, and this pitch is further increased by the backward motion of the eddy.

There are thus several factors which influence the formation of dunes. Of these operating factors the force and direction of the wind, the sand shower, the eddy in the lee of any obstacle, the gravity, the configuration of the surface, and the moisture are the principal ones. If the dune is formed at a certain constant sum-total of these factors, it retains its form as long as these factors are constant.

THE SCULPTURAL FORM OF DUNES.

The forms of dunes have a greater variety than those of ripples, because a dune is the result of many changing winds. While the dunes do not owe their origin to the action of the sand grains, like the ripples, still rippling plays a part in the shaping of every dune. Reversible winds produce dunes having both front and back slope very steep. The first effect of reverse of winds is to turn the top of the dune.[1] During strong winds the troughs are always deeper.[2] On a hard ground, the windward slope can be as steep as the angle of rest, in case the sand supply fails and the wind is strong. If such is the case the dunes are widely separated.[3] This form differs from that of dunes produced in deep sand by dominant wind. The angle of the windward slope in this case decreases with the density of the sand shower, and increases with the power of the wind.

The amplitude of the dune does not exceed one third of the wave-length, and this limit is most nearly approached when the wind blows

1) *Sven Hedin:* A journey through the Takla-Makan Desert, Chinese Turkestan.—Geogr. Journ., VIII: 264—278, 356—372. 1896.
2) *G. Grandjean:* Les Landes et les dunes de Gascogne.—Bull. Soc. Géogr. Coml. de Bordeaux, March 1896.
3) *V. Cornish:* On the formation of sand dunes.—Geogr. Journ. IX., p. 286. 1897.

alternately from opposite quarters, but does not hold in one quarter sufficiently long to reverse the work of preceding winds. *Cornish*[1]) remarks that in speaking of amplitude instead of height of dunes, one avoids the common confusion which results from the fact that the vertical distance from the bottom of the trough to the summit may increase even by raising of the crest or by deepening of the trough.

A dune sufficiently large is stationary, and it is an established law that as the amplitude increases, the velocity of the dune wave decreases. The velocity of the dune is the rate of advance of the crest which takes place by accumulation of sand upon the lee slope. There is also a group velocity of dunes to be recognized, that is, the rate of travel of the sand. Increase of wind will increase formation of new dunes to leeward rather than the rate of travel of the individual dune, and is usually accompanied by a considerable lowering of the general level, especially in the case of simultaneous diminution in the supply of sand.

The sorting action of wind already mentioned is supported by rain-water which washes the finer particles down into the trough, and consequently we find the summit of dunes to consist of coarser material. But on the other hand the lower part of the eddy is gouging out the trough and the finer material is carried away through the combined action of the eddy and the wind. The sand is therefore finer in the dunes generally than in the hollows between them. On a large sandy surface the particles are finer at the extremity towards which the wind blows.

Through this winnowing process the dust which consists of friable matter, having been reduced to the size of powder by grinding between the sands is carried away from the dune district and deposited beyond its limit. It is especially in desert regions, where aridity excludes vegetation and allows the wind to play with full force upon the finer particles of the soil, that we notice the development of sandy deserts covered with quartz sand, yet surrounded by grassy steppes consisting of clay dust. This remarkable distribution of the products of rock disintregration by wind and its effect on the physiography of Northern Africa has been eminently shown by *Walther*.[2]) Already *Buvay*[3]) described the transition between the cultivated coast lands and the desert of Africa, which must be called a steppe, and the genetical relation of these formations is now a generally admitted fact.

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1) l. c. p. 287.
2) Die Denudation in der Wüste.
3) Zeitschr. für Allgemeine Erkunde, Berlin, 1857, p. 290.

If we consider the general appearance and composition of the drift sands we find that they consist in a preponderating degree of somewhat rounded grains of quartz sand with only a very small percentage of other materials. The admixture consists primarily of felspar, of mica, and of various other minerals, such as hornblende, augite and granite, and to some extent of lime, mostly in form of fragments of shells.

In a crystallinic rock, such as granite, we find that the different constituents, felspar, quartz and mica, are present in isolated crystals. As soon as these elements are separated from each other, they acquire a granulated form and constitute what we call quartz sand. The grains of felspar and mica act, however, in a different way than those of quartz, the latter representing crystallographically only one or a few individuals, while felspar and mica consist of many thin lamellae. Hence, when exposed to the decomposing agencies, disintegration of felspar and mica is much more intensive than that of quartz. The different particles of sand are moved more rapidly by the wind the lesser their gravity in proportion to their surface. Mica is so light that the least gust of wind carries its thin lamellae away, and it is further so brittle that it is easily broken into small fragments against other sand particles. The same can be said of felspar, although, perhaps, in a less degree. Here we also have to consider the chemical facility for decomposition. During the night and in the dewy mornings, the felspar which has been opened through the many capillary spaces is chemically decomposed by the moisture, while the quartz has a greater resistance against this agency. Consequently the older the dune sand is and the longer time and water have exerted their influence, the less felspar will be found in it and the more dominant is the quartz over the other minerals. As a rule, all the sand grains, however, exhibit more or less the rounded appearance due to attrition and weathering.

Besides the sand, the wind carries all kinds of light plant remains, thin shells, dry crabs, dead and living insects, and similar particles. All these temporary constituents of the dune are, however, insignificant in comparison with the sand, and are usually so rapidly decayed that they are seldom found in the deeper parts of the dune. The separate grains are mostly covered with a fine mold, in part due to the decomposition of the above organic remains, on which depends the fertility of the sand. The drift sand, though varied with a sprinkling of somewhat rare grains of darker colored substances, is generally a mass of a light color.

The stratification of dunes is usually very mixed, and in the same dune strata, cut in all the four directions of the compass, can be seen. Successive layers dip in various directions, and are abruptly cut short, showing that the growing dune hill was partly cut down by storms and was again and again built up by such disasters. The consolidation of sand is best observed in ripples and rarely well shown in dunes, because the latter are the result of changing winds, and the time involved in their formation is too great for observation.

The fundamental forms of sand dunes include the *transverse* and the *longitudinal.* The former, which is the most common on sea coasts, especially where the wind is of moderate strength or the sand strip comparatively narrow, is that placed at right angles to the prevailing wind; the latter, formed where the wind is so strong as to prevent free lateral growth, is that following the direction of the wind; between these two there is an *intermediate form;* when varying winds act upon this latter form, *conical* dunes are produced. They are, as a rule, *stationary,* while the longitudinal form represents the most rapidly *traveling* dune.

The dunes which are placed parallel to the direction of the prevailing winds have originated quite differently from those which are placed at right angles to the wind. As we have seen, the usual mode of development of a dune is that the sand forms a ridge transverse to the direction of the wind. The sand is blown up on the lower slope on the front, and when it reaches the top it falls down along the lee slope; the ridge growing until it has reached considerable height. The parallel longitudinal dunes are, however, formed through the central part of the dune, being blown further and further forward, while the ends are kept back by various forces. The rule is that such a horseshoe-shaped or *parabolic* dune on the seashore *moves with the convex side in the direction of the prevailing wind.*

Apparently diverse, even opposing effect is produced in sandy deserts, if the observations of *Rolland* and many other travellers regarding the dunes called *Barchanes* are correct. In *Traité de Géologie* of *Lapparent,* 3 Ed., 1893, p. 140, we find the following opinion expressed about these wandering dunes: "Enfin la forme de dunes en marche doit être généralement celle d'un croissant tournant sa convexité vers le vent; par les particules sableuses, ayant moins de hauteur à franchir sur les bords de la dune qu'en son centre, cheminent plus vite à droite et à gauche. La crête doit donc se courber en projectant deux pointes vers l'intérieur. Cette forme *en croissant* a été bien constatée par tous les voyageurs qui ont parcouru le Sahara et les déserts americains."

Now the question arises: How is this phenomenon to be explained? *Cornish*[1] refers to the development of barchanes in the following words: "They form here and there upon the desert floor where the wind will let them. It appears that they neither occur in localities where the sheet of wind has everywhere a complete mastery over the sand, nor where the burden of all the flying sand is everywhere too great for the carrying power of the wind; they dot the desert plain in localities where the sheet of wind has, for the most part, the mastery of the sand, but drops its burden here and there at certain points or more probably along certain strips."

"The *horns* or *cusps* of the barchanes, pointing to leeward, are readily explained, for the lowest parts of the dune travel quickest. A form as of the moon in her first quarter (i. e. that is to say with the cusps pointing in the direction of motion) is the form of front proper to a traveling sand-wave as viewed in plan. In this case gravity does not operate, so that the incoherence of sand does not hinder the formation of the cusp as it does in the profile of dunes."

This explanation seems negatived by the fact that the cusps generally are very insignificant as compared with the body of the dune, and in most cases a difference in size of the cusps can be recognized. Thus Lessár[2] observed in the Kara-Kum desert in Central Asia that the southwesterly cusp always was longer. This seems to indicate that the cusps are formed in a way similar to that of the low ridges which have often been noticed on the lee side of both stationary and wandering dunes on sea coasts. These lee ridges are usually placed at right angles to the length of the dune and are formed by the combined action of the eddy in the lee and the current sweeping around the side of the dune. If we accept this explanation for the formation of cusps in lee of the barchanes, the original form of which tends to the oval, according to *Sokoloff*[3], we will find a satisfactory solution of the action of wind in the development of the barchane without having to theorize about the lower cusps of the dune moving more rapidly than the higher, which cannot be correct, as we know that the force of the wind is considerably greater on the higher parts of the dune hill than on the lower, and that consequently the central and highest part travels quicker. *Steenstrup*[4] has also shown that a parabolic dune never can move with the

1) On the formation of sand dunes, p. 290.
2) *P. M. Lessár:* Die Wüste Kara-Kum. "Izwestija" Russ. Geogr. Soc. 20: p. 115. 1884.
3) Die Dünen. 1894. p. 164.
4) Om Klitternes vandring. 1894. p. 14.

closed side toward the wind, and I must subscribe to his opinion, as I have not, on any of the dunes visited my me, been able to observe a phenomenon of that kind.

Summing up the foregoing discussion on dune forms, we would say that:

1. Dunes are formed in lines transverse to wind in unobstructed places.
2. Dunes are formed in lines parallel with wind in places where some kind of obstruction is in the path of the wind.
3. Wandering dunes have their convexity in the direction of the prevailing wind.

POLYGENETIC ORIGIN OF A DUNE COMPLEX.

The fundamental principles of dune formation established in the previous section must be recognized at the outset of this discussion in order to facilitate an understanding of the conditions which cause the origin and development of a dune complex. With this term, dune complex or dune tract, as distinguished from a solitary dune or a dune massiv, we signify a collection of secondary dune hills interspersed with deep gullies.

The dune complex is formed behind the chain of primary dunes, when the rate of travel of the sand is locally diminished without a corresponding decrease in the supply of sand. The formation takes place either through older dunes having been broken up into rough hummocks by the wind, or through secondary embryonic dunes being started by the piling up of drifting sand around some obstacle, in most cases a congregation of plants.

One of the most important factors determining the development of a dune complex is the presence of ground moisture. Without this factor we would not be able to explain the apparent irregularity of formation of a group of small dunes, where the quality of sand ought to have called for a regular dune massiv. The action of wind alone is insufficient for this modelling of the surface, but in connection with the greater coherence of the sand particles caused by the ground moisture the phenomenon is easily explicable.

It is the irregularity in action of wind, caused by the breaking up of the regular even surface of a dune or a sand field into small elevations and depressions, that governs the development of such embryonic sand hills into a dune complex. In almost every case the latter formation has had such origin from a number of nuclei, while a dune massiv is formed from a single embryonic dune.

If the plants should not influence the development of dunes the ridges would, like large waves, roll over the land until they were stopped either by water or by high mountains. In most cases it is the plants which have caused the broken forms of the sea coast dunes. Inland dunes have, as a rule, a more regular shape.

There is no other geological formation of the present time which is the result of such a combination of factors from the organic and inorganic nature. Dunes are developed wherever the winds can play over the loose sands, and as soon as the sand begins to drift, the ordinary vegetation is destroyed and plants which thrive in drifting sand immigrate, and thus begins the co-operation between the drift sand and the dune plants, the result of which is the dune. Although there is a struggle for power between the moving sand and the plants, it is remarkable with this strife that they both thrive best where they are almost of equal strength. If the plants have gained a victory they will soon be replaced by other plants, and then it can happen that the wind again breaks open the soil and the sand starts to drift afresh.

SAND FIELDS NEAR THE COAST.

As long as an obstruction has caused the formation of a dune, one of these will act as a recipient for the sand, and in this way dunes after dunes are formed until finally a whole sea of sand covered with dunes is formed.

The encroachment of dunes is due not only to the travel of the dunes themselves, but also to the formation of new dunes to the leeward from material supplied by the sand shower.

In some cases, however, when the dunes have not been fixed by a vegetation, the sand skims along the surface like snow drifting before a stiff breeze and accumulates rapidly, covering the plains without forming any hills. Further, the fine material which has been lifted to a certain height in the air, is deposited behind the dune region, and is quickly covered with vegetation, as it offers better condition for plant life on account of its greater coherence and capacity of retaining moisture than the coarser dune sand. These sand fields sometimes cover considerable areas, and it seems often almost inexplicable that no rippling or dune formation takes place. The explanation of their non-formation is to be sought in the fact that the sand-sized particles are too small in proportion to the mass of material, and further, the deposition of dust takes place so rapidly that the wind is not able to carry it away, leaving the coarser particles to accumulate.

CONDITIONS FOR PLANT LIFE.

There is a great variation in the conditions for plant life on different sand formations. The climate has something to do with this result as well as the quality of the soil. Sea air and saline constituents of the soil destructive to some plants may be beneficial to others. The mobility of a drifting sand dune on the coast may be a condition of life to one plant, while dry atmosphere and the stability of an inland sand field may be essential to the growth of another. Even *Pinus maritima*, which has produced such wonderful results on the Landes of Gascony, does not grow everywhere even on sand formations in France. It is therefore necessary to study in every case the natural conditions of the locality before the problems of ecological relationship can be solved.

Some of the conditions of sand formations are, however, everywhere the same and these will here be briefly considered. One of the most important points in this connection is the relation to moisture. The rain-water sinks easily into the sand, the better the coarser the grains are. Generally speaking, the power of retention of water is very small and of all soils sand ranges lowest in this respect. The sandy soil has also a very low power of absorption, and is able to condense only a small portion of the atmospheric moisture. This is especially the case with quartz sand.

Further, sandy soil dries easily, and it is therefore heated quickly by the sun; but it also cools very soon at night. The difference between day and night temperature can be as high as 40-50° C. In consequence of this, sand is subjected to a considerable bedewing at night, a factor which is important for its capability of carrying a vegetation cover. The great variation of temperatures of the soil is disadvantageous to the plants in one respect, they being more liable to injury by frost, than if growing on any other soil. Sand floras, on the other hand, are always developed earlier, because of the greater heat capacity of the soil.

The nutritive value of the sand is very different according to the chemical character of the grains. The commonest form, or quartz sand, is the most barren on account of the insolubility of the quartz grains, and also because of their resistance to decomposing agencies, as already mentioned. Sand consisting of mica, felspar, limestone, and other minerals, disintegrate, however, and have by reason of this a higher nutritive value.

Formation of mould takes place only to a small degree in dry sandy soil, because the organic constituents are so easily decomposed through the admittance of air, and the particles are further quickly distributed and carried out of reach of the plants by sinking with the water through the loose soil. The proportion between organic and inorganic constituents in this soil is too great, the quantity of the former being too small to establish a sufficient supply for the demand of a more luxuriant growth of plants.

This scarcity of plant food results in a more or less open vegetation consisting of low growing plants, which do not give each other the mutual assistance against mechanical influence of wind and other factors, that is evident in the arrangement of plants on most other soils. The injurious effect of the intense light, both direct and reflected from the surface of the sand, has to be guarded against. The transpiration of open sand vegetation, especially on the seacoasts, is always considerable because of the constantly changing atmosphere, resulting from the almost continuous winds. The plants have to develop some means of reducing this excessive transpiration.

Summing up, we may say that the competition for food is more intense, the water supply less, the light stronger, the temperature higher, the transpiration greater, the foothold more uncertain and difficult, the conditions for plant life generally more adverse, than on any other soil.

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The Sand Strand Flora of Marine Coasts

by

Pehr Olsson-Seffer, Ph. D.

CONTENTS

The Sand Strand Flora of Marine Coasts

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1. REVIEW OF THE LITERATURE ON SAND FLORAS.

The earliest data about plants confined to sand formations, particularly coastal dunes, we find in Smallegange's Chronijk van Zeeland, 1696, where it is mentioned (p. 313) that some dunes on the North Sea coast had been planted with Marram-grass or Helm *(Ammophila arenaria)* already in 1307. Maximilian of Austria issued in 1510 a proclamation upon planting the Helm, and in 1567 the government of Holland also prescribed, in an official edict, the planting of this species on the coastal dunes.

The problem of arresting the drifting of sand and of utilizing the dunes has since that time been considered to be of primary importance for Holland, and we find that the Dutch had made great progress by the middle of 1700, when the question was brought into prominence in Denmark and on the coast of Northern Germany.

At Tidsvilde in Sjaelland in Denmark there is still an old monument bearing an inscription in Latin to the effect that the drifting sand at that place had been fixed in 1738 by Roehl, a German by birth, who planted the dunes with Marram-grass. The Danish king resolved in 1779 that every citizen should plant a certain area with this grass, and the document, which is still preserved in the public archives in Copenhagen, gave detailed instructions regarding the mode of planting.

On Wangeroog, one of the North Friesian islands, similar plantations were made at least as early as 1754, from which year there is on record a map by J. D. Tanner.

In 1768 Professor J. D. Titius of Wittenberg wrote a prize essay on fixation of drifting sand on the Baltic coast (Gerhard, p. 286), and his proposals were put into practical tests at Danzig under the direction of a Swede, Abraham Lindström, during 1771. The experiment proved, however, a failure, and it was not until several years later that Sören Biörn, a Dane, succeeded in establishing a plantation on the dunes.

At the same time Baron de Charlevoix-Villers wrote several treatises on the subject of fixing the dunes of Gascony (Grandjean p. 53), and his views were utilized by N. T. T. Bremontier, who in 1788 started the reclamation of the Landes of France, which has changed certain parts of this inhospitable region into fertile fields.

On the coasts of Holland, Germany, Denmark, and France the fixation of dunes, started by these pioneers, has ever since been continued, and similar work was later taken up in various other countries. It lies not within the scope of this review to describe the different phases of this reclamation work as it came to be more and more a practical application of experience gathered by previous cultivators and by scientific investigations.

One of the first studies of the strand flora from a phytogeographical point of view was that of Boll on the beach flora of the German shores of the Baltic, published in 1848.

The coastal sand flora of Eastern Germany has since been studied by Kalmuss, von Klinggraeff, Klinsmann, Krause, Marsson, Ratzeburg, and Schäfer.

Brick gives in his work on the ecology of strand plants of the Baltic a number of valuable suggestions, and in Ackermann's Physical geography of the Baltic there is a number of pages devoted to the coast flora.

The most comprehensive work of recent date on coastal sands is Gerhard's "Handbuch des deutschen Dünenbaues," in which the dunes of the German sea coasts are treated. The flora has been described in this work by Abromeit.

The continuation of the sand region of Eastern Germany along the Baltic shore of Curland has been carefully studied by Klinge, while the sands of the Gulf of Riga are to some extent described by Doss and Robert. We may have to expect in the future a treatise on the dune flora of that region by Dr. Kupffer.

Studies of the dune sands on the shores of Gulf of Finland have been made by Sokoloff and Thesleff. Other dunes of Russia are described by Rauner, and minor inland dunes in Finland by Granit and Hult. Some dunes of the Finnish coast of the Gulf of Bothnia have been worked over by Rosberg. Professor Vilhelm Ramsay recently studied the sand formations on the coast of the White Sea, but his observations are not published.

The small island Gotska Sandön situated in the Baltic, 40 km. N.

of Gotland, and consisting exclusively of sand, has been visited and studied by Sernander, Andersson, Eisen and Stuxberg, Holtz and Johansson.

The only publications, in which the sand flora of the Baltic coast of Sweden is treated, are by Erikson. In an excellent paper he describes in detail the topographical features of the vegetation and also the structural adaptations of the sand strand plants of Eastern Scania, the southernmost province of Sweden. Schultz has recently studied the geographical distribution of the strand plants of the Baltic countries.

Warming's different papers on the sand flora of the Danish North Sea coast are of the greatest importance, giving a good description of this extensive sand district with its typical formations. The observations are made with the critical acumen so characteristic of this author. The review of sand vegetation generally, which Warming gives in his ecological plant geography, is a most comprehensive one.

Feilberg has written on grass cultivation on Skagen, the sandy Northernmost point of Denmark, and Raunkiaer published in 1889 a good paper on the east and south shore of the adjoining part of the North Sea. Of other authors who have written on the flora and ecology of the Danish dunes, we may mention Andersen, Bang, Börgesen & Jensen, Mentz, Paulsen, and Schmidt.

Buchenau has written considerably on the sand flora of the German North Sea coast, and his studies are characterized by acute observations, and suggestive details.

Fischer-Benzon, Focke, Graebner, Hansen, Hock, Hubbe, Knuth, Lemmermann, Meyer, Noldeke, Reinke, Sandstede, and von Seeman have all written more or less about the flora and vegetation of the same coast, and especially on that of the outlying islands.

Among more recent writers on the dune sand of Holland, and its flora, we may mention Dozy, van Hall, Holkema, Lorié, Retgers, Scholtens, Vuyck, Winkler, and de Witt Hamer. Blijdenstein and Brants have briefly referred to the flora of the dunes of this country and Eeden has especially studied the distribution of dune plants, while Giltay paid attention to some of the ecological adaptations.

The vegetation of the sandy coast of Belgium has been investigated by Massart and van der Swaelmen.

Lesage has written on modifications of the leaf of maritime plants when subjected to different environmental conditions.

Various other writers, such as Baraban, Van den Bosch, Chodat, Costantin, Delfortrie, Girardin, Gosselet, Gras, Labats, Masclef, Partiot, Poisson, Sauvage, de Vasselot, and de Vicq have studied the conditions of the dunes on the northern coast of France.

Among authors on the Landes of Gascony may be mentioned Brown, Chambrelent, Dulignon-Desgranges, Durègne, Engler, Fabre, Géneau-Lamarlière, Goursand, Grandjean, Houtreaux, Laval, and McNaughton.

Flahault and Combres have made valuable observations on the dunes of Southern France. Daveau, and especially Willkomm, have written upon the subject as regards the Iberian peninsula. Börgesen in a brief article discussed the sand strand vegetation in Southern Spain.

The sandy beaches on the coast of Norway are touched upon in the works of Blytt, Holmboe, Norman, and Wille. The coastal sands of the British Isles have been to some extent studied by Bailey, Dowker, Rob. Smith, Thompson, and Whilden as regards the flora, while Cornish has carefully investigated their origin and development.

The sand floras of the interior of the European continent we find referred to in the extensive literature on the steppe formation. Borbas described the sand vegetation of the plains of Hungary, and Adamovic the sand steppes of Servia.

From the Mediterranean shores of Africa there are studies by Parrau and Serres, and from the dunes of Italy by Sprenger and Tommasini.

Volkens' important work on the flora of the Arabian desert, although treating of island sands, contains a rich supply of suggestions on the adaptation of psammophile plants.

Other writers on the sand deserts of Northern Africa are Jordan, Kotschy, Riston, Rolland, Schirmer and Walther, the latter having made an especially careful study of the formation of dunes.

During Nordenskiöld's Vega-expedition Kjellman studied the coast flora of Siberia.

In the works of Hedin on his explorations in Central Asia we find much valuable information on the sand desert of Gobi and the dune vegetation of that region, and other travelers have described continental dunes from various other parts of Asia. Helman wrote about the dunes in Chiwa, Nalivkin on those of Ferganah, Radde on the dune vegetation of certain parts of Caucasus.

The extensive sand dunes of India have caused considerable trouble to cultivation, and the sand binding plants of that country have been referred to by Clark, Duthie, and Cleghorn.

Schimper gives in his "Indomalayische Strandflora" a valuable treatise on the vegetation and flora of the coastal sand, and in his

"Pflanzengeographie" the subject is extensively treated with reference to different regions.

Karsten wrote (1891) more especially about the mangrove-vegetation of the Indo-malayan achipelago, and Goebel treated the strand flora of tropical Asia.

In South Africa Thode made a good study of the coast flora, and Werth has described the sand strand vegetation of the Zanzibar Island.

The extensive coastal and interior sand formations of the Australian continent have attracted only little attention by scientific writers so far. We have to note briefer articles by Benbow, Boyd, Maiden, and Walter Smith. .

The New Zealand dunes have been studied by Cheeseman, Cockayne, and Kirk. Diels also wrote on certain ecological features of the flora. He had not, however, himself visited these islands, but based his study on collections, and on information by Dr. Cockayne. The latter made valuable observations on the sand flora also on Enderby, and Chatham islands, and he recently published an excellent paper on the dune flora of the eastern coast of the Middle Island of New Zealand.

Kurtz and Reiche have briefly treated the sand flora of Chili. On the sand dunes of the Pacific coast of North America nothing is written except some brief notes by Davy, Lamb, and McKenney.

The extensive dune formations on the Atlantic coast of the United States, and their flora, have been the subject of study of several writers, as Britton, Gifford, Harshberger, Jelliffe, Mohr, Ross, Rothrock, Westgate, and Webber. The ecological study of the strand vegetation of North Carolina by Kearny is an excellent piece of work. Lloyd and Tracy have treated the insular flora of Mississippi and Louisiana.

The flora of the interior sand hills of North America has been worked over especially by Hitchcock, Rydberg, Smith, Pound, and Clements. Lamson-Scribner has treated the value of grasses as sand stays. Cowles made a study of the vegetation on the sand dunes of Lake Michigan, and Hill has written on the sand dunes of northern Indiana and their flora.

MacMillan's admirable study of the strand flora of the Lake of the Woods is without any equal in the phytogeographical literature of the United States.

Börgesen has carefully studied the strand flora of the Danish West Indies.

From the dunes of Southern Brazil we have an excellent description by Lindman, and Schenck also recently wrote of the strand vegetation of Brazil. Brackebusch has contributed to the knowledge of the sand flora of Argentine. The coast plants of Japan have been treated by Imamura.

Mention may also be made of the general description of dunes which is contained in Richthofen's "Führer der Forschungsreisende," as being a valuable and suggestive treatise.

The present writer has published several papers on sand formations in connection with the inquiry referred to in the following pages.

II. OBSERVATIONS ON CERTAIN SAND FORMATIONS.

BALTIC COASTS.

It has been claimed by certain authors, as *Vogt,* for instance, that maritime dunes are formed only on coasts with tide phenomena. According to him sand particles are thrown up on the shore at high tide, and having been dried during low tide, they are subsequently carried inland by wind. The dunes on the northern coasts of the Baltic where there is no visible tide, as well as the extensive dune formations near many inland seas in America, for instance, show, however, that tides are not necessary for the formation of dunes.

A remarkable coincidence exists between the topographical form of the coast, and the development of dunes. This is nowhere more evident than on the Baltic coasts.

The east coast of Sweden washed by the Gulf of Bothnia, the Åland Sea, and the Baltic, is almost everywhere rocky, and extensive sand formations occur only at a few places. The northernmost location where observations have been made by the writer, was at the mouth of the Dal river, where a visit was made in October 1897. On a very limited area there are sandy beaches, and in one place a few embryonic dunes have been formed on the upper beach. The sand was of a yellowish color, and consisted of medium sized quartz grains, with some admixture of felspar. On the middle beach there were some light accumulations of mould. The sand was slowly drifting back and forth along the beach forming beautiful ripples. The salinity of the sea water was low.

At Saltsjöbaden near Stockholm, at Östanå, and Sandhamn, minor sand formations were visited in 1896, '97 and '99. Only beach formations occurred on the former places and the dunes in the latter locality are not very extensive. The beaches consist generally of very narrow strips of loose material; the gradient of the shore being comparatively steep, the area of influence of the sea is consequently limited, especially as the force of the waves is never very great within this archipelago.

In the neighborhood of the city of Norrköping there is quite an extensive archipelago, consisting of a few larger and many small islands. In June, 1899, I visited a number of these islands, near Arkösund. Of the great number of beach formations investigated only a few were sandy,

FIG. 1. Beach with *Halianthus* community. Swedish East Coast

shingle beaches being far more common. Where sand occurred it was very coarse, except in some sheltered places. All these islands are exposed to the strong winds of the Baltic, and those being only a couple of kilometers distant from the mainland, had no tree vegetation. The salinity of the seawater was here varying from 0.49-0.66%.[1]

On the open coast, facing Kalmar strait, some observations were made in June, 1899. The shores south of the town of Kalmar are very low, more or less muddy. In some places shingle beaches were formed, and these were sometimes covered with fine sand, mixed with clay par-

1) All my measurements of salinity of seawater in the Baltic were made with an areometer (Åderman type) purchased in Stockholm.

FIG. 2. Sand field with *Armeria* community, Swedish South Coast.
PHOTOGRAPH BY ERIKSON.

FIG. 3. Gray dune with pines on Swedish Southeast Coast.
PHOTOGRAPH BY ERIKSON.

ticles. This shore is sheltered by the island Öland from the direct force of easterly winds and waves of the Baltic. The salinity of the sea-water was 0.66%.

In the Blekinge archipelago Torhamn and several islands as well as the shores near Karlskrona were visited June 18th, 1899. The few sandy beaches observed were not extensive, and were formed of a rather fine sand, quite often mixed with clayey residue. On June 19th, 1899, some shores near Karlshamn, especially at Helenebärg and on Boö were investigated. The sandy beaches were formed of coarse material mixed with pebbles. Large boulders were strewn on the narrow beaches. The shores in this neighborhood are usually steep and rocky.

A number of sandy formations were studied at Sölvesborg, June 20, 1899. The shore sloped generally at an angle of 30 degrees. The material was pure yellow quartz sand. The coast is open to the Baltic.

At Åhus there are extensive sand strands, with long stretches of beach formed of pure sand. (See Fig. 1.) Inland there are minor dunes and large sand fields. My observations here were made June 21—22, 1899. The vegetation on these sand formations has previously been studied by *Dr. Erikson.*[1] (Fig. 2.)

The coast near Simrishamn is low and open to the Baltic. Sandy beaches at Horshäll and Brantevik and also north of the town were studied, June 23—24, 1899. The sand is of coarse consistency, and the slope is here generally about 45 degrees.

The whole eastern coast of Sweden is rocky and steep, the hard cliffs are disintegrated only very slowly, and the material is usually washed out to sea except where inlets give a resting place. The only more extensive sand formations on the coast are in the south at the places just mentioned. (See Fig. 3.)

SHORES OF GULF OF FINLAND.

On the steep rocky coasts of Esthonia, on the southern shore of the Gulf, dunes are very rare, and occur only where the calcareous bluff retreats landward, and leaves a narrow sandy strip along the shore. In the eastern part of the Gulf of Finland, from the mouth of Narwa river, the coasts are sandy, and dunes are common. The largest dune district is that between Systerbäck and Björkö, in the innermost part of

1) *J. Erikson:* Studier öfver sandfloran i östra Skåne.—Bih. K. Sv. Vet. Ak. Handl. 22. 3—81. 1896.

the Gulf. The coast is here unsheltered by any islands; and the shore is exposed to the full force of the open sea. The prevailing winds are westerly and southwesterly, that is, those which have a free passage along the whole stretch of the Gulf from the Baltic. They meet no obstacles in their way, and they strike the land with their full intensity. On this coast a series of dunes have been formed following the coast continuously for about 80 km. Although every sign of tides is absent, the sea is very seldom or never quite calm. The constant breakers and the great difference between the high and low water caused by winds have developed the sand formations of this district. Some of the dunes are smaller and some larger; some of them are still drifting before the high winds, constantly changing their form and their position, encroaching more and more on the land. Others again are in ridge form, covered with vegetation, and are stable.

This sand consists of quartz of a yellow-white color, mixed with felspar and mica. The size of the grains is 0.3-1 mm., and they are sometimes larger, up to 3 mm. On this coast, the development of the dunes is promoted by human agency, the natural forests being destroyed and the larger pebbles, which have been left by the wind on the shore, and which retard the advancing sand thrown up by the waves, are collected and transported to St. Petersburg for road-making purposes and thus the sand is given a full opportunity to spread. The form of these dunes is varying. They consist mostly of long hills of very different dimensions, some almost round, others nearing but never completely assuming the horse-shoe form.

These dunes have been studied by *Sokoloff*[1]) and *Thesleff*[2]), and my own observations were made during several visits in May, August and October, 1898.

On the Finnish south coast, which is rocky, there are only a few sand formations. Sandy beaches of the same character as those of the Swedish east coast near Stockholm were studied, near the city of Helsingfors, during 1893—'99 and on the coast of the province of Nyland, 1891—'92, and 1898—'99. On the Hangö peninsula there is a smaller dune district which was made the subject of detailed investigations in June 1895, in July 1896, in August and September 1897, in April, August and September, 1898, and in August, 1899. The sand is here of glacial origin, having been redeposited by waves and wind. The salinity of the sea water was 0.6% at a temperature of +14.0°C.

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1) Die Dünen. Berlin, 1894.
2) Dynbildningar i östra Finland.—Med. Geogr. För. Finl. p. 36—77. 1895.

ISLANDS IN THE BALTIC.

The great island archipelago along the southwestern coast of the Finnish mainland, and thence stretching in a westerly direction towards Sweden, consists of small islands with rocky shores. This is especially the case in the outer part of the archipelago, where the influence of the sea is more conspicuous, and the finer material is very seldom able to find rest on account of the steepness of the shore. In the inner archipelago the beach is covered with boulders ranging from 4 dm. to 1 m. in diameter. Between these boulders the soil consists of sand and gravel, more or less mixed with clay. In Åland pure sand beaches are very seldom of common occurrence. This is especially the case in the Kökar and southern part of the Sottunga archipelagoes. In the Korpo and Nagu archipelagoes sandy beaches are quite common, but sand dunes do not occur. On the shores of the Kimito Island, the flora of which was studied by the writer in 1893,[1] quite a number of sandy beaches are found. Usually it is the innermost part of an inlet, which consists of sand.

The island Runö on the southern side of the Gulf of Finland is low, and sandy beaches are frequent. A number of observations were made in June and July, 1896.

On the island Ösel, visited in 1896 and 1898, sand formations were investigated on the southern coast, facing the Gulf of Riga, and at Rootsiküll, on the western coast. The sandy shore west of the town Arensburg is at Jerwe formed by a very narrow strip of beach, and then rises to a steep sand bank, 12-15 m. high, on which a number of low, circular dunes occur.

The material, of which these are composed, is a comparatively fine sand, the average size of the grains from 16 samples being 0.3 mm. The salinity of the sea water at this place was found to be 0.82 per cent. with a surface temperature at noon of $+16.6°$ C. The shore is open to the waves from south.

On the Swedish side of the Baltic the large island Gotland has sandy shores, especially at its northern end. Their vegetation has been studied especially by *Johansson.*[2] The present writer only visited the coast near Visby on the western, and at Ronehamn on the eastern

1) Bidrag till kännedomen om floran i Kimito skärgård.—Acta Soc. F. Fl. F. XI. No. 11. 1895.
2) Hufvuddragen af Gotlands växttopografi och växtgeografi.—K. Sv. Vet. Ak. Handl. 29: No. 1. 1897.

side, in June, 1899. At the former place the shore was steeper and only small accumulations of sand were formed. The sand was here rather coarse, almost gravelly, and contained much lime. At Ronehamn the coast is low, open to the sea, and exposed to winds. The sand was mixed with large quantities of silt and pebbles.

North of this island there is a small island, Gotska Sandön, composed entirely of sand. It has been visited by several botanists and geologists, and occasional observations of the dunes and their vegetation are found in various works.

Öland, the other large island on the Swedish east coast, was visited in June, 1899. Both the eastern and the western shores are low, and where sand formations occur, they are formed of coarse gravel, and cover only very limited areas.

The island Bornholm, in the southern part of the Baltic, was visited in June, 1899. On the western coast, south of Rönne, there are quite extensive sand formations. At Svaneke, on the eastern side, the coast is rocky, but between the cliffs small deposits of coarse sand were accumulated. The coast is everywhere unprotected and exposed to waves and winds.

WEST COAST OF RUSSIA.

The shores of the Riga gulf are low and sandy, especially in the southern part, and they are also rich in dunes, which in some places reach a considerable height.

Between the Düna river and the watering place Catharinenbad, the belt of dunes varies in width from 0.5 to 2 km. (Fig. 4) and west of the river, especially near the mouth of the Bolderaa river, the sand covers a large area. In many places the sand is drifting. It consists primarily of quartz, but is mixed with felspar and hornblende, and even granates. The average size of the grains is 0.25-0.35 mm. The sand is brought down to the sea in quantities by the rivers and is again thrown up on the shore by wave action. This district was visited in 1898.

The west coast of Curland is bordered by a broad belt of diluvial sand, and it is therefore for its whole length covered with a continuous chain of dunes. At some distance south of Libau the dunes are very high, up to 35 m. The highest dune on this coast, Koope-Kaln, rises 70 m. above the sea. The sand rests in many places, especially near Libau, on a compact stratum of peat, in which trunks of trees often are

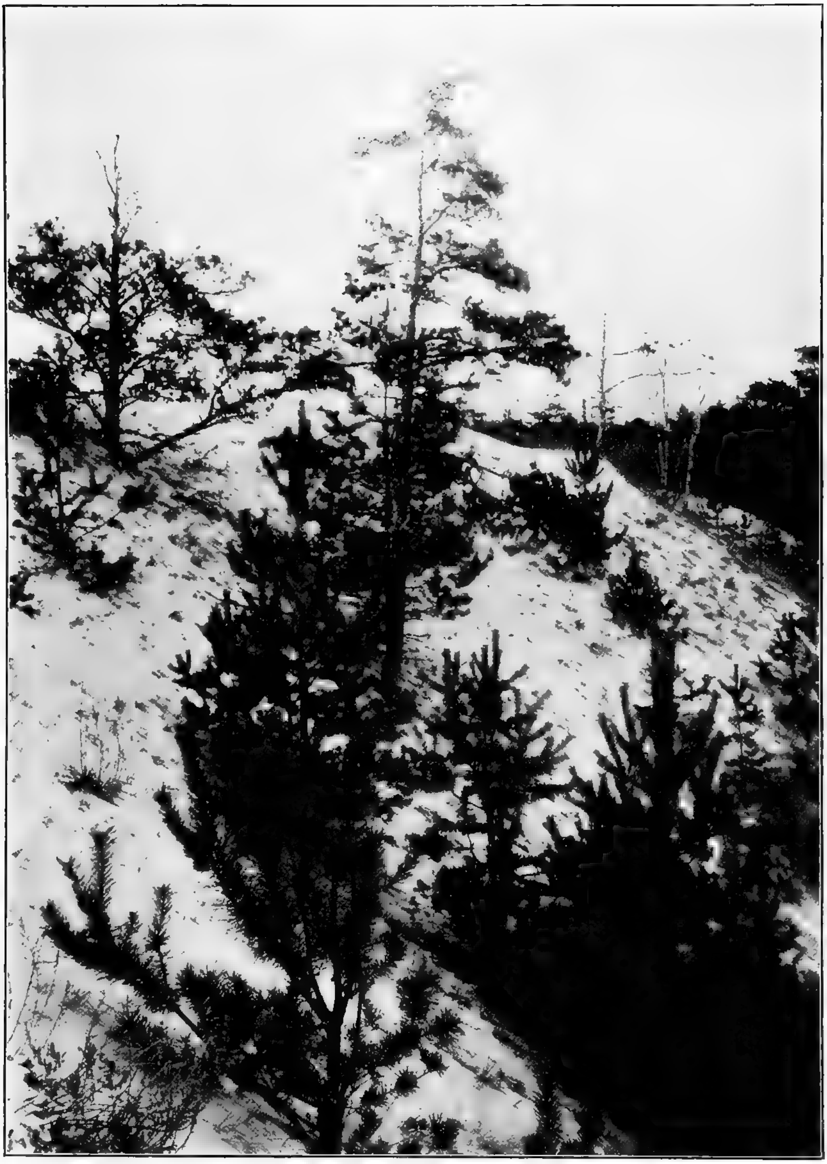

FIG. 4. Temporarily stable dune near Bullenhof, Riga, Russia. The moving sand of the lee-slope is in progress of being naturally arrested by grasses, (*Koeleria glauca* and *Festuca ovina*), herbs, (*Artemisia campestris, Hieracium umbellatum, Pulsatilla pratensis* and others), and by pines (*Pinus sylvestris.*)

PHOTOGRAPH BY KUPFFER.

found. The landward side of the dune belt is bordered by extensive swamps.

The dunes near Libau are formed by a somewhat fine sand averaging 0.15 mm. It is a pure white quartz sand, the admixture of other minerals or other colors being inconspicuous. The salinity of the sea water is about 0.8 per cent.

GERMAN NORTH COAST.

In direct continuation of the last mentioned dunes follow those on the German north coast which is sandy along its whole stretch to Swinemünde. On the long narrow spits, known as Kurische and Frische Nehrung, the dunes have reached a remarkable development and the dune district is second in size to none in Europe except that of Gascogny.

The detailed description we have of these dunes in the comprehensive work of *Gerhard* [1] makes it unnecessary here to discuss their general appearance. In connection with our treatment of the sand vegetation some comparisons will be made.

SWEDISH SOUTH COAST.

We have yet to mention some minor sand formations on the Baltic coasts visited by the author. At Ystad, in southern Sweden, there is a long sandy beach, which was made subject to study in June and July, 1899. The sand is fine quartz, almost pure, yellowish in color. The sloping angle of the beach is about 35 degrees. The coast is here unprotected, as is also the case at Dybeck and Trelleborg, where sandy and gravelly shores occur. The dune district at Falsterbo was not visited. Along the Swedish coast of Öresund there are sandy shores in numerous places, both in the neighborhood of Malmö and Helsingborg. At Engelholms hamn a series of small dunes occur near the mouth of the river. These were studied in 1900.

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1) Handbuch des deutschen Dünenbaues.—Berlin, 1900.

THE NORTH SEA.

The West Coast of Denmark,

from Cap Skagen, the northernmost point of Jutland, is sandy along its whole length, and the sandy shore continues through Schleswig-Holstein to the mouth of Elbe river. (See Fig. 5.) This dune district comprises an area of some 70,000 hectares. The dunes do not run to any considerable height, 32 m. being given as the greatest. A chain of islands follows the southern part of this coast and they are all sandy. On the island of Sylt, the height of the steep coast is 34 m., and on this dunes up to 28 m. in height are developed.

The size of the grains on these dunes along the North Sea coast decreases southwards from Skagen. On Anholt, *Jessen* still found, however, a dune sand in which 91% of the grains had a diameter of over 2 mm. *Jentzsch,* in Gerhard's handbook, mentions that samples of dune sand from Sylt contained grains of the largest size; while the finest sand came from Borkum. On the small island Norderney, outside the German North Sea coast, the sand grains are of very small size, 0.11 mm. in diameter according to *Wessely.*

The Danish and German North Sea dune flora is the best known, many investigators having worked here, principally *Warming* and *Reinke.* The writer's personal knowledge of the dunes on Jutland is confined to a few points, visited in 1900.

SAND DUNES IN HOLLAND.

The belt of sand dunes which, as already mentioned, marks the coast from north of Jutland to Elbe, continues from that river almost without any break along the southern shore of the North Sea to the Straits of Calais, for a distance of about 500 km. In most other countries the dunes are a source of trouble through injury to forests and cultivated fields, but in Friesland, Holland, and Belgium, they are a protection against the invasion of the sea, being natural dykes. Their height is not very remarkable and they very seldom reach over 20 m.

The dunes are especially well developed on the West-Friesian islands and on the mainland between Heider and Hoek van Holland. This dune belt is mostly of a comparatively narrow width, but in some places as in the neighborhood of Haag it covers several kilometers inland from the sea.

Fig. 5. Arresting drift sand with a cover of heath—Denmark.

PHOTOGRAPH BY BANG.

At the last mentioned place the dunes do not show any regular arrangement as is usually the case, but they constitute a large dune-complex in which no order can be recognized. The dunes on this coast are, as a rule, low, but reach sometimes an elevation of 60 m. Westerly winds prevail on all these coasts.

SCOTLAND.

In October, 1899, a passing visit was paid to the dunes at Gullane Point, south of Firth of Forth, not very far from Edinburgh. For a distance of about 10 km. the coast is here sandy, and by far the most extensive dunes of this place are on the eastern shore of Aberlady Bay, where the sandy belt is about 2 km. wide. All stages of development are met with. Sandy shore, embryonic dunes, dune-complexes, and sandy fields. A greater part of these sand formations was fixed by vegetation.

The general conditions did not materially differ from those on other coasts of the North Sea. I have not been able to get reliable information as to the salinity of sea water in the Firth of Forth, but so far out the influence of the river is doubtless comparatively insignificant. The prevailing winds are those from N. N. E.

ATLANTIC COAST OF EUROPE.

Near Plymouth in England

the writer made some observations in October, 1900. Only sandy beaches of small extent were visited. The sand was coarse, mixed with humus, the remains of decomposed seaweeds and marine animals thrown ashore by waves. The beach was exposed to southerly winds, but being in the interior of the harbor it was protected against the currents, and consequently the amount of kelp accumulated was considerable.

On the west coast of France,

from Graves at the mouth of the river Gironde to the bank of l'Adour and even further to the cliffs of Bearn, a series of dunes follow the coast for more than 200 km. This belt having an average width of four to five and in some cases seven to eight km., is in many ways remarkable.

It is the natural border between the Bay of Biscay and the territory known as the "Landes." The sand had for centuries been constantly shifting, making great devastations, until its progress was arrested by plantations. Engineering skill and judicious planting of sandstays and trees has changed this district from desolate, unhealthy marshy moor-lands and unproductive sandy tracts to a habitable, and in some places, fertile country.

According to early writers, the dunes advanced in former times constantly inland covering houses, filling the outlets of rivers, making great damages to cultivations and increasing the unhealthiness of the Landes. The advance of the sand was especially rapid in the neighborhood of Saint Pol-de-Léon; there existed before the year 1666 several villages which had to be abandoned, and which were buried under 6 and 7 m. of sand. In 1722, this dune had progressed more than 24 km., which would indicate a yearly advance of more than 500 m. According to *Brémontier*, the dunes advanced at his time, or about 1790, from 20 to 25 m. a year, and they did great damage to the fields in the neighborhood of Bordeaux.

The whole coast from Gironde to the foot of the Pyrenees presents an aspect in regard to its geological constitution, quite uniform with the sandy coast in the north. Capbreton, situated at the ancient estuary at l'Adour, at the present day covered with dunes, was formerly a flourishing harbor, which has since been replaced by Bayonne. The dunes on this coast are often high, in some places averaging 70 m.

The sand is composed of pure quartz, reduced to minute grains, generally rounded by trituration, and moving easily. The width of the upper beach is about 200 m. from highwater mark to the foot of the littoral dune.

The dunes form a series of parallel ridges, the valleys being of varying width. Whenever the dune valleys, locally called "Lettes", reach a width of 1 km. they are covered with a luxuriant vegetation.

The most frequent winds, and the most violent ones on this coast, are those from the west and south west.

AUSTRALIA.

Sand formations on the west coast

are very common on this island-continent. At Geraldton they are quite high and are constantly shifting. North and South of Fremantle there is a dune district of considerable extent, and this was studied in the fall of 1900 and in September and October, 1902. The coast is open to the Indian ocean and the waves strike the beach with full force. The beach is usually narrow and sloping in an angle of about 30°. (See Fig. 6.) Landwards it is bordered by a series of dunes, often of considerable height. I have measured dunes being 32, 37, 44 m. over the surface of the sea.

FIG. 6. Shrub vegetation on stationary dunes North of Fremantle, Western Australia.

PHOTOGRAPH BY THE AUTHOR.

South of Fremantle the beach is wider and then gradually merges into dunes by the way of low mounds. Here the sand is still drifting rapidly and many of the streets of the outskirts of the town are constantly being filled with sand.

The texture of the sand is coarse. The grains are angular, of a white or in some places reddish color.

On the southern coast of Western Australia there are quite extensive sand formations, but they were not visited by the writer.

Dunes in South Australia.

The greater part of the coast of this state is more or less sandy. At Vincent's Gulf the dunes are especially well developed. The sand grains are of medium size, yellowish in color, and rounded through constant trituration. Sandy beaches and dunes are common also on the Victorian coast. At Port Phillips Head there are some formations which were visited.

Sandy beaches near Sydney.

At Botany Bay, near Kensington, on Cronulla and Bondi Beach sand formations occur. Those at the last mentioned place are the most extensive and have caused some trouble through drifting. The quartz sand is very pure, and of a light color, where dust from the surrounding country has not been blown over the sand. The reclamation which was commenced several years ago, has now considerably changed the original topography of the sand, and in many places the loose material has completely blown away, while in others it is fixed by vegetation.

The drifting at Botany Bay was caused by the rejuvenation of a sand dune, which previously had been covered with vegetation. The sand advanced inland and destroyed a part of the park at this place.

The salinity of the sea water outside this coast was found to be 2.9 per cent. Several visits on various occasions during 1901—02 were made to these sandy beaches.

Drift sands in Queensland.

The beach from Tweed River northwards to Southport consists entirely of sand. The sand forms an elevated bank or floor, on top of which regular dunes are formed. (See Fig. 6.) They advance steadily inland, covering everything and have already done considerable damage to property in the town of Southport.

Further north at Cleveland and Manly there is a long stretch of sandy shore with a few dunes, but there is almost no vegetation on the ground, because everything is destroyed by the thousands of holiday excursionists from Brisbane. Stradbroke Island in Moreton Bay is entirely built up of sand, and is considered by some writers as a single

FIG. 7. Shows how an exceptionally high tide has swept into the dune complex, leveling the lower portions and destroying the non-halophytic vegetation. In front drift débris of wood, *Zostera* and "Kelp" (*Macrocystis, Durvillaea* and others.) Small Soldanella dune 84 cm. high, can be seen on the right, and an embryonic dune covered with one simple plant of Coprosma acerosa in the center. On the level floor tussocks of *Festuca litoralis* and in background *Scirpus frondosus* dunes.

PHOTOGRAPH BY COCKAYNE.

dune[1]) about 60 km. long and 5 km. wide. Its maximum height is 270 m. At Sandgate, north of Brisbane, there is a narrow sand beach, and still farther north, at Coloundra, dunes are found. Fraser's Island in Wide Bay has some very interesting sand formations, and on the opposite mainland, at Pialba, there is a narrow beach between the high, steep bank and the high tide mark. On all these places, visited by the writer at intervals in 1900—1902, the sand is coarse, sometimes even gravelly.

Southeasterly winds are the most effective on this coast. The salinity of the surface water in the ocean is 2.7 per cent.

Along the northern coast of Queensland, at Mackay, and north of Townsville, extensive dunes were observed, but the writer had not the opportunity of examining these.

NEW ZELAND.

Beaches on the North Island at Doubtless Bay were visited in the late fall, 1902. The dune flora of the district is described by *Cheeseman*[2]) and I am not able to add materially to his observations. The sandy beach merges gradually into low sand hills, and behind these there are extensive swamp lands. (Fig. 7.)

HAWAII.

Various sand dunes on the islands of Oahu and Hawaii were visited and studied in detail in 1903, in December, and again in 1906, during the months of August and September.

PACIFIC COAST OF NORTH AMERICA

South of Golden Gate

in California there is a district of sand formations covering an area of about 72 sq. km. From the ocean the sand stretches eastward to near San Francisco Bay, embracing almost the whole end of the peninsula. The greater part of these sand formations is now reclaimed and used for cultivation or as building lots in the city. On the Pueblo lands of

1) *Boyd:* Forestry in connection with the sand dunes of Queensland.—Queensl. Agr. Jour. 1902: 123.

2) On the Flora of the North Cape District.—Trans. N. Z. Inst. XXIX: 333—385. 1897.

San Francisco is situated the beautiful Golden Gate Park, a result of successful reclamation operations, but south of the park there is still an extensive area, where the drift sand is blown about by the winds.

The shore is open to the Pacific and the waves break furiously on the sand. After a strip of gently sloping beach, about 25 m. wide, follows a well developed littoral dune, and inside of this there is a depression, the bottom of which is sometimes level and dry, in other places occupied by small pools of stagnant water. Further inland, small mounds of sand, kept together by vegetation, still persist. A

FIG. 8. Established dune at San Francisco.
PHOTOGRAPH BY THE AUTHOR.

series of small dunes follow and then we find the dunes assuming greater and greater proportions. (Fig. 8.) The vegetation is scanty and the sand drifts in all directions. The main advance goes, however, eastward. Underlying these extensive sand deposits, is a kind of argillaceous sandstone, considered to be of Cretaceous age.

All stages can here be observed, and the even sand surfaces on the slopes of the great dunes offer good opportunities for observations of the ripple phenomenon.

The sand is coarse, mainly consisting of quartz, but is of a dark color, and contains in some places an abundant admixture of organic matter. After rain the surface is often almost gray. I found the cause of this to be minute coal particles, brought down from the atmosphere by the rain. The origin of this coal dust is, no doubt, the smoke from the factories of the city, which settles all over the neighborhood, but is nowhere so easily perceptible to the eye as on the white sand surface.

The salinity of the sea water is according to chemical analysis[1] of sample secured in the spring of 1904, 1.649 per cent. The surface temperature of the water at noon was +12°C. with an atmospheric temperature of +16°C. (III, 10, 04.)

Fig. 9. Pine forest on sand field in lee of the dune chain at Point Pinos, Pacific Grove, Cal. The advancing dune can be seen in background.

PHOTOGRAPH BY THE AUTHOR.

Between Pescadero and Santa Cruz on the San Francisco Peninsula sandy shores and small dune accumulations occur in various places. During the summer 1904 a visit was made to this district. The character of the dune sand corresponds to that of the San Francisco district.

1) Made by *Mr. R. W. Dodd* in the chemical laboratory of Stanford University through courtesy of *Dr. J. M. Stillman*.

MONTEREY BAY.

in its inner part, is lined with a chain of high dunes, which sometimes extend for 1 km. or more. The beach is similar to that south of Golden Gate, but no distinct littoral dune is formed, the dune-complex commencing immediately after the upper beach. Inside of the dune belt usually follow sand fields.

The Hopkins Laboratory is situated on a rocky point at Pacific Grove, and only small patches of narrow sand beach occur between the

FIG. 10. Dunes covered with a *Lupinus* community, at Seventeen Mile Drive, Pacific Grove, Cal.

PHOTOGRAPH BY THE AUTHOR.

bluffs and the ocean in the immediate neighborhood. One kilometer south of the laboratory, at Point Pinos (Fig. 9), sand formations of greater extent again commence. The beach is gravelly or even consisting of shingle for a distance until Moss Beach, where it is sandy.

The recent drift sand has accumulated into small dunes some distance from the shore (Fig. 10), leaving a belt of older consolidated sand bare or covered with a dense carpet of various plants. Further inland the dunes grow in size and finally, about 0.5 km. from the ocean, they reach quite a considerable height. One of these dunes is about 90 m. in height, sloping abruptly on its leeward side to the plain behind.

With a few interruptions by rocky points the sand dune belt continues to Carmel Bay. Here it is, however, quite narrow.

An analysis of the sand at Point Pinos gave the following result:

Quartz	61.2%
Felspar	37.6%
Hornblende	1.2%
	100%

This constitutes a fair sample of the sand in the district. The average size of the grains of 16 samples was 0.35 mm., half of the samples having been secured from the middle of the windward and the other half from the leeward side of dunes.

The prevailing winds at Point Pinos are those from W. and consequently the dunes wander in an easterly direction. It holds true that wherever winds blow in many different directions, as is the case at this place, the arrangement of the dunes is very irregular. Near the lighthouse, situated at the point, the dunes do not have any regular position, but turn in all directions. Only one kilometer further south, where the coast line is straight, the sand ridges are almost parallel to the shore. In cases where the wind has been able to break through these ridges, the central part of the dune has traveled forward more rapidly than the sides, thus leaving ridges transverse to the dunes parallel to the coast. I was here able to observe that similar results to these mentioned were obtained by the wind working through an opening between two advancing dunes, thus pushing the sand forward in the depression, and forming low ridges or cusps to leeward of the dunes. When this work has gone on for some time, the result will be exactly the same as when the wind is cutting through the central part of the dune by pushing the concavity forward until an opening is effected, that is, longitudinal ridges are formed. Fig. 11 illustrates both these modes of work of the wind. We thus find that in some cases the dune apparently travels with its convex side turned towards the wind, and I am inclined to the opinion that the formation of "barkhanes" in Sahara and other deserts, as described by several authors, takes place in this way rather than in that suggested by *Cornish.*

SOUTHFRN CALIFORNIA.

At Santa Barbara in Southern California sandy beaches are common. They are, however, rather narrow, and have a steep slope. The sand is coarse, of a light yellow color. Quite extensive sand deposits are found

Fig. 11. Dunes planted with Ammophila. West coast of Jutland, Denmark.
PHOTOGRAPH BY BANG.

at Santa Monica. Sand dunes and sandy fields stretch inland from the beach. The sand is fine and is easily carried by the wind.

The dunes at Surf, San Diego and some other places in Southern California, as well as those at Point Reyes and Humboldt Bay, Northern California, and the extensive sand formations in Oregon and Washington are as yet unfamiliar to the writer.

MEXICO AND CENTRAL AMERICA.

Mexican Pacific Coast.

At Mazatlan the sandy beaches occurring near the town were studied. They are very small in extension, but interesting on account of the peculiar red color of the sand. Through erosion from some red cliffs extending into the ocean a sand was formed which was then thrown ashore in quantities. It was very coarse, and was not carried by the wind.

The sand at San Blas was also very coarse and of a dark hue, caused by a quantity of organic matter being constantly brought down with the river and deposited at the mouth, whence waves and wind carried it up on the beach and over the sands.

West Coast of Chiapas.

From Salina Cruz southward there is a long sand bank extending as far as the border of Guatemala, at a distance of a few hundred meters to three or four thousand from the coast. This sandbank is in places quite broad, and high dunes are formed. Inside of the bank a long lagoon is formed called the "Estero." Its shores are fringed with mangrove forests. The outer side of the bank is a continuous sandy beach, with a slope of about 35°. The sand is always tossed about by the mighty breakers of the Pacific, and the hot tropical sun assisted by the strong winds causes a rapid disintegration of the sand grains, which are carried over the bank and deposited on the estero side, gradually filling the lagoon. The sands of this bank are of a fluvio-marine origin. It is carried down by the numerous rivers that intersect the lowlands on the southern slope of Sierra Madre, then taken in hand by the waves and currents of the ocean which distribute the material evenly along the coast.

Pacific Coast of Central America.

The writer's experience of this coast is limited to the sandy beaches at Champerico in Guatemala. The slope of the beach is nearly 50°. This unusual steepness is accounted for by the heavy breakers which here strike the coast with full force, and the strong undertow which erodes the submerged beach. The sand was coarse and very little drifting occurred.

Sand Formations at Vera Cruz, Mexico.

These are very extensive and all phases of development can be observed. Sand was drifting at the time of my visit and the formation of ripples was perhaps more clear in all its details than at any other place I have seen. The dunes moved rapidly, unchecked by any vegetation. The sand contained a considerable amount of lime which added to the light color.

III. PRINCIPAL COMPONENTS OF THE SAND STRAND FLORA.

In presenting a list of the principal representatives of the flora on sandy sea shores, I do not intend to discuss the systematic relation or the specific characters of these plants. For ecological purposes this is of minor importance, at least in the present state of ecological knowledge, and in the study of this flora I have often found it to be of greater significance to consider many of the collective species, which have been divided by recent systematists, as "geographical species," whose distribution represents a distinct whole, rather than as systematic units.

As a taxonomic account I give a list of the principal plants occurring on coastal sand formations, with a short description of the vegetative parts of these "species," showing adaptations to the physical conditions of environment. This list does not pretend to be exhaustive, and contains principally those plants only which have come under the writer's personal observation.

TAXONOMIC ACCOUNT.

LIST OF SAND STRAND PLANTS.

RANUNCULACEAE.

Ranunculus acaulis Banks et Solander.

Perennial, glabrous herb, with creeping stolons; leaves slightly fleshy, 3-foliate, with sheathing petioles; creeping scions almost filiform and often subterranean.

Confined to sandy beaches of New Zealand and Chili.

A submersed plant, *R. marinus* L., occurs on the submerged beaches of the Baltic, and on the dunes of California *R. californicus* Benth. is found, but this species is not confined to the coastal sands.

Thalictrum minus Dum. var. *dunense* Buchenau.

Annual herb, with creeping rootstock; stem erect, much branched; leaves tomentose below.

On dunes of East- and West-Friesian islands, North Sea.

DILLENIACEAE.

Candollea glaberrima Steud.

Procumbent shrub, much branched, glaucous; glabrous; leaves flat, linear, obtuse, 1—5 cm. long, sheathing at base, leaving a ring round stem when falling off.

Sand formations near Perth, West Australia.

C. Huegelii Endl.

Shrub with stiff, glabrous, shining branches; leaves rigid, narrow-linear margins revolute, appearing almost terete, acute, often broken at ends, thus appearing truncate, 2—7 cm. long.

Sand formations near Fremantle, West Australia.

C. pedunculata R. Br.

Branching shrub, erect from a thick rhizome, 30—40 cm. high, glabrous; leaves linear, truncate, 1—3 cm. long, margins recurved; narrowed below, with a stemsheathing base, leaving a ring round the stem in falling off.

With preceding species.

Hibbertia grossulariaefolia Salisb.

Shrub, with weak, prostrate stem; leaves small, alternate, with a prominent midrib underneath, flat, petiolate, ovate, mostly coarsely toothed, 2—4 cm. long, glabrous above, pubescent underneath; flowers pale yellow.

Occurs together with several other species of the same genus on sands near the mouth of Swan River, West Australia.

CRUCIFERAE.

Cakile americana Nutt.

Annual herb, with deep root, decumbent stems up to 1 m. long, fleshy leaves, obovate, obtuse, crenate or sinuate toothed; flowers small, purplish. Pod fleshy, dry and corky when ripe.

Sandy shores of east and west coast of North America. Also along the Great Lakes.

C. maritima Scop.

Annual herb, with often meter deep root; stem much-branching, hard at base, erect-decumbent; leaves few, fleshy, with oblong lobes; flowers purplish or white.

On all seacoasts of Europe and Western Asia, North Africa, North and South America, extratropical Australia.

Crambe maritima L.

Perennial herb, glabrous, glaucous, with branched stems, O, 5 m. high; leaves petiolate, large, thick, oblong, undulate, and coarsely toothed, upper leaves small; flowers white; pod globular, indehiscent, with one seed.

Sandy and gravelly seashores of Baltic, Western Europe, and Black Sea.

Erysimum capitatum (Dougl.) Greene.

Perennial herb, stout, erect, 15—45 cm. high, leafy, finely pubescent; leaves narrow, entire; flowers cream-colored.

Seashores of California.

Malcolmia litorea R. Br.

Suffrutescent; leaves obovate-oblong, obtuse, coarsely toothed, covered with a dense grayish tomentum.

On maritime sand dunes of Western Mediterranean. Several other species of the same genus occur on the dunes of that region.

VIOLACEAE.

Viola arenaria DC.

Perennial rootstock; stems tufted, spreading, 5—15 cm. long, finely puberulent; leaves ovate, crenulate, obtuse, somewhat thick; petioles long; stipules incised; flowers violet.

Sandy shores of Europe and Eastern America, but goes also inland.

V. tricolor L.

Annual herb, distributed over Europe and Northern Asia, and is introduced to America. Often found on coastal sand formations, although an inland plant.

PITTOSPOREAE.

Bursaria spinosa Cav.

Shrub, very bushy, somewhat thorny, glabrous; leaves clustered, obovate, obtuse, 1—3 cm. long, narrowed at base, petiolate, green on both sides.

On the coasts of Tasmania and Australia, from Queensland to South Australia (St. Vincent's Gulf), but also found in the interior. A variety *incana* Lindl. is hoary in its young stages, and the under side of leaves are always tomentose. This form is found in West Australia and in the tropical parts of that continent.

Pittosporum crassifolium A. Cunn. and *P. umbellatum* Banks et Sol. are two littoral shrubs occurring on North Island of New Zealand, but are not confined to sand formations.

FRANKENIACEAE.

Frankenia grandiflora C. et S.

Perennial herb, erect or diffuse, slightly suffrutescent, 20—35 cm. high, smooth or somewhat pubescent; leaves entire, obovate, 1—2 cm. long, with revolute margins, sessile or short-petiolate, fascicled in the axils, the opposite pair mostly united by a somewhat membranaceous sheathing base.

Common especially on the marshes of the California sea shore, but spreads into Nevada, Arizona, and New Mexico, preferring saline soil.

A shrubby *F. pauciflora* DC. is common on the sandy shores of Tasmania, West Australia, South Australia, and Victoria, but occurs also in the interior deserts.

F. hirsuta L.

Perennial herb, prostrate, seldom erect; leaves linear or oblong-linear, margins revolute.

A true halophyte, occurring in Southern Europe, North Africa, and Siberia.

F. pulverulenta L.

Annual herb, prostrate; leaves obovate, thickly pulverulent on lower side.

On seashores of the whole Mediterranean, but not confined to sand formations.

CARYOPHYLLACEAE.

Ammodenia peploides (L.) Rupr.

Perennial herb, with long, brown rootstocks, fleshy, glabrous; stems tufted, stout, simple or branched, erect or diffuse, 7—25 cm. high; leaves sessile, clasping, ovate, acute; flowers small.

On sandy beaches and littoral dunes in Northern Europe and Asia, and on the Atlantic coast of North America from New Jersey to the Arctic.

Arenaria serpyllifolia L.

Annual tufted herb, slender, slightly pubescent, much-branched, diffuse, 5—20 cm. high; leaves ovate; flowers white.

Occurs often on dunes of Europe, Northern Asia and is introduced into North America. Not confined to coast.

Cerastium semidecandrum L.

also not unfrequently occurs on dunes of Europe, but is not a sea coast plant. It often varies when growing near the sea.

Sagina crassicualis Wats.

Perennial herb, smooth, stem stoutish and succulent, branching, 3—12 cm. long, decumbent; leaves linear, thickish, 4—10 mm. long, the basal forming a rosette, the cauline connate by broad scarious membranes.

Beaches of California from Monterey to Tomales Bay.

S. procumbens L.

Annual, 3—5 cm. high, branching and decumbent at base, forming tufts, glabrous; leaves subulate, forming at base a short sheath; flowers small.

It is especially a maritime form, *S. maritima* Don., with thicker leaves, which occurs on the coast. Europe, Central Asia, North America, Australia.

Silene gallica L.

Annual herb, hairy, viscid, 15—35 cm. high, erect; lower leaves small, obovate, the upper ones narrow and pointed, flowers small, white.

Common on sand, gravel and waste places in almost every part of the world, and seems to prefer the coast. Abundant on dunes at Fremantle, West Australia, and in Central California.

S. nicaeensis All.

Perennial herb, covered with long viscid hairs; leaves green, linear-oblong, obtuse, acute.

Coastal sands of Mediterranean countries.

Of this genus several species as *S. viscosa* Pers., *S. maritima* With., and *S. inflata* Sm. var. *litoralis* are distinctly maritime near the Baltic, but usually do not occur on sand.

Tissa Clevelandi Greene.

Perennial, viscid, glandular; stems prostrate, forming deep-green mats, 10—30 cm. broad; leaves filiform, conspicuously fascicled in the axils, all longer than the internodes.

On the dunes near San Francisco, Presidio near that city being the type locality.

T. macrotheca (Hornem.) Britt.

Perennial herb, succulent with fusiform fleshy roots, stout stems, 18—30 cm. high, erect or ascending from the short, often branched, woody crown of the thick taproot; herbage deep green, viscid-pubescent above, glabrous below; leaves narrow-linear, 2—4 cm. long; stipules large, ovate.

Common on sands near San Francisco and Pacific Grove, California.

Var. *scariosa* Britton, with paler herbage, glandular-pubescent, or almost glabrous, and short internodes, is frequently met with on dunes at San Francisco and Monterey, although it prefers the bluffs near sea.

T. marina (L.) Britton.

Annual, biennial, or mostly perennial herb, glabrous or with short viscid pubescence; numerous stems branching from base, forming prostrate tufts, 6—12 cm. long; leaves fleshy, on coast, linear, with small, scarious stipules at base; flowers pink or white.

Common on sea shores in many temperate and subtropical countries. Europe, temperate Asia, Australia, New Zealand, North America, and some parts of South America.

PORTULACACEAE.

Portulaca oleracea L.

Fleshy, prostrate annual, seldom exceeding 15 cm., with succulent, alternate leaves, glabrous, cuneate or obovate, obtuse; flowers sessile, yellow, open only in sunshine; seeds many, capsule.

One of the most common sandy sea shore plants in the tropics and in most subtropical countries. Does not occur on California dunes.

Claytonia

is often represented on coastal sands by different species, *C.* (or *Montia) perfoliata* Donn., for instance, at San Francisco, and *C. australasica* Hook. f. on sandhills near Dunedin, New Zealand (Kirk.).

TILIACEAE.

Triumfetta procumbens Forst.

Prostrate perennial; stems 6—12 dm. long, rooting at joints; branches ascending, tomentose; leaves petiolate, ovate, obtuse, 2—5 cm. long, entire, or divided into 3 or 5 lobes, glabrous above, tomentose underneath; flowers yellow; fruit globular, 15 mm. in diameter, covered with prickles.

Occurs on sandy sea shores of Queensland, most of the Pacific islands, and in the Malayan Archipelago.

LINACEAE.

Linum monogynum Forst.

Perennial, glabrous herb, woody at the base, branched or simple, erect, 15—50 cm. high; leaves numerous, narrow, lanceolate, 1—3 cm. long; flowers large, white.

Restricted to New Zealand, where chiefly littoral.

ZYGOPHYLLACEAE.

Zygophyllum Billardieri DC.

Prostrate herb, much-branched; leaves fleshy, opposite, with two distinct leaflets; these oblong or linear, 1—3 cm. long; stipules small; flowers white.

Endemic in Australia, where it occurs on drifting sands in Victoria, South Australia, and West Australia.

RUTACEAE.

Correa alba Andr.

Much-branched compact shrub, 3—12 cm. high, branches covered with a hoary, brown-reddish tomentum; leaves ovate-obovate, obtuse, 1—3 cm. long, coriaceous, somewhat tomentose above, in age glabrous, densely tomentose beneath; flowers pink.

Common on sandy shores of Victoria and South Australia.

RHAMNACEAE.

Ceanothus thyrsiflorus Eson.

Shrub, 1—2 m. high, much-branched; leaves green, oblong-obovate, serrate, 2—6 cm. long; flowers blue.

Coastal sands of California, but not confined to these situations.

Discaria Toumatou Raoul.

Varying from a small thorny shrub to a 6 m. high tree; leaves small, usually glabrous, absent in old plants; branchlets reduced to opposite woody spines, nearly 5 cm. long.

Restricted to New Zealand.

ANACARDIACEAE.

Corynocarpus laevigatus Forst.

Evergreen, glabrous tree, with alternate, oblong leaves narrowed into short, stout petioles.

Very abundant on the coasts of New Zealand, but also found inland.

LEGUMINOSAE.

Acacia retinoides Schlecht, and *A. salicina* Lindl.

are often among the species of this large genus, which occur on the coastal sand formations of Australia, the former being common on dunes in Victoria, the latter the most abundant form on the sandhills round St. Vincent's Gulf in South Australia. *A. pycnantha* Benth. is recommended as suitable for planting on drift sands.

Astragalus arenarius L. Pall.

Low perennial with creeping rootstock, prostrate stems, branching at base, 5—15 cm. long, hairy; leaves pinnate; leaflets linear-lanceolate, flowers bluish-purple.

Has a wide range on coastal sands of Europe, Asia, and North America, but does not extend to the Arctic or to the tropics. Sometimes also on inland sand formations in Europe.

A. Menziesii Gray.

Perennial, stout, erect, 6—12 dm. high; young herbage whitish pubescent, soon green, but hirsute-pubescent; leaflets many, commonly crowded on the rachis, broadly oblong, usually retuse at apex, 10—15 mm. long, stipules broad, not pointed; corolla yellowish-white, with purple-tipped keel; pod 2—4 cm. long, thin-walled, much inflated, ovoid.

Coastal sands of California.

Canavalia obtusifolia DC.

Perennial herb, with trailing stems, glabrous; leaflets broadly obovate, obtuse, 5—7 cm. long, thick; flowers pink.

Common on coastal sands in the tropics of South America, Africa, Asia, and Australia. At Moreton Bay in Queensland.

Crotalaria Cunninghamii R. Br.

Shrub, 6—10 dm. high, terete, tomentose branches; leaves ovate, broad, obtuse, 3—18 cm. long, densely tomentose on both sides, petiole 1—2 cm. long, geniculate above middle; stipules and bracts subulate; flowers large, yellow-green, streaked with dark lines.

Sandy shores of North, South, and West Australia.

Gastrolobium spinosum Benth.

Shrub, 6—8 dm. high, mostly glabrous, but sometimes the young shoots are clothed with evanescent wool; leaves opposite, ovate-cordate, ending in a pungent point, and bordered with prickly teeth, 2—4 cm. long and just as broad, rigidly coriaceous, usually glaucous.

Together with several other species of the same genus common on dunes near Fremantle, West Australia.

Genista monosperma Lam.

Common shrub in the Mediterranean countries on sand, but is not confined to sea coasts. Is often planted on dunes as an effective sand stay.

FIG. 12. *Scirpus frondosus* community on dunes, at New Brighton, Canterbury, New Zealand. In front drift from exceptionally high tide.

PHOTOGRAPH BY COCKAYNE.

Lathyrus litoralis (Nutt.) Endl.

A maritime species occuring on sea shore of Marin Co. and northward in California (Jepson: Flora of Western Middle California, 1901, p. 298).

L. maritimus Bigelow.

Perennial herb, with creeping rootstock, stout, 30 cm. high or more, glabrous, stems sharply angular, spreading; leaves with many pairs of leaflets, these ovate or elliptical; leafstalk ending in a long tendril; flowers large, purple; pod hairy when young, 3—5 cm. long.

Sandy and gravelly coasts of Northern Europe, not going further south than Picardy; Arctic Europe, Asia, and America, where it extends down the eastern coast. A form called *L. californicus* Dougl. is found on sea shores of Washington, and a variety *aleuticus* White, is found in the arctic parts of America.

Lotus corniculatus L. var. *crassifolius* Pers.

Perennial stock, with a long taproot; stems decumbent or prostrate, 1—5 dm. long; leaves pinnate, somewhat fleshy; leaflets ovate, pointed, flowers yellow.

This variety represents a race characteristic to the sea shores of Europe, but is not related to *L. crassifolius* Greene, which is a different plant of Western America, where it does not follow the coast.

Distributed over Europe, Northern and Central Asia, the mountainous districts of East Indian Peninsula, and Australia.

Lupinus arboreus Sims.

Arborescent or suffrutescent, silky pubescent on young stems and lower surface of leaves; petioles short; leaflets narrowly lanceolate, 3—6 cm. long, 9—11 on first leaves, 6—8 on later leaves from the axils, these smaller; corolla sulphur-yellow, keel purple tipped; cotyledon of the seedling petioled.

Sand strands and in the neighborhood of coasts, California.

L. Chamissonis Esch.

Perennial, stems woody below, 3—12 dm. high, densely tomentose; leaflets 7—9, silky-pubescent, oblong-oblanceolate, 1—3 cm. long, petioles short; flowers blue, the banner with a yellow spot.

Sandy soil along the whole Californian coast and Oregon coast.

L. litoralis Dougl.

is a sea shore plant of California, from Point Reyes northward to Vancouver Island. (Jepson l. c.)

L. trifidus Torr.

Annual herb, branched from base, 15—30 cm. high, densely pilose pubescent, the younger parts canescent; leaflets 6—8, linear; corolla blue, with a white spot on the banner.

Coastal sands at San Francisco and Pacific Grove.

Medicago litoralis Rohde.

Annual herb, with obcordate leaflets, toothed at apex, hairy.

On sandy sea shores of the Mediterranean.

M. marina L.

Perennial herb, with obovate leaflets, toothed at apex, tomentose; flowers yellow, large.

Sandy shores of the Mediterranean region.

Oxylobium callistachys Benth.

Tall shrub, young branches angular, clothed with appressed silky hairs; leaves lanceolate, 5—10 cm. long, obtuse, coriaceous, glabrous and reticulate above, silky-pubescent beneath, especially when young; flowers yellow.

Restricted to Western Australia.

O. reticulatum Meissn.

Shrub, 6—10 dm. high, rigid branches, silky-pubescent; leaves opposite, obovate, obtuse, 2 cm. long, coriaceous, reticulate and glabrous in age.

Sea shore sands of West Australia. Occurs also on inland sand formations of that country. With several other species of *Oxylobium* common in the neighborhood of Perth.

Swainsonia

is a genus represented by several species on the sand formations of Australia, especially Victoria, but these plants are not restricted to the coast.

Trifolium fragiferum L.

Perennial stock, creeping stems, rooting at the nodes; leaflets obovate, toothed; leafstalks long, slightly hairy; flowers sessile, white, the head very compact.

Europe, Central Asia, preferring the coast, especially on the Baltic.

T. repens. L.

Perennial plant, glabrous or sometimes slightly hairy; stems creeping, rooting at the nodes; leafstalks long, flowers white, sometimes pinkish.

Europe and Northern Asia, whence spread to many countries. Not confined to coasts or sandy soil, but often occuring on such localities.

Vicia cracca L.

Perennial rootstock; the annual stems climbing, with branched tendrils, 6—12 dm. long, hairy; leaflets numerous, oblong, 20—25 mm. long.

Common in Europe and Northern Asia, whence introduced to North America. Not confined to coast.

Ulex europaeus L.

Shrub, 6—20 dm. high, much branched, hairy; the small branches all end in a thorn; lower leaves lanceolate, upper ones reduced to thorns.

Sandy, dry soil in Western and Southern Europe, but not confined to maritime situations.

Vigna lutea A. Gray.

Prostrate or trailing herb, almost glabrous; leaves pinnately trifoliate, stipulate; leaflets entire, obovate, obtuse, 3—8 cm. long; stipules short and broad; flowers yellow.

Common on sandy shores in tropical Asia, South Africa, Australia, and Pacific Islands, rare in West Indies. On several islands along the Queensland coast, on shores of Moreton Bay and in New South Wales at Newcastle and Botany Bay on coastal sands.

A nearly related form *V. luteola* Benth. occurs on sandy sea shores in different countries, but has not been observed by the writer.

ROSACEAE.

Adenostoma fasciculatum H. et A.

Evergreen shrub, 6—25 dm. high, with virgate branches clothed with leaf-fascicles; leaves linear, rigid, entire, numerous, and mostly fascicled, 8—12 mm. long; flowers small, white.

Although not a sea coast plant, this species is included here, because it is a conspicuous feature of the older dunes of the Californian coast, especially at Monterey Bay. It is one of the characteristic plants of the chaparral formation in certain parts of California.

Argentina anserina (L.) Rydb.

Perennial, stemless herb, silvery with white tomentum especially beneath, rootstock sending out numerous, long, slender, jointed runners from the nodes; leaves 8—15 cm. long, in tufts, unequally pinnate; leaflets in 5—20 pairs, oblong or rounded, with very small ones intermixed, deeply toothed, white-silky, tomentose beneath or on both sides; flower large, yellow.

In temperate countries in both hemispheres, extending to the Arctic. Seems to follow the coast in California, and is never absent from suitable localities on the sea shores of the Baltic.

Fragaria chilensis Duchesne.

Perennial acaulescent herb, with stout runners; upper surface of leaves glabrous; rest of herbage densely pubescent with long weak hairs, especially beneath; leaves of firm texture, dark green, leaflets 1—3 cm. long; flowers 2 cm. in diameter, white.

Coastal sands from San Francisco northward to Alaska. Also in Chili.

Potentilla reptans L.

Perennial herb, with slender, prostrate stems, rooting at the nodes; leaves petiolate; leaflets 5, obovate, coarsely toothed; flowers large, yellow.

Dispersed over Europe, Northern and Western Asia. Also naturalized in New Zealand.

Rosa pimpinellifolia L.

Erect shrub, with widely creeping subterranean stem, much-branched, 2—4 dm. high; leaflets small, glabrous; flowers pinkish.

Europe and temperate Asia, but not in Arctic. Occurs generally not far from the sea, and is a characteristic plant on the dunes of the Friesian Islands (Buchenau).

CRASSULACEAE.

Sedum acre L.

Perennial tufts, procumbent, consisting of numerous short, barren stems, and erect flowering branches, 3—7 cm. high, glabrous, somewhat yellowish; leaves small, thick, ovoid; flowers yellow.

Common in Europe and temperate Asia. Not confined to coastal sands, but frequently occurring there.

Tillaea minima Miers

Low succulent annual, simple or with many ascending branches, 2—7 cm. high; herbage of adult plant reddish; leaves ovate or oblong, obtuse, 2 mm. long.

There is a *Tillaea* common on sandy shores in Australia, f. i. at Moreton Bay, Sydney, Port Phillip, Vincent's Gulf and Perth, and the same form is said to occur in New Zealand and extratropical South America. It is recognized as *T. verticillata* DC. by Bentham, but the difference, if any at all, is inconpicuous between this form and *T. minima* Miers., which is widely distributed in temperate South America and California. When occurring on the coast this species is always more succulent than in inland situations.

T. moschata DC.

Annual herb, with red creeping stems, 8—20 cm. long, succulent, rooting from the axils; leaves 1 cm. long, entire, obovate, obtuse; flowers comparatively large.

Occurs in New Zealand and on adjoining islands, in Southern Chili and Fuegia, as well as on several oceanic islands, as Falkland's and Kerguelen's Land.

T. muscosa L.

Annual herb, 2—4 cm. high, much-branched, reddish, succulent; leaves linear.

In Western and Southern Europe from Mediterranean northwards to Holland.

HALORAGEAE.

Gunnera arenaria Cheeseman.

Fleshy glabrous herb, with slender rhizomes, tufted; leaves 3—5 cm. long, ovate, petioles sheathing at base, with short flattened hairs on upper part. This species shows a remarkable dimorphism in the form of flowers, drupes and even nuts.

Coastal sands of New Zealand.

FIG. 13. Moist hollow between fairly stable dunes occupied by a Soldanella community in which *Gunnera arenaria* Cheesm. is dominating. Upper surface of most Gunnera leaves is covered with sand.

PHOTOGRAPH BY COCKAYNE.

Hippuris vulgaris L. f. maritima.

Perennial rootstock, with annual stems, 3—6 dm. high, stout; leaves entire, linear, acute, 10—15 mm. long; flowers inconspicuous.

Occurs on coasts of Baltic. The typical form is dispersed over Europe and northern North America, and is not a coast plant.

RHIZOPHOREAE.

Rhizophora mangle L.

The common mangrove of all tropical coasts does not, as a rule, occur on sandy shores, but occasional specimens can be found on sandy beaches or fringing sandy islands.

MYRTACEAE.

Calythrix aurea Lindl.

Erect shrub, rigid, not much branched, minutely pubescent; leaves erect, ovate, thick, concave, obtuse, ciliate on margins and midrib; flowers yellow in leafy heads.

Together with other species of the same genus on sands at Swan River, West Australia.

Kunzea pomifera F. Muell.

Rigid, prostrate shrub, glabrous, or young shoots somewhat pubescent; leaves ovate, narrow at base, rigid, spreading, obtuse, 6—12 mm. long; flowers white.

Sandy shores of Victoria and South Australia (St. Vincent's Gulf). Also in interior deserts of Australia.

Leptospermum laevigatum F. Muell.

Tall shrub, glabrous, somewhat glaucous, young shoots often silky; leaves oblong, 1—4 cm. long, 3-nerved, alternate, rigid, entire; flowers white.

Coastal sand formations in Australia (Sydney, Port Phillip, South Australia, and Tasmania). Does not extend to West Australia.

L. scoparium Forst.

Rigid shrub to 7 m. high tree, much-branched; leaves small, ovate, alternate, erect, concave; young shoots covered with silky hairs, adult foliage mostly glabrous.

Australia and New Zealand on the beach. In the latter country it extends to an altitude of 1000 m.

On sand at Moreton Bay and Port Jacksor *L. myrtifolium* Sieb. is quite common.

Melaleuca.

Several species of this typical Australian genus occur on coastal sands, f. i. *M. parviflora* Reich. on sand dunes of Victoria. Not restricted to the coast, however. *M. ericifolia* Smith thrives in very salty situations, growing almost like a mangrove on muddy ocean shores. It is especially well adapted for fixing sand along salt lagoons and in wet places between dunes.

Metrosideros tomentosa A. Rich.

Large shrub or tree with massive spreading arms and stout, tomentose branchlets; leaves 3—10 cm. long, with short petioles, oblong, usually narrowed towards apex, rounded at base, margins flat or recurved, clothed with white tomentum beneath.

New Zealand (North Island only) coasts. Abundant on North Cape.

ONAGRACEAE.

Fuchsia procumbens R. Cunn.

Much-branched; stems prostrate, slender, 15—45 cm. long; leaves alternate, ovate, 1—2 cm. long, shorter than petioles; berry large, glaucous.

Sandy places near highwater mark on Northern coast of North Island, New Zealand.

Oenothera cheiranthifolia Hornem.

Annual caulescent herb, prostrate and radiating from a central radical rosette, crowning the taproot, 45—75 cm. long, rigid and tough; leaves thick, canescently pubescent, obovate-oblong, obtuse, shortly petiolate, 1—3 cm. long; flowers yellow; seeds many.

Coastal sand dunes, California.

O. micrantha Hornem.

Annual; branches procumbent from a short primary axis, not rigid or tough, pubescence hirsutulous; leaves radical, in rosette, oblong-lanceolate, 4 cm. long, slightly undulate, denticulate.

Does not differ materially from foregoing species.

Californian coast from San Francisco southward. According to

Abrams[1] not confined to coast, but also found on sand in the interior valleys of California.

Mesembryanthemum aequilaterale Haworth.

Perennial plant often forming extensive mats; robust, prostrate stems, woody at base, with short ascending flowering branches; leaves opposite, stem-clasping, 4—8 cm. long, glabrous, succulent, linear, triangular, sometimes compressed laterally, acute; flowers rose-colored; seeds minute, numerous.

This species scarcely differs from the South African *M. acinaciforme* L. except in smaller flowers and less succulent leaves.

Follows the coast in California, Chili, and Australia. In the latter country it sometimes ascends the rivers as far as the water is brackish, and it occurs on the salt plains of the interior in a few places. Grows generally on the littoral dune, where that formation is developed.

M. australe Sol.

Perennial; stems prostrate, rooting at base, 3—15 dm. long; leaves opposite; connate at base, triangular, flat above, keeled or convex beneath, acute, fleshy, 2—4 cm. long, often crowded in short auxiliary shoots; some plants have red, others green leaves; flowers rose-colored.

Appears not to be very distinct from *M. crassifolium* L. of South Africa.

Coasts of Australia, New Zealand, South Pacific Islands and California, at San Francisco, where most likely introduced.

M. capitatum Haw.

Perennial, often suffruticose caudex, simple or branched; leaves crowded, very long, triquetrous, glaucescent.

A South African species sometimes cultivated on sand dunes in Australia. The nearly related *M. pugioniforme* L. from South Africa is also a good sand stay.

M. crystallinum L.

Prostrate annual or biennial, much-branched, stems thick, about 3 dm. long, covered with transparent vesicles; leaves undulate, succulent, obovate, obtuse, narrowed into a stemclasping petiole; flowers white or pink.

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1) L. R. Abrams: Flora of Los Angeles and vicinity, p. 271, 1904.

Common on sea coasts of South Africa. Also on the coasts of Southern Europe, Canary Islands, California and Australia (South and West Australia).

M. edule L.

Stems stout, spreading, prostrate, angular. Leaves opposite, fleshy, 7 cm. long, shortly connate at base, linear, triquetrous, concave above; keel serrulate.

Coast of South Africa, whence introduced into many countries as a sandstay and then naturalized, f. i. on North Island of New Zealand.

Tetragonia expansa Murray

Succulent perennial, branched, erect or prostrate, 3—6 dm. high, glabrous, papillose; leaves alternate, plane, rhomboid-ovate, 4—5 nerved beneath, 2—8 cm. long, abruptly narrowed into a broad petiole, entire, acute or obtuse; flowers small, yellow; fruit angular with 2—4 spines.

On coast of Australia, New Zealand, and adjoining islands, Japan, Polynesia, temperate South America and California (Pacific Grove and shores of San Francisco Bay).

T. trigyna Banks & Sol.

Stems suffruticose, 2—15 dm. long, almost trailing and climbing; leaves alternate, broadly ovate, abruptly narrowed into the petiole, papillose.

Australia, Tasmania, New Zealand and adjoining islands.

A number of species of this genus occur on the sandy sea shores of South Africa.

UMBELLIFERAE.

Angelica litoralis Fries.

Perennial, 1—2 m. high, 2—3 ternately divided; leaflets ovate, acute, serrate; petioles thick, the upper ones much inflated; flowers greenish-yellow.

Occurs on gravelly and stony shores of the Baltic.

A. rosaefolia Hook.

Suffruticose plant, chiefly littoral in New Zealand (Kirk: Student's Flora of New Zealand).

Apium prostratum Labill.

Root stout; stems prostrate, 15—60 cm. long, stout, grooved; leaves 2—3 pinnate; leaflets sessile; obovate, narrow-linear, membraneous.

Sea shores of Australia, Tasmania, New Zealand, South Pacific Island, South America, South Africa, and several oceanic islands.

Crantzia lineata Nutt.

Small, creeping, glabrous perennial, with solitary or tufted, erect, cylindrical leaves, springing from the nodes; rhizomes slender, rooting at the nodes; leaves 1—12 cm. long, linear-fistular, obtuse, sometimes compressed, especially when growing in elevated situations.

North America on the Atlantic and certain parts of the Pacific Coast; New Zealand and Chatham Island. Is a saltmarsh plant, but occurs often in moist hollows between dunes.

Daucus maritimus Lam.

Biennial, with leaves in rosette, densely covered with a short tomentum.

Mediterranean countries, where often found on sand dunes.

Eryngium maritimum L.

Perennial root herb with deep root; about 8 dm. high, stiff, erect, much-branched, glabrous, glaucous; leaves stiff, broad, sinuate, divided into 3 broad, short lobes, veined, bordered by coarse teeth, radical leaves petiolate, others clasping.

Common on maritime sands of Europe, North Africa and Western Asia, mostly growing on the upper beach or the littoral dune.

E. vesiculosum Labill.

Perennial, with stout root; stems 5—15 cm. long, prostrate, but never rooting at the nodes; radical leaves rosulate, lanceolate-oblong, narrowed into a flat petiole, 3—9 cm. long, deeply toothed; teeth spinescent.

Sandy beaches of New Zealand and Australia.

Hydrocotyle Novae Zealandiae DC.

occurs sometimes on sandy beaches of North Island, New Zealand, in a form, described by Kirk (in his Student's Flora, p. 189) as *H. robusta.*

ARALIACEAE.

Pseudopanax Lessonii C. Koch.

Much branched shrub or small tree; branches stout; leaves 2—5 foliate; leaflets sessile, 2—10 cm. long, obovate, obtuse, thick and coriaceous, glossy, entire or sinuate-serrate; veins indistinct; petioles 5—15 cm. long.

Sea coast of North Island, New Zealand.

RUBIACEAE.

Coprosma acerosa A. Cunn. f. *arenaria* Kirk.

Low shrub, seldom more than 1.5 m. high; branches often interlaced; leaves narrow, close-set; bark yellowish-brown.

On drifting sands of New Zealand, rarely inland.

C. Baueri Endl.

Shrub or small tree, glabrous except the young shoots, which are sometimes minutely pubescent; branchlets stout, terete; leaves somewhat fleshy, broadly ovate, narrowed into a short slender petiole, rounded at the tip; margins often recurved, glossy; stipules broad, acute, minutely toothed; peduncles axillary.

Coast of New Zealand.

Galium verum L.

Perennial from woody rootstock, glabrous; stems much-branched at base, decumbent, 15—30 cm. long; flowers yellow.

Europe and temperate Asia. Not confined to the coast, but occurs often on upper beach and littoral dune, not infrequently together with *G. mollugo.*

VALERIANACEAE.

Valeriana officinalis L.

Perennial stock; creeping runners; erect flowering stems, 15—20 cm. high; leaves pinnate with many lanceolate segments, 2—6 cm. long, coarsely toothed, somewhat hairy underneath; flowers white or pinkish.

Common in Europe and temperate Asia. Not confined to coast, but frequently occurring on upper beach near brackish water.

Valerianella olitoria Poll.

Annual herb, glabrous, 6—15 cm. high, erect or ascending, branching from base, radical leaves caespitose, oblong, 3—5 cm. long, rounded at top, entire, narrowing at base; stemleaves narrower, clasping, coarsely toothed.

Common in Europe, especially in the south.

CAMPANULACEAE.

Campanula rotundifolia L.

Perennial, with slender, creeping rootstock; radical leaves ovate, others narrow-lanceolate, entire; flowers blue.

Common on dry places throughout Europe, but not confined to coast, although it frequently occurs on established dunes.

Jasione montana L.

Biennial, with tufted leaves, linear or lanceolate, somewhat hairy; flowers blue.

Widely spread in Europe.

It is especially the form *litoralis* Fries, prostrate and tufty, which occurs on the dunes of the Baltic.

COMPOSITAE.

Achillea millefolium L.

Perennial herb, common in Europe and North America, but not confined to the coast, although it frequently occurs on dunes.

Anaphalis margaritacea (L.) B. & H.

Is abundant on dunes at San Francisco and Pacific Grove, but is not restricted to coastal sands.

Angianthus eriocephalus Benth.

Low, slender annual, 2—5 cm. high, leaves narrow-linear, opposite, entire, woolly-white.

On coast sand formations in Victoria and Western Australia. Occurs also in Tasmania.

Artemisia absinthium L.

Shrubby, with short stem, much-branched and leafy, annual flowering stems hard, 3—6 dm. high, white-gray tomentose; leaves small, divided into oblong, linear, obtuse lobes.

Near the sea in Europe and temperate Asia, whence introduced to North America and New Zealand.

A. campestris L.

Perennial stock, sometimes shrubby, low, branched; annual branches spreading, 3—4 dm. long, glabrous, somewhat reddish; leaves small, once or twice pinnate, with few narrow-linear segments, green on upper surface.

Frequently on shores, although not restricted to coast. Europe and temperate Asia. Several forms of this plant occur on the coastal dunes of Germany, as *sericea* Fr. and *stramentisia* G. Beck.

A. maritima L.

Suffrutescent, much-branched, decumbent, covered with white tomentum; leaves twice pinnate, with narrow-linear segments.

Maritime sands of Western Europe, Mediterranean, Black Sea, and Caspian Sea.

A. pycnocephala DC.

Perennial herb, with stout stem, 4—8 dm. high, somewhat woody at base, crowded with leaves, once or twice pinnately divided into linear entire segments; herbage densely silky-villous; flowers yellow.

Coastal sand dunes of California, from Monterey northwards.

A. Stelleriana Bess.

Perennial, densely white-tomentose; stem-branched, 3—7 dm. high, bushy; branches ascending; leaves obovate, 2—8 cm. long, pinnatifid into oblong, obtuse, usually entire lobes; densely tomentose beneath, but green and glabrous above in age.

Sandy sea beaches, Kamtschatka, Southern Sweden, Denmark, England, Ireland, Atlantic coast of North America.

A. vulgaris L.

Perennial, thick and woody stock, erect flowering stems, 5—10 dm. high, glabrous; leaves pinnatifid, with lanceolate, pointed lobes, coarsely toothed, dark green and glabrous above, white tomentose underneath.

Common in Europe, Asia, and North America. Not confined to coast.

Aster (Olearia) axillaris F. Muell.

Erect shrub, much-branched, 1—3 m. high, white-tomentose; leaves obovate, or linear, 1—2 cm. long, obtuse, entire, with revolute margins, glabrous and shining above, white-woolly beneath.

On coastal sand dunes in Victoria, South Australia (St. Vincent's Gulf), and Western Australia (Perth). Also in Tasmania.

A. (Olearia) glutinosus Benth.

Much-branched shrub, 1—1.6 m. high, glabrous, glutinous; leaves narrow-linear, acute, 1—4 cm. long, flat, margins somewhat recurved.

Sandy coasts of Tasmania, Victoria and South Australia.

A. (Olearia) ramulosus Benth.

Shrub, 1—2 m. high, much-branched, pubescent, sometimes glutinous; leaves small, spreading, obovate, petiolate, obtuse, with revolute margins, glabrous above, woolly beneath.

Together with other species of this genus on dunes in Victoria, but not confined to coast. In Tasmania, New South Wales, and South Australia.

A. (Olearia) Solandri Hook. f.

Much-branched shrub, 1—4 m. high, branchlets stout, puberulous; white-yellowish tomentose beneath; margins recurved.

Usually on coast; New Zealand, especially on North Island.

A. Tripolium L.

Perennial herb, glabrous, 2—3 dm. high, erect or decumbent; leaves linear, entire, somewhat succulent; rayflowers purplish.

Maritime coasts of Europe, and temperate Asia.

Baccharis pilularis DC.

Evergreen shrub, prostrate on sand, 2—15 dm. high; branchlets angular; leaves sessile, obovate, 1—3 cm. long, sinuately toothed.

The more erect form is widely spread inland in California, while the prostrate form is confined to the coast. Rare south of Point Conception according to Abrams.

Bidens bipinnata L.

Glabrous annual, 0.5—1 m. high; branches angular; leaves thin, pinnately divided; leafsegments again divided into small, deeply toothed lobes; flowers yellow.

On sandy shores of Queesnland, as Moreton Bay. Is common in various situations in the eastern part of North America and in the tropics of that continent.

Calocephalus Brownii F. Muell.

Low, rigid, much-branched shrub, 3 dm. high, covered with a white, woolly tomentum; leaves alternate, linear, obtuse, 2 mm. long.

On sea coasts of Tasmania, Victoria, South Australia and Western Australia.

Cassinia fulvida Hook. f.

Erect shrub, about 1 m. high, much-branched; branches covered with a yellowish, subviscid tomentum; leaves narrow, linear, spreading, margins slightly curved, clothed with fulvous tomentum; glutinous above. Midrib obvious below.

Restricted to New Zealand, where it goes up to 1200 m. from sea level.

C. retorta A. Cunn.

Shrub, 1—3 m. high, with slender branches, covered with gray tomentum; small, erect, narrow-linear leaves, with recurved margins, underneath covered with whitish appressed tomentum.

On North Cape, New Zealand.

Cirsium occidentale Nutt.

Biennial herb, stout, 4—10 dm. high, white with thick coating of cottony wool; leaves pinnatifid, not very prickly, glabrate above, canescent beneath; flowers purple.

Common on established dunes near San Francisco, and follows the coast southward in California, extending inland among hills of coast ranges.

Corethrogyne obovata Benth.

Perennial with decumbent stems, 3—6 dm. long; leaves 2—3 cm. long, obovate, obtuse, toothed above middle, densely white-woolly; disk flowers yellow, ray flowers violet blue.

On sand dunes of California, from Pacific Grove northward.

C. virgata Gray.

Suffrutescent, erect, 2—10 dm. high, branched; herbage woolly; leaves oblanceolate, serrate; disk flowers yellow, ray flowers violet blue.

Coast of California.

C. viscidula Greene.

Perennial, tall, slender; stem and flowers at flowering time purplish, glandular-scabrous; leaves narrowly-oblanceolate, acute, serrate, viscid-glandular; disk flowers yellowish-brown; ray flowers violet blue.

On sand dunes at Monterey Bay, California.

Cotula coronopifolia L.

Small perennial glabrous herb, with succulent, clustered, creeping stems, rooting at the nodes; branches ascending, 10—20 cm. high;

leaves alternate, often distant, sheathing at the base, lanceolate, nearly linear, entire or pinnatifid, 25 cm. long; flowers yellow.

Widely dispersed. West coast of Europe, from Spain (Cadiz) to Denmark, and Norway (Sognefjord), South Africa, Australia (New South Wales to Western Australia), Tasmania, New Zealand, Chatham Islands, California (supposed by Behr to be introduced), Chili and Brazil. Occurs in wet places among the dunes.

C. perpusilla Hook. f. and *C. Traillii* Kirk

are two other species occurring occasionally on blown sand in New Zealand (Kirk).

Diotis maritima Cass.

Perennial rootstock, creeping; stems branching at base, hard, 20—30 cm. high, covered with a dense, white tomentum; leaves alternate, oblong, entire, 1 cm. long; flowers yellow.

A plant nearly related to Achillea. Occurs on maritime sands of Europe, from the Mediterranean to the British Islands.

Ericameria ericoides (Less.) Nutt.

Low evergreen shrub, with decumbent or ascending main stems and numerous erect branchlets; foliage punctate, resinous; leaves linear-terete, 2—5 mm. long, fascicled; flowers yellow.

Common on sand dunes of California.

Erigeron acris L.

Common on established dunes in Europe, but not confined to coast.

E. glaucus Ker.

Perennial herb, with mostly entire leaves, stem very leafy at base, the cauline leaves much reduced, flowering stems erect, 10—25 cm. high, commonly one-headed, arising from a radical tuft of leaves crowning the fleshy caudex and often from rosulate offsets terminating prostrate woody branches; stems pilose pubescent; leaves finely pubescent, spatulate, obovate, entire, rarely with a small tooth on either side below the apex, 2—8 cm. long, upper cauline small and scattered.

Coast of California. Abundant on dunes at San Francisco.

Eriophyllum staechadifolium Lag.

Suffruticose plant, 6—10 dm. high; leaves alternate, pinnately parted into 5—7 lobes, the margins revolute, and the under surface white with a dense feltlike tomentum; upper surface green, and tomentum of stems deciduous; flowers yellow.

Coastal sands and sea cliffs in California.

Franseria bipinnatifida Nutt.

Perennial branching herb, with procumbent stems, 6—10 dm. long, somewhat hirsute; leaves twice or thrice pinnately parted into oblong lobes, canescent.

Common on sandy shores in California.

FIG. 14. Dune covered with *Franseria* community, at San Francisco.
PHOTOGRAPH BY THE AUTHOR.

F. Chamissonis Less.

Perennial branching herb, woody at base, stems procumbent, 6—10 dm. long, hirsute; leaves narrow-ovate, with cuneate base, serrate or the lower laciniate.

Coastal sands of California; not so common as foregoing species.

Gnaphalium chilense Spreng.

Annual or biennial, with several stems, erect from a decumbent base, stout, 15—75 cm. high, densely clothed with leaves, narrowly spatulate, the short decurrent bases broad; herbage woolly.

On dunes at San Francisco and Pacific Grove, but not confined to the coast.

Grindelia robusta Nutt. var. *maritima.*

Perennial herb, with ascending or erect stems, 3—4 dm. high, herbage ligthly pubescent; leaves oblong, obtuse, serrulate; heads filled with white gummy exudation; rays yellow.

Sometimes on drift sand, but prefers hard ground near coast, California.

Helichrysum arenarium (L.) DC.

Perennial herb with single stems, densely white-tomentose; leaves sessile, obtuse, the lower oblong-obovate, the upper linear-lanceolate; flowers yellow.

On dunes of Northern Germany, but also inland in certain parts of Europe.

H. cinereum F. Muell.

Erect, much-branched shrub, 1—1.5 m. high; branchlets tomentose; leaves linear, obtuse, 1—2 cm. long, with revolute margins, glabrous above, tomentose beneath, sometimes succulent.

Common on sand dunes in Victoria. Also said to occur in New South Wales and Tasmania.

Hieracium pilosella L. and *H. umbellatum* L.

are commonly found on established dunes along the Baltic, but are adventive from inland.

Jaumea carnosa (Less.) Gray.

Perennial glabrous herb, with many slender stems, from the fleshy crown of the taproot, mostly simple, 10—15 cm. long, decumbent at base and rooting at the nodes; leaves linear, entire, fleshy, opposite, 20—25 mm. long; flowers yellow.

Sandy beaches, California.

Lessingia Germanorum Cham.

Annual herb, low, diffusely branched, 10—20 cm. high; herbage with appressed white tomentum, wholly glabrate in age, at least on branches; lowest leaves pinnatifid, those of the branchlets scattered, linear and usually entire, not gland-bearing; flowers yellow.

Common on sand dunes of California from San Francisco southwards, but not confined to the coast.

Matricaria inodora L. var. *maritima* L.

Perennial herb, erect or spreading, much-branched, 3—5 dm. high, leaves succulent; disk flowers yellow, ray flowers white.

Common on the Baltic shores.

Senecio Colensoi Hook. f.

Stem erect, simple or much-branched, woody at the base, flexuose, grooved, the whole plant covered with white tomentum. Some are white on both surfaces, others only beneath. On the shore they are fleshy and glabrous. Leaves polymorphic, entire, obovate to lanceolate, narrowed into short petioles with broad wings. The leaves vary, however, greatly in form.

North Island, New Zealand.

S. lautus Sol.

Prostrate, decumbent or erect, glabrous or pubescent, annual or biennial, 8—60 cm. high; stem and branches stout or slender, grooved; leaves succulent, 2—5 cm. long, lanceolate, narrowed into a petiole, pinnatifid.

A very variable species occurring on coasts of New Zealand, comparatively seldom inland.

S. spathulatus A. Rich.

Much-branched perennial; leaves obovate, toothed irregularly, the lower petiolate, the upper stemclasping, all fleshy; 2—4 cm. long.

Sandy shores in New South Wales (Bondi), Victoria and Tasmania.

S. silvaticus L. and *S. viscosus* L.

are not uncommon on sand formations of the Baltic coasts, but are not confined to such situations.

Solidago spathulata DC.

Perennial herb, with glabrous, slightly glutinous herbage; stems 35—45 cm. high, branched at base, decumbent, thickly clothed with broad leaf bases; leaves basal, spatulate, rounded at apex, narrowed to a long marginal petiole, serrate above the middle; flowers yellow.

On sand dunes at San Francisco and Monterey, California.

Sonchus arvensis L. *maritimus* G. F. Meyer.

Perennial; creeping rootstock; stems 6—10 dm. high; leaves long, pinnatifid, lobes lanceolate, curved downwards, bordered by large prickly teeth; the lower petiolate, the upper stem-clasping; flowers yellow.

S. asper Hill. var. *litoralis* Kirk.

Perennial herb, with stout roots; stems 30—45 cm. high, robust; radical leaves rosulate, closely appressed to the ground, somewhat fleshy, ovateoblong, obtuse, often waved, toothed, cauline leaves few, acute, amplexicaule.

Coast of New Zealand.

Tanacetum cam phoratum Less.

Perennial herb, strong scented, villous-tomentose when young, the wool more or less deciduous in age; stems robust, decumbent or ascending, 3—10 dm. long; primary and secondary divisions of the leaves much crowded, the latter oblong, the margin more or less revolute; flowers yellow.

On sand dunes of California from San Francisco to Puget Sound, along Upper Great Lakes and from Hudson Bay to Maine on the Atlantic coast of North America.

T. vulgare L.

Occurs usually on the coast near the Baltic, but in New Zealand, where it also is found, it is not observed to favor maritime situations.

Taraxacum officinale Web.

is often found on seashores of the Baltic, especially in a prostrate, glaucous form *corniculatum* Kit.

Troximon apargioides Less.

Perennial herb, with deep taproot, low and tufted, stem erect or ascending from a woody caudex, 18—40 cm. high; leaves narrow, pinnatifid.

On sand dunes at San Francisco.

GOODENOVIEAE.

Scaevola suaveolens R. Br.

Prostrate perennial, covered with appressed silky hairs; leaves alternate, obovate, petiolate, thick, entire; flowers blue.

Common on coasts of Australia. In Queensland at Wide Bay and Moreton Bay, in New South Wales (Manly Beach, Botany Bay), Victoria (Porth Phillip) and South Australia.

EPACRIDEAE.

Cyathodes acerosa R. Br.

Tall shrub with spreading branches; leaves scattered, spreading, linear, rigid, with a pungent point, recurved margins, about 1 cm. long; flowers white; large pulpy drupe.

Sand dunes of Victoria. Also in Tasmania and New Zealand.

Leucopogon margarodes R. Br.

Low shrub, branches pubescent; leaves oblong-lanceolate, obtuse, margins recurved, 5—15 mm. long.

Coastal sands in Queensland (Moreton Bay) and New South Wales (Newcastle).

L. Richei R. Br.

Tall shrub, glabrous; leaves oblong-lanceolate, obtuse, recurved margins 1—3 cm. long.

Common on sea shores of Australia. Queensland (Moreton Bay), New South Wales (Porth Jackson), Victoria (Porth Phillip), Western Australia (Perth). Also on Chatham Islands.

PLUMBAGINACEAE.

Armeria vulgaris Willd.

Acaulescent perennial, with a close tuft of linear, flat or revolute-channeled leaves; flowers rose color.

On coasts in temperate countries in Northern and Southern Hemisphere, but not in the tropics.

Statice auriculifolia Vahl.

Perennial, tufted, branched, leaves 2—3 cm. high; resembles *S. limonium* L.

Coasts of Western Europe and the Mediterranean, usually on rocks, rarely on sand.

S. limonium L.

Stemless perennial, with tufts of radical leaves 5—15 cm. long, obovate, glabrous, fleshy, petiolate, flowers rose colored.

On coastal sands and salt marshes in Western Europe, Mediterranean, Western Asia, California, South America.

S. reticulata L.

is a form still smaller than *S. auriculifolia,* and occurs on coastal sands of Mediterranean and Western Asia, and is said to go on the west coast of France.

PRIMULACEAE.

Anagallis arvensis L.

Annual, glabrous herb, with 15—30 cm. long, procumbent or ascending stem; leaves opposite, entire, broadly ovate, acute, sessile, 12 mm. long; flowers bright red.

Usually near the coast, but also inland on cultivated soil. Europe, temperate Asia, Africa, and on Atlantic and Pacific coast of North America, where introduced, as in Australia.

Glaux maritima L.

Succulent perennial, with creeping rootstock; stem glabrous, branching, 8—15 cm. high; leaves small, opposite, sessile, ovate or almost linear, entire; flowers purplish or white.

Widely dispersed in Europe, temperate Asia, and North America. On the eastern coast it ranges from New England north, while on the Pacific it occurs from San Francisco to Alaska. Also in the interior in limited areas on subsaline soil.

Primula sibirica Jacq.

Perennial herb, with fibrous roots; glabrous, green; leaves ovate or obovate, entire, petiolate; flowers lilac.

In arctic America, Greenland, Northern Europe, and Asia to Kamtschatka.

Samolus repens Pers.

is a saline marshplant, sometimes found on moist sand in Australia, New Zealand, and New Caledonia.

S. Valerandi L.

occurs on similar localities as the former species, being dispersed in some form over almost all temperate and warmer regions of the globe.

MYRSINEAE.

Aegiceras majus Gaertn.

One of the commonest mangroves, ranging from Ceylon and the Indian Peninsula to the Eastern Archipelago and the South Pacific Islands. Also in Australia on the Queensland coast and at a few places in New South Wales.

APOCYNEAE.

Alyxia buxifolia R. Br.

Low shrub, spreading, glabrous; leaves opposite, shortly petiolate, obovate, obtuse, thick, margins recurved.

Abundant on coastal sand dunes in Victoria and South Australia. Also in Western Australia (Perth) and Tasmania.

LOGANIACEAE.

Mitreola paradoxa R. Br.

Erect, branching annual, slender, 7—12 cm. high, glabrous; leaves linear-lanceolate, connate, sheathing at the base, 6—10 mm. long; flowers small, white.

On coastal sand in Tasmania and Australia. Victoria (Port Phillip), South Australia, Western Australia (Fremantle).

GENTIANACEAE.

Erythraea australis R. Br.

Erect glabrous annual, 15—45 cm. high, with few branches; leaves sessile, lanceolate, obtuse, the lower stem-clasping, 1—3 cm. long; flowers pink.

Common on all Australian coasts, and also in a few inland places. New Caledonia.

Differs very little from *E. spicata* Pers., the common form in the Mediterranean countries.

E. litoralis Bab.

Annual, much branched, 5—25 cm high, leaves narrow, forming a spreading radical tuft, the upper in pairs, narrow-linear; flowers red.

Common in Europe and Central Asia.

E. Muehlenbergii Gris.

Annual, simple, or branched from base; 5—15 cm. high; leaves oblong, obtuse, 1—2 cm. long; flowers rose colored.

Coast of California from Monterey to San Francisco.

E. pulchella Sw.

Low annual, with single much-branched stem; leaves thin, ovate, the radical opposite; flowers small, red.

Coasts of Baltic.

HYDROPHYLLACEAE.

Phacelia Douglasii (Benth.) Torr.

Annual herb, branched from the base, with ascending or decumbent stems, 10—20 cm. long, herbage puberulent and hirsute with spreading hairs; leaves linear, pinnatifid; corolla light blue.

Coastal sands of California from San Francisco southward.

BORRAGINACEAE.

Amsinckia lycopsoides Lehm.

Annual, with erect stems, branching; the branches sometimes decumbent, 3—6 dm. long, herbage light yellowish-green, hairy, the hairs often conspicuously hardened; leaves ovate-lanceolate, usually with entire margins.

Coastal sands near San Francisco.

Cryptanthe leiocarpa (F. & M.) Greene.

Annual, with strong taproot, branched from base with many erect or ascending branches, 12—30 cm. long; stems in sand short, sometimes caespitose.

Coastal sands of California.

Heliotropium curassavicum L.

Prostrate, much-branched perennial, fleshy, glabrous, glaucous; stems 15—90 cm long, spreading; leaves oblong, obtuse, narrowed into a short petiole, 1—3 cm. long; flowers sessile, small, white with a yellow eye.

Widely spread on sandy sea coasts of North and South America, West Indies, South Africa, Australia (Western Australia to New South Wales), Pacific Islands. Sometimes on alkaline lands in the interior (Australia, California).

CONVOLVULACEAE.

Convolvulus Soldanella L.

Prostrate, trailing perennial, up to 5 dm. long, with creeping rootstock; stem succulent, glabrous; leaves deep green, thick, 3—5 cm. in diameter, reniform, entire, on long stout petioles; corolla funnelform, up to 5 cm. broad, pink or purplish and white.

Common on sandy sea shores in extratropical countries. Extends in Europe from Mediterranean as far as the East-Friesian Islands (Buchenau).

Seems not to vary much in appearance on the coasts of California, Europe, and Australia, as far as the writer has seen, but Cockayne[1]) remarks a considerable variation in forms from New Zealand and Chatham Island: "The trailing stems of C. Soldanella, furnished with a few fleshy leaves, are very short, being rarely more than 4 cm. in length; the rest of the plant is subterranean, with the exception of the flowers. These latter are large, lilac and white in color, semiprostrate, with their peduncles buried beneath the sand right to the base of the calyx. This small development of C. contrasts greatly with the same species, when growing on the sand dunes at some distance from the sea in many parts of New Zealand. There it forms great masses trailing over the sand, or, when growing in sheltered positions amongst other plants, it actually assumes a climbing habit of growth."

This species does not differ much in habit from the sea coast form of *C. sepium* L. and it has also been reduced to this by F. v. Mueller[2]) although it exhibits characters, which certainly justify its being considered a different species.

Cressa cretica L.

Small, erect, much-branched perennial, 7—15 cm. high, silky-pubescent; leaves sessile, linear or ovate-lanceolate, entire, 5 mm. long.

On sandy coasts of the warmer parts of Europe, Asia, Africa, Australia, and America. In California and Australia it also occurs in the interior on saline soil.

Evolvulus alsinoides L.

Perennial, much-branched, prostrate; 15—30 cm. long stems, silky-hairy; leaves lanceolate, entire, sessile, 1—2 cm. long, obtuse or acute; flowers small, white or bluish.

Abundant on Queensland coast, and also found in New South Wales (Clarence River), South and West Australia. Reported from many places of the interior.

Ipomaea carnosa R. Br.

Prostrate or creeping glabrous perennial; leaves petiolate, ovate, obtuse, cordate at base, succulent, 1—3 cm. long; flowers large, white; seeds woolly and hairy.

On sea coasts of warm countries in America, Africa, and Asia. Also occurs on the Mediterranean coasts, and on the shores of Gulf of Carpentaria in Australia.

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1) A short account of the plant covering of Chatham Island.—Trans. N. Z. Inst. XXXIV. p. 257.

2) Fragmenta Phytographiae Australiae, VI, p. 100.

Is nearly related to *I. pes caprae* Roth, and differs mainly by having a more succulent, narrower leaf, less prominently veined.

I. palmata Forst.

Glabrous, twining; leaves digitately divided into 5—7 ovate-lanceolate, obtuse, 3—5 cm. long lobes; corolla purple or white; seeds pubescent, with long silky hairs.

On tropical coasts in Asia, Africa, and America. In Australia quite abundant at Moreton Bay, and near Tweed River and Port Jackson in New South Wales. Also on North coast of North Island, New Zealand.

I. paniculata R. Br.

Perennial; stems trailing, glabrous, leaves palmately divided to below middle into 5—7 ovate-lanceolate, obtuse lobes; the whole leaf 12—20 cm. long and broad; flowers large.

Tropical coasts of Asia, Africa, Australia, and America. Also in West Indies.

I. pes caprae Roth.

Glabrous perennial, with up to 40 m. long, prostrate, trailing stems; leaves orbicular, obtusely 2-lobed, somewhat fleshy, 5—8 cm. long, on long petioles; flowers large, pink; seeds hairy.

On sandy shores of the tropics. Abundant on East Australian coast southward to Richmond River. Used in India (Madras) as a sand stay.

SOLANACEAE.

Nicotiana glauca Grahan.

from Argentine and Uruguay is grown in a few places on coastal sands of Australia, and is considered by some authors as a very good sand stay.

Solanum nigrum L.

in various forms is often found on dunes in Northern Europe and California, and *S. sodomaeum* L. on those of Australia, New Zealand, and the Iberian Peninsula, but both species are inland plants.

SCROPHULARIACEAE.

Castilleja latifolia H. & A.

Root-parasitic perennial herb, (sometimes suffrutescent), 15—45 cm. high; herbage viscid-pubescent, leaves thick, alternate, ovate or obovate, mostly less than 3 cm. long, sessile; flowers dull-yellowish, the bracts and calyx lobes more showy than corolla.

Coastal cliffs and sands of California.

Collinsia bartsiaefolia Benth.

Annual herb, finely puberulent; leaves somewhat fleshy, ovate, 3 cm. long.

On sand formations from San Francisco southward along Californian coast.

Linaria supina Desf.

Perennial; stem short, much-branched, 10—15 cm. long, high, decumbent, glabrous; leaves linear; flowers yellow.

On sandy soil especially near the sea in Western Europe; very common in Spain and Southern France.

L. vulgaris Moench.

Perennial; rootstock creeping; stems erect, 3—10 dm. high, glaucous, green, glabrous; leaves linear or narrow-lanceolate; flowers yellow.

Common in Europe and temperate Asia. Often on dunes, but not confined to coast.

Mimulus Langsdorffii Donn. var. *grandis* Greene.

Perennial, with stolons at base, stems simple or branching, 6—10 dm. high; leaves elliptical, serrate, lower petiolate, upper sessile; flowers large, yellow.

Moist sand on California coast.

M. repens R. Br.

Perennial, prostrate, glabrous, rooting at nodes; leaves sessile, sometimes stem-clasping, oblong, obtuse, fleshy, 5—10 mm. long; flowers blue, with yellow center.

Marine coasts of Australia, Tasmania, and New Zealand. Collected by the author near Sydney and Melbourne. Occurs also in the interior on saline soil.

Odontites simplex Hrtm.

Annual, with few branches; leaves fleshy, ovate-lanceolate, serrate; flowers purple.

Coasts of Baltic, mostly on gravelly soil.

Scrophularia californica Cham.

Perennial, very like *S. nodosa* L.

Common in California and Nevada, but not confined to coastal sands, although often found there.

FIG. 15. Vegetation on sand dunes near Ajaccio on Corsica, consisting of *Ammophila arenaria* and *Scrophularia ramosissima*.
PHOTOGRAPH BY BORGESEN, NOV. 1897.

S. nodosa L.

Coarse, erect perennial found on moist places in Europe, temperate Asia, and parts of North America, often on the coast.

Veronica macroura Hook. f.

On coast of New Zealand, but not confined to sand formations.

V. longifolia L. var. *maritima* L.

is a perennial common on coasts of the Baltic, but occurs rarely on sand.

VERBENACEAE.

Avicennia officinalis L.

Erect shrub of considerable height; branches, lower side of leaf and inflorescence white with a close tomentum; upper surface of leaves usually glabrous in age, black and shining when dry; leaves opposite, coriaceous, entire, ovate-lanceolate, 5—7 cm. long, acute, petiolate.

Common in tropical Asia, Africa, Australia, and America, growing in marshes and inundated sandy places.

Vitex trifolia L.

Low shrub, the branches, lower surface of leaves and inflorescence white, undivided or of 3—5 leaflets, often white on both surfaces, usually glabrous on upper side in age; flowers bluish.

Common on tropical coasts of Asia, and Australia southward to Moreton Bay.

The variety *obovata* has a peculiar habit of growth on the beaches along Gulf of Carpentaria. The black rope-like stems run over the surface of the sands to a length of 10 m. or more, sending up shoots 3 dm. high at short intervals. (J. F. Bailey in letter.)

MYOPORINEAE.

Myoporum viscosum R. Br.

Shrub, erect, 1—2 m. high, glabrous; leaves alternate, lanceolate or ovate, tuberculate-glandular, obtuse, entire; flowers white.

On coastal dunes of South Australia (St. Vincent's Gulf) together with *M. serratum* R. Br. from which it does not differ much. The latter is found in Tasmania, Victoria, South and West Australia. *M. laetum* Forst. is common on some New Zealand coasts, and can easily be grown on the middle beach.

LABIATAE.

Galiopsis tetrahit L.

Annual, 15—30 cm. high, with stiff hairs, stems swollen under the nodes; leaves petiolate, ovate, pointed, coarsely toothed; flowers small, purplish white.

Common through Europe and temperate Asia. Not confined to coast, but often occurring on marine beaches and dunes.

Prunella vulgaris L.

In damp places in Europe, Northern Asia, Northern America, and Australia (except Western Australia). In tropical Asia and South America it is found in the high mountains.

Scutellaria hastaefolia L.

Perennial herb, with erect stems, simple or little branched; leaves petiolate, truncate at base, ovate or ovate-lanceolate; flowers bluish.

On the coasts of the Baltic, but also found in Central France and in Northern Italy.

Stachys ajugoides Benth.

Annual, stems creeping in sand, simple, 2—5 dm. long; herbage densely villous or silky pubescent; leaves oblong, 2—6 cm. long, acute or obtuse, petiolate, upper sessile; flowers whitish.

On sand dunes of California, but not confined to coast.

Westringia rosmariniformis Sm.

Tall, bushy shrub, branches, underside of leaves and inflorescence silvery white with densely appressed hairs; leaves in fours, linear or lanceolate, obtuse or acute, 1—3 cm. long, coriaceous, glabrous and shining on upper surface, margins revolute.

On sand dunes in New South Wales (Port Jackson).

PLANTAGINACEAE.

Plantago arenaria W. K. ver. *divaricata.*

Annual herb, with erect sometimes branched stem; leaves narrow linear or filiform, margins revolute, pubescent.

On sandy sea shores of the Mediterranean countries.

P. coronopus L.

Perennial, hirsute; leaves radical, in a dense tuft, linear, acute, entire or sometimes pinnately divided into linear lobes, hairy.

Marine sands of temperate Europe, Western Asia, and North Africa. Introduced to Australia, where also found on roadsides in Victoria, South Australia, and Tasmania.

P. hirtella H. B. K.

Acaulescent perennial, with thick root, pubescent herbage; leaves oblong-lanceolate, 7—30 cm. long, 2—3 cm. wide.

Coast of California, mostly on clay-bluffs, or in moist alkaline soil away from coast.

P. lanceolata L.

Perennial; rootstock short, woody; leaves erect, spreading, lanceolate, 5—10 cm. long, somewhat hairy, tapering into a petiole at base.

Common in Europe and temperate Asia, whence introduced to many parts of the globe. Not confined to sea coasts, but occurs frequently on marine sands.

P. maritima L.

Low perennial herb, with fleshy linear leaves, pointed, entire or slightly toothed.

Marine coasts of Europe, Asia, South Africa, Patagonia, North America (along the Atlantic and Pacific Oceans). Occasionally inland in Europe in high mountains.

P. psyllium L.

Annual herb, with erect branched stem; leaves narrow linear-lanceolate, pubescent.

Common in the Mediterranean countries. Occurs often on the sea shore sands, but is not confined to these.

NYCTAGINACEAE.

Abronia latifolia Esch.

Perennial, succulent herb with stout stems, 3—6 dm. long, prostrate, only leaves and flowering peduncles ascending and erect; leaves broadly ovate to suborbicular, broader than long, truncate at base, 1—4 cm. long; petioles longer than leaves; calyx yellow.

Sand dunes on coast of California from Monterey northward.

A. maritima Nutt.

Stout, prostrate, pubescent, viscid; leaves thick, broadly ovate, rounded at base, 3 cm. long, petioles short, flowers red.

Coast of California from Santa Barbara to San Diego.

Greatly resembles previous form in habit.

A. umbellata Lam.

Perennial, with slender, prostrate stems, 2—10 dm. long, viscid; leaves almost glabrous, roundish ovate, the margin often sinuate, 2—4 cm. long, narrowed at base to a slender petiole; calyx rose-purple.

Sand dunes along coast of California from Columbia River to Lower California.

PROTEACEAE.

Banksia marginata Cav.

Common on coastal sand dunes at St. Vincent's Gulf in South Australia (Tepper), but not confined to coast.

Several other species of this genus occur on the dunes of Victoria and Western Australia, as well as on those on the Queensland coast.

ILLICEBRACEAE.

Corrigiola litoralis L.

Annual, with numerous stems, procumbent or ascending, slender, glabrous; leaves linear, obtuse, tapering at base.

On sandy sea shores of western and southern Europe, and on the Mediterranean coasts. Sometimes in the interior of Europe.

Pentacaena ramosissima H. & A.

Perennial herb, tufted; prostrate stems forming dense mats, 12—45 cm. broad, pubescent; subulate pungent leaves crowded on the stems, 1 cm. long; silvery-hyaline stipules, ½ or nearly as long.

Coast of California. Abundant on dunes at San Francisco and Pacific Grove.

CHENOPODIACEAE.

Atriplex Billardieri Hook. f.

Much-branched herb, prostrate, succulent, spreading, covered with papillas like Mesembryanthemum; leaves shortly petiolate, ovate, obtuse, entire, 5—15 mm. long.

Sandy beaches near highwatermark. Coasts of Victoria, Tasmania, and New Zealand.

A. californica Moquin.

Perennial herb; prostrate stems, wiry, slender, mostly herbaceous, often much branched and forming a thick mat; root cylindrical, large, 1—3 cm. thick, fleshy; herbage greenish, finely white-mealy or somewhat glabrate in age; leaves thinnish, ovate-lanceolate, 5—17 mm. long, sessile or narrowed at base into a short petiole.

Sandy beaches of California, from San Francisco to San Diego.

A. cinerea Poir.

Branching shrub, whitish with a scaly tomentum; leaves lanceolate or oblong, obtuse, entire, petiolate, 1—5 cm. long.

Coast of Tasmania and Australia. Observed by the writer at Moreton Bay, Queensland; Botany Bay, New South Wales; Port Phillip, Victoria; Port Adelaide, South Australia; Fremantle, West Australia.

A. hastata L.

Annual, slender, with 3—7 dm. long, ascending branches; herbage mealy, scarcely succulent; leaves triangular-hastate, entire or sinuate-dentate, 2—5 cm. long, often as broad or broader, petioles 8—12 mm. long.

Coasts of Europe and Northern Asia.

A. leucophylla Dietr.

Perennial herb, with prostrate stems, densely light brown-scurfy, 3—12 dm. long, somewhat woody at base, many short ascending branches; leaves thick, orbicular to elliptic, 10—25 mm. long, sessile, 3-nerved.

Sand formations on the coast of California, from San Francisco southward to San Diego.

A. patula L.

Annual, stout, succulent, erect or prostrate, 25—50 cm. high, with few ascending branches; herbage green, only the growing parts somewhat mealy; leaves petiolate, the lowest often opposite, lanceolate-hastate, coarsely toothed, 4 cm. long, the upper lanceolate, entire.

Widely dispersed in Europe, Asia, and Africa northward to the Arctic. Introduced to Tasmania and Australia, where found in neighborhood of cities. Also near San Francisco.

Several other species and forms of *Chenopodium* occur on various coasts, but the author has not studied this genus sufficiently to be able to discuss the geographical distribution of these greatly varying forms.

Beta maritima L.

Perennial, with erect or spreading branched stems, 3—6 dm. high; leaves large, broad, fleshy, green, the upper small, narrow; flowers green.

Coastal sands of Europe, Western Asia, and North Africa, especially in localities where the sand is mixed with silt.

Chenopodium californicum Wats.

Perennial, stout, erect or decumbent at base, 4—7 dm. high from a large simple or branched root; herbage green, very little mealy; leaves broadly triangular, truncate or cordate at base, unequally sinuate-dentate, 3—i cm. long, petioles 2—10 cm. long.

Sand dunes of California from Pacific Grove southwards, but is not confined to the coast.

Ch. glaucum L.

Much-branched, diffuse annual, prostrate at base, stems ascending 3—6 dm., glabrous, striate, furrowed; leaves petiolate, the lower lanceolate, coarsely sinuate-toothed, 1—4 cm. long, the upper gradually smaller, narrower, almost entire, all green above and whitish underneath.

On middle beach of sea coasts in Europe, temperate Asia, Australia, Tasmania, New Zealand.

Other species of this genus are often found on coastal sands, but are not confined to these locations.

Kochia hirsuta Nolte.

Annual, with erect, ascendent or procumbent stems; leaves terete, filiform.

Sea shores and saline places in France, Belgium, Denmark, Northern Italy, and some places along the Baltic. Also in Western Asia.

Several related species are found in Australia, both on coastal and inland saline sands. At Port Adelaide, South Australia, Fremantle and Albany, West Australia, the author found specimens belonging to this genus, but was not able to identify them.

Rhagodia Billardieri R. Br.

Diffuse shrub, foliage fleshy, covered with mealy tomentum; leaves alternate, linear or lanceolate, obtuse, petiolate, 1—3 cm. long, green above and white underneath, margins recurved.

Abundant on many places of the American coast, as in West Australia, at St. Vincent's Gulf, S. A., in Victoria (Port Phillip). Also found in New South Wales and Tasmania.

Salicornia ambigua Michx.

Perennial succulent herb, with leafless, 12—30 cm. long jointed stems, from woody rootstocks, erect or decumbent and rooting at the joints; herbage greenish; branches opposite; spikes slender, terminal, not thicker than the sterile portions of the stem.

Coasts of North America, from New England to Florida, and from Oregon to San Francisco. Like all other species of this genus it usually grows in salt marshes, but is also found in lagoons and moist places between the dunes.

S. arbuscula R. Br.

Erect, bushy shrub, 15—90 cm. high, with numerous short and slender branches, internodes dilated at top.

Sea coast of Australia and Tasmania, but also in some places in the interior in saline soil.

S. australis Sol.

Procumbent stems, woody at base, with erect branches, 5—12 cm. high, internodes not dilated at end, usually terete or sometimes 2-lobed.

On sea coasts of Australia, Tasmania, and New Zealand, avoiding dry sandy places. Collected by the writer in Victoria and Western Australia.

S. herbacea L.

Annual, glabrous, bright green or reddish, succulent, erect, 10—15 cm. high, with a few erect branches, shooting from nodes.

Coasts of Europe, temperate Asia (also in the interior), and Eastern North America.

Salsola kali L.

Annual, procumbent, glabrous or seldom somewhat pubescent, 15—45 cm. high; leaves alternate, sessile, hard and rigid, the lower terete or dilate at base, 2—6 cm. long, the upper shorter, thicker, flattened above.

Sea coasts of temperate and sometimes tropical countries. In Australia also in the interior.

Suaeda maritima Dumortier.

Much-branched annual or biennial, erect, 15—45 cm. high or spreading, glabrous, succulent, with a hard and sometimes woody base; leaves alternate, sessile, linear, of green reddish color.

Sea coasts of Europe, temperate Asia, and America. Also in New Zealand, Tasmania, and Australia, where the plant is more suffrutescent.

BATIDAE.

Batis maritima L.

Low shrub, approaching *Chenopodium* in general appearance, occurring on the sea ocasts in West Indies, Florida, and Hawaiian Islands, principally on muddy shores, but also at times on sand.

POLYGONACEAE.

Chorizanthe pungens Benth.

Annual, with prostrate branches, 5—30 cm. long; leaves spatulate, 1—3 cm. long, opposite, petioles of cauline leaves 10 mm. long, those of the radical 25 mm.

Sand hills on Californian coast, from San Francisco to Monterey Bay.

Eriogonum latifolium Smith.

Perennial herb, stout, tomentose, the indurated caudex with short leafy branches; leaves 2—5 cm. long, oblong to ovate, obtuse or acute at apex, rounded or cordate at base, margin often undulate, upper surface glabrate, densely woolly beneath; petioles often margined.

Sand formations along California coast, occasionally together with other species of the genus.

Muehlenbeckia adpressa Meissn.

Stem woody at base, prostrate or climbing; leaves petiolate, lanceolate or hastate, obtuse, 2—7 cm. long, margins crisped, glabrous; flowers small, green.

On the sea coast of Tasmania, Victoria, South Australia, and West Australia (Fremantle).

M. complexa Meissn. is a species occasionally occurring on sea beaches of North Cape, New Zealand.

Polygonum aviculare L.

Annual herb, prostrate, with branches leafy to the end, glabrous and green, stems wiry, minutely striate, sometimes meterlong; leaves oblong, acute, 1—2 cm. long, shortly petiolate.

Almost everywhere on the globe, especially in temperate climates.

Very variable, especially on sea shores, where a number of forms occur, as yet insufficiently known.

P maritimum L.

Perennial, somewhat woody; branches short, thick; leaves glaucous, thick, larger than in *P. aviculare,* which it resembles, especially when young.

P. Rayi Bab.

is a nearly related form, differing only in the fruits.

The distribution of these forms is not well known, but they are found in a number of widely separated localities.

P. paronychia Cham. & Schlecht.

Suffrutescent perennial, with prostrate or ascending stems, 3—10 dm. long, branches leafy above, clothed below with old sheaths; these large, 1—2 cm. long, brown and 5-nerved, margin lacerate above, persistent, the segments becoming hairlike in age; leaves linear-lanceolate, 15—30 mm. long, acute, the margin revolute.

Coastal sand dunes of California, from Pacific Grove to Puget Sound.

Rumex acetosella L.

Perennial herb, with tufted stems, often running red, about 25 cm. high, creeping rhizome; radical and lower leaves hastate or sagittate, the upper reduced or branches leafless, and ending in the reddish (pistillate) or yellowish (staminate) panicle.

Common in most temperate and subtropical countries, often occurring on coastal sands, but not confined to these.

R. conglomeratus Murr.

Perennial herb, with slender, mostly clustered stems, 10—12 dm. high; leaves oblong or ovate, slightly undulate, 10 cm. long, reduced above, petiolate, rounded at base.

Dispersed in Europe, temperate Asia, Australia, and California, apparently introduced into the two last mentioned countries. Sometimes on coastal sands, f. i. at Pacific Grove, California, where it has a characteristic prostrate form.

R. crispus L.

Perennial, with thick rhizome, stems furrowed, stoutish, 6—10 dm. high; leaves bluish green, the radical narrow-elliptical to oblong-lanceolate, strongly undulated with crisp margins, the base often decurrent upon the petiole, up to 20 cm. long, the upper smaller, passing gradually into bracts.

Common in Europe and temperate Asia, especially on roadsides and waste places, but also on sea shores. Also in North America and Australia, where supposed to be introduced.

R. maritimus L.

Annual or sometimes biennial, with stem 3—4 dm. high, much branched, minutely pubescent, erect or procumbent; leaves linear-lanceolate.

Beaches and marshes, especially near the sea, but also inland. Europe, temperate Asia, Atlantic coast, and interior valleys of North America.

THYMELAEACEAE.

Pimelea arenaria A. Cunn.

This plant, characteristic for the driftsands of New Zealand and Chatham Island, is described by Cockayne[1] in the following words:

" The long cord-like underground stems put forth adventitious roots near their extremities, which latter, bending upwards, raise themselves above the encroaching sand. The leaves are all most densely silky on the under surface, a most efficient protection against excessive transpiration. Owing to the leafy extremities of the stems being erect, the semi-rosettes of leaves can receive the incident light to the best advantage.

"It is probable that the oldest portions of the plant—*i. e.*, the most deeply buried portions—die, while the plant continues to increase by the rooting of its terminal shoots."

P. prostrata Willd. is another species also found on North Cape of New Zealand.

P. serpyllifolia R. Br.

Low shrub, rigid, densely branched, glabrous; leaves opposite, ovate or oblong, coriaceous, somewhat concave; flowers small, yellow.

Common on coastal sands of Victoria, South and West Australia, but mostly in the interior. Also in Tasmania.

ELAEAGNACEAE.

Hippophaë rhamnoides L.

Shrub, 3—12 dm. high, with a scaly scurf, silvery on under surface of the leaves, thin on upper side—rusty on young shoots; axillary shoots ending in a prickle; leaves alternate, linear, entire.

Common in Europe, Central and North Asia.

EUPHORBIACEAE.

Adriana tomentosa Gaudich.

Shrub, 6—12 dm. high, covered with a stellate tomentum; leaves alternate, usually glabrous on upper side, petiolate, deeply 3-lobed, with narrow, obtuse lobes.

Sand dunes of South Australia (according to Tepper), coast of North and Northwest Australia.

Beyeria opaca F. Muell.

Erect shrub, 3—6 dm. high; leaves oblong or linear, obtuse, with revolute margins, white underneath.

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1) A short account of the plant covering of Chatham Island, p. 260.

Sea coasts of Victoria, South Australia, and Tasmania.

Closely related to following species.

B. viscosa Miq.

Tall shrub, flowering branches viscid; leaves oblong-lanceolate, obtuse, petiolate, margins recurved, glabrous above, white-tomentose underneath, 2—5 cm. long.

Coastal sands of Moreton Bay, Queensland, Victoria, and Western Australia (Perth). Also in Tasmania and the interior of New South Wales.

Croton californicus Muell.

Perennial herb, suffrutescent at base, with branching stem, erect or diffuse; 4—12 dm. high; herbage hoary, upper side of leaves green, finely stellate-pubescent; leaves oblong, 2—4 cm. long; petioles 1—3 cm. long, staminate plant more slender and shorter branched.

Coastal sand dunes of California, from San Francisco to Los Angeles.

Euphorbia atoto Forst.

Diffuse, glabrous perennial, 30—45 cm. high, branches slender; leaves opposite, shortly petiolate, oblong, obtuse, more or less cordate, thick, 2—3 cm. long.

Sea coasts of East India, Malayan Archipelago, Islands of Pacific, North Australia, and Queensland southward to Moreton Bay.

E. glauca Forst.

is a specimen common on dunes in New Zealand.

E. Paralias L.

Perennial, with short, hard, almost woody stock and erect stems, 15—25 cm. high; leaves short, concave, leathery, pale green.

On coastal sands from Belgium southward in Europe, and extending into Mediterranean. Also on the southern coasts of British Islands.

E. terracina L. var. *retusa.*

Perennial, with long stolons; leaves linear-lanceolate to oblong-linear; very glaucous.

Coastal sands of the Mediterranean countries, Canary Islands, Azores, and Medeira. Very common on the dunes of Spain.

Ricinocarpus cyanescens Muell.

occurs on coastal sands in Western Australia together with several other species, not sufficiently studied by the author. At Moreton Bay *R. pinifolius* Desf. was found, and near Port Fairy, Victoria, a plant, probably the same species. This genus is not confined to the coast.

URTICACEAE.

Urtica dioica L. and *U. urens* L.

are not infrequently found on coast formations of the Baltic, but are immigrants from inland.

MYRICACEAE.

Myrica californica Cham.

Densely branched evergreen shrub, with fragrant alternate, simple, almost entire or serrate leaves, thick, glabrous, oblong, tapering above to an acute apex, narrowing below to a petiole, 7—12 cm. long; fruit globose, purplish-brown, covered with a coat of whitish wax, 6 mm. in diameter.

Sand dunes on coast of California, and ravines of outer coast ranges.

CASUARINEAE.

Casuarina quadrivalvis Labill.

and several other species occur on the dunes of Australia, especially in Victoria, South and West Australia, but their range is principally inland.

CUPULIFERAE.

Quercus agrifolia Née

in a low, prostrate form is found on coastal dunes of California, f. i. at Seaside, Monterey.

SALICACEAE.

Salix caprea L.

Tall shrub, with large, ovate leaves, grayish green, tomentose underneath, entire.

European and North Asian species, often planted on dunes of Germany.

S. daphnoides Vill.

Low tree or tall shrub, with oblong-lanceolate leaves, serrate, glabrous above, glaucous underneath.

Often on dunes along the Baltic coasts. Extends also in to Central Russia and Siberia.

S. lasiolepis Benth.

Tree or large shrub, with oblong leaves, somewhat serrulate, dull green above, gray-pubescent beneath.

On dunes of California, especially near San Francisco. Extends also inland.

Salix repens L.

Low, straggling shrub, with stems creeping underground, rooting at base, ascending to 3—6 dm.; foliage silky-white; leaves oblong-lanceolate, 2 cm. long, entire, silky on both sides.

On sand formations of Europe and Northern Asia.

Several varieties, especially *argentea* Sm., are met with on dunes of Northern Europe.

S. viminalis L.

Shrub, with long branches, 7—15 cm. long leaves, silvery white underneath.

In wet places in Europe and Northern Asia.

Several other species, such as *S. nigricans* Sm., *S. cinerea* L., *S. aurita* L., *S. purpurea* L., *S. pentandra* L., *S. dasyclados* Wimm., *S. fragilis* L., *S. alba* L., and *S. amygdalina* L., are found occasionally on the dunes of the Baltic.

CONIFERAE.

Callitris robusta R. Br.

often occurs on the dunes of Australia, but is not confined to the coast.

Juniperus communis L.

is common on the sand formations of the Northern Baltic, and sometimes occurs in a low prostrate form, similar in habit to the variety *nana,* which does not, however, grow on sand in the Finnish Archipelago, where it occurs.

Pinus maritima Lam.

Large tree, with branches in whorls; leaves in twos, dark green, 15—20 cm. long, rigid, stout; cones from 10—15 cm. long, about 6 cm. broad, growing in clusters of from 4—8 or more.

Common on sand dunes of the Mediterranean countries, and is extensively planted on the dunes of Western France; its occurrence in India, Australia, New Zealand, Japan, and China is usually attributed to artificial planting.

P. radiata Don.

is found only on the established dunes and immediately inland from these at Pacific Grove, and within a limited area in two other similar localities, one in San Luis Obispo county, one in Santa Cruz county, California.

HYDROCHARIDACEAE.

Halophila ovalis Hook. f.

Submerged marine plant, common on the shores of Moreton Bay, Queensland, and Port Phillip, Victoria. Also in Tasmania, New South Wales, and South Australia, preferring muddy shores, but also on sand.

IRIDACEAE.

Sisyrrhinchium bellum Wats.

A somewhat prostrate, low form is found on the dunes at Point Pinos, Monterey, California, but it is not a different species, as it will under cultivation in moist, rich soil exhibit exactly the same characters as the inland form. This was tested by the author at Stanford University in the summer of 1904.

AMARYLLIDEAE.

Pancratium maritimum B.

Perennial herb, with large bulb; leaves erect, long, broadly linear, glaucous.

Sandy sea shores of Western France, Iberian Peninsula, and Mediterranean countries.

LILIACEAE.

Allium arenarium L.

Stem 25—35 cm. high, single; leaves cylindrical, hollow, furrowed above, with long sheaths; flowers red.

Sand in a few places on the Baltic coasts.

A. schoenoprasum L.

Stems 2—3 dm. high, usually many together; leaves narrow, cylindrical, hollow, one sheathing the stem at base.

In Northern Europe and Asia, and in mountains in Southern Europe. Britton & Brown (Flora of Northern United States and Canada) say regarding its distribution in America:

"In moist or wet soil, New Brunswick to Alaska, south to Maine, northern New York, Michigan, Wyoming, and Washington."

Asparagus officinalis L.

Perennial, with creeping rootstock, and annual branching stems, erect, 3—6 dm. high; leaves short, subulate; flowers small, greenish white.

On marine sands of Western Asia, Mediterranean, and Western Europe northward to English Channel; escapes to similar localities in E. America, according to Professor Dudley.

JUNCACEAE.

Juncus acutus L.

A form closely approaching *J. maritimus* Lam. and found on marine sands on the Atlantic and Mediterranean coasts of Europe, and on the Caspian Sea, but not on the Baltic or North Sea, nor in the Southern hemisphere.

J. anceps Laharpe var. *atricapillus* Buch.

Rootstock creeping; stems erect, compressed, leafy.

Observed only between the dunes on the E. Friesian Islands off the German shore of the North Sea.

J. balticus Willd.

Rootstock creeping; stems hard, 3—6 dm. high, cylindrical, leafless, sheathed at base by brown scales.

In high northern latitudes in Europe, Asia, and America, found as far south in the United States as California. Not confined to coastal sands.

J. bufonius L.

Small annual, pale-colored; stems numerous, tufted, 3—20 cm. high, branching; leaves short, slender.

Occurs almost everywhere, and is common in moist places between the dunes.

J. capitatus Weig.

Annual, slender, tufted, 5—8 cm. high; stems numerous; leaves short, slender.

Marine sands of Southern Sweden, Northern Germany, Holland, Western and Southern Europe.

J. compressus Jacq. var. *Gerardi* Bab.

Perennial, with creeping rootstock; stems 30—45 cm. high, erect, slender, compressed at base, with a few radical leaves, narrow, grooved.

Common in Europe, from Mediterranean to the Arctic, and in Northern Asia.

J. falcatus Mey.

Perennial, with slender, creeping rootstock; stems 15—25 cm. high, leafy, terete, in compressed tufts.

Driftsand at Pacific Grove, San Francisco and other places on Californian coast.

J. maritimus Lam.

Perennial, with densely tufted stems, horizontal rhizome, rigid, 6—10 dm. high, with sheathing scales at base, of which one or two inner ones terminate in a rigid, terete, pungent stem-like leaf, shorter than the real stems; flowers in little clusters.

In maritime marshes and moist sands on shores of Atlantic North America, Europe from Mediterranean to the Baltic, where rare, Caspian Sea, and in New Zealand, Tasmania, and Australia from Queensland to Western Australia. Also in the interior of Australia.

NAJADACEAE.

Najas marina L.

Slender, branching, submerged plant, with stout stems, often armed with prickles twice as long as their breadth; leaves linear, with 6—10 spine-pointed teeth on each margin; the broad sheathing base entire or with few teeth on each side.

Widely distributed in Europe, temperate and tropical Asia, Algeria. North America, West Indies, Brazil, Australia, and Hawaiian Islands.

Phyllospadix Scouleri Hook.

Submerged maritime herb, with elongated, narrow-linear, radical leaves, 1.5—5 mm. wide, from much-branched, creeping, brittle rootstock.

Together with another species, *R. Torreyi* Wats., from which it does not differ essentially in habit, growing on sand covered stones and rocks on the submerged beach of the Pacific coast of North America.

Potamogeton marinus L.

Perennial marine plant, with filiform, branched stem; very leafy: leaves narrow-linear, 5—15 cm. long, 1 mm. broad.

In salt water in Europe and North America. Often confused with the following species.

P. pectinatus L.

Perennial marine plant, with threadlike stem, very narrow leaves, 5—8 cm. long, sheathing at base.

On submerged beaches of Europe and North America. In some cases in inland waters of the latter continent.

Ruppia maritima L.

Submerged aquatic herb, with 6—10 dm. long, filiform forking stems; leaves 5—8 cm. long, almost capillary, with a broad sheathing base.

In salt and brackish water over nearly the whole globe, excepting South America. Also in the interior of North America.

Very variable and divided into several species.

Triglochin maritimum L.

Perennial, with short rootstock, the terminal portion of which is covered with the sheaths of old leaves; stem 15—45 cm. high; leaves about 5 mm. wide, fleshy with membranous sheaths.

Coasts of Europe, Asia, and North America. Also in interior of latter continent in saline situations. On Pacific coast from San Francisco northward to Arctic Ocean.

T. striatum Ruiz. & Pavon.

Rootstock small, stoloniferous; leaves narrow-linear, shorter than the scape; fruits nearly orbicular.

Brackish water in North America, extratropical South America, New Zealand, Tasmania, and Australia from Moreton Bay along south coast to Fremantle.

Zanichellia palustris L.

Inconspicuous submerged aquatic, with capillary stems and leaves; these alternate or mostly opposite, 1—3 cm. long.

Widely spread over the whole globe. Often in ponds between dunes.

Zostera marina L.

Submerged maritime perennial, with elongated and very narrow grass-like leaves, with sheathing bases, 3—7-nerved, 3—10 dm. long, 5—12 mm. broad, obtuse.

In shallow water on submerged beach, especially on mud, on coasts of Europe, North Eastern Asia, Arctic and North Atlantic coast of North America, and on the Pacific coast at least as far south as San Pedro, California (Dudley).

Z. nana Roth.

Submerged marine plant, with creeping rhizome, emitting short stems; leaves narrow-linear, grass-like, 3—6 dm. long, notched at the end, base narrow and sheathing.

Coasts of Europe, South Africa, Japan, New Zealand, Tasmania, and on the southern coasts of Australia.

RESTIACEAE.

Leptocarpus simplex A. Rich.

In swamps and swampy saline stations, and also frequently on dunes, in New Zealand.

CYPERACEAE.

Carex arenaria L.

Perennial, with creeping rootstock, emitting small tufts, 7—40 cm. high, leafy at base; culms erect, slender, slightly scabrous above; leaves very long, pointed.

Marine sands of Europe, Western Asia, and Virginia, where adventive from Europe (Britton & Brown).

C. distans L.

Stems 25—40 cm. high, tufted, obtusely angled, smooth; leaves short, narrow, rigid; margins scabrous.

Common on sea coasts of Europe and Western Asia, occurring from Mediterranean to Scandinavia.

C. extensa Gooden.

Perennial, tufted, slender, 3—6 dm. high; leaves narrow, stiff, erect, often convolute.

On marine coasts of Europe from Mediterranean to the Baltic.

C. halophila F. Nyl.

Stems obtusely angled, slender, 3—5 dm. high; leaves broad, of yellowish-green color.

Sea shores of northern part of Gulf of Bothnia.

C. Hookeriana Dewey.

Perennial, with creeping rootstock, clothed with imbricated, nerved, purplish scales; stems 10—30 cm. high, sharply angled, scabrous; leaves shorter than stem.

Sand dunes on coast of California. Also in interior of North America and Europe.

C. maritima Muell.

Stems obtusely angled, smooth, clothed at base with sheaths breaking up into threadlike fibers; leaves broad, pale.

Sea shores of the Baltic.

C. pumila Thunberg.

Rhizomes creeping, stems 10—20 cm. high; leaves longer, rigid with subulate points.

On sandy shores of extratropical South America, New Zealand, Chatham Island, Tasmania, and Australia, from Moreton Bay to South Australia.

C. salina Wahl.

Perennial, with creeping rootstock, stem 6—12 cm. high, obtusely angled, smooth; leaves pale, 2—3 mm. broad.

Sea shores of Northern Europe and America, from the Arctic to New England on the east coast, and to Northern California on the Pacific coast.

Eleocharis uniglumis Link.

Perennial by horizontal creeping rootstocks; culms stout, terete or somewhat compressed, caespitose, striate, 15—30 cm. high, higher when in water; leafless, with one or two sheaths at the base.

Widely distributed in Europe, Asia, North America, from Canada to California.

Lepidosperma gladiata Labill.

Perennial rhizome; rigid stems, 1—12 dm. high, flattened, but convex on both sides about center, with acute smooth margins; leaves equitant, usually about 1 cm. broad, length of stem.

Common on coastal sand dunes in Tasmania and Australia, especially in Victoria, South and West Australia. On the western coast of Australia also other species of this genus are met with.

Remirea maritima Aubl.

Low, branching perennial; stems from creeping and rooting base, ascending, 7—10 cm. high; leaves rigid, 2—7 cm. long, linear, with short, imbricate sheathing bases, pungent point.

Sandy sea coasts of most tropical countries. Africa, East India, Malayan Archipelago, Queensland, tropical America.

Scirpus americanus Pers.

Perennial; stem 3—6 dm. high, slender, triangular, continued as an entire pungent involucre 4—10 cm. beyond the inflorescence.

In moist places and brackish lagoons between dunes on Californian coast. Also in interior of North America.

S. frondosus Banks & Sol.

Cockayne says[1] of this species: "The most characteristic plant of the whole New Zealand area. It can form settlements and hold its own positions where no other New Zealand flowering-plant can exist, and only the most constant and furious winds can destroy a dune where it is properly established. Indeed, for sandbinding power it is probably not equalled either by *Ammophila arenaria* or by *Elymus arenarius.*"

S. maritimus L.

Perennial, with creeping rhizome, often thickened into hard tubers; stem 3—10 dm. high, triangular, smooth; leaves often longer than stems.

Common in tropical and temperate countries. In Australia from Queensland to Western Australia, especially frequent on coastal sands.

S. nodosus Rottb.

Creeping rhizome; stems rigid, rush-like, terete or slightly flattened, 3—10 dm. high, leafless, except the sheathing scales at the base.

In South Africa, extratropical South America, several Oceanic Islands, New Zealand, and Australia, from east to west along the coast.

S. rufus (Huds.) Schrad.

Perennial, with slender rootstock; culms tufted, smooth, slender, erect, compressed, 7—30 cm. high; leaves terete, smooth, channeled, the lowest sheathing.

In Northern Europe and Canada, seldom, however, on sand.

S. pungens Vahl.

Perennial, with creeping rhizome; stem slender, 3—9 dm. high, acutely triangular; leaves few, 1 or 2 sheathing.

Western part of Mediterranean, extratropical North and South America, New Zealand, and Australia.

GRAMINEAE.

Agropyron arenicolum Davy

is a maritime dune grass found at Point Reyes in California.

1) l. c. p. 261.

A. junceum Beauv.

Perennial grass, with pungent leaves, rigid; roots extensively creeping. Sea coasts of Europe and Northern Africa on drifting sands.

A. repens L. var. *litoreum* Schum.

Perennial, with creeping jointed rootstock; stiff, ascending stems; sheaths shorter than internodes.

Common on coastal sands of Europe, Asia, and North America; also in the interior of the latter continent.

A. scabrum Beauv.

Common on dunes in New Zealand and Australia, but also inland.

Agrostis alba L. var. *maritima* G. Meyer.

Perennial, stoloniferous; stems decumbent at base, 3—9 dm. high; leaves rigid, glaucous, scabrous, 7—15 cm. long.

Grows especially in moist places between the dunes. Baltic south coast.

Ammophila arenaria (L.) Link.

Tall perennial grass, with long rigid leaves; creeping rootstock; stems 6—12 dm. high, sheaths long; blades convolute and polished without, scabrous and glaucous within.

Coastal sands of Europe, North Africa, and North America. Introduced to many other countries as an effective sandstay.

A. baltica Link.

Is by most authors considered to be a hybrid of the former species, which it resembles in habit, and *Calamagrostis epigea*. This is, however, not yet proved by experiments. Occurs on coastal sand dunes of Northern Germany and Southern Sweden.

Andropogon provincialis Lam.

Perennial grass, with erect culms, smooth and glabrous, 10—15 dm. high; leaves smooth, acuminate.

Southern Europe, where often planted on dunes. *A. furcatus* Muhl. is a North American form with a wide range along the eastern sea board. By some authors, as Hackel, it is considered to be identical with *A. provincialis.*

Aristida plumosa L.

Perennial caespitose grass, with ascendent culms; leaves acute filiform.

Northern Africa, both on the coast and inland. *A. pungens* Desf. is another grass from Northern Africa, which not infrequently is planted on sand dunes on the coasts of Mediterranean.

Arundo conspicua Forst.

Abundant on sand dunes of New Zealand, but also distributed inland.

Avena praecox P. B.

Slender annual, densely tufted, 7—15 cm. high; leaves short.

Coastal and inland sands, Central and Southern Europe.

Calamagrostis epigea Roth.

Perennial, with creeping rootstock; stems 10—13 dm. high, erect, firm; leaves long, narrow, somewhat glaucous.

Widely dispersed over Europe and Western Asia. Not confined to coastal sands.

Corynephorus canescens Bernh.

Small tufted perennial, 10—15 cm high; leaves fine, convolute.

Sand formations of Southern and Central Europe, eastward to Caucasus and northward to Southern Sweden. In Norfolk and Suffolk, England, on sea shores.

Cynodon dactylon (L.) Pers.

Perennial grass, with prostrate, creeping and rooting stems, sometimes very long, covered with undeveloped, striate sheaths; roots and tufts of leaves produced at the nodes; blades 2—5 cm. long, stiff, glaucous green.

In all hot and some temperate countries, such as Southern Europe, whence it ranges to Northern France, and Australia. Not confined to coastal sands, but often a roadside weed, as in California, where it is introduced.

Dactylis litoralis Willd.

Perennial grass, with long creeping stolons; leaves rigid, glaucous.

Coasts of Mediterranean, but also on the salt steppes of Eastern Europe and Western Asia.

Distichlis maritima Raf.

Perennial grass, with stout, creeping, scaly rootstock; stems stout, rigid, erect, 10—45 cm. high, often branched below, leafy; leaves pale green, narrow, rigid, very acute, strictly 2-ranked; sheaths glabrous, slightly bearded at the base; ligule reduced to a mere ring, blade 5—15 cm. long, spreading, rigid; margins minutely ciliate.

Varies somewhat, being shorter and more rigid in some places with shorter, stiffer, and more distinctly distichous leaves.

Common near salt and brackish water in America, Tasmania, and Australia. Characteristic on coastal dunes of Victoria and South Australia.

Elymus arenarius L.

Glaucus perennial grass, with stout, widely creeping stoloniferous rootstock; stems tall, rigid, stout, erect, 1—2 m. high; sheaths smooth, channeled; ligule a narrow truncate ring; blades 30—45 cm. long, 10—15 mm. wide, flat or with more or less convolute margins below.

Coastal sands of northern hemisphere. In North America from Greenland and Labrador to Alaska, southward to Maine, Lake Superior and California (San Francisco). Occasionally inland also in Europe.

Festuca litoralis Lab.

Stems 3—10 dm. high, forming dense tufts of pale yellow color; leaves almost cylindrical, erect, rigid, pungent-pointed, glabrous, length of the stem.

Common on coastal sand dunes of New Zealand and adjacent islands, Tasmania and Australia, from Wide Bay, Queensland, to Western Australia.

F. ovina L.

Perennial, densely tufted, 15—50 cm. high; leaves radical, narrow, almost cylindrical.

Common on established dunes, but not confined to coast.

F. rubra L. var. *arenaria* Osbeck.

Perennial, with creeping rootstock, shooting stout, reddish stolons; stems ascending, rigid, hairy; leaves stiff, on upper side grayish green, darker beneath. Resembles much *Agropyrum junceum.*

Common on the coasts of Baltic.

F. uniglumis Sol.

Annual, tufted, 10—15 cm. high; leaves narrow, convolute.

On sandy shores of Mediterranean and on coast of Western Europe northward to England.

Glyceria maritima Reich.

Perennial, with creeping rootstock; stems decumbent or erect, 2—6 dm. high; leaves smooth, glabrous, short, narrow, convolute; sheaths exceeding internodes.

Coastal sands of Europe, Western Asia, Mediterranean, and North America, from Nova Scotia to Rhode Island on the Eastern coast, and on the Pacific to San Francisco.

G. stricta Hook. f.

Tufted, glabrous, erect annual, 3—5 dm. high; leaves narrow, erect, with broad sheaths.

On sea shores of New Zealand, Tasmania, and Australia, from Victoria to Western Australia.

Hordeum maritimum With.

Annual, coarse, tufted, stems decumbent at base, 3—6 dm long; glaucous.

Marine coasts of Western Europe, and of the Mediterranean.

Imperata arundinacea Cyrillo.

Perennial grass, with long roots and 3—10 dm. high erect culms; leaves erect, narrow, often longer than the stem.

Widely distributed in the Mediterranean countries, Southern and Western Asia, Cape Colony, Australia, and Polynesia. Often planted as a sandstay especially in wet localities.

Ischaemum muticum L.

On tropical coasts of Asia, Polynesia, and Queensland, southward to Rockingham Bay.

Koeleria cristata (L.) Pers.

Tufted, pale green, pubescent or silky perennial; stoloniferous rootstock; stem 3—9 dm. high, slender; sheaths striate, ligule very short; blades narrow, obliquely auriculate at the base.

A very variable plant, common on coastal sand dunes, but not confined to these, in Europe, Central Asia, America, New Zealand, and in a few places in Australia (probably introduced).

Lagurus ovatus L.

Annual, erect, 10—30 cm. high, leaves hoary, sheaths swollen.

Common on coastal sands of Western Europe, from Mediterranean to the English Channel.

Lepturus incurvatus Trin.

Annual, decumbent, much branched at base; 10—30 cm. high, with short, fine leaves.

Fig. 16. Sandy shore on St. Croix, Danish West Indies, with *Coccoloba* community.
PHOTOGRAPH BY BORGESEN.

On marine coasts of Europe, from English Channel along west coast to Mediterranean and Caspian Sea.

L. repens R. Br.

Perennial, creeping grass, with branching stems; leaves spreading, glaucous, glabrous.

Drifting sand on some islands of the tropical coast of Queensland and in Southern Pacific.

Paspalum distichum L.

Stems creeping and rooting, ascending to 4 dm., covered with leaf-sheaths; leaves linear-lanceolate, flat, glabrous.

Widely dispersed in tropical countries, usually on heavy soil, but occasionally on coastal sands. Also in Australia, from Queensland along the southern coast to West Australia, in New Zealand, and in North America from Southern California to Florida.

Phleum arenarium L.

Annual, erect, 5—20 cm. high; leaves short.

Coastal sands of Europe, from Mediterranean to the Baltic.

Poa compressa L.

Perennial, with creeping rootstock; stems erect, 10—30 cm. high, flattened at base; leaves short, with flattened sheaths.

Widely dispersed in Europe, Northern Asia, and North America except the arctic region. Frequently on coastal sands, but not confined to these.

P. Douglasii Nees.

Perennial grass, with slender, widely creeping rootstock; stems tufted, 20 cm. high.

Peculiar to the coastal driftsands of California.

Polypogon litoralis Smith.

Perennial, procumbent, tufted, 3—6 dm. high, leaves short, narrow, scabrous on both sides.

Salt marshes and dune lagoons on sea coasts of Western Europe, Mediterranean, North and South America.

P. monspeliensis Desf.

Annual, procumbent and geniculate at base, 3—5 dm. high; leaves flat, broad, somewhat scabrous; sheaths smooth.

Often on coastal sands, but not confined to these. Widely dispersed in Central Europe, from Holland and France to far into Central Asia, and in North America, from Atlantic coast to California, where it is chiefly found in the mountains. Also in Africa.

Schoenus nitens Hook. f.

Perennial, slender stem from creeping rhizome, 15—30 cm. high; leaves few at base, short, terete, but furrowed along inner side, sheaths not bearded.

Marine coasts of Australia, from Moreton Bay to Western Australia, usually in clayey soil, but also frequently in sand. Also in Tasmania, New Zealand, and extratropical South America.

Spartina stricta Sm. var. *glabra* Muhl.

Perennial grass, with creeping, scaly rootstock, stems erect, stout, 4—12 dm. high, leaf-blades long, flat, smooth, tapering from about 1 cm. wide near the middle to long, slender points; edges rolled inward when dry.

Sea coasts of Europe, from North Sea to Mediterranean, North America, along the Atlantic coast and in a few places on the Pacific.

Spinifex hirsutus Lab.

Stout stems; creeping, forming large tufts; leaves often over 3 dm. long, margins involute, woolly; the male plant has sessile spikes in a terminal head, each spike about 5 cm. long, spikelets sessile in the spike, 15—20 mm. long; the female plant has numerous spikelets in large globular head, the spikelet 20—25 mm. long, acute.

On sandy shores of New Zealand, New Caledonia, Tasmania, and Australia, from Queensland to West Australia.

A slightly differing form, occurring near Fremantle in Western Australia, has been referred to as *S. longifolius* R. Br., but its right as a distinct species is doubtful.

S. squarrosus L.

Resembles foregoing species in habit. The heads are large, radiating, and when the seeds are matured, the heads become detached, and are easily carried by the wind along the sand, thus dispersing their seeds.

On sandy shores of India.

Stipa tenacissima L.

Perennial grass, with long, slender leaves. Resembles in habit

Ammophila arenaria, for which it is a substitute on the dunes of the Iberian Peninsula.

It occurs on sandy tracts everywhere in the western parts of the Mediterranean. A closely allied species, *S. arenaria Brot.,* is found on similar localities in Spain and Portugal.

S. teretifolia Steud.

Perennial; stems in dense tufts, 45—75 cm. high; leaves long, slender, terete.

On middle beach and in salt marshes on coasts of Australia (Western Australia to Victoria), Tasmania, and New Zealand.

Thuarea sarmentosa Pers.

Creeping and rooting perennial, forming short tufts; leaves flat, lanceolate, 3—5 cm. long, densely silky-pubescent on both sides.

On sandy beaches in the tropics from Madagascar to Samoa.

Zoysia pungens Willd.

Rhizome creeping; stems erect, 5—15 cm. high; leaves flat or convolute, with rigid, pungent points, glabrous; spike terminal.

Coastal sands of tropical and Eastern Asia, New Zealand, Tasmania, and Australia, from Moreton Bay to Victoria.

OPHIOGLOSSACEAE.

Ophioglossum arenarium E. G. Britton.

Rootstock slightly thickened, with 1 or 2 stalks, stem rigid, erect, 5—17 cm. high, bearing the sessile lanceolate fleshy leaf below the middle; blade 2—5 cm. long, acute or apiculate.

Gregarious in a colony of many plants in sandy ground under trees at Holly Beach, New Jersey. (Bull. Torr. Bot. Cl. 24: 555. 1897.)

O. vulgatum L.

Perennial rootstock; stem single, 8—15 cm. high, with one oblong, entire leaf, 5—8 cm. long, narrowed into a sheathing footstalk.

Although not confined to the coast this plant is often found on inundated sands in the Finnish Archipelago, and on the Swedish east coast.

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The following list contains the principal works on the subject, but does not pretend to be exhaustive. Several other references will be found in the text, not having been included in the bibliography because of their not being so intimately related to the general subject as to be of interest except in special cases.

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