12. Any diameter of the circle ABC will invert into a rectangular hyperbola.

Let the diameter be taken which is perpendicular to the line $a=o$; the equation of its inverse is

$$\frac{\sin(B-C)}{a}+\frac{\sin B}{\beta}-\frac{\sin C}{\gamma}=o$$

This conic cuts the circle ABC at the extremity H of the diameter which passes through the vertex A of the triangle of reference; it also passes through the points $\left(-\frac{1}{a}\frac{1}{b}\frac{1}{c}\right)$ and the orthocentre of the triangle ABC: its centre is at the middle point of the line BC: the tangent to the conic at A passes through the symmedian point (abc) of the $\triangle$ ABC, while the tangent at H passes through the point $(-abc)$.

ART. XXX.—*Some Observations on the Coastal Vegetation of the South Island of New Zealand.—Part I: General Remarks on the Coastal Plant Covering.*

By L. COCKAYNE, Ph.D.

[*Read before the Philosophical Institute of Canterbury, 8th August,* 1906.]

CONTENTS.

1. INTRODUCTION.

IN this series of papers no attempt will be made to give a detailed description of the whole coastal vegetation of the South Island. This introductory paper is purposely quite general, and intended chiefly to pave the way for future work, and to save repetition when dealing with the formations themselves. As for these latter, only those will be described which I have had some special opportunity of examining during the last few years. Each account will treat of some special part of the coast, and be complete in itself, therefore no classification of the formations will be attempted, nor any such presentation of them in a connected sequence as would be necessary were the coastal vegetation of the South Island as a whole the theme. The treatment of the formations, too, will be far from exhaustive. Such can only be expected from local botanists. Some attempt, however, will be made to give a word-picture of each formation, and details will be furnished regarding the conditions under which such exists, while something will be said as to the life-forms of the most important constituents. As in my former phytogeographical papers, the term "formation" is adhered to on the score of priority,* while that of "association" is restricted to those smaller combinations or groups of plants which are frequently clearly defined within a formation.†

At the conclusion of this paper are included, in the Bibliography, the names of the more important papers referring to my subject. It must, however, be pointed out that these usually contain but little matter of ecological interest, and that for the most part they are lists of plants. In fact, so little has, up to the present time, been published regarding the coastal vegetation of the South Island that I do not consider it necessary to give a summary of our knowledge on the subject.

Properly speaking, the South Island of New Zealand does not form a distinct phytogeographical province. Strange as it may seem, Cook Strait forms no line of demarcation between the North Island and the South Island floras—so far, at any rate, as the lowland region is concerned. It is not until latitude 42°‡ south is reached that the South Island vegetation

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* See, on this head, Olsson-Seffer, P., "The Principles of Phytogeographic Nomenclature," Bot. Gaz., vol. xxxix, p. 183 (1905).

† Such are now clearly recognised by many ecologists—*e.g.*, Ganong, W. F., Bot. Gaz, vol. xxxvi, pp. 301, 302 (1903); Harshberger, J. H., *ibid.*, p. 372; Smith, W. G., Scot. Geol. Mag., vols. xx, xxi, p. 620, p. 20. This latter botanist also uses the term "sub-association."

‡ Latitude 38° south forms a much more natural floral boundary, to the north of which lies the "northern province" of New Zealand, as it may be called, while from 38° south to 42° south is the "central province,"

properly commences; but it must be pointed out that this limit is at best but a very artificial one. Notwithstanding the above, it is a convenient and quite legitimate plan to discuss the vegetation of either Island as a whole, and the method of treatment here adopted can, with the above explanation, lead to no misconception.

Regarding the term "coastal vegetation," it is not generally feasible to set any hard-and-fast limit as to its boundaries. Generally speaking, it is confined to quite a narrow zone following the coast-line, and determined, amongst other things, by the salt in the soil, the average distance sea-spray may blow inland, and the configuration of the land. In some places there are distinct traces of ancient shores, and such may contain in large part maritime plants, but unless these are in fairly close proximity to the sea they will not be specially dealt with.

As some of the notes, &c., made use of in the preparation of this paper were taken during several voyages in the Government steamer "Hinemoa," I thank most sincerely the Hon. W. Hall-Jones, M.H.R. (at that time Minister of Marine), for the opportunities thus afforded of visiting some little-known places on the coast and many of the adjacent small islands. To Captain J. Bollons, who assisted me in every way possible to carry on my work, my most hearty thanks are due. I must also express my gratitude to Messrs. F. G. Gibbs, M.A., D. Petrie, M.A., H. J. Matthews, J. Crosby-Smith, and T. F. Cheeseman, F.L.S., who have furnished me with much valuable information, and in other ways materially assisted this work.

2. Physiography and Climate.

The extensive coast-line of the South Island, facing the actual ocean for some 4,845 km., and extending in many places far inland, affords, as may well be supposed, a very considerable diversity of stations for plant-life, with the consequence that a by no means uniform plant covering clothes the shore and its environs. This absence of uniformity, far greater than might have been expected from differences of latitude, is in large part due to the fact that, thanks to the position of the Southern Alps, a quite different climate occurs, generally speaking, in the east than in the west, south, and many parts of the north. In fact, to mention two extremes, the west has an average rainfall of more than 253 cm., the extreme south-west corner having, in-

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and from this latter parallel to the southern extremity of Stewart Island is the "southern province." Lat 42° is, however, only a boundary so far as the vegetation near the coast is concerned; inland the southern province reaches much further north.

deed, twice that amount, while certain parts of the east coast hardly get 50 cm.* The number of rainy days, too, is much greater in the west than in the east. The climate of the west is also comparatively uniform, whereas in that part of the east where dry conditions prevail the summers are hotter and the winters colder than elsewhere on the coast—in fact, — 8° C. is not uncommon close to the shore of the Canterbury Plain. Much of the east, too, is subject to violent hot and dry north-west winds, known nowhere else in New Zealand, and which have been sufficiently described by me elsewhere (11; p. 110).

The form of the coast-line is varied. In some places high mountains descend steeply—at times, indeed, almost perpendicularly—to the water; in others there are steep cliffs against which the sea dashes; while in many places the land is comparatively flat, being frequently raised but a few feet above the sea-level, or in some parts so low as to be subject to inundation.

The exposure of the coast with regard to the ocean is very various. Large stretches of land abutting directly upon it are subject to the full fury of wind and wave; and this, of course, is much augmented if they face the prevailing wind, or lessened if there is some sheltering headland. In other parts of the coast, on the contrary, are deep fiords, extending for many miles inland, and there, of course, very much calmer conditions prevail, to which the vegetation bears ample testimony. Shallow estuaries shut off from the sea by banks of gravel and sand are not uncommon, and here another condition of affairs exists for plant-life. Similar conditions are also afforded by tidal rivers, along whose banks coastal formations extend inland.

The geological structure of the coast is of considerable phyto-geographical importance. Here it need only be pointed out that rocks of diverse kinds occur—volcanic, granitic, calcareous, sandstone, shale, &c. How far plant-distribution is correlated with the composition or age of the geological formations has not been worked out at any detail as yet for any part of New Zealand; at most a few very general facts are available.

As for the actual sea-shore, it may be sandy, rocky, shingly, gravelly, or muddy. Shells in many places also are abundant. Sandy shores merge into dunes, generally of no great height. Gravelly and rocky shores are succeeded by cliffs, stony terraces, gravelly dunes, steep banks, &c., while muddy shores are frequently the forerunners of salt meadows. Boggy and swampy places also occur near the sea, fed by fresh-water

* See the highly instructive rainfall map of the South Island (36; p. 238).

brooks and springs. Streams, too, sometimes flow over the shore. In both these cases special conditions occur for plant-life, but such, it may be pointed out, are not coastal unless salt be present in excess.

3. Ecological Factors.

The special factors with regard to coastal vegetation are superabundance of salt in the soil, and high or frequent and prolonged winds. Together with these comes a more equable climate than further inland, so far as extremes of temperature are concerned, but at the same time there is often strong insolation and bright illumination. The biotic factor, apart from introduced animals and those concerned in fertilisation, is of little moment, with the exception of the part played by the small land-crabs in the salt meadows, whose innumerable holes must assist materially in aerating the soil, and to some measure, also, in draining the ground.

As for the salt in the soil, this comes either through the flooding of the ground more or less frequently, or through sea-spray blowing inland. The effect of the former is strongly marked, and on it the most typical halophytic formations depend—*e.g.*, salt meadows, salt marshes, and brackish-water vegetation. As for the effect of sea-spray, it has probably been very much overestimated. Quite recently T. H. Kearney (27) has shown this to be the case for certain parts of the east coast of North America, and he comes to the conclusion that dune plants, and even those of the strand, for the most part do not owe their adaptations against transpiration to excess of salt in the soil, but to other conditions, and that they are rather ordinary xerophytes than halophytes.

The above explanation seems to meet New Zealand conditions. Thus, the large shrubby nettle, *Urtica ferox*, is a common maritime plant, growing in some instances on the upper strand not far from high-water mark. But, as is well known, that genus is one which is distinctly averse to salt in the substratum (Warming, 44; p. 304). *Macropiper excelsum*, another frequent coastal plant, belongs also to the same category. *Mesembrianthemum australe*, an extremely succulent plant, usually grows on the face of cliffs, where salt could not penetrate to any extent. The "coastal scrub" at the base of the Bluff Hill would most certainly be non-existent were there excess of salt in the soil, and yet some of its members overhang rocks covered with seaweeds. In short, the effect of spray seems to be largely dependent upon the position of a formation with regard to the prevailing wind, and upon the frequency and force of this latter. And this brings me to the point that, in New Zealand at any

rate, the wind factor cannot be overestimated. Its mechanical effect is everywhere apparent along the coast. The palm in north-west Nelson, the forests clothing the great mountains rising out of the sea in the south-west, the shrubs hugging the ground on the shore of Foveaux Strait, all exhibit an extreme wind-shorn appearance. But the wind not only exerts an influence on plant-form, but it markedly affects the distribution of the formations themselves. This is admirably illustrated by the vegetation on the Bluff Hill, to quote a specific example. On the sheltered side is mixed forest (taxads, *Weinmannia*, and *Metrosideros*), with the belt of shrubs mentioned above between it and the sea, but as the wind-swept side of the hill is approached the forest dwindles and finally gives way to xerophytic shrubs (*Cassinia vauvilliersii*, *Leptospermum scoparium*); finally the coastal scrub vanishes, and a scanty meadow of very low-growing herbs alone remains.

The soil factor, of course, also plays a prominent part both in the form of the plants and the distribution of the formations. Dunes, salt meadows, gravelly and sandy shores, and clayey hills occupied by low tussock-grass are well enough known to require no special mention here. In the south, however, are wet, peaty flats or slight slopes, frequently more or less mixed with sand, and which are, in fact, coastal moors. On these is a very distinct vegetation, containing, it is true, many characteristic salt-meadow plants, which, however, do not give the stamp to the formation. On the contrary, special species are dominant, such as *Euphrasia repens*, *Gentiana saxosa*, *Plantago hamiltonii*, *Montia fontana*, *Epilobium nummularifolium minimum*, *Crassula moschata*, and *Rumex neglectus*, while the rock-ferns *Asplenium obtusatum* and *Lomaria dura* are frequently conspicuous.

The rainfall, and, more important still, the number of rainy days, is a factor not peculiar to the coast, but nevertheless of vital importance to the distribution of the formations. As pointed out in the introduction, there is a vast difference between much of the eastern coast and the whole of the western, with the consequence that one is dominated by arborescent formations and the other by meadows. The north in large measure, and the south and south-west, for the same cause are rain-forest districts. On the east, too, are local climates where forest comes, or originally came, to the shore-line, as at the base of the Seaward Kaikouras and thence southwards to the Waiau River, Banks Peninsula, and the neighbourhood of Dunedin. Even in Eastern Canterbury are many evidences of former forests to be seen in swamps near the coast, and Riccarton Bush is the surviving remnant of such forests, whose presence most likely

depended rather on edaphic than climatic conditions—*i.e.*, on subsoil water rather than number of rainy days.

The above rain-forests are not, strictly speaking, "coastal," but are merely the ordinary lowland forests of the particular locality. But their seaward margin is frequently distinctly modified by coastal conditions. Thus, there may be a dense growth of shrubs or low trees, as originally pointed out by Hector (21), forming a definite plant-association or maybe formation, which at times exhibits a zonal arrangement of its members, defined by their wind- or spray-resisting powers, the trees or shrubs being gradually more xerophytic from within outwards. In other places *Phormium tenax* may form a natural wind-break between the forest and the actual shore, reaching so close to the water that seaweed and pieces of driftwood may be stranded at its base.

Certain edaphic formations are not affected by the rainfall. Thus the dunes at Martin's Bay, in the very centre of the wet region, maintain clearly their desert character, while at the head of the western sounds far inland in the heart of vast forests are muddy flats covered with the usual halophytes. With rock formations, on the other hand, it is quite the contrary. These vary much in their plant covering according to the rainfall. On the dry east coast, masses of the succulent *Mesembrianthemum australe* depend from rock-crevices and alone hide in a few places the bareness of the surface. But in the west great walls of rock are covered with arborescent plants, the constant wet being most favourable for peat-production, which, lodging on ledges and in hollows, forms a thin soil, which the plants can use, thanks to the far lateral spread of their roots. Between such fertile cliffs and those of the east there are many transitions in harmony with the water conditions of the station.

4. Dunes, Salt Marshes, and Salt Meadows.

The absence of uniformity in the coastal formations, as mentioned previously, is not without some striking exceptions. Such are found in the case of those before-mentioned formations which depend on some special edaphic rather than climatic influence. Of these, the most common are dune, salt-marsh, and salt-meadow formations. Not only are dunes, salt meadows, and salt marshes remarkably uniform throughout the South Island, but through nearly the whole of the New Zealand biological region—a sandhill in the north of Auckland, for instance, not differing much from one of the extreme south of the South Island, Stewart Island, or even of Chatham Island (12; p. 259 *et seq.*). To find a dune floristically and even ecologically distinct one must visit the Auckland Islands, whose sandhills

contain none of the characteristic New Zealand psammaphytes (13; p. 237). But there are a number of differences in New Zealand dunes, and these are sufficiently marked to enable a botanist conversant with the coast to tell within certain limits to what part of New Zealand a particular sandhill would belong. One example will suffice here, and, as it is an interesting case of representative species, it is worth emphasizing. The genus *Cassinia* is represented in New Zealand by six species, one of which—*C. albida*, Cockayne—would be considered by many as a variety only, and another, *C. amœna*, is confined to the North Cape. As for the remaining four, all are common at sea-level, while two of them ascend into the subalpine region. As for their life-forms, they are very similar, being of the ericoid, sclerophyllous type with tomentose leaves. Commencing at the subantarctic islands, *C. vauvilliersii* occurs near the coast to the south of the South Island, where it is succeeded by *C. fulvida*, this in its turn giving place to *C. leptophylla* in the central province, and this to *C. retorta* in the northern province. Everywhere *Scirpus frondosus* is the leading sand-binding plant, but in the central and northern provinces this is reinforced by *Spinifex hirsutus*. But no more need be said here as to the above edaphic formations, as they will receive detailed treatment in the special part of this series.

5. Physiognomy of Coastal Vegetation.

Formerly the physiognomy of vegetation was merely a geographical concern pure and simple, but this is no longer the case, since it is recognised that the life-form of a plant is a physiological matter depending on the relationship of form to outer factors and to inner causes. This being so, the general appearance of the landscape as determined by the presence of certain dominant species becomes an affair of high biological interest. Now, the scenery may be affected in two ways: either some particular plants or life-forms may be especially striking, or it may be a group or even the character of a whole formation that may specially catch the eye. Thus, taking New Zealand as a whole, the scenery is distinctly affected by the abundance of *Cordyline australis* and *Phormium tenax*, while that life-form the "tussock" is perhaps the most striking characteristic of large areas. On the other hand, where forests dominate the landscape their individual members exert little influence, it being their evergreen character and close growth which stamps their physiognomy.

Coming now to the subject of this section, *Cordyline australis*, *Phormium tenax*, *P. cookianum*, and tussock-grasses play frequently quite a prominent part in the physiognomy of the

coastal vegetation, the first-named dotting stable dunes or grassy hillsides, the second forming long belts just above high-water mark, or in the case of *P. cookianum* especially beautifying barren cliffs, and the tussocks occurring in many situations and under various conditions. But the above are not specially coastal plants, and it is the coastal formations proper which supply the peculiar features. Walking along a sandy shore the only plant which may be seen for miles is *Scirpus frondosus*, with its tufted, stiff leaves especially conspicuous through their yellow colour. Further from the shore, however, as the dunes become more stable, are here and there the curious low-growing bushes of *Coprosma acerosa arenaria*, with their interlacing extremely wiry stems of a distinct reddish-yellow colour, and associated with them the more upright-growing but also yellow *Cassinia fulvida*. Further from the sea still may be a dark-coloured heath of *Leptospermum scoparium*, relieved, however, by huge tussocks of green *Arundo conspicua*, with its straw-coloured plumes in summer.

Tidal rivers, shores of estuaries, and salt meadows are distinguished by lines, groups, or thickets of the roundish, black-coloured bushes of *Plagianthus divaricatus*, while the floor of the meadow owes its green turf to a number of close-growing herbaceous plants furnished with far-creeping stems.

Generally speaking the appearance of the coast is desolate enough, but in the wettest regions this is not the case, for here it is not coastal plants adapted for peculiar and severe conditions which dominate, but the luxuriant rain-forest. This, although black in the distance, becomes much more pleasing at a closer view, when its varied greens are evident, and glimpses of tree-ferns appear through the foliage. Here, however, as pointed out before, is frequently a protecting hedge of closely packed tall shrubs, and of these *Olearia operina*, with its toothed lanceolate leaves white with dense tomentum on their under-surface, *Senecio rotundifolius* with its large, round, leathery leaves, and the tender-green *Veronica elliptica*, give a distinct character to this exterior vegetation. This is sometimes varied by the presence of large quantities of *Freycinetia banksii*, and with this liane creeping right out on to the shore in stiff tangled masses the scene becomes distinctly tropical in aspect. Nor is this tropical character much changed when the long line of *Phormium* fringes the shore; where, too, in north-west Nelson, the beautiful palm *Rhopalostylis sapida* raises its huge feathery leaves above the other and frequently wind-shorn foliage; or where, in north and east Marlborough, the great glossy leaves of *Griselinia lucida* crown some rocky point.

Quite different from the above is the steppe character, where

slopes in the east are covered with brown tussocks of *Poa cæspitosa*, from amongst which rise up dark-coloured semi-pyramidal masses of the liane *Muehlenbeckia complexa*, which has assumed a shrubby habit, and stiff, erect, dull-green bushes, quite leafless, of a species of *Carmichælia*.

Many other physiognomic peculiarities could be cited, but it would lead to a general account of formations, here obviously out of place. Other characters which affect the landscape depend upon the blooming of various plants, and this is dealt with to some extent in another section.

6. THE SMALL COASTAL ISLANDS; ENDEMISM.

Not the least interesting portions of the coast, if they may be so included, are the islands situated at no great distance from the mainland with which they have been connected at some earlier period. Of such islands some have been inhabited for a considerable time, while a few are still in their virgin state (14). In the former case the effect of man and herbivorous mammals on a primeval vegetation is fairly easy to estimate, since their area is small enough for close observation. Dog Island and Centre Island, which are to be treated of, are of this class, while the Open Bay Islands and the yet unexplored Solanders belong to the other category. The limited size of these small coastal islands, too, permits detailed observations to be taken as to the distribution of formations, the effect of introduced plants, the change of edaphic conditions on the vegetation, and the like. Finally, it is in such spots that relics either of former vegetation not existing elsewhere or of incipient species might be expected.* As for the latter, a variety of *Brachycome thomsoni* named *minima* is reported by Kirk for Dog Island (34; p. 260), and I mentioned a form of *Veronica elliptica* as peculiar to the Open Bay Islands (14A; p. 371). On East Cape Island, in February, 1905, I collected a very robust and fleshy plantain, which is either a new species† or Colenso's *P. picta*. Other examples are afforded by the more distant islands—*e.g.*, *Veronica gigantea* of Chatham Island, closely related to the common *V. salicifolia*, and *Acæna sanguisorbæ* var. *antarctica* of the Southern Islands.

But it is as a haven of refuge that islands figure more conspi-

* See also, regarding this question, Laing and Blackwell (35; p. 302 *et seq.*).

† This plant I have raised from seed in a soil containing no excess of salt, and in a greenhouse. The early leaves of the seedlings are, however, extremely fleshy. Of course, such fleshiness may not be shown in future generations, but that it is present at all is suggestive and interesting.

cuously, and as this is an important phytogeographical matter having a bearing on general plant geography, I am going into the facts at some length. That some species have been more widely spread on the mainland than at present is known in some cases. Thus *Lepidium oleraceum* was so common at the time of Captain Cook's visit that he fed his crew on it, calling it "scurvy-grass." This plant is now virtually extinct on the mainland, but abounds on certain of the small outlying islands. *Sicyos australis** has become quite rare on the mainland, but on the Little Barrier Island and other islands in the north it is abundant, climbing high up *Metrosideros tomentosa* or straggling over *Macropiper excelsum*. The magnificent *Meryta sinclairii* is no longer to be encountered on the mainland, and is only known from the Three Kings, where it is plentiful (8A), and the Hen and Chickens.† If a plant, abundant on a far-distant island, occurs very rarely or over an extremely limited area on the mainland, it seems reasonable to conclude that it was once much more widely spread, especially when geological evidence proves that the island is the younger land. Thus *Suttonia chathamica*, a common tree of the Chatham Island forests (12; p. 277), was found by G. M. Thomson in one station in the south-east of Stewart Island. *Hymenanthera chathamica*, an equally common Chatham Island tree, has been observed at one spot in the Wellington Province, North Island, by Sir James Hector (34; p. 46). Other similar cases are: *Pratia arenaria*, which is confined to the Southern Islands and Chatham Island, where it is abundant in various formations; *Urtica australis*, common in both the last-mentioned groups and almost reaching the South Island, since it occurs on both Dog and Centre Islands, in Foveaux Strait; *Archeria racemosa*, found on the mountains of both Great and Little Barrier Islands and on the Coromandel Ranges of the North Island; *Stilbocarpa lyallii*, common in Stewart Island, Ruapuke and others of the Stewart Island group, but only recorded in the South Island from near Preservation Inlet. *Lepyrodia traversii*, the most characteristic bog plant of the Chathams (12; p. 287), and for a time thought to be endemic, is now known, thanks to the researches of Cheeseman (7), to be abundant in some of the Waikato swamps. The endemic genus *Myosotidium* of the Chatham Islands was also probably much more widely

* Kirk states (34; p. 183) that the plant on the outlying islands differs in leaf-form from that of the mainland. If this is always the case, and the two forms come true from seed, here is another example of an incipient species.

† During my recent visit to the Poor Knights Islands I saw no trace of this tree (15).

spread,* and it is hard to believe that the Australian *Styphelia richei* did not reach the above group by way of New Zealand originally.

7. SOUTHERN AND NORTHERN LIMITS OF COASTAL PLANTS.

The coastal formations consist, as is shown further on, of two classes of plants—viz., the coastal plants proper, and those which are common inland. Now, although the strictly coastal plants are usually of wide distribution, not only in the South Island, but through much of the New Zealand biological region, some are confined to a small area, and others again only reach a certain distance to the north or the south, as the case may be. Considering first this latter category, the question is at once opened up as to the reason why certain plants have a definite northern and southern limit. This inquiry is much easier to propound than to answer in the present state of knowledge. At first sight the matter under consideration might seem merely to be a question of climate—that when, say, a northern plant of a frostless climate reached a point where frost occurred, it could advance no farther; or such a plant, again, might require for its well-being a certain average maximum of heat. But an examination of the facts shows that there is something much more far-reaching in the matter than the above; but this can be best understood by citing some specific examples. Take, first of all, the case of the kauri (*Agathis australis*), which, although not a coastal tree, may fairly be used as an example, since the matter under consideration concerns the whole New Zealand flora, while the kauri, moreover, is one amongst a number of plants which are confined to the north, roughly speaking, of the 38th parallel of latitude. Now, south of this line for a considerable distance, especially on the west of the North Island, there are no climatic conditions which should inhibit the growth of this tree in many places. Moreover, at Wellington, more than 3 degrees to the south of the kauri limit, this tree grows famously in cultivation, producing cones regularly. Even at Christchurch, in the South Island, in the Domain, where —9° C. has been frequently recorded, the kauri grows well and has recently fruited. Also, a young plant has withstood the cold of this winter in the garden of the biological laboratory, Canterbury College, in a position where it could get no sun, and where a plant of *Veronica elliptica* collected by me in Campbell

* G. M. Thomson is also of opinion that this plant must have formerly existed in New Zealand, and he suggests that it may have died out or been "eaten out by some more recent form of animal life, perhaps by moas, which were formerly enormously abundant, and were vegetable-feeders" (43; p. 315).

Island was killed outright. Finally, so far south as Dunedin, the kauri is by no means difficult to cultivate.* *Metrosideros tomentosa*, the pohutukawa, is the characteristic tree of certain coastal rock formations of the northern part of New Zealand, and has much the same distribution as the kauri (33; p. 238), yet, without any apparent reason, it also does not extend beyond a certain latitude, although it is perfectly hardy near the shores of Cook Strait, being a frequent plant of gardens in Wellington and elsewhere. *Corynocarpus lævigata*, the karaka, a plant probably more susceptible to frost than either of the above, occurs spontaneously as far south as Banks Peninsula, about lat. 44°, but further does not go, although quite hardy on the Otago Peninsula, and doubtless easily able to grow on any part of the west coast. *Pittosporum crassifolium*, another coastal tree of the kauri region, is perfectly hardy in the Christchurch Domain, and yearly produces abundance of fertile seeds, which germinate on the soil beneath the tree; indeed, there is no reason to doubt that this plant could hold its own, so far as climate is concerned, in any part of the whole New Zealand forest region. Many other examples could be cited, but these will suffice.

Now, in all the above and similar cases it may be argued that an abnormally severe frost, such as occurs at times, would damage these trees to so great an extent that they would not be able to cope with the more hardy indigenous vegetation. Doubtless this is in part true Such frosts do occur. Leaving out of the question the doubtful record of −25·5° C.† in Central Otago in the winter of 1903, there is no question that the cold then was exceptionally severe. T. W. Adams reports (1; p. 288) how "the exceptionally severe winter of 1899" killed at Greendale, on the Canterbury Plain, the introduced *Eucalyptus globulus*, 70 ft. high and nearly 3 ft. in diameter, and how *Leptospermum scoparium* and *Cordyline australis* were also killed. But at the same time it must be pointed out that many groves of *Cordyline* on the Malvern Hills and on the foothills of the Southern Alps, and much *Leptospermum* in the same localities at a much higher elevation than Greendale, and probably exposed to a lower temperature, were not damaged at all. Further, it is a well-known fact, to which others and myself have drawn attention, that certain New Zealand plants exist at the very limit of their frost-enduring capacity (see Rutland, 39; and Cockayne, 10). But another class of facts opens up a different

* T. W. Adams calls attention to this matter of the kauri (see 1; p. 286).

† Report of Department of Lands and Survey, New Zealand, 1904.

aspect of the case. I refer to those southern plants which only reach a certain distance northwards. *Senecio rotundifolius* is an example. This, as will be seen further on, is an important constituent of a somewhat local plant formation found in the south-west of the South Island. It is also abundant in Stewart Island, but is not found on the east of the South Island at all, although many stations are most suitable, nor is it found on the west coast beyond latitude 44°, or on the south coast beyond the eastern boundary of Bluff Harbour (14B). Yet on the east, this plant, cultivated at Dunedin, forms magnificent hedges, while it is grown with success even as far north as Auckland City. Here there is, then, no question of frost, or even of any damage from a hotter summer climate; if there is any inhibitory climatic factor in this case it would be rather a question of want of moisture. A still more interesting example is *Veronica elliptica*. This plant, which is also a native of Tierra del Fuego, is a most common feature of coastal rocks and cliffs in the southern part of the South Island, and it extends even to the far-off Auckland and Campbell Islands. But in the northern part and north-east of the South Island it is quite wanting, nor does it occur at all in the North Island or the Chatham Islands, in both of which, however, there are rock-loving veronicas. Now, although this is a strictly southern plant, being identical possibly with the Fuegian species of the same name, it cannot, as shown above, tolerate much frost.* This species, then, seems more suited to the warmer north, and yet, as stated above, it is quite wanting in the North Island. The distribution of *Crassula moschata*, too, is interesting. This low-growing succulent herb, a native also of the Fuegian region, occurs in abundance on the Southern Islands. In the South Island it is common in the south and south-west, but further north it is quite local, wide reaches of coast being destitute of this species, although so far as station and climate go they are quite suitable. It occurs sparingly on Banks Peninsula, and then, so far as I know, is not found again until the shores of Cook Strait are reached, which it crosses, and is finally found in the neighbourhood of Island Bay, Wellington, and its vicinity, but does not occur further north.

From the above cases it seems evident that extremes of climate is only one of the factors with regard to the distribution of coastal plants in New Zealand. Rather, perhaps, than heat or cold alone is the matter one of the ecological optimum†

* A plant of *Veronica elliptica*, originally from the Bluff, grown in my former garden near New Brighton on an ancient sand-dune since 1897, has never thriven, being yearly cut back by frost.

† For explanation of this term see Schimper (41: p. 44).

of any special plant. Many plants would extend farther to the north or the south, but they encounter competitors better equipped for the struggle—*i.e.*, more in harmony with the surroundings than themselves. A plant which is slightly more suited than another for a particular station must evidently become the victor in the struggle for existence, although both outwardly may appear equally matched in every particular. The distribution of *Sophora chathamica* is an interesting case in point. Judging from the behaviour of the closely allied *S. microphylla* on the volcanic hills of Banks Peninsula, where this plant is abundant, one would conclude that similar hills on Chatham Island would be the habitat of *S. chathamica*. On the contrary, it is quite absent in such stations, being evidently not able to cope with the lowland forest plants, and it is confined to a narrow strip of limestone country near the margin of the great lagoon. In this place the difference of soil evidently equalises the struggle, and it and the other lowland forest trees there exist side by side (12; p. 271).

Further, in considering the above question, the diverse origin of the New Zealand flora must not be lost sight of. Roughly speaking, there is a northern element, consisting of Malayan, Australian, and Polynesian genera or species, which may be called a "subtropical element"; then there is a southern element, consisting of South American and so-called antarctic genera and species, to which must be added some endemic species also, and this element may be called, with Schenck and Skottsberg, "subantarctic" (41, 42). The species composing these two classes have come to New Zealand probably at very different times and by slow degrees during great extensions of the land surface. Some of the subantarctic species may be actually New Zealand, if this country has originally formed a part of a palæoceanic continent. Between these alien plants, the subtropical and the subantarctic, a fierce struggle must have taken place—just such a conflict, indeed, as is now in progress between the indigenous and introduced plants in New Zealand, these latter mostly plants of temperate Europe. From the former struggle have resulted our present plant formations, in some of which the subtropical element is dominant, while in others the subantarctic flourishes.*

The present distribution of certain plants is of interest with regard to this struggle. Thus, as pointed out before, north of the 38th parallel is a powerful subtropical element. South of

* This view I have already published in a series of "popular" articles which appeared recently in various New Zealand daily papers, entitled "New Zealand Plants and their Story."

this line many of the northern species and genera are wanting, but a large proportion extend south, some just crossing Cook Strait, others finding their southern limit at Banks Peninsula, or at other definite points east and west, while others, again, extend right to Stewart Island and even to the Southern Islands. In the same way the subantarctic element, including in this some of the endemic genera—*e.g.*, *Celmisia*, *Olearia*, *Aciphylla*—has pushed northwards, leaving here and there outposts or settlements cut off from the main body, such as the *Crassula moschata* at Island Bay, Wellington, before mentioned, but especially the patches of *Nothofagus* in northern Auckland. Generally speaking, in this struggle the subtropical element is the conqueror, the subantarctic plants being driven into the more unfavourable stations, such as lowland bogs, the subalpine region where pure *Nothofagus* forests flourish, or alpine heights.

As to how finally the various combinations of plants have come about which make the formations and associations, it seems in the present state of knowledge vain to inquire. The action of minor climatic changes is but little known. Our ignorance is great regarding the mutual reactions of plants on one another when brought into contact, reactions which must have much to do in determining what plants shall finally occupy a station. In this matter experiment is imperative, and a fruitful field is open in New Zealand, where, with the introduction of so many exotic plants and animals, unpremeditated experiments are even now in progress everywhere.

Finally, to sum up the matter, all that can be said about the distribution of the New Zealand coastal plants is that it is the resultant of a large number of causes. The historical factor and evolution determine the species, climate and soil sort them out into groups, and the struggle for existence, which is governed by the life-forms and constitutions of the competitors, finally fixes the formation—that is, so far as a formation may be termed a fixed entity.

8. Local and Limited Distribution.

Coming now to those plants mentioned above as being confined to a small area, the following citations must suffice, but these include some of the most striking amongst New Zealand plants: *Helichrysum purdici* occurs, so far as is known, only in one or two stations on the north shore of the Otago Harbour, and there are only a few plants in each locality. I found by cultivation that this plant would not endure much frost. *Olearia insignis*, so far as its coastal distribution is concerned, is limited to cliffs on the Marlborough coast,* and it is sometimes accom-

* Inland it is frequent on rock-faces, and it ascends to the alpine region in the Kaikoura Mountains.

panied by the beautiful *Veronica hulkeana*. *Celmisia lindsayi* occurs only on rocky faces and stony *débris* in the neighbourhood of the Nuggets and Catlin's River, south-east Otago.* This is a remarkably easy species to cultivate. The thickets of *Olearia operina* are found only at the West Coast Sounds, and the closely allied *O. angustifolia*, so far as its South Island distribution is concerned, has been recorded from only one locality, the base of the Bluff Hill, Foveaux Strait, although it is an abundant plant on some parts of the coast of Stewart Island and the neighbouring small islets. *Capsella procumbens*, one of Petrie's numerous discoveries, has been recorded only from Oamaru. *Lepidium banksii* occurs only on the southern shores of Cook Strait. *Stilbocarpa lyallii*, a common plant of Stewart Island and of some of the islands adjacent, is found, according to Kirk, only in the South Island in the vicinity of Preservation Inlet.

9. Primitive and Modified Formations.

The coastal plant formations of settled districts are usually in a much more primitive condition than are those of the adjacent lowlands. The nature of the soil, and its possession in some instances of more salt than is beneficial for the majority of plants, has had the effect of keeping away the rank and file of the invading host of foreign plants which now form such a marked feature in many districts in New Zealand. Certain parts of the coast, especially in the west, are far removed from the inroads of domestic animals, and there the plant covering is truly primeval. On the other hand, certain formations, which at first sight appear primitive, on a closer examination prove to have been modified considerably by fires, drainage, grazing animals, and introduced plants. For instance, the majority of dunes at the present time are certainly much more unstable than they were originally, their great protector, *Scirpus frondosus*, being eaten by rabbits and other animals.† Also, these dunes, inhospitable as they appear, are not seldom thickly occupied by introduced plants, which have quite overcome the original plant inhabitants. A very striking case is that of *Lupinus arboreus*, introduced in the first instance as a sand-binding plant, but which now forms dense thickets in all parts of many dunes except the most unstable. Also, *Ulex europæus* and *Sarothamnus scoparius*, planted originally as hedge plants, occupy wide areas and frequently struggle with each other and with the tree-lupin for the supremacy. In some places the forest which came to near high-water mark has been cut

* Regarding the occurrence of this plant inland see Cockayne (14c).

† See, for instance, F. Truby King (28).

down, and a second growth, easily mistaken for a primitive one, now occupies the ground. An actual sea-beach may be occupied exclusively, or almost so, by introduced plants. Thus the steep, unstable gravel beach at Kaikoura abounds with *Sherardia arvensis* and *Scandix pecten-veneris*, the only indigenous plant present being *Rumex obtusifolius*.* The effect of drainage may be well observed where such operation has been carried on in a salt meadow, the native plants decreasing as the ground gets drier, and finally introduced grasses being dominant. Even slightly brackish water is not free from the foreign element, the customary dense red mat of *Azolla* having to give place to *Glyceria fluitans*, or to the watercress, *Nasturtium officinale*.

10. MOUNTAIN PLANTS ON THE COAST.

There is at times a close ecological resemblance between some coastal plant formations and those of higher altitudes. This is probably owing to the fact that somewhat similar climatic and edaphic conditions are provided. Alpine plants must in many instances have been driven into the mountains by a more vigorous lowland vegetation, such as lowland mixed forest or tussock meadow, and where these formations cannot exist—*e.g.*, owing to sea-breezes, halophytic conditions, or a too scanty supply of soil, such as rocky places or a gravel beach provide—then subalpine or alpine plants, or those ecologically related to such, may find a haven of refuge. The *Olearia insignis* formation alluded to above is an excellent example, since it not only occurs on cliffs facing the ocean and lapped by the waves, but, with few members added or changed, it ascends high into the mountains. *Claytonia australasica*, a plant of stony, subalpine river-beds, shallow running water, and alpine shingle-slips, descends to sea-level on sandhills near Dunedin (37; p. 544), and also on the shores of Foveaux Strait. *Helichrysum selago*, a shrub of subalpine and alpine rock-faces, occurs on ancient sea-cliffs near Cape Saunders, Otago Peninsula. In the West Coast Sounds, *Cordyline indivisa*, a plant of subalpine or montane forests, is not infrequent on cliffs quite near the water's edge. Coastal scrubs, as I have pointed out elsewhere, are frequently closely related to subalpine scrub, both ecologically and floristically. Finally, to quote an easily observed North Island example, certain shady cliffs near Island Bay, Cook Strait, have a fairly rich vegetation of *Phormium cookianum*, *Aciphylla squarrosa* var., *Senecio lagopus*, and a broad-leaved

* See also Kirk's remarks on this subject (34A; p. 18).

form of *Craspedia fimbriata*, while on the stony beach are large, circular, silvery patches of *Raoulia australis*.*

Many more examples of mountain plants growing naturally at abnormally low altitudes could be given, but the subject is of too much importance for a brief treatment such as could be afforded here.

11. Occurrence of Coastal Plants Inland.

So long ago as 1871, Mr. T. Kirk (29) pointed out how certain coastal plants occurred far from the reach of tidal waters in the Waikato district. Among these species were such well-known coastal plants as *Selliera radicans*, *Ruppia maritima*, *Scirpus maritimus*, and *Leptocarpus simplex*. To explain this distribution Kirk called in Hochstetter's conception of an ancient shallow arm of the sea in the middle Waikato basin. Since that time many more facts as to occurrence inland of coastal plants have been recorded. Thus several occur on the shores of the central North Island lakes, of which perhaps the most interesting is the beautiful tree *Metrosideros tomentosa*, which occupies similar positions on the cliffs of Lake Taupo, Lake Rotoiti, &c., to what it does on the coast of the northern floristic province. Near hot springs at Ohinemutu and elsewhere grow *Leptocarpus simplex* and *Triglochin striatum filiforme*.

The South Island also supplies some interesting examples. On the Maniototo Plain or its neighbourhood Petrie recorded *Chenopodium triandrum*, *C. glaucum ambiguum*, *Atriplex buchanani*, *Senecio lautus*, and *Ranunculus acaulis*. From near Lake Wanaka he collected *Selliera radicans* (37). *Linum monogynum* occurs on the upper Canterbury Plain and reaches to the base of the Southern Alps, and to similar altitudes in south Nelson. *Angelica geniculata*, which Kirk did not believe to extend inland, was noted by me at a slight elevation on the Rock and Pillar Range, Otago, and also at the Lower Waimakariri Gorge, where it is accompanied by other coastal plants.

How far all the above cases denote a former shrinkage of the land and extension of the coast-line inland is not for a botanist to settle, but certainly, so far as geological evidence goes at present, they are suggestive, to say the least.

A more interesting case, perhaps, is that of the limestone rocks at Castle Hill, Canterbury, the Weka Pass, and else-

* This subalpine "patch plant" is also common on stony river-beds of the lowland region, reaching high-water mark near the mouth of the Rakaia, which it has probably reached in the first instance through water-carriage.

where. Here the well-known coastal fern, *Asplenium obtusatum*, and the shore groundsel, *Senecio lautus*, grow abundantly. If such a distribution is correlated with the marine origin of the rocks, then it is evident that species can exist under special conditions for enormous periods of time. It may be pointed out in favour of the fern being a relic that it grows normally on any kind of rock, and even on wet peat, and the limestone can have no special advantage as a spot where the spores could germinate and thrive over any other open rock station.

12. FLOWERS OF THE COASTAL PLANTS.

The flowers of the coastal plants are usually not very striking, but this is, indeed, the case with the majority of New Zealand lowland plants. Some, however, are distinctly showy: *Samolus repens procumbens* in due season spreads white sheets of bloom over the salt meadows, contrasting with yellow masses of *Cotula coronopifolia*. In the neighbouring marshes and shallow, sluggish streams the flowers of *Mimulus repens*, of a bright lilac, marked with yellow on the lower lip and throat, are distinctly pretty. *Olearia operina*, *O. insignis*, and *Senecio monroi* would attract attention in any flora, not merely from their handsome flowers, but from the form of their leaves and the contrast of the green with the tomentose surfaces. All the veronicas have a profusion of pretty flowers, and, in addition, those of *V. elliptica* are very sweetly scented. The white-flowered *Gentiana saxosa* is very beautiful, trailing over rocks or banks near the sea on some small island in Foveaux Strait, or on the south coast. Where *Metrosideros lucida* hangs, in the south, over the shore of some land-locked harbour, its myrtle-like leaves dipping almost into the water, the masses of bright-crimson flowers in due season are a glory. The coastal scrub at times is here and there adorned with the drapery of purest white of *Clematis indivisa*. On bare cliffs of the Marlborough coast hang the long, soft, lilac racemes of *Veronica hulkeana*, emerging from the foliage of shining green. In the north, according to Mr. H. J. Matthews, the shores of D'Urville Island and Pelorus Sound are decorated in late January with multitudes of the truly lovely flowers of *Euphrasia cuneata* —white, with a yellow eye, and striped with purple.

Finally, even stations so desolate as the dunes are enlivened by the large delicate flowers of *Calystegia soldanella* (white striped with lilac), by the silvery bushes of *Pimelea arenaria*, the snowy masses of *Leptospermum*, and the tall, waving, shining plumes of *Arundo conspicua*.

13. Coastal Distribution as an Aid in defining the Floral Districts.

Up to the present time no attempt has been made to divide the South Island into various floristic small divisions.* Such are, in fact, very difficult to delimit. This arises from the fact that the species of wide areas are not known, and can be only guessed at, and also that these smaller divisions must overlap and be likewise in some measure artificial. It seems interesting to inquire whether the distribution of the coastal plants can shed any light on this matter. Such minor divisions may be termed "districts," just as the three larger have been named "provinces," the whole of the New Zealand area forming a "region."

On the south side of Cook Strait the dunes with *Spinifex hirsutus*, and the cliffs with *Coprosma baueri*, give a distinctive character to that area. Here, too, are *Entelea arborescens*, *Corynocarpus lævigata*, *Veronica speciosa*, *Euphrasia cuneata*, *Griselinia lucida*, and some other plants which are peculiar to the district or only reach south for a short distance.

Cliffs with a formation of *Olearia insignis*, *Phormium cookianum*, and *Veronica hulkeana* are distinctive of east Marlborough, and that distinction is heightened in comparison with Canterbury by the groves of *Corynocarpus lævigata*, *Myoporum lætum*, and *Dodonæa viscosa*, while on the summits of rocks is *Griselinia lucida*. The nikau palm (*Rhapalostylis sapida*), according to Mr. H. J. Matthews, is a feature of the shores of west Nelson. Here, too, is *Veronica gracillima*. On the volcanic rocks of Banks Peninsula is the fine *Senecio lagopus*,† and, at a greater altitude, the beautiful *Veronica lavaudiana*—this, however, not really a coastal plant. South-west Otago, as mentioned before, is characterized by the coastal thickets of *Olearia operina* and *Senecio rotundifolius*, and by the fine *Aciphylla intermedia*. The shores of Foveaux Strait have the coastal moors before described, with *Gentiana saxosa* and *Euphrasia repens*.

From the above, then, it seems clear that the coastal plants and formations are distinctly an aid towards defining the floristic districts of the South Island.

14. Floristic Details.

The pteridophytes and spermaphytes composing the coastal vegetation consist in part of species confined to the coast or

* For this purpose the geographical divisions have been used hitherto, and these are quite unsuitable and unnatural from both the biological and floristic standpoint.

† *Senecio saxifragoides* of Hooker's Handbook and Cheeseman's Manual, with which determination, in the face of Raoul's plate and the habitat of his *S. lagopus*, I cannot agree. Laing and Blackwell also hold the same opinion (35; p. 438).

occurring inland only under special conditions, and in part of ordinary lowland or even mountain plants.

Of the plants peculiar to the coast there are ninety-four species, including certain well-marked varieties, belonging to sixty-five genera and thirty-five natural orders. Of the natural orders *Chenopodiaceæ* have ten species, *Scrophulariaceæ* nine, *Compositæ* eight, *Cyperaceæ* and *Gramineæ* each seven, *Umbelliferæ* six, *Cruciferæ* and *Potamogetonaceæ* each five, *Filices* and *Aizoaceæ* each three, and the remainder one or two each.

Of the sixty-five genera the following are well-known maritime genera elsewhere, or possess characteristic halophytic species: *Lepidium, Tissa, Tetragonia, Eryngium, Apium, Samolus, Chenopodium, Suæda, Atriplex, Salicornia, Triglochin, Ruppia, Bromus, Carex.*

Turning now to the species, fifty, or 53·1 per cent., are endemic; twenty-seven, or 26·5 per cent., occur in eastern Australia or Tasmania, where they are not necessarily coastal plants: thirteen, or 13·7 per cent., are subantarctic; and nine, or 9·5 per cent., are cosmopolitan, these latter being excluded from the Australian and subantarctic estimates.

With regard to local distribution in New Zealand, sixty-four, or 68 per cent., of the ninety-four species occur also in the North Island of New Zealand; thirty, or 31·9 per cent., are found only in the South Island or Stewart Island, and of these it is interesting to note that a large part—namely, sixteen—are confined (or nearly so) to the south, south-east, or south-west; finally, nine occur only in the north of the Island ("Northern Province"), but eight of these are more or less common North Island plants, where they occur in analogous formations, and the exception *Lepidium banksii* is probably not really a species.

If we further consider the foreign element of the coastal flora we find that of the nine cosmopolitan plants three live submerged in brackish water, and four are salt-marsh or salt-meadow plants—*i.e.*, there are seven which would tolerate the immersion of their seeds in salt water.

Of the twenty-seven members of the Australian element, eight are grasses, rushes, or cyperaceous plants, eighteen halophytes common in salt meadows or marshes, or which live on rocks exposed to the sea-spray, and one a submerged brackish-water plant.

The subantarctic element also, with the exception of *Veronica elliptica* and *Carex trifida*, consists of plants of more or less salt-saturated ground. As for the *Veronica* and the *Carex*, nothing is known as to the salt-resisting capacity of their seeds.

Leaving the halophytes out of the question, the *Coprosmæ*

of Norfolk Island has succulent drupes, and *Sicyos* has barbed fruits.

The endemic element is not nearly so evidently coastal as the foreign. Many of the species are ecologically just as much alpine as maritime plants, and look, indeed, quite out of place on the sea-shore to one acquainted with our alpine vegetation. The endemic *Scirpus frondosus* is interesting as belonging to an endemic section of the genus, while ecologically it is highly specialised as a sand-binding plant, which characteristic was developed in the absence of grazing animals; and so, notwithstanding its coriaceous texture, it is frequently damaged by those which have been introduced by settlement.

The distribution of the South American element is of some interest, since it shows that so far as the coastal plants are concerned those of subantarctic origin are not confined by themselves to any part of the coast. Of the thirteen species, ten occur abundantly from the north of the North Island to the south of the South Island. *Crassula moschata*, most abundant and luxuriant in the south, reaches, however, the north shore of Cook Strait. There remain, then, as more or less specially southern or south-western forms, only *Carex trifida* and *Veronica elliptica*, and these occur on the east also, at least as far north as Dunedin.

However, this special distribution by no means disproves what has already been stated as to the struggle between the "subtropical" and "subantarctic" elements, because, in the first place, the coast is an unfavourable region for plant-life, and, in the second, all the species except three are also Australian, some having a wide range as well. And the above three species, which are essentially southern in their distribution, are purely subantarctic.

15. Life Forms and Adaptations of the True Coastal Plants.

Special details regarding the life forms of the coastal plants proper are briefly given in the table towards the end of this paper. Here a few general remarks are alone necessary.

A considerable number of the plants are halophytes, and these exhibit more or less the typical succulence of that class. Many have the rush-like habit, and of these *Leptocarpus simplex* has extremely stiff stems. Sand-binding plants—*i.e.*, those which rapidly grow at the extremities of their shoots as they are being buried, rooting at the same time—are present on the dunes, and exhibit the habit in various degress of intensity. On the salt meadows are turf-forming plants with crowded small leaves and far-creeping stems by which

they increase rapidly. Indeed, vegetative reproduction of this kind is frequent amongst coastal plants, and is manifestly of advantage to the denizens of wind-swept, barren stations. Certain shrubs have the ericoid habit; others have leaves clothed below with dense tomentum. *Pimelea arenaria* has small leaves closely covered with white silky hairs.

The twiggy, divaricating habit of growth so characteristic of New Zealand, and which bears every mark of having been evolved in a region of frequent winds of long duration, is shown in *Coprosma acerosa arenaria* of the dunes, *Plagianthus divaricatus* of the salt marsh, and *Hymenanthera crassifolia* of rocks. This latter has much thicker and stiffer branches than is usual in this class of plants.

None of the shrubs lose their leaves in winter except *Plag. divaricatus*, which is practically deciduous, though in some localities a few leaves remain in the interior of the bush. Some of the salt-meadow and salt-marsh herbaceous plants have their leaves in part or altogether destroyed during the winter, and so late as early September a salt meadow in Canterbury looks as if burnt up by drought.

The three ferns are evergreen, and have coriaceous leaves, though those of *Lomaria banksii* are not strongly so. *Lomaria dura* and *Asplenium obtusatum* frequently develop short trunks.

The grasses are of the "steppe" character, excepting *Calamagrostis billardieri* and *Bromus arenarius*, both of which have thin, flat leaves. *Atropis stricta* has a ring of dead leaf-sheaths at the base of its leaves, as in many New Zealand inland grasses and those of deserts. *Senecio rotundifolius* and *Olearia operina* and its close relative *O. angustifolia* have extremely coriaceous leaves, and are in habit like shrubs of the subalpine region. So, too, are *Aciphylla latifolia* and *A. lyallii* ecologically equivalent to subalpine meadow plants.

The roots of the psammaphytes and rock plants are long, those of the salt marsh and salt meadow of medium size or even short. *Plagianthus divaricatus* has long horizontal roots, thus recalling those of the mangrove *Avicennia officinalis*, and growing in a somewhat similar station at times. When it grows in firm ground it still has roots of the same kind. The subantarctic "trunk-forming" habit such as we see in *Carex secta* is occasionally to be found in *Leptocarpus simplex*. Such "trunks" are not living structures, but are made up of dead roots and rhizomes, and are an excellent contrivance for raising a plant out of excess of water.

Stilbocarpa lyallii belongs to a class to itself, since one plant can extend over many square metres of ground by means of

long arching runners which root at the nodes, there producing a thickish rootstock, from which many huge leaves raised high on long hollow stalks arise, each mass of leaves looking like an independent plant, as indeed it really is. Such a plant is an example of those large-leaved subantarctic plants which seem altogether too luxuriant for their surroundings. (See Cockayne, 13; p. 259.)

Lianes are not common amongst the true coastal plants, there being only *Tetragonia trigyna, Angelica geniculata* (if this be included among the "coastal"), and occasionally *Calystegia soldanella.* Parasites are altogether wanting. *Griselinia lucida* is frequently epiphytic in North Island forests, but in the South Island, where it seems strictly a coastal plant, it is confined to rocks.

Heterophylly, where absolutely different leaves appear on the same plant, or where there is a juvenile stage distinct from the adult, or a prolonged juvenile form, is wanting among the real coastal plants, though it is so common a phenomenon in New Zealand, and shown even by some inland-coastal plants. *Hymenanthera crassifolia* and *Plagianthus divaricatus* may, however, be considered to exhibit it to some small extent.

On the other hand, many of the plants are "plastic" enough. *Coprosma baueri* is a tree on dry clayey hillsides and a prostrate shrub on rocks. In both cases it has thick, rolled leaves. But when it is grown in the shade and in a wind-still atmosphere it has thinner, much larger, and quite flat leaves (Cockayne, 15A). Shade, too, has a most marked effect on the leaves of *Selliera radicans.* In other cases the nature of the soil and its water content makes the difference. Thus *Rumex neglectus* grows most luxuriantly amongst the coarse shingle of an upper shore, whereas in the wet soil of a coastal moor it is so stunted as to be hardly recognisable. *Cotula dioica,* however, may be much more luxuriant in the mud of a river-flat exposed to brackish water than when growing in a dry salt meadow. But this plant varies much in form and character in the same meadow, and doubtless some of the forms are rather constitutional and perhaps hereditary than merely the result of a special stimulus. *Myoporum lætum* is usually a low tree, but on the Moko Hinou Islands and Cuvier Island it is quite prostrate, with slender, flexible branches. *Dodonæa viscosa,* too, is either a tree, a shrub, or a prostrate plant according to its position. At Kaikoura in a salt meadow I collected a form of *Salicornia australis* with abnormally slender shoots, but which on cultivation in ordinary garden soil soon acquired a more typical form. This latter case is of interest, since the Kaikoura station was limestone, and the chemical nature of the ground seems to have

been the determining factor in change of form. The colour of the shoots of *Leptocarpus simplex* seems to vary with the environment, it being dull-green in the salt marsh but more or less red in the drier ground. *Calystegia soldanella*, as already noted, is prostrate usually, but where a support is available it assumes the climbing habit. *Veronica elliptica* is usually a tall shrub, but Mr. H. J. Matthews informs me it is a low-growing prostrate plant at West Wanganui Inlet, its most northern habitat. The form of this plant, also, as I have shown (14A; p. 371) is different on the Open Bay Islands from elsewhere on the coast. *Senecio lautus* is a luxuriant plant with pinnatifid leaves when growing on gravel shores or clay banks, but when on dry rocks its leaves become small and frequently entire. Finally, *Cotula coronopifolia* has both a land and a water form.

16. Details as to the Inland-coastal Plants.

With regard to those plants which belong also to inland formations, the most important will be dealt with in the special part of this series of papers. But here it must be pointed out that where climatic conditions permit the lowland forest to reach the shore, the coastal plants are much increased in number by many forest plants which are not truly maritime. These not only spread on to the beach, but may occupy rocks which were formerly a part of the mainland. In this latter case the plants are remnants of a former forest, and it is remarkable how some of them, which have no special adaptations, can exist in positions fully exposed to wind and sea-spray. One striking example may be cited. At Jackson's Bay, South Westland, stands on the beach a rock which is an island at high water, but can be approached at low tide. On its summit is a dense growth of *Coriaria ruscifolia*, *Nothopanax arboreum*, *Coprosma fœtidissima*, *Veronica salicifolia*, *Phormium tenax*, &c.; while on a covering of peaty soil on the face of the rock, below the above, is a dense mat of the charming liliaceous *Enargea marginata*, a plant of the forest-floor in certain parts of the North and South Islands and Stewart Island. Leaving out of consideration the above class of plants, there are also true coastal forests—or, more properly speaking, belts of trees and groves, some of whose members are much more frequent on the coast than elsewhere, and many of which perhaps ought to be included amongst the coastal plants proper—at any rate, such are true coastal formations: *Myoporum lætum* (*Myoporaceæ*), *Urtica ferox* (*Urticaceæ*), *Dodonæa viscosa* (*Sapindaceæ*), *Corynocarpus lævigata* (*Cornyocarpaceæ*), *Griselinia lucida* (*Cornaceæ*),

Macropiper excelsum (*Piperaceæ*), and in the extreme north *Dysoxylum spectabile* (*Meliaceæ*), *Paratrophis banksii* (*Moraceæ*). The palm *Rhopalostylis sapida* may also be included here.

But there is also a large element of the coastal vegetation the members of which are common inland plants, some even ascending high into the mountains. The following are more or less common examples, and they occur for the most part on the stable dunes.

A. Shrubs or low trees: *Liliaceæ — Cordyline australis; Leguminosæ — Carmichælia cunninghamii* (?), *Sophora microphylla; Violaceæ—Melicytus ramiflorus; Rhamnaceæ—Discaria toumatou; Epacridaceæ—Styphelia frazeri; Myrtaceæ—Leptospermum scoparium, Metrosideros lucida; Rubiaceæ—Coprosma propinqua; Thymelæaceæ—Pimelea lævigata repens; Compositæ—Cassinia fulvida, C. leptophylla, Olearia solandri.*

B. Lianes: *Polygonaceæ — Muehlenbeckia adpressa, M. complexa; Pandanaceæ—Freycinetia banksii.*

C. Parasites: *Loranthaceæ—Loranthus micranthus.*

D. Herbaceous plants (excluding grasses, sedges, rushes, &c.): *Iridaceæ — Libertia ixioides; Liliaceæ — Phormium tenax, P. cookianum; Orchidaceæ — Microtis porrifolia, Thelymitra longifolia; Caryophyllaceæ — Scleranthus biflorus; Rosaceæ — Acæna novæ-zelandiæ; Onagraceæ—Epilobium nerterioides; Umbelliferæ — Crantzia lineata; Scrophulariaceæ — Mazus pumilio; Plantaginaceæ—Plantago raoulii; Compositæ—Celmisia longifolia, Microseris forsteri, Raoulia australis.*

E. Grasses, sedges, &c.: *Typhaceæ — Typha angustifolia; Gramineæ—Hierochloe redolens, Zoysia pungens, Poa cæspitosa, Arundo conspicua; Cyperaceæ—Scirpus nodosus, Schœnus concinnus, Mariscus ustulatus, Cladium vauthiera, Carex lucida, C. appressa, C. ternaria.*

Had the coastal plants of the whole New Zealand biological area been under consideration the list of plants of all denominations would have been greater, since many important North Island coastal plants are absent, and the outlying islands possess some remarkable ones peculiar to themselves.

Before leaving the inland-coastal plants it is interesting to note the stations that several occupy, both inland and on the coast, as it shows the apparently wide range of conditions that many can tolerate. This is more apparent than real, since it can be seen without any special explanation that such seemingly diverse stations frequently agree in this, that they are physiologically dry, and so their plant inhabitants can find quite a congenial home on the stable dunes, for example. The following will serve as examples:—

Name of Plant.	Stations.
Cordyline australis ..	Swamps, clayey hillsides, stony river-beds, open forests, dunes.
Discaria toumatou ..	River-fans, stony plains, river beds and terraces, dry hillsides, rocks, dunes.
Styphelia frazeri ..	High alpine meadows, stony plains, river beds and terraces, clayey hills, dunes.
Leptospermum scoparium	Open forest, stony plains, dry montane slopes, old river-beds, swamps in constant water, bogs in *Sphagnum*, near solfataras and hot springs, dunes, brackish swamps.
Pimelea lævigata var. *repens.*	Subalpine tussock meadows, stony river-beds, stony plains, dunes, rocks surrounded at high water.
Cassinia fulvida ..	Montane and subalpine tussock meadows, stony plains, river-beds, dunes hardly stable, stable dunes.
Muehlenbeckia complexa ..	Taxad forests, river-terraces, montane meadows on stony ground, tussock slopes near sea forming semi-pyramidal dense bushes.
Phormium tenax ..	Lowland swamps, dry hillsides, moist hillsides, banks of streams, wet ground in river-beds, rocks, dunes, upper strand.
Phormium cookianum ..	Subalpine meadows, banks of subalpine streams, subalpine scrub, coastal cliffs.
Scleranthus biflorus ..	Montane and subalpine meadows, stony river beds and terraces, stony plains, dunes, coastal cliffs, shingly shores.
Acæna novæ-zelandiæ ..	Hillsides, dunes.
Crantzia lineata ..	Muddy shores of subalpine lakes, banks of tidal rivers to low-water mark, muddy shore, rocks, coastal moors.
Celmisia longifolia ..	Subalpine and hilly meadows, stony plains, subalpine and montane bogs, rocks, stable dunes.
Microseris forsteri ..	Montane and subalpine meadows, coastal rocks and cliffs.
Raoulia australis ..	River-beds to subalpine region, stony plains, dunes, shingly beaches.
Aciphylla squarrosa ..	Hilly meadows, dunes, shingly beaches.
Arundo conspicua ..	Swamps, wet ground in river-beds, rocks, margins of streams, dry hillsides, stable dunes.
Carex ternaria ..	Swamps, subalpine bogs, forests, dunes.

17. INTRODUCED PLANTS.

As the coastal formations become modified by the action of man through drainage, burning, and so on, and by the trampling of cattle, horses, and other introduced animals, their grazing and manuring, a large number of introduced plants make their appearance even in a formation so antagonistic as a wet salt meadow, and by slow but sure means the indigenous plants are ousted and a new formation comes into being. Such gradual changes are a distinct study in themselves, and must be reserved

for the special part of this series. Likewise, the burning or uprooting of an artificial formation, such as that of *Ulex europeus*, or *Lupinus arboreus* on the dunes, is a special case of the same kind, and plants could there gain a footing which would have no chance on an unmodified dune. And this leads the way to the repetition of that great truth which I have stated before, that in a formation where man and introduced animals have never penetrated there are few or no introduced plants. Therefore it is very hard indeed at the present time to estimate what introduced plants have come naturally from the inland modified formations into the coastal region. On the virgin Open Bay Islands, for example, I only noted *Poa annua* (15). But, however they may have come, there are now a considerable number of introduced plants on many parts of the coast, where the formations are to all intents and purposes primitive. Some of these have been planted to stop the drifting sand—*e.g.*, *Ammophila arenaria, Elymus arenarius, Lupinus arboreus,* and *Mesembrianthemum edule. Ulex europeus* and *Sarothamnus scoparius* of the same formation have escaped in the first instance from hedges.

The following are common everywhere, and some extend to high-water mark on shingly beaches: *Hypochœris radicata, Holcus lanatus, Bromus sterilis, Rumex obtusifolius, R. acetosella, Œnothera odorata, Trifolium repens, T. arvense, Silene quinquivulnera, Ranunculus sceleratus, Nasturtium officinale, Sagina apetala, Chenopodium album, Senebiera coronopus, Stellaria media, Medicago denticulata,* and *Glyceria fluitans.* But the introduced plants vary much in different parts of the coast, some being confined to limited areas and special conditions, and their names and distribution are quite beyond the scope of an introductory article.

18. Origin of the Coastal Vegetation.

There is no space to inquire at any length into the origin of the coastal vegetation. The fact that nearly all the species can be cultivated easily in ground devoid of salt and far from the seashore* shows that such plants are little dependent on their special and peculiar environment for their well-being. On the other hand, many garden plants can be grown successfully close to

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* I have cultivated or seen cultivated under non-coastal conditions the following coastal plants: *Veronica elliptica, V. lewisii, V. macroura, V. macroura cookiana, V. speciosa, V. dieffenbachii, V. chathamica, Plantago,* sp., of the Auckland Islands, *Plantago,* sp., East Cape Island, *Crassula moschata, Salicornia australis, Myosotidium nobile, Myosotis capitata albiflora, M. antarctica traillii, Aciphylla intermedia, Samolus repens, Lepidium tenuicaule,* various coastal forms of *Cotula dioica, Stilbocarpa lyallii, Plagianthus divaricatus.*

the sea, even in the most wind-swept localities,* if they are afforded shelter—*i.e.*, if the wind factor be eliminated. The seeds of many maritime plants are easily capable of spreading inland by various means, and yet there is the comparatively large number (94) of species which are confined exclusively to the coast. All the above points distinctly to the supposition that *the coastal plants as a whole occupy their peculiar station not from choice, but from necessity, and that they are ordinary inland plants* which have been driven out of the more hospitable ground by better-equipped competitors. Of course, having finally settled down in a halophytic or psammaphytic station, it goes without saying that such plants would in some instances, in course of time, develop those special adaptations which distinguish coastal plants.

Certain inland xerophytes (see list in Section 16) which commonly grow under coastal conditions owe their position to their xerophytic structure and the abundance of room offered in the open coastal formations for plant-colonists. It is easily conceivable that if certain causes changed the condition of existence for such inland xerophytes, the plants of the coast might be the sole survivors. In this way, too, without any special competition with other plants, coastal species may have originated. Such, in one instance, I have shown to be the case in Chatham Island, where *Phormium tenax*, formerly a most common plant, is day by day becoming restricted to a few special stations owing to the attacks of domestic animals and drainage (12).

19. Some Differences between North Island and South Island Coastal Vegetation.

Before concluding, a few words seem desirable on certain general differences which exist between the coastal vegetation of the North and South Islands. As already pointed out, the coastal vegetation proper of the South Island does not commence until parallel 42° S. is crossed, this being, however, a by no means rigid line of demarcation. To the north of this limit the formations are closely related to those of the southern part of the North Island. It is therefore between the vegetation of the northern and southern floristic provinces that a comparison may be drawn, rather than between the two Islands as a whole. These two provinces, even on the coast, are more or less different in many ways, but these differences have a twofold origin, the

* At New Brighton, Canterbury, a garden sheltered by a paling fence has been for some years on the actual shore, and many kinds of ordinary garden plants thrive excellently. The gardens of the lighthouse-keepers, where excellent vegetables are raised, are admirable examples of the same kind. So, too, are the many inland European plants which now grow naturalised close to high-water mark so frequently.

one floristic, the other ecological. These two classes are, however, somewhat closely associated.

The floristic difference is one of genera and species. As for the latter, twenty-seven are peculiar to the North Island coast, of which some sixteen are confined to the northern province, and it is some of these plants which strongly affect the physiognomy of the vegetation. On the other hand, the peculiar southern plants play a similar *rôle*.

But the ecological difference is still more marked. This is shown chiefly in the fact that some of the northern formations have a tropical or subtropical stamp, a feature dependent partly on historical and partly on climatic factors, especially rainfall; while the southern bear a subantarctic impress, the result of the very frequent cold south-west gales.

The viviperous mangroves fringing tidal rivers and estuaries, their pneumatophores emerging from the mud; the trunks of *Metrosideros tomentosa* projecting from the coastal cliffs, densely covered with huge masses of the epiphytic *Astelia banksii*, looking like a tropical bromeliad; the succulent *Peperomia* clothing dry banks or rocks; and *Entelea arborescens*, with its great, thin leaves, are tropical enough, to quote some examples.

On the other hand, the prevailing tone of the southern province, so far as the coast is concerned, and leaving out of the question those edaphic formations common to the two Islands, is distinctly subantarctic. Here stout tussocks, coastal moors, and shrubby growths resembling those of the high mountains form a distinct feature. But even here, on the west more especially, the tropical appearance is not wanting, and, indeed, is striking enough. *Freycinetia banksii* comes right on to the upper strand, forming the fringe of a truly subtropical forest, ecologically speaking, out of which peep the feathery fronds of tall tree-ferns, and within the dim light of which filmy ferns and luxuriant liverworts abound.

20. List of Coastal Plants Proper, their Distribution and Life-forms.

In the following list the various elements of the coastal flora are thus indicated: A = endemic, B = Australian, C = subantarctic, Cos. = cosmopolitan, whether entirely or confined specially to warm regions. Other elements are indicated by an abbreviated name of the special region, as Nor. I. = Norfolk Island, Polyn. = Polynesian Islands, N. Cal. = New Caledonia, &c. For the New Zealand distribution, 1 = North Island, 2 = South Island, 3 = Stewart Island, 4 = New Zealand sub-antarctic (Southern) Islands, 5 = Chatham Islands, 6 = Kermadec Islands. The terms used for distribution on the South Island coast speak for themselves.

Name of Plant and Natural Order	Distribution			Station.	Life-form of Plant.
	General	New Zealand	South Island.		
FILICES					
Asplenium obtusatum, Forst...	C, B	1, 2, 3, 4, 5, 6	All	Rocks, cliffs, peaty ground	Moderate-sized fern with very stout rhizome and thick coriaceous leaves.
Lomaria dura, Moore ..	A	2, 3, 4, 5	S E., S., S W.	Rocks, cliffs, peaty ground	Moderate-sized fern with thick, coriaceous, dark-green, rather narrow leaves, stout rhizome or sometimes a short arborescent stem.
Lomaria banksii, Hook f. ..	A	1, 2, 3	E, W., S.	Rocks, cliffs, stony ground	Rather small fern with narrow, dark-green, somewhat coriaceous leaves and stout woody rhizome.
SPERMAPHYTA.					
POTAMOGETONACEÆ					
Ruppia maritima, L. ..	Cos.	1, 2, 5	All	Lagoons, tidal streams	Slender, much-branched, aquatic herb with long filiform submerged stems, filiform leaves, and minute hermaphrodite flowers.
Zostera nana, Roth ..	Cos.	1, 2, 3	All	Muddy estuaries, between tide-limits	Grass-like aquatic herb with slender, far-creeping, matted rhizomes, narrow, thin, green, ribbon-like leaves, minute monœcious flowers, and rather short roots from the nodes.
Zostera tasmanica, Martens ..	B	1, 2	All (?)	As for *Z. nana*, but frequently in deeper water	As for *Z. nana*, but rhizomes farther-creeping and leaves longer.
Zanichellia palustris, L. ..	Cos.	1, 2	E.	Shallow estuaries, tidal streams	Slender, submerged, aquatic herb with much-branched filiform stems and filiform leaves forming close masses and minute monœcious flowers.
Althenia bilocularis (T. Kirk), Ascherson	A	2	E.	Shallow estuaries, tidal streams	Very slender, submerged, aquatic herb with branched filiform stems, very narrow leaves, and minute diœcious flowers.

Name of Plant and Natural Order.	Distribution			Station.	Life-form of Plant
	General	New Zealand.	South Island.		
SCHENZERIACEÆ.					
Triglochin striata, Ruiz and Pav., var. *filifolia*, Buchanan	B, C	1, 2, 3, 5	All	Salt marsh, salt meadow	Small perennial herb with stoloniferous rhizome giving off tufts of erect, slender, filiform, flaccid leaves and short fibrous roots. Flowers numerous, minute, greenish.
GRAMINEÆ.					
Spinifex hirsutus, Labill. ..	B, N. Cal.	1, 2	N., N.E.	Sandy shore, dune	Very stout, bamboo-like, sand-binding grass with extremely long, woody, creeping stems, rooting deeply, and long, silvery, coriaceous, involute leaves densely clothed with silky hairs. Flowers dioecious. Infrutescence with long spines specially adapted for spreading by wind.
Calamagrostis billardieri (R. Br.), Stend.	B	1, 2, 5	All	Dunes	Medium-sized, erect, tufted, perennial grass with thin, rather broad, flat, striated leaves and rather long roots.
Poa astoni, Petrie	A	2, 3	S., S.E.	Rocks, cliffs ..	Densely tufted perennial grass with narrow, tapering, slender, involute leaves, persistent leaf-sheaths, and long roots.
Atropis stricta (Hook. f.), Haek.	B	1, 2	All	Salt meadow ..	Rather small grass with tufted leafy culms clothed at base with dead leaf-sheaths. Leaves annual, sheathing almost the whole culm, pale-green, soft, involute. Roots short, slender, white, matted.
Atropis novæ-zealandiæ (Petrie), Haek.	A	2	S.	Salt meadow ..	Rather small very pale green grass with densely tufted leafy culms, 3–4-noded, of stouter habit than *A. stricta*. Leaves conduplicate, soft, thin.

Festuca littoralis	B	1, 2, 3, 5	All	Dunes	Densely growing perennial tussock-grass with erect, pale-yellow (green when young), rigid, closely involute, smooth, pungent leaves.
Bromus arenarius, Labill. ..	B	1, 2	N.	Dunes	Rather small annual grass, covered everywhere with soft hairs. Leaves linear, thin, flaccid, soon withering.
CYPERACEÆ.					
Elæocharis neo-zealandica, C. B. Clarke	A	1, 2	N.	Dunes	Very small sedge with short, slender, assimilating stems and slender creeping rhizome.
Scirpus frondosus, Banks and Sol.	A	1, 2, 3, 5	All	Unstable dunes ..	Very stout sand-binding sedge with extremely thick, woody, much-branching, far-creeping rhizome many metres in length, and giving off numerous tufts of extremely rigid, thick, coriaceous, curved and channelled, yellowish leaves, expanded below into broad, resin-exuding membranous sheaths, and tapering at apex into long points. Roots long.
Scirpus americanus, Pers. ..	B, C, S. Eur., N. Am	1, 2, 5	All	Salt marsh, salt meadow	Moderate-sized rather rush-like plant with perennial, moderately stout, long, black, woody rhizome, triquetrous, green, erect, slender, annual stems, and short, narrow, sheathing leaves.
Scirpus robustus, Pursh. ..	B, N. Am.	1, 2	All	Salt marsh, brackish streams	Tall rush-like plant with stout, perennial, creeping stem and three-angled leafy culm furnished with a few broad, flat, grassy leaves.
Carex litorosa, Bailey ..	A	1, 2, 3	All	Salt marsh, muddy shore	Moderately tall sedge forming close pale-green tussocks. Leaves narrow, rather thick, concave in front, convex behind. Roots moderate, rather matted.
Carex trifida, Cav.	C	2, 3, 4	N.(?) W., S.E., S.	Wet peaty ground where water lies	Extremely tall robust sedge forming dense and large tussocks. Leaves long, broad, tapering to fine point, bright-green, subcoriaceous but flexible, channelled on upper surface, covered with wax between numerous ribs of under surface. Roots long.

Name of Plant and Natural Order.	Distribution			Station.	Life-form of Plant.
	General.	New Zealand.	South Island.		
Carex pumila, Thunb. ..	C. D. E. Asia	1, 2, 3	All	Dunes and dune hollows, sandy shores, sandy beds of estuaries in shallow water at high tide	Rather small sedge with far-spreading, deeply buried, flexible rhizome producing from nodes scanty tufts of short, stout, leafy culms with flexible, thick, glaucous-green, incurved leaves, arching and tapering to a point. Roots fibrous with many short lateral rootlets.
RESTIONACEÆ.					
Leptocarpus simplex, A. Rich.	A	1, 2, 3, 5	All	Salt marsh, dunes	Tall rush-like plant forming close dense masses of crowded, hard, stiff, terete, wiry, smooth, green or reddish, assimilating, slender stems coming from a far-creeping, stout, woody rhizome. Roots wiry, frequently more or less horizontal. Flowers dicœcious.
JUNCACEÆ.					
Juncus maritimus, Lam., var. *australiensis*, Buchen.	B	1, 2	N., N.E., N.W.	Salt marsh, salt meadow	Stout rush forming close masses or large tufts of densely growing, rigid, wiry, brownish stems.
LILIACEÆ.					
Arthropodium cirrhatum (Forst. f.), R. Br.	A	1, 2	N, N.W.	Cliffs	Rather large herbaceous plant with broad, pale-green, soft, rather thick and fleshy leaves and stout rootstock with many long fleshy roots. Flowers white, rather large and showy.
POLYGONACEÆ.					
Rumex neglectus, T. Kirk. ..	A	1, 2, 3, 4	S., S.W., S.E.	Shingly shore, coastal moor	Perennial creeping herb with spreading rhizome and leaves varying much in size according to situation, green, rather thin, horizontal. Roots stout, long. Flowers inconspicuous.
CHENOPODIACEÆ.					
Rhagodia nutans, R. Br. ..	B	1, 2, 6	N., N.E.	Cliffs	Prostrate suffruticose plant with more or less mealy tomentum on leaves and young stem.

					Leaves small, flat, thin. Flowers minute, semi-dicœcious. Root long. Fruit fleshy.
Chenopodium triandrum, Forst. f	A	1, 2	N.E., S.W.	Cliffs	Suffruticose trailing plant with small, thin, green, more or less mealy, membranous leaves. Flowers very minute.
Chenopodium glaucum, L., var. *ambiguum*, Hook. f.	B	1, 2, 3	All	Salt meadow, gravelly shore	Annual, much-branched, prostrate, succulent herb with fleshy green leaves, white with meal beneath. Flowers small. Root medium.
Atriplex cinerea, Poir. ..	B	1, 2	N.	Salt meadow ..	Small branching shrub covered with appressed scurfy tomentum. Leaves medium, thin. Flowers dicœcious, small.
Atriplex patula, L. (including var. *hastata*)	Cos.	1, 2	All	Salt meadow ..	Annual herb varying in habit from erect to prostrate. Leaves moderate-sized, flat, rather thin. Flowers small, moncœcious.
Atriplex buchanani, T. Kirk. ..	A	1, 2	N E., S.	Cliffs	Much-branched, prostrate, semi-suffruticose plant forming small greyish-white patches. Leaves small, rather thin, densely clothed with scurfy tomentum. Flowers moncœcious, minute. Root long.
Atriplex billardieri, Hook. f. ..	B	1, 2, 3, 5	S.	Sandy or gravelly shore	Succulent prostrate herb with much-spreading radiating shoots covered everywhere with watery papillæ. Leaves small, thick, succulent and fleshy. Flowers moncœcious, small. Root long.
Salicornia australis, Sol. ..	B	1, 2, 5	All	Salt meadow, rock	Semi-suffruticose plant with numerous spreading, semi-prostrate, succulent, almost leafless, assimilating stems, the upper parts of which die in winter together with much of the cortex. Flowers minute. Roots stout, woody, frequently spreading horizontally.
Sueda maritima, Dum. ..	Cos.	1, 2	All	Open salt marshes	Much-branched semi-suffruticose plant varying in height, with short, thick, succulent, semi-terete or cylindrical leaves and small greenish flowers.

Name of Plant and Natural Order.	Distribution			Station.	Life-form of Plant.
	General	New Zealand.	South Island.		
Salsola kali, L.	Cos.	1, 2	N.E.	Sandy shore ..	Rigid, semi-procumbent, loosely and much branched herb with rather short, thick, dull-green, succulent, semi-terete, prickle-pointed leaves. Flowers small. Root long.
AIZOACEÆ.					
Mesembrianthemum australe, Sol.	B, Nor. I. Howe	1, 2, 5, 6	All	Cliffs, rocks, stony shore	Suffruticose trailing or creeping plant with very long, rooting at nodes, rather thin stems and largish, thick, succulent, triquetrous leaves. Flowers large, whitish or pink. Roots long, rather slender.
Tetragonia expansa, Murr. ..	B, C, Nor. I., Howe, Jap.	1, 2, 3, 6	All	Sandy shores, gravelly shores	Semi-erect, spreading, or decumbent herb with succulent rather thick leaves. Flowers small, yellow, fairly conspicuous. Root long. Fruit horned.
Tetragonia trigyna, Banks and Sol.	B	1, 2, 3, 5, 6	All	Sandy shore, coastal shrubs beyond shore	Trailing or climbing semi-suffruticose plant with long stems and leaves, &c., much as in *T. expansa*. Fruit succulent.
CARYOPHYLLACEÆ.					
Colobanthus muelleri (*typica*), T. Kirk.	A	1, 2, 3, 5	All	Cliffs, rocks, stony shores	Tiny perennial herb with very small, channelled, rigid leaves in small rosettes. Flowers small. Root long, stout above.
Tissa media (L.), Dumort. ..	Cos.	1, 2, 3	All	Salt meadow, rocks	Prostrate or semi-erect herb with linear, viscid-pubescent, succulent, tufted leaves. Flowers pinkish, moderately conspicuous Roots very stout, long.
RANUNCULACEÆ					
Ranunculus recens, T. Kirk ..	A	1, 2	E.	Dunes	Small, low-growing, perennial herb with small, thick, coriaceous leaves in a rosette from a stout rootstock. Flowers small, yellow. Roots long, stringy.

Ranunculus acaulis, Banks and Sol.	C	1, 2, 3, 4, 5	All	Sandy, muddy, and stony shore	Prostrate perennial herb with pale, slender, creeping, underground stem and small, succulent, 3-lobed or 3-foliate pale-green leaves close to the ground forming patches of small rosettes. Flower yellow, small, usually buried in sand up to the calyx. Ripe flower-stem arching into or towards ground frequently. Roots long, fleshy.
CRUCIFERÆ.					
Capsella procumbens, Fries. ..	Cos.	2	E.	Cliffs	Slender low-growing herb with small leaves and numerous stems, decumbent below, ascending above. Flowers minute, white.
Lepidium oleraceum, Forst. f., var *acutidentatum*, T. Kirk	A	1, 2, 3, 4, 5	All	Rocks, rocky shores	Tall semi-suffruticose plant with thick stem and fair-sized, rather thick, glabrous leaves. Flowers white, moderately conspicuous. Root stout, long.
Lepidium banksii, T. Kirk (perhaps, as Cheeseman suggests, identical with the preceding)	A	2	N.	Station (?) ..	As for preceding.
Lepidium flexicaule, T. Kirk ..	A	1, 2	N.W.	Station (?) ..	Procumbent, fleshy, glabrous herb with numerous branched stems and medium-sized pinnatifid leaves. Flowers white, small.
Lepidium tenuicaule, T. Kirk..	A	2, 3	E., S.E., S.	Gravelly shore ..	Low-growing herb with numerous short, procumbent, slender branches and much-cut slightly fleshy leaves close to the ground. Root extremely thick, taproot. Flowers white, small.
CRASSULACEÆ.					
Crassula moschata, Forst. ..	C	1, 2, 3, 4, 5	All	Rocks, wet cliffs, shallow-water pools, coastal moor	Succulent herb with tufted stems, prostrate below ascending above, very small thick leaves, and inconspicuous white flowers. Root moderate.
Crassula helmsii (T. Kirk), Cockayne	A	2	N.W.	Station (?) ..	Herb with numerous slender stems forming large patches and distant, small, linear leaves. Flowers minute.

Name of Plant and Natural Order	Distribution			Station.	Life-form of Plant.
	General	New Zealand.	South Island		
LINACEÆ.					
Linum monogynum, Forst. f. ..	A	1, 2, 3, 5	..	Rocks, cliffs, dunes, clayey hills and banks	Somewhat tall, rather slender, bushy, suffruticose plant with numerous small, rather narrow, more or less patent, soft, slightly fleshy, palish-green leaves and deeply descending, long, stout, and woody taproot. Flowers rather large, white, showy.
EUPHORBIACEÆ.					
Euphorbia glauca, Forst. f. ..	Nor. I.	1, 2, 5	All	Dune, gravelly shore	Tall stout herb with far-reaching deeply buried rhizome and stout, erect, fleshy stems with rather large, crowded, fleshy, glabrous leaves. Flowers small. Root long.
TILIACEÆ.					
Entelea arborescens, R. Br. ..	A	1, 2	N.	Station (?) ..	Low tree with moderate trunk and round crown. Leaves very large, thin. Flowers abundant, white, large. Fruit covered with large rigid bristles.
MALVACEÆ.					
Plagianthus divaricatus, Forst.	A	1, 2, 5	All	Salt marsh, salt meadow	Ball- or cushion-shaped, much divaricatingly-branched, almost deciduous shrub with stiff slender twigs and numerous small leaves. Flowers almost unisexual, numerous, very small, yellowish-white, sweet-scented. Roots stout, frequently spreading horizontally.
VIOLACEÆ.					
Hymenanthera crassifolia, Hook. f.	A	1, 2	N., E., N.W. (?)	Cliffs, rocks ..	Dense-growing, low, evergreen shrub with very rigid, thick, tortuous, interlacing branches frequently forming a dense stiff mat flattened against the substratum. Leaves numerous, small, thick. Flowers inconspicuous, on underside of branches. Fruits succulent, white with dark blotches.

THYMELIACEÆ.					
Pimelea arenaria, A. Cunn. ..	A	1, 2, 5	All	Dunes	Much-spreading shrub forming low cushion-like bushes of slender flexible branches clothed above with dense silvery tomentum. Leaves small, closely silvery-tomentose beneath. Flowers white, in close heads, conspicuous, polygamo-dicœcious. Fruit fleshy. Roots cord-like, long.
HALORRHAGIDACEÆ.					
Gunnera hamiltoni, T. Kirk ..	A	2, 3	S	Station (?) ..	Creeping, much-branched, perennial plant with stout rhizome and numerous coriaceous small brownish-green leaves with stout, reddish, channelled petioles, in broad flat rosettes forming patches. Monœcious. Flowers small. Fruit fleshy.
Gunnera arenaria, Cheesem. ..	A	1, 2	N.E., S.	Moist hollows, amongst dunes, or flat sandy ground at back of dunes	Creeping perennial herb forming large round patches close to the ground of stout runners, fleshy and juicy, rooting at nodes, where they bear small rosettes of rather long-petioled, thick, subcoriaceous, small leaves. Flowers inconspicuous, monœcious, dimorphic. Fruit fleshy. Roots fleshy, moderate
ARALIACEÆ					
Stilbocarpa lyallii, Armstg. ..	A	2, 3	S.W.	Rocky shore, in dry peaty ground, among coastal shrubs	Very large herbaceous evergreen plant with long arched runners swollen into rootstocks at nodes, which root below and give off above bright shining-green, long-petioled leaves with large, thin, orbicular-reniform blades. Flowers small, reddish-purple. Plants cover large areas and increase enormously vegetatively. Roots thick, long, rather woody.
UMBELLIFERÆ					
Hydrocotyle tripartita, R. Br., var. *hydrophila* (Petrie), Cheesem.	A	2, 3	E., S.	Shallow brackish water	Small creeping herb with short filiform stems and minute, shining, tripartite leaves. Flowers inconspicuous.
Eryngium vesiculosum, Lab. ..	B	1, 2	N., N.W., E.	Salt meadow ..	Low-growing herb with prostrate rooting stems and crowded, stiff, rosulate, moderate-sized, spiny thin leaves. Flowers in dense heads, pale-blue.

Name of Plant and Natural Order.	Distribution			Station.	Life-form of Plant.
	General	New Zealand.	South Island.		
Apium prostratum, Lab. ..	B, C	1, 2, 3, 4, 6	All	Salt meadow, dune, stony beach, rock	Prostrate or suberect perennial herb with thick stems and rather thick, usually large leaves, but varying much in size and texture. Flowers white, small. Root very stout and long.
Apium filiforme (A. Rich), Hook. f.	Isle of Pines	1, 2	All	Salt meadow, coastal moor, stony beach	As for preceding, but stems slender and prostrate, and much smaller in all its parts.
Aciphylla intermedia (Hook. f.), Benth. and Hook.	A	2, 3	S.E., S., S.W.	Sandy and gravelly shore, cliff	Tall perennial herb with stout erect stems full of milky juice and broad much-divided leaves with stout long petiole. Flowers white, conspicuous through their number, rather unpleasantly scented. Root thick, long.
Aciphylla lyallii (Hook. f.), Benth. and Hook.	A	2	S.W.	Sandy and gravelly shores	As for preceding, but leaf-segments much narrower.
PRIMULACEÆ.					
Samolus repens (Forst.), Pers., var. *procumbens*, R. Knuth.	B, C	1, 2, 3, 4, 6	All	Salt meadows, salt marsh, rock	Creeping herb with wiry underground stems and short, erect, leafy branches. Leaves small, rather fleshy. Flowers white, numerous, and conspicuous though small. Root medium, wiry.
GENTIANACEÆ.					
Gentiana saxosa, Forst.	A	2, 3	S.W., W., S.	Sandy peaty ground, coastal moor	Tufted herb with rather stout stems, prostrate below but ascending near apices. Leaves closely crowded, fleshy, shining, often arching downwards. Flowers large, white, conspicuous, only slightly raised above foliage. Root rather stout, long.

CONVOLVULACEÆ.					
Calystegia soldanella (L.), R.Br.	Cos.	1, 2, 3, 5, 6	All	Dune, sandy and stony beach	Creeping but occasionally climbing perennial herb with thick and partly subterranean fleshy stems and long-stalked, moderately large, fleshy, reniform leaves. Flowers showy, white with lilac stripes. Roots long.
BORAGINACEÆ.					
Myosotis capitata, Hook. f., var. *albiflora*, Armstg.	A	2, 3, 4	S., S.E.	Shady damp rocks in peat	Stout perennial herb with pale-green, medium-sized, densely-hairy, thick, soft leaves in semi-horizontal rosettes, below which are the persistent leaves of the previous year. Flowers raised considerably above leaves, white, rather small. Roots medium.
Myosotis antarctica, Hook. f., var. *traillii*, T. Kirk	A	2, 3	S., S.W.	Gravelly beach, dune	Low-growing, tufted, perennial herb with slender, spreading, leafy branches, small hispid leaves, and minute white flowers.
SCROPHULARIACEÆ.					
Mimulus repens, R. Br. ..	B	1, 2, 3	N., E, S., N.W.	Shallow streams in salt meadow, salt marsh	Perennial herb with rather thick, creeping, succulent stems, rooting at nodes, prostrate or erect branches, and small succulent leaves. Flowers showy, bright-lilac with protuberances on lower lip yellow dotted with orange. Root medium.
Glossostigma submersum, Petrie	A	2	E.	Tidal shore of lagoon	Minute, slender, branched herb forming small close mats on the ground, stems rooting at nodes, and leaves minute. Flowers extremely small and inconspicuous.
Veronica speciosa, R Cunn. ..	A	1, 2	N.	Station (?) ..	Rather tall stout shrub with spreading branches and large, thick, coriaceous, dark-green, glossy leaves. Flowers showy, in dense racemes, crimson.
Veronica divergens, Cheesem	A	2	W.	Coastal scrub (?)	Small laxly-branched shrub with slender twiggy branchlets and small leaves. Flowers rather small, white, in slender racemes.

Name of Plant and Natural Order.	Distribution.			Station.	Life-form of Plant.
	General.	New Zealand.	South Island.		
Veronica amabilis, Cheesem. ..	A	2	S.	Coastal scrub ..	Tall shrub with not very dense, erect, rather slender stems furnished near their extremities with rather large, slightly thick, willow-shaped leaves. Flowers showy, in long racemes of white flowers.
Veronica amabilis, Cheesem., var. *blanda*	A	2, 3	E., S.W.	Coastal scrub ..	Much as preceding, but with denser habit and perhaps thinner leaves. Flowers white, showy.
Veronica lewisii, Armstg. ..	A	2	E.	Station (?) ..	Moderately tall close-branched shrub with stout branches, medium-sized pale-green leaves, and medium racemes of large pale-lilac flowers.
Veronica elliptica, Forst. f. ..	C	2, 3, 4, 5 (?)	S.E., S., W.	Rocks, cliffs, coastal scrub	Tall, much-branched, evergreen shrub of dense habit with numerous rather small, pale-green, thick, close-set leaves and short racemes of large, sweet-scented, pale-lilac flowers, finally becoming white.
Euphrasia repens, Hook. f. ..	A	2, 3 (?)	S.	Coastal moor ..	Small perennial herb with (for size of plant) stout creeping stem, rooting at nodes and giving off numerous prostrate or semi-erect short branches, forming extremely dense roundish patches or semi-cushions. Leaves three-lobed, minute. Flowers small, but conspicuous owing to extreme abundance, white with purple line down centre of limb, and white-and-orange tube.
PLANTAGINACEÆ.					
Plantago hamiltonii, T. Kirk (This, if not a good species, is certainly a distinct form of *P. triandra*, Bergg.)	A	2	S.	Coastal moor, peaty bank	Small, perennial, evergreen herb having rather broad, small, rather thick, coriaceous, shining-green but with purplish-brown base, almost glabrous leaves, overlapping and forming close flat rosettes which grow crowded together and

					form a dense covering to the ground. Root-stock short and fleshy. Flowers very small. Root long and fibrous.
RUBIACEÆ.					
*Coprosma bauer*i, Endl. ..	Nor. I.	1, 2, 6	N., N.W.	Cliffs, hillsides, rock	A small tree with gnarled branches, or a more or less prostrate shrub. Leaves shining-green, rolled more or less, fleshy. Flowers dioecious, not showy. Fruit fleshy.
Coprosma acerosa, A. Cunn., var. *arenaria*, Cheesem.	A	1, 2, 3, 5	All	Dune	Evergreen shrub with much interlaced, very wiry, yellow-coloured, twiggy branches and small narrow leaves forming a dense, low, flat bush Flowers dioecious, inconspicuous. Roots long.
CUCURBITACEÆ.					
Sicyos australis, Endl. ..	B, Nor. I., Howe	1, 2	N.	Station (?) (Queen Charlotte Sound, collected first voyage of Captain Cook, but now probably extinct in this habitat)	Tendril-climbing liane with stout succulent stem and long-petioled, thin, large, membranous leaves. Flowers monoecious, small, greenish. Fruits small, densely covered with barbed spines. Roots long.
CAMPANULACEÆ					
Wahlenbergia saxicola (R. Br.), A. D C., var. *congesta*, Cheesem.	A	2	N.W.	Sand	Creeping perennial herb with much-branched and interlacing stems forming dense matted patches and small leaves. Flowers medium, pale-blue.
GOODENIACEÆ.					
Selliera radicans, Cav. ..	B, C	1, 2, 3, 5	All	Salt meadow ..	Procumbent perennial herb with stout, chestnut-brown, wiry, creeping, underground stem and thick, fleshy, vertical leaves forming a dense turf. Flowers white, fairly conspicuous. Roots medium, slender.
COMPOSITÆ					
Brachycome thomsoni, T. Kirk (excluding var. *membranifolia* and var. *polita*)	A	2, 3	E., S.	Peaty ground ..	Medium-sized perennial herb with stout creeping rhizome and stems and glaucous fleshy leaves glandular-pubescent. Heads medium, with white ray-florets. Roots fibrous, moderately long.

Name of Plant and Natural Order	Distribution.			Station	Life-form of Plant
	General	New Zealand.	South Island		
Olearia operina (Forst. f.), Hook. f.	A	2	S.W.	Coastal scrub .	Stout, tall, evergreen shrub with thickish, rigid, tomentose branches having rather large, lanceolate, coriaceous leaves densely tomentose on under surface, showy heads of flowers with disc yellow and ray-florets white, and long roots
Olearia angustifolia, Hook. f...	A	2, 3	S.	Rocky ground ..	As for preceding, which it almost exactly resembles in every respect except the disc-florets are purple.
Helichrysum purdiei, Petrie ..	A	2	E.	Stony bank ..	Evergreen, suffruticose, spreading, wiry, more or less prostrate plant with many slender branches tomentose at their tips and small membranous leaves tomentose beneath. Flower-heads inconspicuous. Roots long.
Cotula coronopifolia, L. ..	B, C	1, 2, 3, 5	All	Salt meadow, salt marsh, shallow water	Evergreen herb with soft, succulent, creeping or floating stem and medium-sized, narrow, rather fleshy leaves. Flower-heads yellow, rather showy. Roots medium.
Cotula dioica, Hook. (including all its forms excepting those specially inland)	A	1, 2, 3, 4	All	Salt meadow, coastal moor	Small, evergreen, perennial herb with far-creeping stem rooting at nodes, and close-growing, aromatic, rather fleshy, green or brownish leaves. Flowers rather pale, not showy.
Senecio lautus, Forst. f. (excluding var. *montanus* and var *discoidens*)	B	1, 2, 3, 5, 6	All	Rocks, cliffs, stony shores, clayey banks	More or less erect biennial (?) herb with succulent leaves varying much in size and form according to station. Flower-heads small, yellow. Roots medium, stout.
Sonchus asper, Hill, var. *littoralis*, T. Kirk (I think this is a good species, and in a paper now in the press am dealing with it as such)	A	1, 2, 3	..	Cliffs	Stout perennial herb with thick stems bearing rosettes of rather large, pale-green, rather thick leaves, which have a very fleshy midrib. Young leaves densely tomentose. Flower-heads moderately large, florets white. Root long, thick, and full of latex.

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ART. XXXI.—*Supplementary Note on the Defoliation of* Gaya *in New Zealand.*

By L. COCKAYNE, Ph.D.

[*Read before the Philosophical Institute of Canterbury, 14th November,* 1906.]

IN the "Transactions of the New Zealand Institute" for 1904 I published a note to the effect that *Gaya lyallii* var. *ribifolia*, growing at an altitude of less than 3,000 ft., was in its natural habitat a deciduous tree, notwithstanding the general opinion to the contrary. I also suggested that, in all probability, *Gaya lyallii* (the western plant) was also deciduous at all altitudes. Previously to this, it had been looked upon as a fact that the New Zealand forms of *Gaya* were evergreen at below 3,000 ft. and deciduous at above that altitude—a very remarkable biological fact indeed, if true. Even in the recently published "Manua