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The Flora, Vegetation and Soils of Macquarie Island

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INTRODUCTION

History of Macquarie Island. Macquarie Island was discovered in 1810 by Captain Hasselborough in the "Perseverance," whilst looking for new sealing grounds. During the following five years the island was visited by a large number of ships which landed parties of men and returned later to collect vast cargoes of fur seal skins.

This slaughter soon rendered the fur seal extinct, and the trade transferred its attention to penguins and sea elephants, which were exploited for their oil till as late as 1918. In 1933 the Government of Tasmania declared the island to be a sanctuary for all native fauna.

Botanical history. During the 140 years of its history Macquarie Island has been visited by a number of scientific expeditions, and several biologists secured passages with sealing ships. However, apart from the Australasian Antarctic Expedition (A.A.E.) and the Australian National Antarctic Research Expeditions (A.N.A.R.E.), none stopped longer than a fortnight.

The first knowledge of the flora came in 1830, when a collection of 8 species was forwarded to Kew (Cheeseman, 1919). This included all conspicuous species of the flora with the notable exception of *Stilbocarpa polaris,* presumably omitted because of difficulties in preserving.

No additions were made to this list until Dr. Scott, of Otago University, reached the island in 1880 on a sealing ship. His report (Scott, 1883) included a list of vascular species collected, the actual number being determined by Cheeseman (1919) as 18.

In 1894 Mr. A. Hamilton, also of Otago, spent thirteen days on the island. His report (Hamilton A., 1895) included a list of 32 vascular plants, native and introduced, a most praiseworthy effort for so short a stay. This list included two endemic grasses, *Poa hamiltoni* and *Deschampsia penicillata,* both of fairly rare occurrence. Indeed *Deschampsia penicillata* was not found again until 1950.

Although two scientific expeditions made short calls at the island no additional botanical work was carried out until the arrival of the A.A.E. in 1911. During the first two years a party of five men was stationed on the island, including a biologist, Mr. H. Hamilton, and a geologist, Mr. L. R. Blake. During the years 1914-15 the island was occupied by parties of three men who maintained a radio and meteorological station.

H. Hamilton, the son of A. Hamilton, although working mainly on zoology, made a comprehensive collection of vascular plants. This collection, which was the subject of Cheeseman's report (1919) included all previous records, with the exception of *Deschampsia penicillata* and *Uncinia riparia*, and four new records, *Puccinellia macquariensis, Juncus scheuchzerioides, Scirpus aucklandicus* and *Carex trifida*. The latter two species grow only on the west coast, which had not been visited by previous investigators. The discovery of *Puccinellia macquariensis* added the third endemic species to the flora.

The geologist, L. R. Blake, collected 10 soil samples. These were all surface samples from highmoor peats, beach deposits and scree slopes. These samples were packed wet and not analysed till 1916. These data and Blake's observations on soils were included in Mawson's report (1943). Unfortunately, several of these observations on the soils are entirely wrong, presumably because they were made without the aid of soil pits. Blake's charts of the island, which were found to be most reliable, have been used as the base for the vegetation maps in the present report.

In November, 1930, the British, Australian, New Zealand Antarctic Research Expedition (B.A.N.Z.A.R.E.) made a short stay at the island. No record was published on the vascular plants, but analysis of 10 soil samples collected is included in Piper's paper (1938). These samples also were collected only from highmoor peats, beach deposits, and scree slopes, and with the exception of a two-foot beach profile were all surface samples. The analytical figures published show them to be typical samples, but most were lower than normal in organic content.

No further expeditions visited the island until 1948, when the first A.N.A.R.E. party established the present station on the isthmus near the extreme north end of the island. During 1948-49 an excellent collection of vascular plants was made by N. Laird, Tasmanian Government Photographer attached to the Expedition. This collection, numbering 2,000 sheets of specimens, included all previous records with the exception of *Deschampsia penicillata* and *Deschampsia chapmani*, and has been divided between the Tasmania Museum and the Melbourne Herbarium. Further smaller collections were made by the biologists of the 1948-49-50 A.N.A.R.E. parties.

The writer's own collection (1950-51), another 2,000 sheets, will be made available by the Expedition to interested institutions. This collection contains all previous records, as well as two new records, *Myriophyllum elatinoides* and an undescribed species of *Hydrocotyle*. A further small collection was made in 1951-52 by a micro-biologist, J. Bunt, which included all records except *Myriophyllum elatinoides*.

Geography, physiography and geology. Macquarie Island (Lat. 54° 30'S, Long. 158° 57'E.) lies approximately 800 miles south-east of Tasmania, 600 miles south-west of New Zealand, and 900 miles from the nearest point of the Antarctic Continent. Politically, it is a part of the

District of Esperance in the Australian State of Tasmania.

The island is 21 miles long with its main axis running N15°E. It has a maximum breadth of 3 miles and an area of 46 square miles. Its outlying islands, Judge and Clerk, 9 miles N.N.E., and Bishop and Clerk, 20 miles south, are mere strings of barren rocks.

The island is a mountain range rising abruptly from the sea. It is ringed completely by steep slopes or cliffs, and may conveniently be divided into three physiographic units: Slopes, plateau, and coastal terrace (raised beach).

The slopes which surround the plateau are usually between 600 and 1,000 feet in elevation, and vary in steepness from 25°-80° with an average of 40°-45°. They are dissected by a few large, low-level glacial valleys and by many cascading streams.

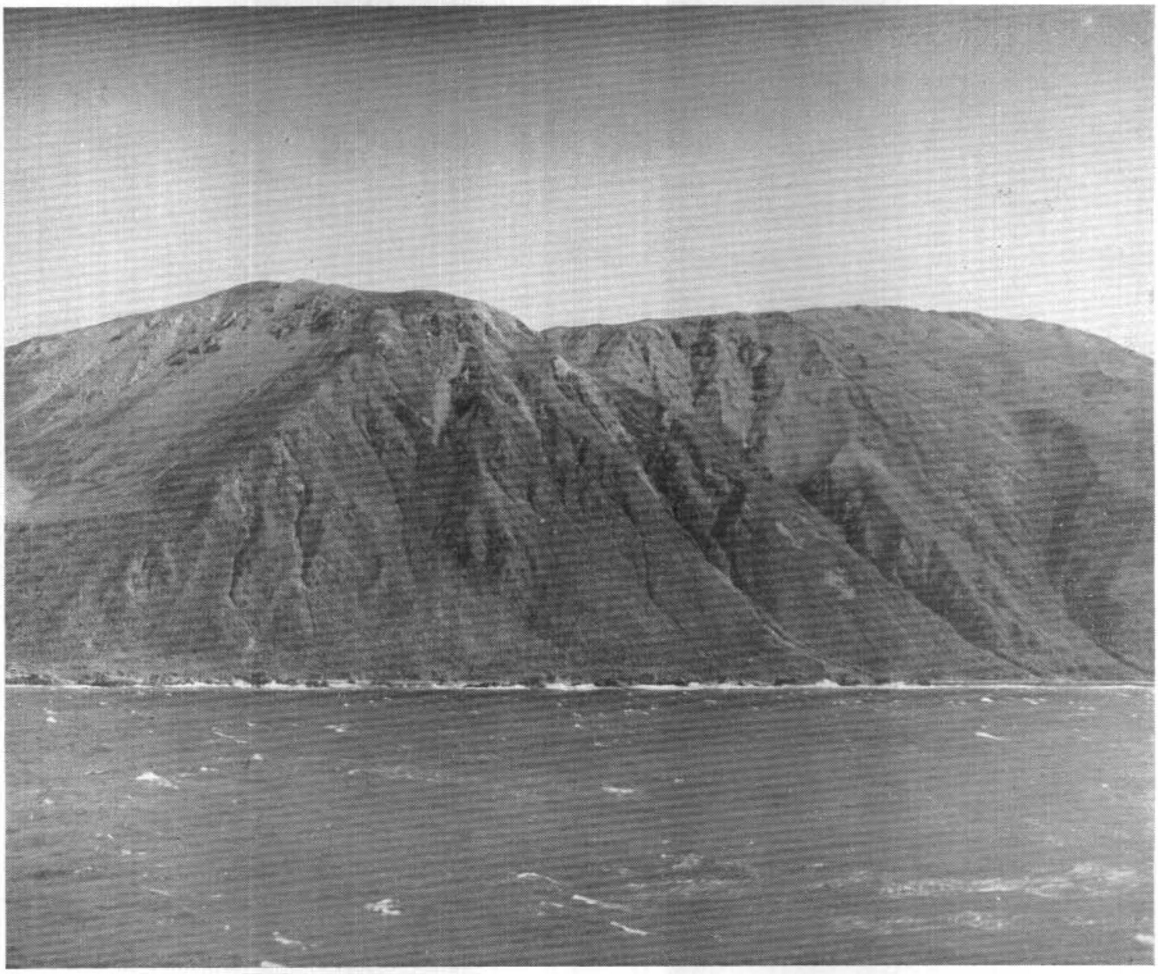

Plate 1. Coastal slopes, east coast. Steep slopes arising from a narrow coastal terrace and dissected by cascading streams. (Photo, N. Laird).

The plateau itself consists of flats and glacially-rounded ridges and hills. The slopes here rarely exceed 25°. Many small mountains rise from the general level of the plateau. They are fairly uniform in height, with the highest point, Mount Hamilton, at an elevation of 1,423 feet.

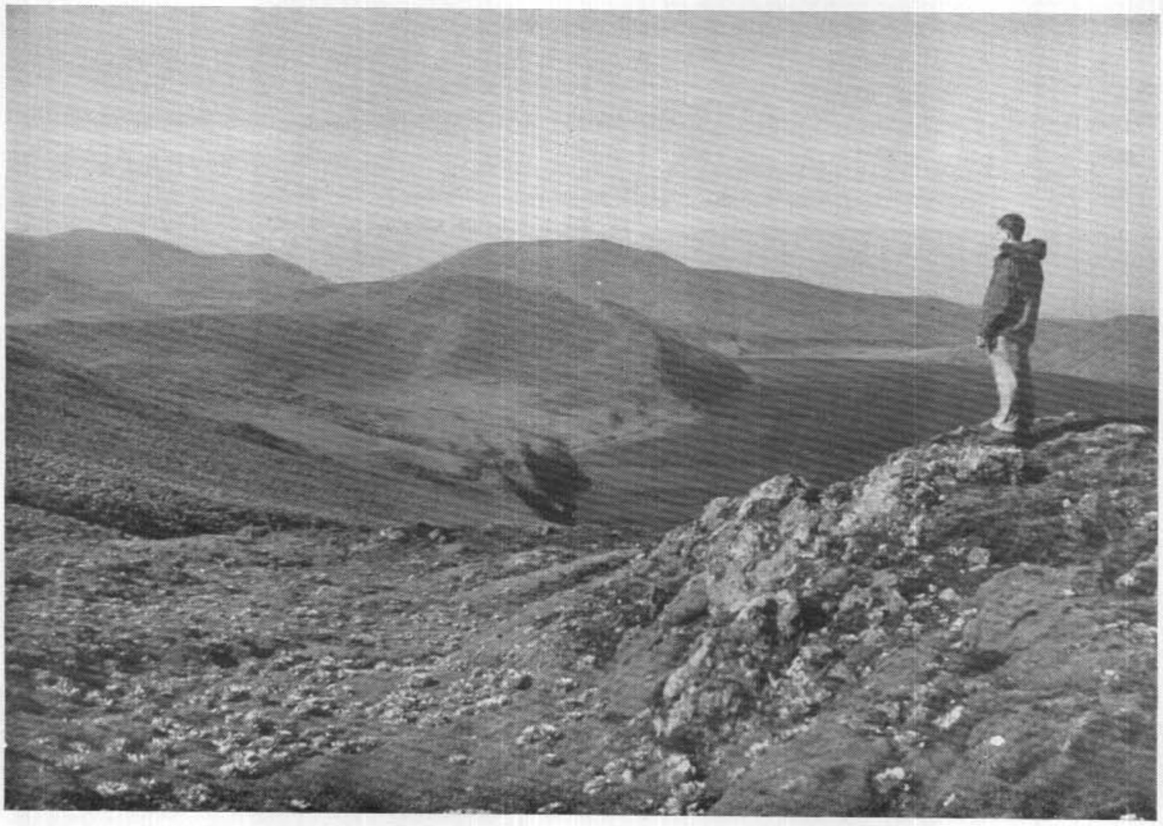

Plate 2. The plateau overlooking Prion Lake. (ANARE Photo).

Lakes and ponds are very frequent on the plateau, their total extent approximating to 1 square mile, with the largest, Major Lake, having an area of 113 acres. Some of these lakes drain away by soakage, others feed well-defined streams. In 1911, Major Lake was undrained (Mawson, 1943), but it now feeds a shallow stream. Running streams occur frequently and are found in even the smallest drainage basins in peat soils.

Plate 3. New exit to Major Lake, Mount Blake in background. (ANARE Photo).

The coastal terrace rings the island, except for a few scattered areas of the southern half of the west coast and a mile or more of the south coast. In these areas steep cliffs rise directly from the sea. The coastal terrace is often as small as 10 yards in breadth on the east coast and reaches its maximum width of a half mile on the northern half of the west coast.

This terrace consists of beach sands and gravels and is a raised beach formed by the elevation of the island since the recession of the last ice age melted the great mass of ice resting on the island (Mawson 1943).

The beaches are in the main composed of rounded shingle, but in a few bays they are of grey sand formed from fragmented basic rocks. Shingle beaches are common on the east coast, but are rare on the west coast which is almost continually exposed to a strong westerly swell. Spray from this swell causes a noticeable haze even on windless days.

The ice ages have left a very marked impression on the island's physiography. The highlands exhibit all the usual glacial features, e.g. great expanses of boulder clay, glacial valleys, roches moutonnées, ice-formed lakes and scattered erratic boulders. There are, however, none of the knife-edge peaks characteristic of nunataks. Every hill and mountain shows the action of a dense ice sheet.

The geological history of the island was summarised by Mawson (1943) as follows: "The first formed rocks were basaltic flows and sills which suffered from sub-aerial erosion, and then subsided to a considerable depth, receiving a deposit of globegerina ooze. Then followed a volcanic period which ended with a larger area of land in the region than at present. After some peneplanation, glaciation on a grand scale intervened. There is no geological evidence that suggests even indirectly that there was any land in the region not buried under ice."

The rocks of the island are all basic and igneous, the more important being gabbros, ultrabasics, pegmatites, calc-alkali dolerites, alkali dolerites, calc-alkali basalts and alkali basalts.

Climate. The climate may be classed as a cold temperate, or sub-polar oceanic climate. Its most outstanding features are the small range of temperature variation, high humidity and high wind velocities.

All figures quoted for the periods from January 1912 to November 1913 and from December 1914 to November 1915 come from the published reports of the A.A.E. (Series B, Vol. III, 1929). Figures for the period March 1948 to December 1951 come from the published A.N.A.R.E. Reports (Series D, Vols. I-IV, 1950-1953).

The weather stations of both expeditions were situated in the centre of the isthmus at an elevation of 25 feet. In this site relatively little interference could be expected from the surrounding land.

Temperature. Temperature data for the seven years of published records are given in Tables 1 to 4 and summarised in Table 5.

The mean temperature is 40.0°F. which is not abnormal for the latitude. However, the range of temperature is remarkably small. The difference between the means of the hottest and coldest months is only 6.0°F. whilst the mean diurnal range is only 5.7°F. The absolute maximum recorded during seven years' observations is 52.7°F. and the minimum 17.0°F.—a difference of only 35.7°F.

These figures illustrate one of the most important aspects of the climate, i.e., the lack of any period of warm temperatures. This is typical of the climates of subantarctic islands and contrasts sharply with lands of the northern hemisphere in similar latitudes. These lands are mostly continental and have a far greater range of temperature, including a period in summer when the temperature rises much higher than in the subantarctic islands. The latter are all surrounded by great expanses of relatively deep water which has a stabilising effect on temperature.

Twenty-four temperature readings were taken by A.A.E. personnel at elevated points on the island. When these are compared with simultaneous readings from the weather station at sea level they show an average drop of 5.7°F. per 1,000 feet. This indicates that the mean temperature of the highest peak (1,423 feet) approximates freezing point.[1]

TABLE 1.

Mean Hourly Temperature (°F.)

	1912	1913	1914-15	1948	1949	1950	1951	Mean
January	44.5	43.2	41.6		43.1	44.8	43.2	43.4
February	43.0	42.5	42.1		42.9	42.2	43.7	42.7
March	41.9	42.3	42.1		41.5	41.2	43.8	42.1
April	40.9	40.7	39.4	41.0	40.2	40.1	41.5	40.5
May	40.1	37.2	39.0	40.2	40.2	39.5	39.7	39.4
June	38.1	36.3	37.2	39.2	37.8	36.2	37.9	37.5
July	38.0	36.7	38.1	37.2	35.5	38.5	37.9	37.4
August	38.3	38.2	37.8	37.6	36.5	35.9	37.4	37.4
September	38.6	37.0	39.2	37.6	36.9	39.1	38.7	38.2
October	39.9	38.9	37.4	38.7	39.6	40.0	37.7	38.9
November	41.4	39.6	39.5	40.3	40.0	40.1	40.4	40.2
December	43.8	—	39.8	42.6	42.3	41.4	43.5	42.2
Mean	40.7		39.4		39.7	39.9	40.5	40.0

TABLE 2.

Mean Daily Maximum Temperature (°F.)

	1912 (1)	1913 (1)	1914-15 (1)	1948	1949	1950	1951	Mean
January	48.0	46.7	44.5		45.5	47.5	46.3	46.4
February	45.3	45.5	45.1		45.3	45.0	46.6	45.5
March	43.9	44.8	44.4		43.4	43.8	46.8	44.5
April	43.2	42.9	41.7	44.0	41.7	43.0	44.5	43.0
May	42.0	40.0	41.3	42.9	41.8	42.4	42.1	41.8
June	40.6	39.1	39.5	42.1	40.2	39.0	40.6	40.2
July	40.7	39.8	40.6	39.5	38.1	41.3	41.0	40.1
August	41.0	40.4	40.3	40.9	39.2	39.2	40.3	40.2
September	41.1	40.0	41.3	40.7	40.0	41.8	42.3	41.0
October	42.5	41.4	40.3	41.5	41.9	43.2	40.5	41.6
November	44.5	42.9	42.9	43.5	42.3	43.8	43.4	43.3
December	47.2	—	43.2	45.2	45.2	44.3	46.7	45.3
Mean	43.2		43.3		42.1	42.9	43.4	42.7

(1) These figures were taken without a screen and may therefore be unreliable.

TABLE 3.

Mean of Daily Minimum Temperature (°F.)

	1912	1913	1914-15	1948	1949	1950	1951	Mean
January	41.7	39.5	38.6		40.8	42.6	40.3	40.6
February	41.0	39.3	40.1		40.0	38.5	40.4	39.9
March	39.5	39.8	39.2		38.9	38.1	40.1	39.3
April	38.1	37.8	36.3	37.4	36.1	36.4	38.6	37.2
May	37.2	34.2	36.2	37.1	37.6	36.0	36.9	36.5
June	35.4	32.7	34.2	35.8	35.2	32.5	33.6	34.2
July	35.1	33.7	36.5	34.6	32.2	35.3	34.7	34.6
August	35.1	35.9	35.0	34.4	32.7	31.8	34.1	34.1
September	36.0	33.5	36.6	34.3	33.1	35.8	33.0	34.6
October	36.7	35.3	37.6	36.2	36.1	36.4	34.2	36.1
November	38.8	36.3	36.7	37.3	37.3	36.3	37.3	37.1
December	40.7	—	36.7	40.5	39.4	38.5	40.4	39.4
Mean	37.9		37.0		36.6	36.5	37.0	37.0

TABLE 4.

Extreme Maximum and Minimum Temperature (°F.)

	1912		1913		1914-15		1948		1949		1950		1951		Extreme	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	51.2	35.5	49.0	35.1	47.9	34.5			48.4	37.2	51.3	38.3	49.6	36.9	51.3	34.5
February	47.5	35.3	48.8	32.1	47.9	35.9			48.2	35.1	47.6	32.4	49.2	34.6	49.2	32.1
March	46.9	35.3	47.0	35.9	49.3	33.0			46.3	31.0	46.1	34.2	50.1	34.8	50.1	31.0
April	47.8	32.7	47.0	32.0	44.8	31.7	47.7	31.0	47.4	31.1	44.9	26.3	47.2	32.9	47.8	26.3
May	44.7	27.8	42.6	28.8	45.3	27.8	46.2	28.3	47.1	31.2	44.8	28.6	47.9	27.0	47.9	27.0
June	44.0	30.3	43.0	22.7	43.9	24.3	45.0	25.4	43.4	27.7	43.2	21.6	44.9	27.1	45.0	21.6
July	43.3	26.7	43.1	27.1	44.5	24.9	43.1	29.2	42.6	22.0	44.4	28.4	44.4	27.9	42.6	22.0
August	45.2	26.3	44.0	28.4	44.3	27.4	44.3	26.0	42.4	27.6	43.3	17.0	43.8	24.0	45.2	17.0
September	44.7	28.5	45.1	23.1	44.8	25.9	46.0	27.9	44.4	21.4	43.9	28.3	46.8	18.7	46.8	18.7
October	45.0	30.7	44.7	25.0	44.0	25.7	44.7	31.1	46.4	34.9	46.2	30.2	45.2	25.0	46.4	25.0
November	49.0	33.0	46.2	28.1	46.9	31.2	45.9	32.5	45.7	32.7	50.2	31.0	49.3	30.0	50.2	28.1
December	51.8	34.2			47.3	33.1	47.8	36.2	49.4	37.0	47.8	34.0	52.7	33.4	52.7	33.1
Extreme	51.8	26.3	49.0	22.7	49.3	24.3	47.8	25.4	49.4	21.4	51.3	17.0	52.7	18.7	52.7	17.0

TABLE 5.

Summarised Temperature Table (°F.)

	Extreme Max.	Mean of Daily Max.	Mean	Mean of Daily Min.	Extreme Min.
January	51.3	46.4	43.4	40.6	34.5
February	49.2	45.5	42.7	39.9	32.1
March	50.1	44.5	42.1	39.3	31.0
April	47.8	43.0	40.5	37.2	26.3
May	47.9	41.8	39.4	36.5	27.0
June	45.0	40.2	37.5	34.2	21.6
July	42.6	40.1	37.4	34.6	22.0
August	45.2	40.2	37.4	34.1	17.0
September	46.8	41.0	38.2	34.6	18.7
October	46.4	41.6	38.9	36.1	25.0
November	50.2	43.3	40.2	37.1	28.1
December	52.7	45.3	42.2	39.4	33.1
Mean		42.7	40.0	37.0	
Extreme	52.7				17.0

TABLE 6.

Precipitation (Inches)

	1915	1948	1949	1950	1951	Mean
January	5.15		2.60	3.97	4.30	4.01
February	3.22		4.10	3.66	2.92	3.47
March	4.53		2.78	4.19	4.83	4.08
April	4.44	3.42	3.36	3.42	4.38	3.80
May	3.95	2.60	1.83	4.28	3.07	3.15
June	3.44	2.20	1.73	3.13	2.70	2.64
July	3.93	2.22	3.11	2.14	3.68	3.02
August	3.73	2.24	3.18	2.83	3.27	3.05
September	3.29	4.24	4.07	3.56	2.88	3.61
October	3.24	2.76	3.52	3.08	2.44	3.01
November	3.36	1.25	2.94	4.27	2.29	2.82
December	3.58	3.12	3.84	4.02	4.85	3.88
Total Annual	45.86		37.06	42.55	41.61	40.54

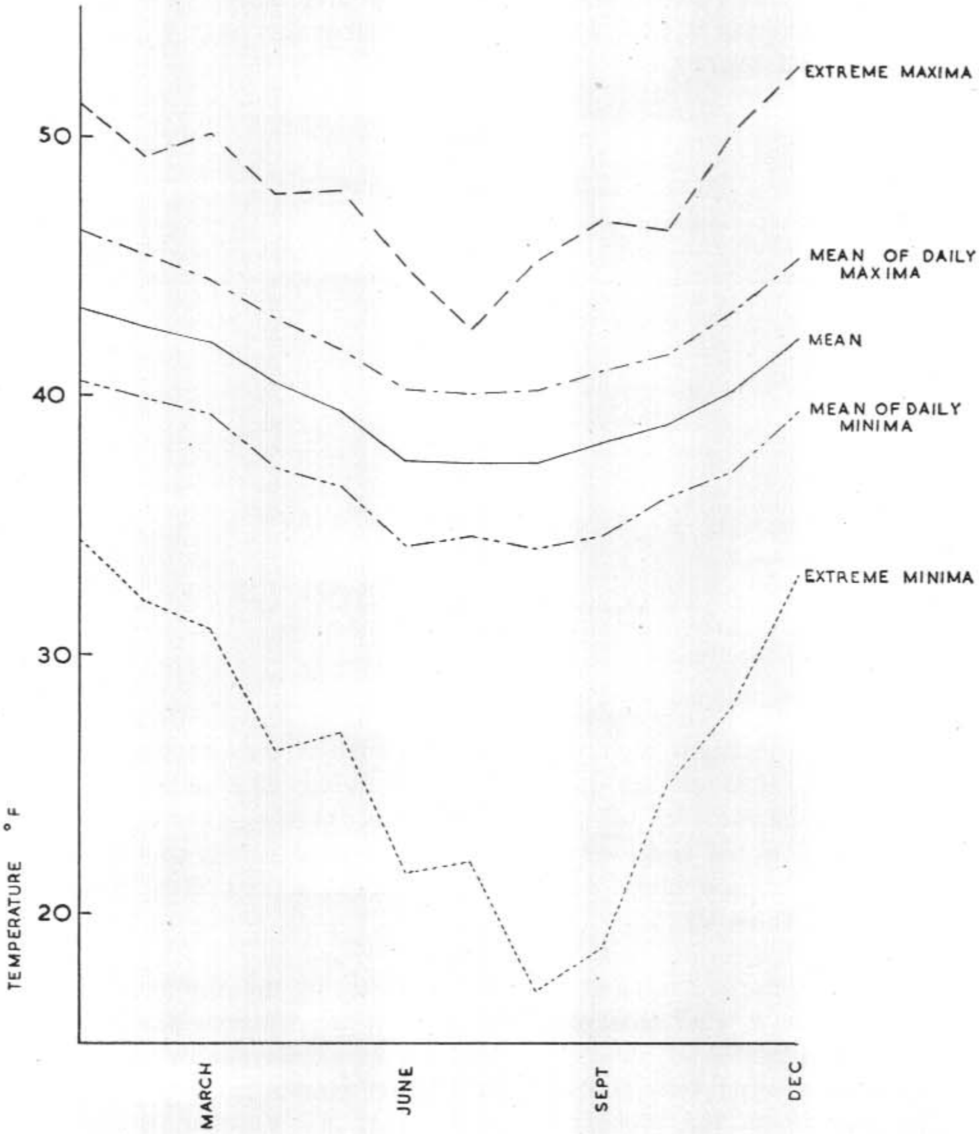

Fig. 1. Annual Variation of Temperatures at Macquarie Island.

No figures are available for evaporation, but an indication of the great excess of precipitation can be obtained from the figures for relative humidity, Table 7. The average is extremely high, 92%, whilst a figure cf 100% is often maintained for 24 hours and more. The minimum humidity recorded is 43% and such low readings are only obtained for a few scattered hours.

TABLE 7.

Mean Hourly Relative Humidity (%)

	1912	1913	1914-15	Mean
January	89	90	91	90
February	94	95	93	94
March	94	95	91	93
April	95	95	89	93
May	95	91	93	93
June	93	90	92	92
July	91	89	91	90
August	90	92	94	92
September	93	91	94	93
October	86	94	92	91
November	88	94	94	92
December	90		93	91
Mean	92		92	92

Wind. Consistent high winds are a feature of the climate, the mean velocity for 1951 at the weather station being 22.2 m.p.h., and the maximum gust recorded being over 100 m.p.h. Gusts exceeding 60 m.p.h. are frequent at all times of the year. The wind comes predominantly from the west and north-west with occasional storms from the south and north (Table 9).

No records are available for wind velocities on the highlands. There appears to be a wind shadow at the base of the western plateau slopes and a concentration of wind movement on the higher ridges and saddles. Estimates of wind velocities in these higher regions place them at least 25% greater on the highest ridges than at the weather station, and quite possibly much more.

Sunshine and cloud. The average annual cloud cover is $\frac{7}{8}$ths and the average sunshine 1.8 hours per day. This sunshine is, however, concentrated in the period from October to March when plant growth is most active.

TABLE 8.
Mean Wind Velocities (M.P.H.)

	1912	1913	1914-15	1948	1949	1950	1951
January		15.3	16.8		16.6	19.0	22.9
February	11.1	14.4	11.8		20.5	21.2	21.2
March	11.2	11.6	18.6		23.2	21.5	27.6
April	11.4	17.0	11.8	19.1	24.8	23.2	19.2
May	13.1	13.6	14.0	13.0	23.2	21.9	22.9
June	13.4	13.7	16.4	21.2	23.2	19.8	27.8
July	13.3	14.1	23.6	15.1	21.4	23.2	22.7
August	14.4	13.4	14.4	17.7	23.5	24.5	21.4
September	11.3	16.4	17.2	21.9	24.7	23.6	31.9
October	17.65	19.3	20.3	15.5	18.7	22.7	19.8
November	15.2	10.6	13.5	18.2	18.5	22.5	14.4
December	15.1	—	21.1	20.0	13.0	22.8	14.1
Mean	14.1		16.6		20.9	22.2	22.2

TABLE 9.
Wind Direction (%)

N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	N.W.	NNW
5.0	1.6	0.6	0.1	0.3	0.1	2.2	0.3	1.2	2.2	5.0	8.7	22.2	13.7	25.9	10.9

It is beyond question that the climate is the most important factor affecting the vegetation and soils. The lack of any period of warm temperatures, the prevalence of high winds and little sunshine combine to provide a habitat most unfavourable for plant growth and soil development.

TABLE 10.
Mean Daily Sunshine Duration (Hours)

	1912	1913	1914-15	1948	1949	1950	1951
January	2.5	4.0	1.7		3.4	2.8	3.5
February	1.6	2.1	2.6		5.0	3.6	3.4
March	1.6	1.3	1.2		2.5	3.1	3.2
April	0.7	1.3	0.4		1.5	1.3	1.7
May	0.2	—	0.4		0.9	0.7	1.3
June	0.0	—	0.0		0.7	0.6	0.5
July	0.2	—	0.1	0.8	0.8	0.9	0.9
August	—	0.6	0.2	1.2	1.3	1.3	1.6
September	0.7	0.8	0.6	2.2	2.6	2.1	1.0
October	1.5	0.8	1.1	2.9	3.6	3.5	1.6
November	1.3	—	2.9	3.9	2.3	4.6	2.4
December	2.1	—	1.7	4.0	3.0	2.9	2.6
Mean			1.1		2.3	2.0	2.0

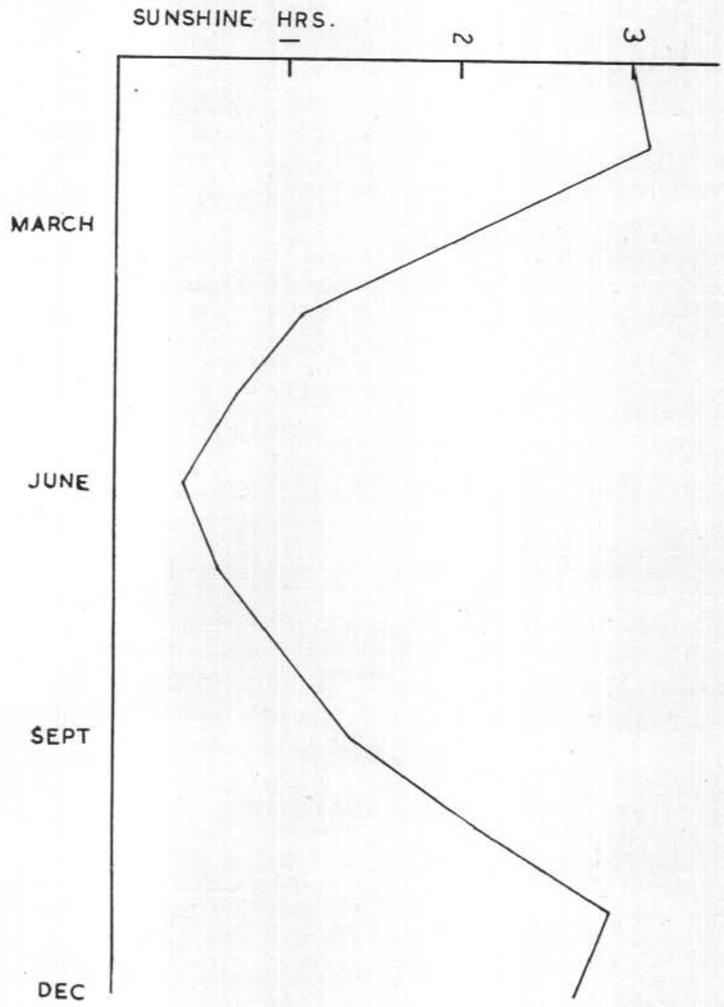

Fig. 2. Annual Variation in Daily Mean Sunshine Duration at Macquarie Island.

ORIGIN OF THE FLORA OF MACQUARIE ISLAND

There are two possible explanations for the presence of vascular plants on oceanic islands. Either they migrated along an almost continuous land connection in past ages, or the species bridged the gap by means of a long distance method of dispersal.

Macquarie Island is a long way from any large land mass, 600 miles from New Zealand and 800 miles from Tasmania; 4,600 miles to the east across the Southern Ocean is South America. The nearest land to the west is Iles de Kerguelen, 3,200 miles away. Its closest neighbours are the Auckland and Campbell Islands, 400 miles distant.

Macquarie Island stands on a large submarine ridge separated by a narrow deep from the continental shelf of New Zealand, from which arise the Auckland and Campbell Islands. It is separated from the Antarctic Continent by another far broader deep.

There are no sedimentary rocks on the island, but geological evidence shows the island emerged from the sea in the Cretaceous period. At the Pleistocene age the island was far larger than now, and was completely covered by an extensive ice sheet (Mawson, 1943). During this time its western coast was eroded away by the sea.

An examination of the present day world distribution of Macquarie Island species shows two main affinities: First, to the New Zealand subantarctic islands and Australasia, and secondly to the whole group of subantarctic islands and South America (circumpolar species).

The floras of the Falkland Islands and South Georgia show a circumpolar element and a purely South American element. Iles de Kerguelen, Marion Island, Iles Crozet and Heard Island, all very isolated from any land mass, have only the circumpolar element.

Thus, the origin of the floras of the various antarctic and subantarctic areas must be considered.

TABLE 11.

Distribution of Macquarie Island Species.

	Auckland and Campbell Islands	Antipodes Islands	New Zealand	Australia	Iles de Kerguelen	Heard Island	Marion Island	Iles Crozet	South Georgia	Falkland Islands	Ile Amsterdam	Tristan da Cunha	Tierra del Fuego	South America	Graham Land
Ranunculus biternatus					x		x	x	x	x	x	?	x	x	
Cardamine corymbosa	x	x	?							x			x	x	
Stellaria decipiens	x	x											x	x	
Colobanthus muscoides	x	x													
Colobanthus crassifolius	x	x	x				x		x	x			x		
Montia fontana(1)	x		x	x	x		x	x		x			x		
Acaena adscendens		x			x		x	x	x	x			x	x	x
Acaena anserifolia	x	x	x	x					x		x	x			
Crassula moschata	x	x	x		x		x	x		x			x	x	
Myriophyllum elatinoides			x	x						x				x	
Callitriche antarctica	x	x			x		x	x		x			x	x	
Epilobium linnaeoides	x	x	x			x			x						
Epilobium nerterioides	x		x												
Azorella selago					x		x	x		x			x	x	
Stilbocarpa polaris	x	x				x									
Coprosma pumila	x	x	x	x											
Pleurophyllum hookeri	x														
Cotula plumosa	x	x			x		x	x							
Juncus scheuchzerioides	x	x	x		x					x			x	x	
Luzula campestris(1)	x	x	x	x					x					x	
Scirpus aucklandicus	x	x	x	x							x				
Uncinia riparia	x	x	x	x											
Carex trifida	x	x	x							x			x	x	
Agrostis magellanica	x	x	x		x		x	x		x			x	x	
Deschampsia chapmani	x	x				x									
Deschampsia penicillata	EN	DEM	IC												
Puccinellia macquariensis	EN	DEM	IC												
Poa foliosa	x	x	x												
Poa hamiltoni	EN	DEM	IC												
Festuca erecta					x					x			x		
Blechnum penna-marina		x	x	x	x		x	x	x	x	x	x	x	x	
Polystichum vestitum	x	x	x	x									x	x	
Polypodium billardieri	x	x	x	x	x		x	x		x	x	x	x	x	
Lycopodium saururus	x	x	x	x	x		x	x		x			x	x	
Hydrocotyle sp.	Genus found in Tristan da Cunha, New Zealand and Australia.														

(1) Found widely distributed in the North and South Temperate Zones, but no species is common to South Africa.

The Antarctic Continent is roughly circular, its coast approximating to the Antarctic Circle, with an indentation towards the pole below Macquarie Island and a jutting peninsula (Graham Land) which extends to within 600 miles of South America. Although most of the Continent is covered by a perpetual ice sheet some ice-free areas exist, notably mountain ranges, nunataks and certain isolated areas along the coast.

The vascular flora numbers two species only, *Deschampsia antarctica* and *Colobanthus crassifolius*. These are found in Graham Land on ice-free areas but are extremely rare and have never been observed in fruit (Rudmose Brown 1938).

The antarctic flora has not always been so poor. Fossil floras have been found in Graham Land, the South Shetland Islands (52°S) and various other points along the coast, even at 5,000 feet on the Beardmore Glacier (85½°S). The rocks containing these fossils are of various ages, but none are post-Tertiary.

North-east from Graham Land are the South Shetland Islands (61°-63°S), the South Orkney Islands (61°S) and South Sandwich Islands (55°-60°S). All these islands are covered by ice sheets, and despite numerous explorations no vascular species has ever been recorded from them (Rudmose Brown, 1927).

Other islands without vascular plants are the Balleny Islands (66°-68°S) which have never been properly explored, and Bouvet Oya (55°S). Both these island groups are also covered by ice sheets.

West of the South Orkneys lies South Georgia (54°S), heavily glaciated in the uplands but with much ice-free land near the coast. It has a vascular flora of 19 species, all of which are also found in Tierra del Fuego, 1,000 miles distant; 13 of these species occur in other sub-antarctic islands (Skottsburg, 1905).

The Falkland Islands (52°) stand on the continental shelf of South America, 200 miles distant. They support a flora of 160 vascular species including some woody shrubs, of which the non-endemics are found in South America; many are also circumpolar (Skottsburg, 1909).

There is a submarine ridge running from South America to Graham Land which never drops far below 1,000 fathoms. South Georgia, the South Orkney Islands and the South Sandwich Islands are the highest points of this ridge, which has been postulated as the remnant of an old land bridge.

The flora of South America below 45°S contains over 750 species and has many species in common with the subantarctic islands and with New Zealand. In addition, it shows many relationships with the New Zealand flora in the higher groups of genera and families. Tierra del

Fuego (53°-55°S) is separated from the American mainland by the narrow Straits of Magellan. It has a flora of 440 species including many of circumpolar distribution, some of these being absent from the American mainland.

The Prince Edward Islands (47°S) lie 4,250 miles east of Cape Horn. There are two main islands, Prince Edward and Marion. The latter, with a recorded flora of 14 species, is 12 miles in diameter and 4,250′ high. Iles Crozet (47°S) are 450 miles east of Marion Island. The largest island of this group, Ile de la Possession, measures 18 miles by 9 and supports 17 species (Shench, 1906).

Iles de Kerguelen, 750 miles east of Iles Crozet, consist of several large and innumerable small islands separated by small straits, and cover an area of 2,000 square miles. The highest point is 6,000 feet and the uplands are heavily glaciated; but the mean temperatures and wind velocities on the lowlands are comparable with those at Macquarie Island. It has a native flora of 29 species, including 6 endemics, together with 21 species accidentally introduced by man. All non-endemics are also found in Tierra del Fuego or in the various subantarctic islands (Shench, 1906).

Macquarie Island (54½°S) lies 600 miles south-west of New Zealand. It is the southernmost of the subantarctic islands of New Zealand which include Campbell Island, Auckland Islands, the Snares, the Antipodes and Bounty Islands.

In addition to these there are three more island groups which, though not strictly subantarctic, have a few species in common with Macquarie Island. The Tristan da Cunha Islands in the South Atlantic (38°-40°S) have a flora of 105 species with South African and South American affinities. In addition, there is a small Fuegian or circumpolar element including four Macquarie species (Christopherson and Erling, 1934 and 1937). Ile Amsterdam and Ile St. Paul are in the South Indian Ocean (37°-38°S). The flora was listed as only 39 in 1905 but is probably greater. A high percentage of these are circumpolar species (Shench, 1906). Islas Juan Fernandez, off the South American coast (34°S), have two species in common with Macquarie Island, but this is merely an indication of the relationship of the South American and New Zealand floras.

Roughly speaking, the climate at all these islands tends to become more severe as latitudes increase but there is no direct correlation. Other factors such as the proximity of continental land masses and the movement of air masses are important. Thus Macquarie Island has a milder climate than Heard Island or South Georgia although it is situated in a slightly higher latitude.

TABLE 12.

Number of Species on Antarctic and Subantarctic Lands.

	Latitude	Longitude	Mean Temp. (°F.)	Distance to Nearest Continent with Floristic Affinities (miles)	Type of Land	Length of Island or Largest Island in Group (miles)	No. of Species
Graham Land	64°-70°	60°W	32°	600	Continental	—	2
South Shetland Islands	61°-63°	54°-62°W	32°	550	Islands on Continental Shelf	42	0
South Orkney Islands	61°	45°W	32°	700	Islands on Submarine Ridge	30	0
South Sandwich Islands	56°-59°	28°W	32°	1200	,, ,, ,,	9	0
South Georgia	54°	37°W	34°	1000	,, ,, ,,	116	19
Bouvet Oya	55°	4°E	32°	2500		5	0
Heard Island	53°	73°E	32.7°	5500	Oceanic Island	27	8
Iles de Kerguelen	48°	70°E	37.8°	5500	,, ,,	70	29
Prince Edward Islands	46°	50°E	(38°)	4250	,, ,,	12	14
Iles Crozet	46°	50°E	(38°)	4800	,, ,,	14	17
Macquarie Island	55°	160°E	40°	600	,, ,,	21	35
Falkland Islands	52°	60°W	43.8°	300	Islands on Continental Shelf	100	160
Campbell Island	52°	68°W	44.5°	300	,, ,, ,,	11	130
Auckland Islands	50°	66°W	46°	300	, ,, ,,	20	150
Tierra del Fuego	53°-55°	70°W	42°	—	Continental	—	440
Patagonia	53°-45°	70°W		—	,,	—	750
Tristan da Cunha Islands	37°	10°W	(50°)	1000	Oceanic	8	102
Ile Amsterdam	37°	78°E	(50°)	1500	,,	6	39

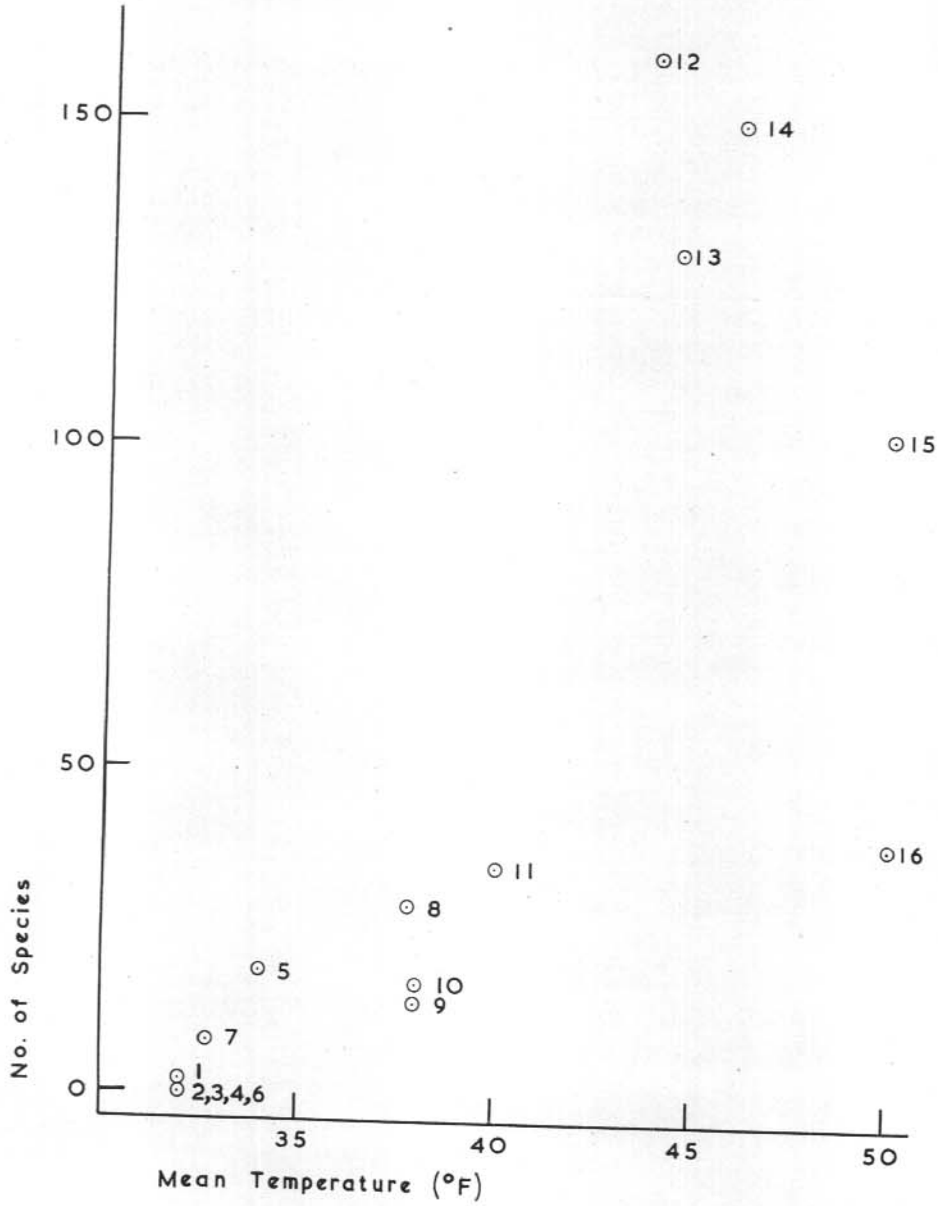

Fig. 3. Relation between number of botanical species present on subantarctic islands and annual mean temperature.

1. Graham Land
2. South Shetland Islands
3. South Orkney Islands
4. South Sandwich Islands
5. South Georgia
6. Bouvet Oya
7. Heard Island
8. Iles de Kerguelen
9. Prince Edward Islands
10. Iles Crozet
11. Macquarie Island
12. Falkland Islands
13. Campbell Island
14. Auckland Island
15. Tristan da Cunha Islands
16. Ile Amsterdam

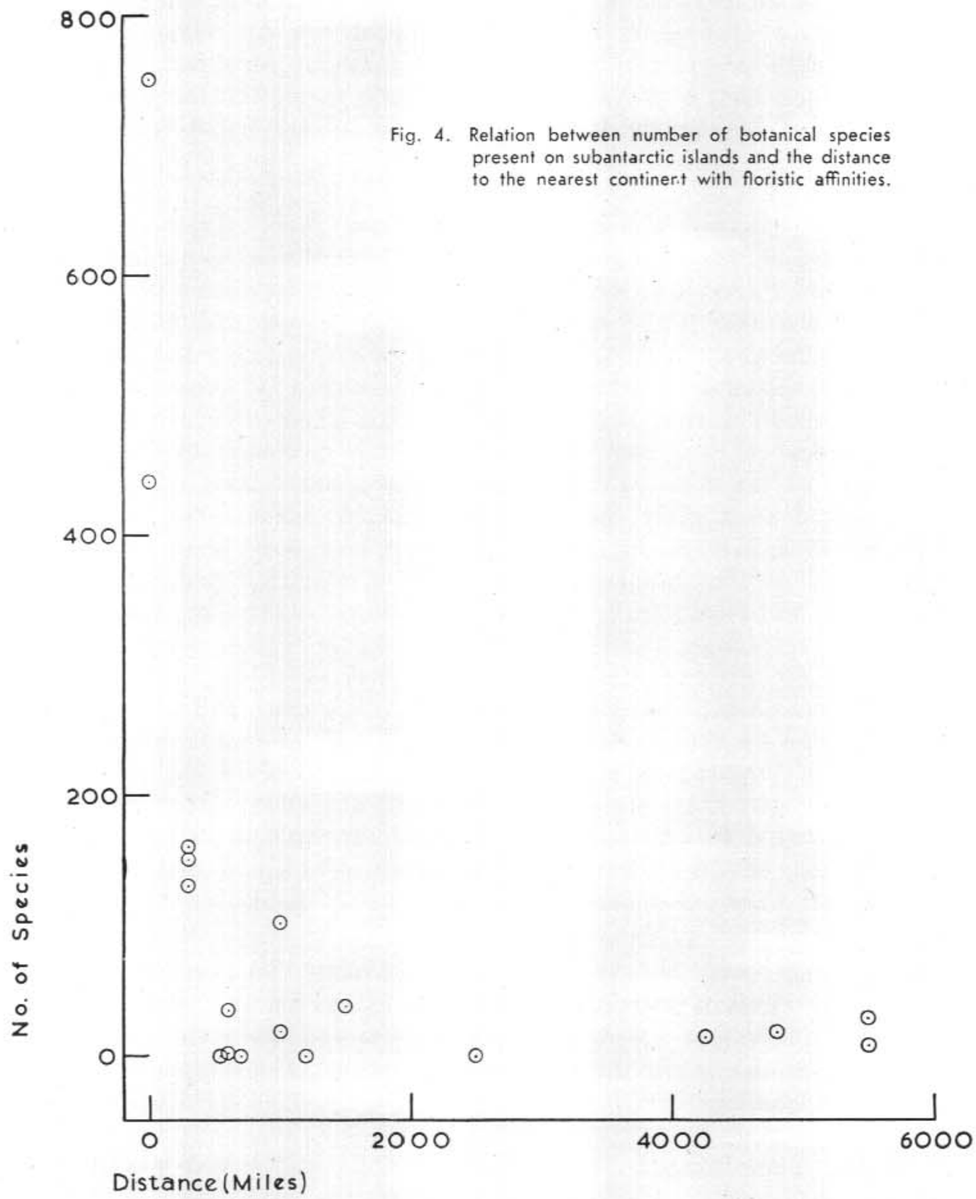

Fig. 4. Relation between number of botanical species present on subantarctic islands and the distance to the nearest continent with floristic affinities.

The foregoing table and graphs show that the number of species decreases with isolation and with decreasing temperature. There is also a tendency for an increase in species as the size of the land mass increases for, apart from providing more ecological niches, the larger mass is associated with a greater range of temperature, resulting in higher summer values, e.g., at Kerguelen the absolute maximum temperature is higher than at Macquarie Island though the annual mean temperature is lower.

Endemic element in the Macquarie Island flora. There are three endemic species on Macquarie Island—*Deschampsia penicillata, Poa hamiltoni* and *Puccinellia macquariensis.* The first two have very closely related species also found on the island, *Poa foliosa* and *Deschampsia chapmani.* Between these species-pairs there are striking morphological and floral similarities. So close is the relationship between *Poa foliosa* and *Poa hamiltoni* that it is undeniable that their divergence from a common stock is relatively recent. The most probable explanation is that plants of the relatively widespread *Poa foliosa* became established on the island soon after the retreat of the ice sheet. The population being small, rather rapid accidental divergence took place and when further seed of *Poa foliosa* arrived genetical isolation had been established, with the result that the two populations could live side by side without intercrossing.

The relationship between *Deschampsia chapmani* and *Deschampsia penicillata* can be explained similarly. On the other hand, the origin of *Puccinellia macquariensis* is most probably due to accidental drift in a small population; this species has probably descended from species of *Puccinellia* found on the other New Zealand subantarctic islands, namely the doubtfully distinct *Puccinellia antipodia* (Auckland and Antipodes Islands) and *Puccinellia chathamica* (Chatham Islands).

Species pressure on the subantarctic islands. The species pressure is not high. This is shown on Macquarie Island by the wide range of habitats of individual species and also by the establishment even under natural conditions of the three introduced species, *Poa annua, Cerastium triviale* and *Stellaria media.*

In the more isolated Iles de Kerguelen, 21 introduced species have been able to become established even though the native species number only 29 (Shench, 1906).

Pre-glacial history of the Macquarie Island flora. As already mentioned there are numerous remains of a pre-glacial flora to be found in various geological strata on the Antarctic Continent. Moreover the affinities between the South American alpine flora and those of New Zealand and Australia are so great as to imply some close relationship. Various theories account for this, e.g. the theory of Continental Drift, Sunken Land Bridges, or migration by Behring Strait. These theories could account for a common antarctic flora which would also extend to Macquarie Island.

Glacial history. As previously mentioned, Macquarie Island was covered by an ice sheet in the Pleistocene Age. Ice-free nunataks would, therefore, have provided the only possible areas on which the Tertiary flora could have survived during the Ice Age; but there are no sharp pinnacles characteristic of former nunataks on the island.

Moreover, it seems unlikely that the majority of the present day species could survive a more severe climate[(1)] such as undoubtedly existed in Pleistocene times on Macquarie Island. Increase in wind velocity has a marked effect in limiting the number of species which can survive, even though competition between individual plants is greatly reduced. It would be most likely that increasing cold would have the same effect, especially as it would result in greatly changed edaphic conditions.

The absence of all vascular species on ice-covered islands at the present day indicates such islands do not provide a suitable habitat for plant growth. No introduced species has been able to grow there, let alone establish itself.

The theory that the Macquarie plants are pre-glacial survivors is untenable as they could not have grown and reproduced during the Ice Age. Therefore, some form of migration must have occurred in post-glacial times.

Methods of migration. The theories of Continental Drift and Sunken Land Bridges offer explanations for the origin of a flora, by means of quite short dispersal mechanisms, but as there is no evidence that they have occurred since the recession of the ice sheet, and as Macquarie Island has therefore been isolated since the Pleistocene, other dispersal methods must have restocked the island. Any theory of dispersal must be capable of explaining the very great distances involved. Four Macquarie Island species are found also in Tierra del Fuego, 4,000 miles distant, and in Kerguelen 3,200 miles away but not at the nearby Auckland and Campbell Islands. Moreover, many of the circumpolar species

(1) Two species, *Deschampsia antarctica* and *Colobanthus crassifolius* are now found in Graham Land, growing in what is probably an analagous climate to that prevailing in the Pleistocene on Macquarie Island, but these are extremely rare and scattered.

also found in the Auckland and Campbell Islands must also have traversed these distances in post-glacial times.

Possible dispersal agencies are wind, sea and migratory animals.

Wind. The species with very small seeds may have arrived as a result of wind transport. Evidence for this migration of light objects over long distances is that pollen grains of *Podocarpus* have been found in Graham Land, 600 miles from the nearest source of supply in Tierra del Fuego (Fritsch). Moreover, the prevailing wind for the entire subantarctic zone is westerly, encircling the globe between latitudes 45° and 60°S. However only half the species at Macquarie Island have small seeds. If wind distribution were a major factor in stocking the island one would expect a much higher proportion of mosses and ferns and also flowering plants with dust seeds. Seed dispersal by wind may, therefore, account for the occurrence of a few species but it cannot explain the presence on the island of plants with large propagules, e.g. *Stilbocarpa polaris.*

Sea drift. The ocean currents reaching Macquarie Island are compatible with a theory of sea transport of seeds to the island. A bottle found on Macquarie was released from the Auckland Islands, and another from somewhere south of the Cape of Good Hope. Driftwood on the island has been provisionally identified as a New Zealand beech (*Nothofagus solanderi*). However, for such a theory to be valid seeds would have to be viable after more or less intimate contact with sea water for a prolonged period, probably never less than one year. That any seed could survive this prolonged immersion and still germinate is doubtful. The objection that any seed so dispersed will not reach a suitable habitat does not hold so well for Macquarie Island. Large pieces of driftwood are common in sites, which otherwise appear uninfluenced by the sea, bearing normal terrestrial vegetation. These must have been deposited by very exceptional storms. In one such piece of driftwood a pebble of quartz quite foreign to the island was observed; seeds could possibly be carried in a like manner.(1) Nevertheless, there is no evidence that any such method of transportation and establishment has occurred.

Migratory animals. (i) *Seals and penguins.* These visit the island in great multitudes, arriving from various places in the Subantartic Zone and Australasia. Moreover, they land on sites suitable for plant growth. Probably no seed would survive the journey if carried externally and seals have never been observed eating terrestrial vegetation. Penguins have, however, been observed eating leaves of *Stilbocarpa polaris* but only soon after their arrival on the island. Seeds are often caught in the leaves of these plants and are probably eaten as well. Whether this

(1)However a few species, notably *Azorella selago,* do not grow in such habitats.

happens prior to migration, and if so whether the seeds could be retained in the animal for a long enough period, is doubtful. They would need to be retained for many days even for the journey from the Auckland Islands; still, the possibility cannot be fully dismissed.

(ii) *Migratory birds.* On Macquarie there are numerous species of flying birds which are also found in other parts of the Subantarctic Zone and New Zealand (Falla, 1937). Most leave the island in the autumn and return in the spring.

TABLE 13.

Migratory Birds at Macquarie Island and their Distribution in Antarctic and Subantarctic Zones.

Migratory Birds at Macquarie Island	Also Recorded from			Relative Abundance at Macquarie Island
	Antarctica	Subantarctic Islands	New Zealand	
Wandering Albatross, *Diomedea exulans*		x		Small numbers (15-50).
Black-browed Albatross, *Diomedea melanophris*		x	x	Small numbers (50-200).
Light-mantled Sooty Albatross, *Phobetria palpebrata*		x	x	Moderate population (100-300)
Giant Petrel, *Macronectes giganteus*	x	x	x	Large population (2,000-10,000)
Grey Petrel, *Procellaria cinerea*		x	x	Very small numbers.
White-headed Petrel, *Pterodroma lessoni*		x	x	Large population
Blue Petrel, *Halobaena caerulea*		x	x	Very small numbers
Dove Prion, *Pachyptila desolata*	x	x		Large population (10,000-?)
Sooty Shearwater, *Puffinus griseus*		x	x	Moderate population
Dominican Gull, *Larus dominicanus*		x	x	Large population (1,000-2,000)
Skua Gull, *Stercorarius skua lonnbergi*		x	x	Large population (2,000)
Grey Duck *Anas superciliosa*			x	Moderate population (100-300)

In addition to the foregoing birds (Table 13) there is a small list of birds breeding on the island which are not commonly found elsewhere, though they are quite capable of migrating. These are the Macquarie Island cormorant, the Macquarie Island wreathed tern and the now extinct parrakeet and rail.

Further, the island is occasionally visited by various stragglers from the avifauna of other regions. Thus from New Zealand there have been observed the following birds: A white egret, a Pacific bar-tailed godwit, a knot, a snipe, a mallard and a swamp harrier. These are certainly only a small selection of the stragglers that reach the island. Further, starlings and redpolls have recently established themselves in small numbers.

The similar distribution patterns of the migratory birds and of the flowering plants indicate that these birds are most probably the agents of dissemination.

TABLE 14.

Seeds and Fruits of the Vascular Species.

Species.	Approximate Volume in c.mms.	Adaptions
Epilobium linnaeoides	Seed .05	
Epilobium nerterioides	,, .05	
Juncus scheuchzerioides	,, .1	
Callitriche antarctica	,, .05	
Crassula moschata	,, .1	
Montia fontana	,, .1	
Colobanthus muscoides	,, .1	
Colobanthus crassifolius	,, .1	
Azorella selago	,, .1	
Agrostis magellanica	,, .2	Fruit very hairy, small.
Cardamine corymbosa	,, .3	
Stellaria decipiens	,, .3	
Hydrocotyle sp.	mericarp .4	Seed very small.
Scirpus aucklandicus	Seed .4	
Luzula campestris	,, .5	
Deschampsia chapmani	,, .5	Fruit very hairy.
Deschampsia penicillata	,, .5	Fruit very hairy.
Uncinia riparia	,, 2	Fruit barbed.
Poa foliosa	,, 2	Fruit very hairy.
Poa hamiltoni	,, 2	Fruit very hairy.
Festuca erecta	,, 2	
Carex trifida	,, 2	Fruit pointed.
Puccinellia macquariensis	,, .5	Fruit very hairy.
Ranunculus biternatus	Fruit 3	Fruit has small hook.
Cotula plumosa	Seed 3	Fruit hairy.
Coprosma pumila	,, 4	Fruit sticky.
Acaena anserifolia		Fruit has tenacious barbs.
Acaena adscendens		Fruit has tenacious barbs.
Pleurophyllum hookeri	Fruit 5	Fruit hairy.
Stilbocarpa polaris	Fruit 4-5 mm. dia.	Fruit extremely hard.
Myriophyllum elatinoides	No seeds on island	Seeds elsewhere very small.

Little is at present known of the migratory habits of sea birds in the Southern Ocean but despite the small numbers of birds ringed, many instances of birds travelling great distances are known, including flights from Macquarie Island to South Georgia and Australia.

It is significant that all the species on Macquarie fit into one or more of the groups of seeds which could conceivably be carried by birds; e.g. small seeds in mud on the birds' feet or bodies or caught amongst feathers or in the many crevices on the birds' horny feet, hooked fruit caught in feathers or down, hard fruit eaten and later excreted, fleshy fruit eaten or adhering to the birds' beaks.

The majority of seeds are small to minute in size and are carried presumably on birds' feet. They would have to be transported in a non-stop flight since the birds' alighting in the sea would result in removal of the mud or seeds or at any rate in a reduction of the seed's viability. Mud and seeds on higher parts of the birds' bodies would be unaffected, but mud in such places is rare and the chance of its being deposited in a suitable habitat is much smaller.

These birds do alight in the water and many species have been frequently observed swimming; all have webbed feet. It is quite conceivable, however, that a bird might fly non-stop over the great distances involved especially if carried by the storms which are frequent occurrences in these regions, sometimes with wind velocities up to 100 m.p.h. Thus a bird might fly the 3,200 miles from Kerguelen to Macquarie in under two days with sea conditions which would discourage it from alighting.

With seeds carried in the digestive tracts of birds the time of flight must necessarily be less than the time taken for the seed to pass through the bird if that seed is to be successfully established. However, it is noted that the two species so adapted (*Stilbocarpa polaris* and *Coprosma repens*) are not circumpolar. The former occurs only in the New Zealand subantarctic islands and the latter throughout Australasia. The minimum distance to be covered in these cases is only 400 miles. Occasional storms of up to 90 m.p.h. occur from the direction of these islands and are marked by the appearance of occasional stragglers from the New Zealand avifauna. Thus a bird could arrive on Macquarie after a flight of only a few hours—six or even less. Moreover, birds have been observed eating the fruits of the species concerned. The objection that birds do not eat before flight does not hold, as many birds arriving at the island are not intentional migrants and were probably borne away by strong winds as the stragglers from other regions indicate. Thus it is possible that a seed could be brought by a bird and arrive in a viable state. The birds' habitats on land would allow them to pick up seeds and later redeposit them in a suitable habitat since large rookeries are widespread over the island. Nesting burrows are found all over the highlands. Any seed, then, deposited by the petrels, shearwaters, albatrosses and skuas would have a good chance of arriving at a site where it could germinate and, given low competition, establish itself.

With *Myriophyllum elatinoides*, the only obligate aquatic on the island, the seeds could easily be deposited in a stream or lake as most of the migratory birds swim or alight on such places.

Moreover, the birds frequent similar sites in the Auckland, Campbell and Stewart Islands, in other subantarctic islands and in Tierra del Fuego. The birds spend long periods on land, frequently in places where seeds are abundant. Thus the chance of their procuring seeds is quite high.

Even though a bird has landed in a suitable habitat with viable seed it must be redeposited before the new species can establish itself. With seeds carried in the digestive tract, these are simply excreted; seeds on beaks may fall or be scraped off. Hooked seeds may be rubbed off when the bird sits to sleep or when nesting or may fall off with the feathers when the bird moults. With seeds in dried mud, these may fall off with further drying or wash off with rain or ground water near the nest or elsewhere. Seeds on burrowing birds may be easily rubbed off during the burrowing operations.

In 1948 N. Laird observed several small unidentified seeds and one large fruit of *Stilbocarpa polaris* adhering to the feet of several black-browed albatrosses. These birds regurgitate an oily fluid as a means of defence. As it dried this fluid had adhered to the birds' feet, enclosing the seeds noted. Seeds held in such a manner would probably be retained for long periods in flight or whilst the bird was resting at sea and yet would be soon rubbed off again after landing.

A seed 5 mm. long and totally different from that of any recorded species was found by J. Bunt in 1951 on the shores of Waterfall Lake. This seed could belong to a species already established on the island but not seen by any collector. The possibility of this cannot be ignored even though the large size indicates that it may belong to a relatively large plant and the area has been investigated carefully on several occasions. However, the seed most probably was transported to the island by birds. Waterfall Lake is almost continually inhabited in summer by a flock of giant petrels estimated to number over 600. These birds spend a great part of each day swimming in the lake or resting on its banks.

The possibility of accidental human transport can be ruled out. The seed is probably foreign to Australia and in any case the area is very infrequently visited and had not been seen by man for at least six months.

Thus migratory birds provide a mechanism by which the island could have been restocked in post-glacial times.

Arguments against long distance dispersal. Various arguments have been advanced against long distance dispersal (Cain, 1944):

1. A high degree of endemism in an insular flora indicates the relic nature of the flora. For Macquarie Island it has been previously noted that at least two of the three endemics are not relics but recent endemics. Undoubtedly the percentage of endemics (10%) is high (though not approaching that of Hawaii with over 80%), but the time since glaciation is sufficient for their formation when it is considered that the species pressure is not intense. Moreover, the Sewell Wright effect (Huxley, 1942) of random evolution of small populations must be a potent factor in their formation.

In the other subantarctic islands it is seen that with increasing severity of climate the percentage of endemics rapidly drops to nil. Heard Island and the Antarctic Continent itself have no endemics and South Georgia with 18 species has only one doubtful endemic sub-species. If the subantarctic floras were pre-glacial relics there is no reason to suppose that the percentage of endemics would have decreased because of the severity of the ice age. However, a higher present day temperature indicates that a greater period of time has elapsed since glaciation and thus that immigrant species have had a greater opportunity to undergo speciation.

This tendency indicates that the degree of endemism on Macquarie Island cannot be used as an argument against the theory of long distance dispersal originating the flora, but rather the reverse.

2. It is very difficult for an immigrant species to enter a closed community of plants which are well established and adapted to the area. It has already been mentioned that the species pressure is low and thus the plant associations are relatively "open" even at the present day. After the recession of the Pleistocene ice cap this difficulty would have been non-existent as no plants or at most a few relic species were avail-

able to colonise the island. Thus this argument is not applicable to post-glacial Macquarie Island.

3. The floras of the world would be markedly different if long distance dispersal was generally operative. The past history of Macquarie Island differentiates it sharply from the world in general, in that since the ice age no method of recolonisation other than long distance dispersal has been possible. In other places, in the northern hemisphere particularly, plants could migrate by quite short dispersal methods and would so establish themselves that long distance dispersal could not compete.

Moreover, the floras of Macquarie and of the other subantarctic islands differ in one very important respect from other floras, viz., in the high percentage of species belonging to cosmopolitan genera. Good (1947) lists 47 cosmopolitan genera defined as genera present on all five continents, and of these 14, with 15 species, occur on Macquarie Island out of a total of 31 species of flowering plants. The percentage of species of these cosmopolitan genera are given for various floras.

TABLE 15.

Cosmopolitan Genera in the Arctic, Antarctic and Subantarctic.

Flora.	Percentage of species of cosmopolitan genera.	Total number of species in flora.
Greenland	23	102
Novaya Zembla from 69°-70°N	23	168
72°-73°N	21	135
74°-75°N	27	49
75°-76°N	6	16
76°-77°N	0	4
Arctic Europe	26	625
Arctic America	21	240
South American Mainland below 50°S	26	445
Tierra del Fuego	28	440
Hermit Island (off Tierra del Fuego)	24	54
Stewart Island (off New Zealand)	19	600
Falkland Islands	36	445
Auckland Island	30	125
Campbell Island	32	99
Antipodes Islands	42	45
Macquarie Island	48	31
South Georgia	43	14
Tristan da Cunha Islands	45	75
Gough Island	45	22
Marion Island	50	8
Ile de la Possession	62	13
Iles de Kerguelen	62	21
Heard Island	50	8
Ile Amsterdam and Ile St. Paul	68	19

From the table this marked difference between true oceanic islands and continental areas and islands can be seen.

The factors which operate to make a genus cosmopolitan are a wide range of tolerance, an effective means of dissemination and a reasonable age; but there is no reason to suppose that these genera are much older than a great proportion of genera, and their greater range of tolerance could not explain the wide difference between continental areas and oceanic islands especially when floras of similar size and under similar climatic conditions are compared.

The important thing is that these genera have a more efficient means of dissemination than others and are therefore to be found on remote oceanic islands.

4. The chance of a favourable combination of circumstances is so small as to make it impossible. It is argued in the case of South Georgia that even if one new species were introduced every hundred years, the flora would be much greater than now. Such objections are, of course, mutually contradictory. The first states that very few, if any, species could be so transported, the other that if they could many more would have become established than actually have. The truth would seem to lie between the two, especially when it is remembered that the chance of a species becoming established is greatly increased by the lack of competition on Macquarie Island. It is only necessary for one seed of any monoecious species to reach a suitable habitat and become established, for that species to become a part of the island's flora. In this regard it is interesting to note that *Coprosma pumila*, dioecious elsewhere in its range, has many plants, if not all, on Macquarie Island which are monoecious.

Conclusion. Thus the fluctuations of the total number of species with temperature and isolation of the land mass, the proportions and types of endemics of the various islands, the high percentage of species of cosmopolitan genera, the low species pressure and the improbability of the flora being pre-glacial survivors all point to the fact that the flora of Macquarie and most other subantarctic islands originated by long distance dispersal. Migratory birds provide a probable, if unproven, mechanism for this dispersal, a mechanism supported by the character of all the propagules of species found on the island.

DESCRIPTION OF THE VEGETATION

The vegetation of Macquarie Island can be divided into five main formations, namely grassland, herbfield, fen, bog and feldmark. Each formation consists of one or more alliances, associations and sub-associations as defined by Beadle and Costin (1952).

The distribution of the main formations is given in the two vegetation maps and may be summarised as follows:—

(a) *Grassland* (*wet tussock*). This is found on all steep coastal slopes up to a height of 1,000 feet, in immature river valleys and inland slopes protected from severe winds, on the flats of the coastal terrace except when the water table is very high, and occasionally on upland flats protected from severe winds.

(b) *Herbfield.* This community occurs on slopes and flats subject to moderate winds and on all areas with a high water table (one to eighteen inches below the surface) where wind velocity is not too severe. It is found in sheltered valleys, on slopes up to a maximum height of 1,200 feet and on the raised beach terrace.

(c) *Fen.* This community occurs in the valley floors of the plateau and in small patches on the raised beach terrace. It appears only where the water table is at the surface of the ground or slightly above it, and where the water is neutral or alkaline due to contact with the basic rocks and mineral soil of the island.

(d) *Bog.* Bog communities occur extensively in one area only on the island, namely at Handspike Point on the raised beach terrace. It appears only where the water table is at the surface of the ground or slightly above it and where the water is acid and low in soluble salts due to contact with peat soil.

(e) *Feldmark.* This formation is found in all areas subject to high wind velocities. It covers the greater part of the island above 600 feet elevation but is occasionally found as low as 300 feet.

More precise information on distribution with regard to the various external factors is given under the description of the respective floristic groups.

GRASSLAND (WET TUSSOCK)
POA FOLIOSA ALLIANCE

This alliance consists of seven associations. The association occurring at any one site depends on the exposure to sea spray, the maturity of the soil and the effect of animals.

Seven associations are recognised. These are described below. Floristic lists and frequencies are given in Table 16.

I. *Poa foliosa* association.

II. *Poa foliosa—Poa hamiltoni* association.

III. *Poa foliosa—Stilbocarpa polaris* association.

IV. *Poa foliosa—Polystichum vestitum* association.

V. *Poa foliosa—Stilbocarpa polaris—Polystichum vestitum* association.

VI. *Stilbocarpa polaris* association.

VII. Maritime communities.

I. *Poa foliosa* association. This association consists of two sub-associations which differ in respect to the subordinate species and to the total cover of the dominant. The occurrence of a particular sub-association is dependent on whether or not sea elephants are opening up the community through their movements.

(a) *Poa foliosa: Cardamine corymbosa* sub-association. The typical community is dominated by the growth of *Poa foliosa* in tussocks. The plants form a continuous overhead canopy but have their bases isolated in groups formed on the tops of stools of very fibrous peat. These stools tend to be hemispherical and may be up to 3 feet high, 6 feet in diameter and 10 feet apart.

The leaves of *Poa foliosa* grow another 2 to 3 feet 6 inches above the tops of the stools spreading out and interlocking with neighbouring tussocks. The surrounding ground is covered by a layer of dead leaves still attached to the tops of the stools which leaves little bare ground on which other plant species may grow. However, several species do occur, notably *Stellaria decipiens* and *Cardamine corymbosa,* which are well able to endure the low light intensities. (They are also frequently found under the thick broad leaves of *Stilbocarpa polaris.*)

Plate 4. Tussock grass. *Poa foliosa*: *Cardamine corymbosa* sub-association. Typical stand 3 feet high with a dense leafy canopy. Soil—highmoor peat. (Photo, N. Laird).

(b) *Poa foliosa: Cotula plumosa, sub-association.* This community is a biotic climax formed by a modification of the climax association by sea elephants which use the ground between the stools as wallows during the breeding season. The mechanical movements of the seals result in a lessening in density of the tussocks of *Poa foliosa,* a decrease in vigour of the individual tussocks, a removal of the litter of dead leaves and the frequent formation of pools between the tussocks. As a result the canopy of leaves of *Poa foliosa* is not complete and several species are found frequently which do not occur in the *Cardamine corymbosa* sub-association, notably *Cotula plumosa* and *Poa annua.*

The *Poa foliosa* association occupies only a third of the area covered by the alliance. Of this the greater part of the area on coastal flats is covered by the *Cotula plumosa* sub-association, while the *Cardamine corymbosa* sub-association covers the rest of the area including the steep slopes.

Poa foliosa association is incapable of growing in soils with a stagnant water table. However, it does grow in pure stands alongside or even in streams, which is probably due to the greater aeration of stream water and possibly to the lower concentration of organic matter, toxins, etc., in stream water.

The occurrence of stream-side communities is very noticeable on the raised beach terrace where lines of high tussocks mark the passage of any small stream traversing the *Pleurophyllum hookeri* alliance.

These communities resist the onslaught of rabbits for longer periods than the surrounding vegetations probably because the site is less accessible to rabbits.

With increased exposure to wind the association no longer forms tussocks. The lessened growth rate leads to a reduction in size of the stool and the plants form a mat 12-18 inches high over the ground surface. Thus the canopy remains unbroken and the appearance of additional species is still dependent on the occurrence of soil slips.

II. *Poa foliosa—Poa hamiltoni* association. This association is similar to the *Poa foliosa* association but up to 50% of the tussocks of *Poa foliosa* may be replaced by *Poa hamiltoni*. The association occurs extensively only in one area, Nuggets Creek, but is found in small patches around the coast wherever penguins congregate.

The dominants may occur without any attendant species or together with the same species as in the *Poa foliosa* association.

The dependence of this association on penguin manure is fully discussed under the effects of animals. It is a biotic climax.

III. *Poa foliosa—Stilbocarpa polaris* association. This association is dominated by tussocks of *Poa foliosa* and large plants of *Stilbocarpa polaris*. All stages are observable from the first very rare appearance of *Stilbocarpa polaris* to its complete dominance in large stands. As a rule *Stilbocarpa polaris* comprises from 5-20% of the vegetation, occurring in isolated clumps. In this association *Stilbocarpa polaris* grows to a height of 2 feet 6 inches, generally a little below the level of the surrounding tussocks. Its leaves are all roughly at the same height. Under its broad, thick leaves, up to 20 inches in diameter, very little light penetrates but almost always a few plants of *Stellaria decipiens, Cardamine corymbosa* and moss species are found. There is very little undecomposed plant remains under these leaves. The association has a closed canopy similar to the *Poa foliosa* association and, apart from the greater frequency of plants growing under *Stilbocarpa polaris* leaves, the subordinate species are similar to those in the *Poa foliosa* association.

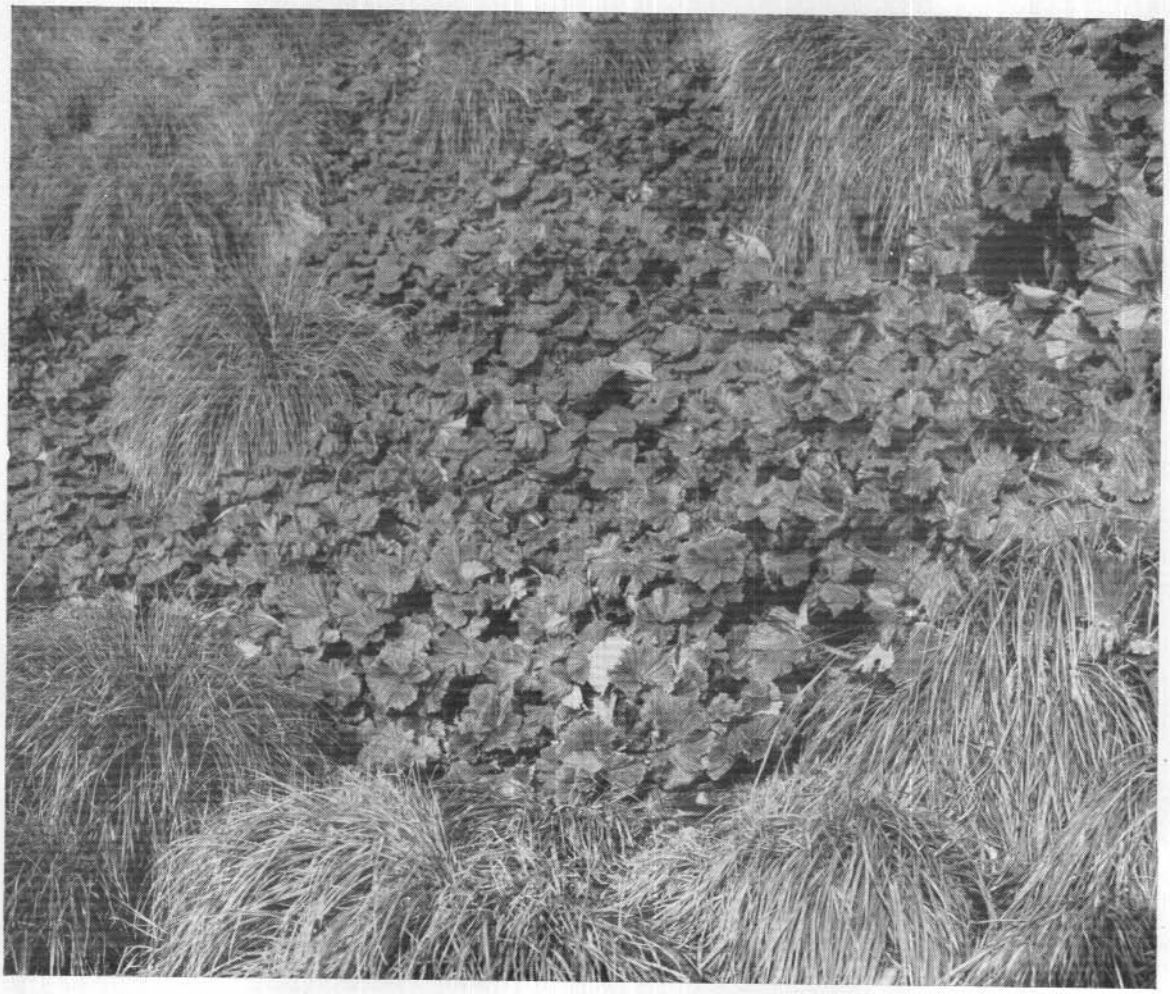

Plate 5. *Poa foliosa—Stilbocarpa polaris* association. Soil — highmoor peat. (Photo, N. Laird).

The association occupies the greatest part of the area of the *Poa foliosa* alliance. It replaces the *Poa foliosa* association on areas subject to the loss or addition of material by soil slips. In some places it is merely a stage in the succession from bare exposed areas to the climax *(Poa foliosa)* association. More frequently it occurs on areas subject to small soil slips and additions. In the latter case it is a topographical climax but it is unprofitable to differentiate between the two types.

IV. and V. The *Poa foliosa—Polystichum vestitum* and the *Poa foliosa—Stilbocarpa polaris—Polystichum vestitum* associations.

In areas on the east coast and occasionally on the west coast, *Polypodium vestitum* enters the *Poa foliosa—Stilbocarpa polaris* association, less frequently than the *Poa foliosa* association, as a co-dominant. Apart from this local change in dominants there is no change in the community.

The ferns grow almost to the height of the surrounding tussocks, generally as isolated plants but occasionally in dense stands. In New Zealand the woody stem may be 4 feet high, but on Macquarie Island it is never more than 6 inches high. Its leaves form a dense canopy under which no other species can grow.

VI. *Stilbocarpa polaris* association. Small areas are completely dominated by the tall growth of *Stilbocarpa polaris.* The leaves are up to 2 feet 6 inches in height and form a continuous canopy, but a few species are quite common under the leaves. These species constitute the ground layer but they never exceed 20% cover.

The association grows on soils modified by loss or gain of soil material and may be a seral community but more frequently is a true topographical climax.

ECOTONE COMMUNITIES

There are no ecotone communities between the *Poa foliosa* and *Azorella selago* alliances, though rare single plants of *Poa foliosa* may grow in an *Azorella selago* cushion. Wherever the boundaries of these two alliances meet without an intermediate area of *Pleurophyllum hookeri* alliance there is always a major topographical change and the boundaries of the two alliances are very sharply defined. The transition zone in such areas is always less than a yard in width.

TABLE 16.

Poa foliosa Alliance

Climax Associations

	Poa foliosa association		*Poa foliosa*—*Polystichum vestitum* association	*Poa foliosa*—*Poa hamiltoni* association	*Poa foliosa*—*Stilbocarpa polaris* association	*Poa foliosa*—*Stilbocarpa polaris Polystichum vestitum* association	*Stilbocarpa polaris* association
	Cardamine corymbosa sub-association	*Cotula plumosa* sub-association					
VASCULAR PLANTS							
Poa foliosa	D	D	Co-D	Co-D	Co-D	Co-D	
Cardamine corymbosa	O	VR	O	O	C	C	
Stellaria decipiens	O	VR	O	O	C	C	C
Stellaria media	(L) O		(L) O		(L) O	(L) O	C
Callitriche antarctica		C		O	R	R	O
Cotula plumosa		C					
Poa annua		C		O			
Polystichum vestitum			Co-D			Co-D	
Poa hamiltoni				Co-D			
Agrostis magellanica		VR					
Acaena anserifolia	VR				VR	VR	
Blechnum penna-marina	(L) A						
Stilbocarpa polaris		O			Co-D	Co-D	D
MOSSES							
Drepanocladus aduncus	O	O	O		O	O	R
Brachythecium c.f. salebrosum	O	O	O		O	O	R
Thuidium furfurosum	VR		VR		R	R	VR
Rhacomitrium crispulum					VR	VR	
Pottia c.f. heimii	VR						
Percentage cover	100	80	100	60-100	100	100	100
Type of climax	Climatic	Biotic	Climatic	Biotic	Topographical or Seral		

D = Dominant. Co-D = Co-Dominant A = Abundant C = Common O = Occasional R = Rare

VR = Very Rare (L) = Local Occurrence only.

POA FOLIOSA—PLEUROPHYLLUM HOOKERI ECOTONE

The ecotone between these two alliances consist of five main communities. Floristic lists and frequencies are given in Table 17. These communities are:

1. *Poa foliosa: Poa annua* sub-association.

2. *Poa foliosa—Stilbocarpa polaris: Agrostis magellanica* sub-association.

3. *Poa foliosa—Stilbocarpa polaris—Pleurophyllum hookeri* association.

4. *Stilbocarpa polaris—Pleurophyllum hookeri* association.

5. *Poa foliosa—Carex trifida* association.

Between 5 and 10% of the area mapped in the vegetation map as *Poa foliosa* alliance bears ecotone communities between this alliance and the *Pleurophyllum hookeri* alliance. Their occurrence is due to position of the water table or of wind exposure intermediate between the requirements of the two alliances. One or both factors may be operating. Whilst they represent intermediate stages between the two alliances these ecotone communities are of an essentially stable nature and maintain their structure because of the topographical position which they occupy. All gradations exist between the two alliances and the various associations have been treated in order as stages in a sequence, from *Poa foliosa* to *Pleurophyllum hookeri* alliance.

1. *Poa foliosa: Poa annua* sub-association. This community is dominated by scattered tussocks of *Poa foliosa* maintaining up to 40% cover. The intervening ground is completely covered by a low-growing mat of small plants dominated by *Poa annua* or, where the water table is high, by lush growths of *Callitriche antarctica*.

The community occurs only in a small area on the raised beach terrace on the southern shore of Hasselborough Bay. The position of the water table is intermediate between that required for the two alliances and so the community is probably an ecotone. However, it is unlike any other ecotone community, in that the area between the tussocks of *Poa foliosa* is dominated by the introduced grass *Poa annua*. How *Poa annua* attained this subdominant position is puzzling. Presumably the community was originally a normal stand of the *Poa foliosa—Stilbocarpa polaris—Pleurophyllum hookeri* association and the *Stilbocarpa polaris* and *Pleurophyllum hookeri* were later replaced by *Poa annua*. But since it is unlikely that the introduced *Poa annua* was better fitted to the environment than the native species, the most plausible explanation seems to be that the original community was damaged by sea elephants and *Poa annua* was then able to enter the community and prevent the regrowth of the original species. The first stages of such a change have been observed elsewhere in many places on the raised beach terrace where the seals have killed off the *Pleurophyllum hookeri* elements of an ecotone community leaving bare ground between scattered tussocks. The Hasselborough Bay area is within the potential range of sea elephants, though few were seen in the immediate area in 1950-51.

2. *Poa foliosa—Stilbocarpa polaris: Agrostis magellanica* sub-association. This community is dominated by *Poa foliosa,* either as tussocks or as scattered individual plants, together with *Stilbocarpa polaris.* The proportion of *Stilbocarpa polaris* varies from 0% to 80%. Associated with the dominants are many elements of the *Pleurophyllum hookeri* alliance which are not found with the topographical climax *Poa foliosa—Stilbocarpa polaris: Cardamine corymbosa* sub-association. It represents the first stage in the ecotone from *Poa foliosa* to *Pleurophyllum hookeri* alliances. The composition of the association varies, depending on whether wind exposure or water table is the more important factor; in the former, *Coprosma pumila* predominates; in the latter, *Agrostis magellanica.*

3. *Poa foliosa—Stilbocarpa polaris—Pleurophyllum hookeri* association. This association differs from the preceding in the reduction in density of *Poa foliosa,* which never has more than 20% cover, and in the appearance of *Pleurophyllum hookeri,* which constitutes up to 40% of the ground cover. The smaller species common to the *Pleurophyllum hookeri* alliance are much more frequent. This community then represents the second stage in the ecotone.

4. *Stilbocarpa polaris—Pleurophyllum hookeri* association. This community is dominated by plants of *Stilbocarpa polaris* and *Pleurophyllum hookeri.* The percentage of dominant *Stilbocarpa polaris* varies from 0-60%. Associated with the community are nearly all of the smaller growing elements of the *Pleurophyllum hookeri* alliance. The plants of *Stilbocarpa polaris* are much taller than in the *Pleurophyllum hookeri* alliance. Here the species grows to 18 inches high whilst in

the *Pleurophyllum hookeri* alliance they play only a subordinate role, rarely growing more than 3 inches in height.

This association then represents the final stage in the usual ecotone between *Poa foliosa* alliance and *Pleurophyllum hookeri* alliance.

5. *Poa foliosa—Carex trifida* association. This community is dominated by scattered plants of *Poa foliosa* and *Carex trifida* together with a strong growth of the smaller species of the *Pleurophyllum hookeri* alliance. It occurs only in a few small areas on the raised beach terrace at Handspike Point and apparently represents the ecotone between *Poa foliosa* association and *Pleurophyllum hookeri—Carex trifida* association due to an intermediate position of the water table.

Location of Poa foliosa—Pleurophyllum hookeri ecotone. The *Poa foliosa: Poa annua* sub-association and the *Poa foliosa—Carex trifida* association occur only in the limited areas mentioned, but the other three ecotone communities occur in a variety of topographical positions:—

(a) *High level slopes.* Generally the transition zone between *Poa foliosa* alliance and *Pleurophyllum hookeri* alliance is narrow with no intermediate ecotone community. This transition is usually associated with a sudden change in slope from the raised beach terrace to the plateau accompanied by a sudden increase in wind exposure and the appearance of a high water table. However, on very high exposed slopes elements of the Pleurophyllum hookeri association are able to grow together with the *Poa foliosa* alliance, and with increasing wind exposure all three ecotone communities occur.

(b) *Low slopes.* On lower slopes leading up from a *Pleurophyllum hookeri* flat, ecotone communities may be formed, limited below by the high water table and above by the increased wind exposure (Fig. 3). Ecotones in such sites are fairly common. Any or all of the three main ecotone communities may occur in such sites.

(c) *Upland valleys.* In sheltered positions in the upland valleys one or more of the three main ecotone communities occur wherever the water table drops below 18 inches, e.g. on small hillocks, raised 10-20 feet above the general valley level, and on the steeply sloping banks of creeks and lakes. Ecotone communities in such localities are rare because the wind velocity in the upland valleys is generally very high and sheltered spots are few.

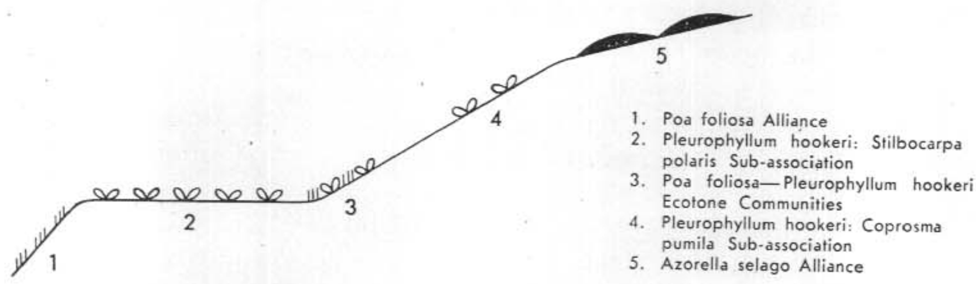

Fig. 5. Cross Section Showing Sequence of Communities in an Upland Valley, Macquarie Island.

Ecotone communities grow on the sand bar crossing Island Lake. They receive moderate protection from the wind but are subjected to a high water table. As this water is frequently interchanged with lake water it is better aerated and less saturated with organic matter than the water table on a peat flat, and the appearance of *Poa foliosa—Pleurophyllum hookeri* ecotone communities here is analagous to the growth of *Poa foliosa* association in or alongside a flowing stream. The occurrence of an ecotone community is due to the intermediate position of wind exposure.

(d) *Low level river valleys.* Geographically mature valleys with extensive river flats bear large stands of *Pleurophyllum hookeri* alliance. Immature valleys with no flats bear only *Poa foliosa* alliance. Valleys intermediate between these bear ecotone communities of greater or less extent.

The occurrence of ecotone communities in these valleys is due to intermediate positions of the water table. Wind plays no part, though material carried down by land slips may. All three of the main ecotone communities may occur in such sites. Ecotone communities also occur in mature valleys between the boundaries of the two alliances.

(e) *Raised beach terrace.* On the raised beach terrace the normal transition, between the *Pleurophyllum hookeri* alliance adjacent to the slopes and the *Poa foliosa* alliance adjacent to the sea, is very sharp. The *Pleurophyllum hookeri* alliance grows on a flat 15 feet above a similar flat bearing *Poa foliosa* alliance. The transition between the two is marked by a short steep slope. However, certain areas at the same height as the *Pleurophyllum hookeri* alliance bear only ecotone communities. This is due to the lower level of the water table caused partly by better drainage and partly by the greater accumulation of material brought down by land slips from the slopes behind. (Fig. 4).

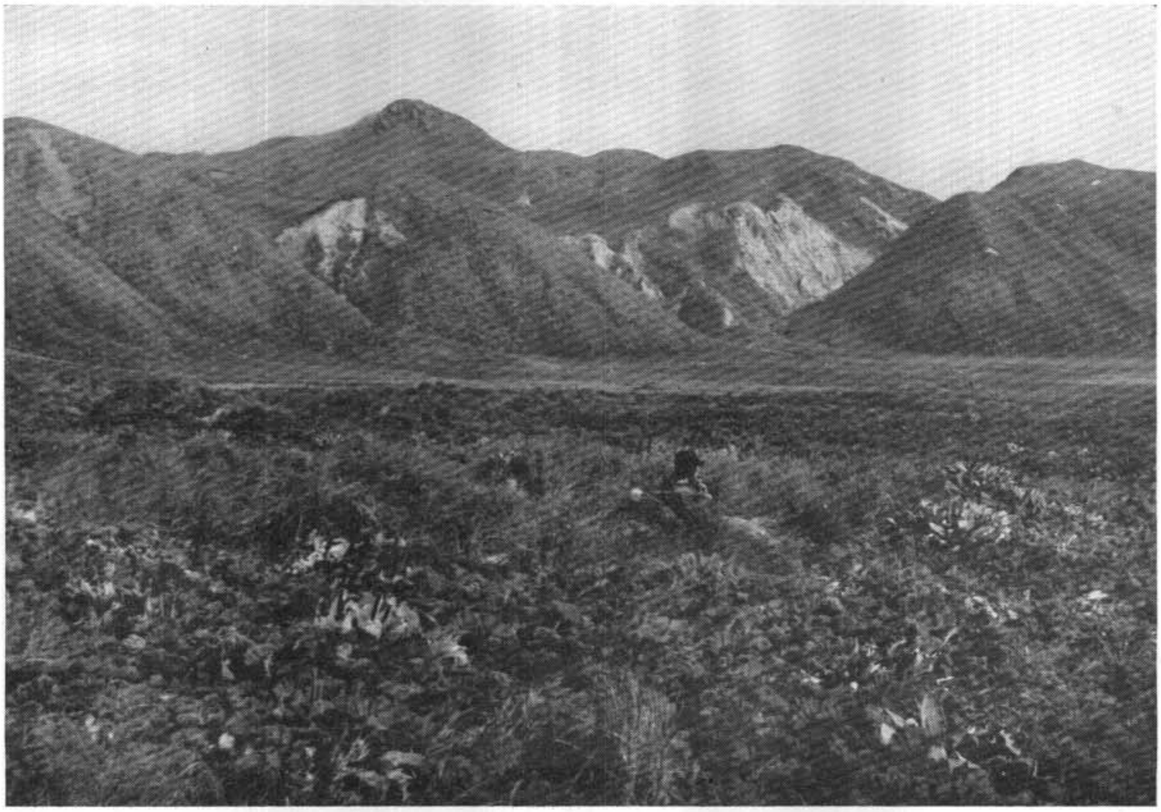

Plate 6. Ecotone community on the raised beach terrace, west coast. *Poa foliosa—Stilbocarpa polaris—Pleurophyllum hookeri association.* (ANARE Photo).

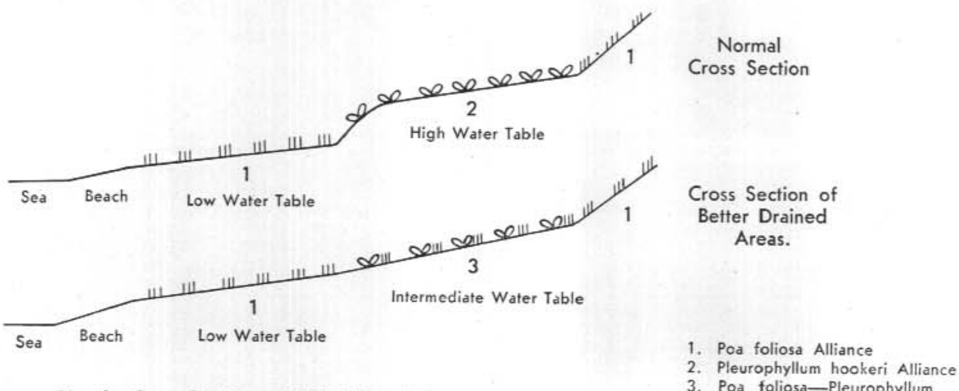

Fig. 6. Cross Sections of Raised Beach Terrace.

TABLE 17

Floristic Composition of *Poa foliosa*—*Pleurophyllum Hookeri* Ecotone Communities

	Poa foliosa: *Poa annua* sub-association	*Poa foliosa*—*Stilbocarpa polaris*—*Agrostis magellanica* sub-association	*Poa foliosa*—*Stilbocarpa polaris*—*Pleurophyllum hookeri* association	*Stilbocarpa*—*polaris*—*Pleurophyllum hookeri* association	*Poa foliosa*—*Carex trifida* association
Poa foliosa	D	Co-D	Co-D		Co-D
Stilbocarpa polaris		Co-D.	Co-D	Co-D	F
Cardamine corymbosa	O	C	O	O	C
Stellaria decipiens	R	C	O	O	C
Acaena anserifolia		C	R		
Callitriche antarctica	F	O	O	R	R
Poa annua	A	O	R		
Cotula plumosa	R				
Deschampsia chapmani	F	R	R	R	
Agrostis magellanica	O	C	F	A	C
Luzula campestris		O	C	F	O
Festuca erecta		O	C	F	O
Epilobium nerterioides		R	O	C	
Epilobium linnaeoides		R	O	O	
Acaena adscendens			R	O	
Carex trifida					Co-D
Cerastium triviale		R	R	R	
Ranunculus biternatus	R	C	O	O	C
Colobanthus crassifolius	R		R	R	
Uncinia riparia				O	R
Pleurophyllum hookeri			Co-D	Co-D	
Coprosma pumila		C	C	F	

D = Dominant A = Abundant C = Common R = Rare

Co-D = Co-Dominant F = Frequent O = Occasional VR = Very Rare

COMMUNITIES SERAL TO THE *POA FOLIOSA* CLIMAX

Seral communities on slopes. The greater part of the area of the *Poa foliosa* alliance is on steep slopes bordering the plateau which vary from 30° to sheer, averaging 40°-45°. Naturally, these slopes are subject to many slips. The greater area bears the topographical climax, *Poa foliosa—Stilbocarpa polaris* association. The growth of any of the communities on these slopes results in an increase in depth and weight of peat which eventually reaches an unstable state. When the peat is saturated after a particularly strong rainy period, and is consequently at its heaviest, land slips occur which lay bare the mineral soil below the peat. In addition, peat and stones of varying sizes may accumulate on the lesser slopes and the steepest slopes may be continuously bare and covered by a layer of very fine wet clay or "rock flour". All these substrata provide starting points for plant successions which, depending on topography and the resultant frequency of slipping, may reach any point up to the climatic climax *Poa foliosa* association.

Successions can be traced on various types of bare areas as follows:—

(i) *"Rock flour" screes.* These occur only on very steep slopes (55°-90°) which are generally situated on the sides of small steep creeks cutting into the plateau. They may be up to 800 feet in height. These screes consist of a layer of grey-green clay-loam, very moist, and containing a moderate percentage of small rock fragments. Underlying this is rock which is partly decomposed often to great depths but which still retains most of the physical character of solid rock. The surface "rock flour" is almost continually saturated and accumulation is prevented partly by solifluction and partly by slipping and rainwash. It is extremely low in humus and has a high pH (about 8).

These screes may be bare over large areas with only a few species, notably *Poa annua* and *Ranunculus biternatus* making a transitory appearance. If the surface of the scree remains stable small patches of vegetation appear, followed by narrow strips which may run down the whole length of the scree slope. These strips of vegetation are at first dominated by mosses with several small vascular species growing amongst them, e.g. *Colobanthus crassifolius, Epilobium* spp. Gradually grasses and sedges appear, followed by *Pleurophyllum hookeri* and *Stilbocarpa polaris,* and last of all *Poa foliosa.*

The last stages in this succession are identical with the *Poa foliosa—Stilbocarpa polaris* association and the *Poa foliosa* association. Some of the stages are similar to the ecotone between *Poa foliosa* and *Pleurophyllum hookeri* alliances but their formation is due to different factors which result in slight changes in composition.

TABLE 18.

Stages in the Sere on Rock Flour.

	I	II	III	IV	V	*Sub-Climax Poa-foliosa—Stubocarpa polaris* Association	*Climax Poa foliosa* Association
VASCULAR PLANTS							
Stellaria media	R					(L) R	
Poa annua	R	R	R	R	R		
Ranunculus biternatus	R	R	R	O	O		
Agrostis magellanica	R	R	F	A	F		
Epilobium linnaeoides		C	O	R			
Epilobium nerterioides	VR	C	O	R			
Colobanthus crassifolius		C	O	R			
Cardamine corymbosa		C	C	C	O	C	O
Montia fontana		O	O	O			
Stellaria decipiens		R	R	O	O	C	O
Festuca erecta		R	F	A	F		
Cerastium triviale			R	R			
Uncinia riparia			R	R			
Acaena anserifolia			C	F	F	VR	VR
Luzula campestris			F	A	F		
Pleurophyllum hookeri			R	F	C		
Stilbocarpa polaris			R	A	D	Co-D	
Poa foliosa				R	C	Co-D	D
MOSSES							
Drepanocladus aduncus		F	F	C	O	O	O
Breutelia pendula		F	C	R			
Brachythecium c.f. salabrosum		F	C	C	O	O	O
Bryum laevigatum		F	C				
Lembophyllum clandestinum		C	O	O	R		
Thuidium furfurosum		O	O	R	R	R	VR
Dicranoloma robustum		O	R				
Distichium capillaceum		C					
Macromitrium longirostre		O					
Rhacomitrium crispulum		O	O	O			
Bartramia papillata		R					
Pogonatum alpinum		R					
Dicranoweisia antarctica		R					
Bryum Amblyophyllum		R					
Amblystegium serpens		VR					
Zygodon menziesii		VR					
Pottia c.f. heimii							VR

D = Dominant. A = Abundant. C = Common. R = Rare. Co-D = Co-Dominant, F = Frequent. O = Occasional. VR = Very Rare.

These communities have been called seral, and the various stages are readily observed. However, it is obvious in many places that owing to the steepness of the slope the sere is never completed before a fresh slip removes all the accumulated peat and vegetation. Thus several large areas never proceed past the first stage.

(ii) *Sere on rock scree.* Slopes below an exposed rock face are constantly receiving fragments of rock. These are generally more than

6 inches long though sometimes boulders up to 12 feet in length may occur. Such slopes are frequently devoid of plant life as the surface of small stones is unstable, but in more favourable conditions various species grow. Under the influence of water from a small soak, *Montia fontana* first appears, but *Ranunculus biternatus* and *Poa annua* are generally the primary colonisers, followed by *Agrostis magellanica, Acaena anserifolia* and, if near the sea, *Colobanthus muscoides*. In such sites *Agrostis magellanica* reaches its most luxuriant growth. At this stage plant cover is approximately 50%. *Festuca erecta, Stilbocarpa polaris, Pleurophyllum hookeri* then enter the community and the later stages of its development roughly parallel those of "rock flour" screes.

Plate 7. Scree slope sere. Sub. climax *Poa foliosa—Stilbocarpa polaris* association in foreground. (Photo, N. Laird).

(iii) *Sere on mineral subsoils.* The tussock clad slopes, even under natural conditions, are subject to slips of the peat layer. Accumulated peat finally becomes too heavy in one spot and a slip starts, the mass gathers momentum and strips off the peat below it, finally coming to rest at the foot of the slope. Soil profiles dug at the foot of several slopes show this very well, especially when the vegetation on the slope is the *Poa foliosa—Stilbocarpa polaris* association. Traces of old slips can also be seen in the frequent vertical strips which bear various stages of sub-climax vegetation sharply delineated from the surrounding climax vegetation. These strips may be 700 feet in vertical height.

Though small slips occasionally occur, only one major slip (500 feet vertical) was observed under natural conditions in the period November 1947-March 1951. However, on steep slopes in the areas grazed by rabbits, bare areas due to peat slips are the rule rather than the exception. The one major slip occurred in February, 1951, and so regeneration could not be observed by the author. The effect of the slip was to strip off the 2-5 feet surface layer of peat and expose the mineral sub-soil

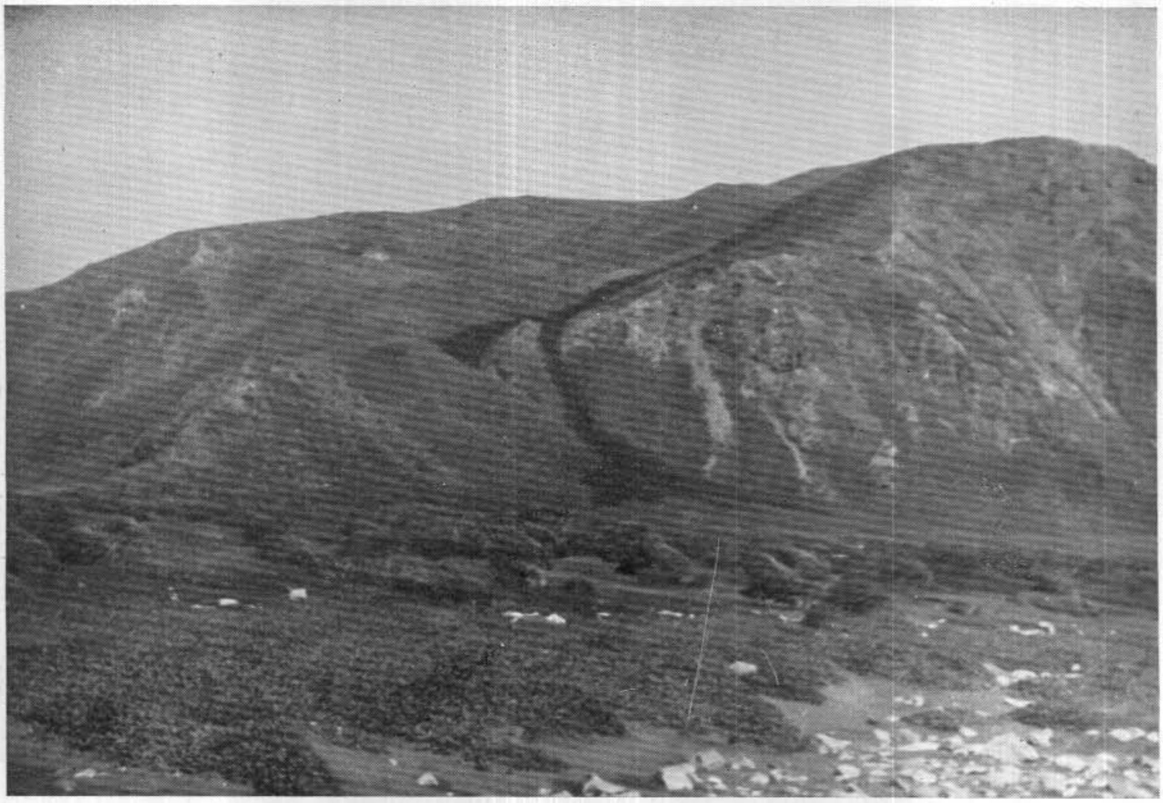

Plate 8. Newly formed land slip, North End. (ANARE Photo).

below. Re-colonisation probably followed a pattern similar to that of "rock flour" screes.

MARITIME COMMUNITIES

Under this heading have been grouped all communities which are strongly influenced by sea waves or spray. They are not seral communities, as they are in equilibrium with the present day climatic and topographical conditions. Since Macquarie Island has risen considerably since the Ice Age, the areas originally covered by maritime communities have been replaced by climax communities. These maritime communities, then, must roughly correspond to the various long term successions and are most conveniently described as such.

(d) *Coastal rock communities.* The first plants to appear above the wave-washed marine algae are small clumps of the endemic grass, *Puccinellia macquariensis,* which may grow so close to the sea that they are drenched by waves during exceptional storms. Two species of moss and several lichens then appear between the scattered clumps of *Puccinellia macquariensis.* Blue-green algae and bacteria also play a part in the early stages of this succession but their exact effect has not been observed. Once above wave influence, cushions of *Colobanthus muscoides* appear. These cushions commence to grow in small crevices in the rock and then spread over the rock surface, frequently attaining a diameter of 18 inches and a depth of 6 inches. The cover of *Puccinellia macquariensis* and *Colobanthus muscoides* at this stage rarely exceeds 5%. In certain chance localities scattered round the island *Crassula moschata* grows with this community. At first it forms a tightly packed mat, growing on peat of its own formation. More distant from the sea the individual stems are larger and have a more upright growth.

Still further from the sea several other species appear growing in the *Colobanthus* cushions, e.g. *Cotula plumosa* and occasionally *Agrostis magellanica, Poa foliosa* and *Ranunculus biternatus.* These plants are greatly reduced in size but generally flower and fruit. Further inland *Cotula plumosa* is capable of growth independent of the *Colobanthus muscoides* cushions and is then replaced by successive communities dominated by *Agrostis magellanica, Stilbocarpa polaris* and finally by *Poa foliosa.* All these stages are illustrated in Table 19. The last three communities completely cover all the rock surface. In such positions climax *Poa foliosa* association often grows in one foot or less of very fibrous peat on top of solid unaltered rock.

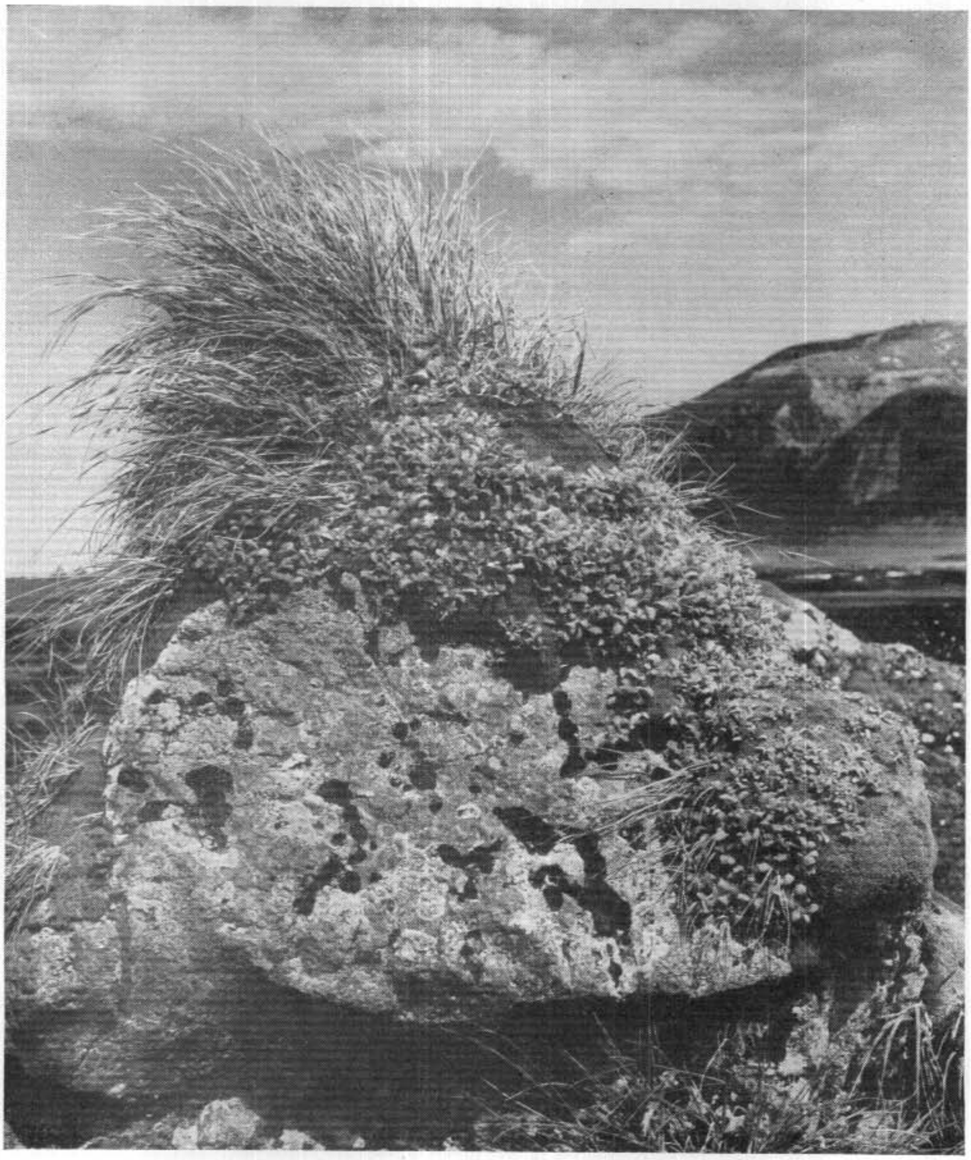

Plate 9. Coastal rock communities. Dark patches of *Muelleriala crassifolia*, large cushions of *Colobanthus muscoides* supporting *Cotula plumosa* and *Poa foliosa*. (Photo, N. Laird).

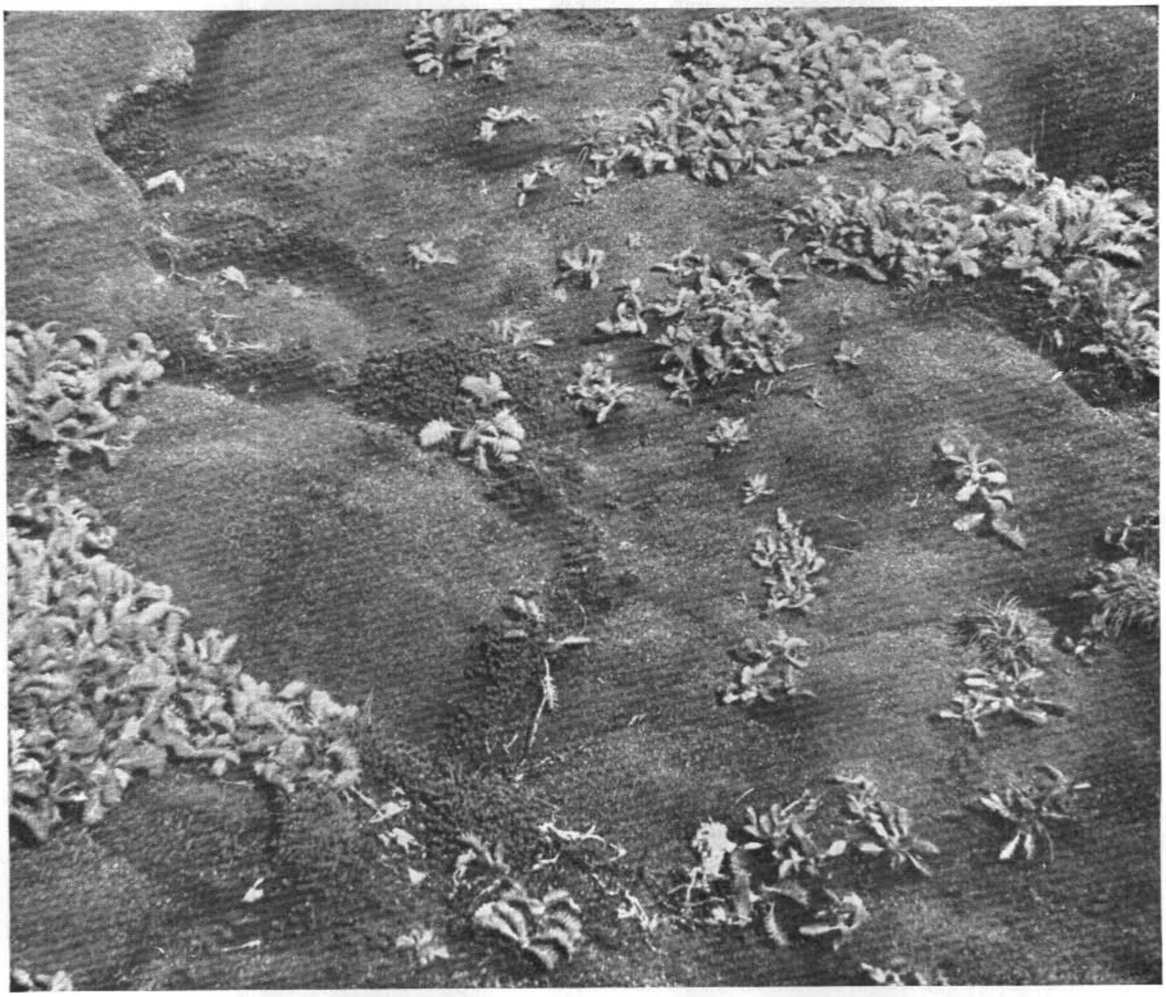

Plate 10. Cushion of *colobanthus muscoides* supporting *Cotula plumosa, Crassula moschata* (middle left) and *Puccinillia macquariensis* (extreme right). (Photo, N. Laird).

(b) *Beaches and sand patches.* The majority of the beaches are of shingle-rounded stones averaging 4 x 3 x 1 inches. In the more sheltered bays the beaches are of sand and small sand pockets collect amongst the coastal rocks. In addition wind-blown sand is deposited on *Poa foliosa* slopes in a few small areas behind sandy beaches.

The boundary between *Poa foliosa* association and the beaches is always extremely sharply defined. Only rarely does any plant grow on the beaches and then only a few scattered plants of *Cotula plumosa.* This

TABLE 19.

Maritime Communities

Stages in the Lithosere on Coastal Rocks

	Increasing Protection from Spray.							
	Arbitrary Stages.							
	1	2	3	4	5	6	7	8
VASCULAR PLANTS								
Puccinellia macquariensis	C	C	C	O				
Crassula moschata		(L) R	(L) C	(L) C				
Colobanthus muscoides		R	C	A				
Cotula plumosa				O	D	O	O	Climax
Poa foliosa (In *Colobanthus muscoides* cushions)				R				Poa foliosa
Poa foliosa (Individual plants)					VR	R	C	Asso-ciation
Poa foliosa (Tussocks)								D
Stellaria decipiens						R	O	O
Cardamine corymbosa						R	O	O
Agrostis magellanica				VR	VR	D	O	
Pleurophyllum hookeri						O	O	
Stilbocarpa polaris						R	D	
Luzula campestris						O	O	
Festuca erecta							R	
Epilobium nerterioides							R	
Ranunculus biternatus			VR			O	O	
MOSSES								
Muelleriella crassifolia		R	C	C	C			
Pottia c.f. heimii (local)				O	C	C	O	
Ceratadon purpureus			O	O	O	O		
Dicranoweisia antarctica				R	R			
Totula robusta						VR		
Drepanocladus aduncus						O	O	
Brachythecium c.f. salabrosum						O	O	
LICHENS	R	C	C	C				
Percentage Cover	0-2	3	5	10	100	100	100	100

D = Dominant. CoD = Co-Dominant . A = Abundant. F = Frequent.
C = Common. O = Occasional. R = Rare. VR = Very Rare.

dearth of vegetation is due to the instability of the sand or shingle. Major changes in the contours of beaches were frequently observed in the course of one year (1950-51), even on the relatively sheltered east coast.

As the sea is still retreating from the beaches the *Poa foliosa* association must be advancing. In a large area of the west coast the association has advanced more than a half mile since the ending of the last Ice Age. This advance is apparently normally accomplished by lateral growth of individual tussocks of *Poa foliosa*. However, where small streams reach the beach, a layer of organic matter is left where the streams disappear beneath the sand or shingle. This layer is frequently colonised by *Cotula plumosa* but owing to its proximity to the sea it is commonly destroyed by penguins and seals and the patch is recolonised by algae; then *Callitriche antarctica* appears, and later *Cotula plumosa*. The small patches of sand piled up against rocks and other obstacles in the maritime region bear luxuriant growths of *Cotula plumosa*.

In several places on the island the wind is depositing sand on slopes bearing *Poa foliosa* association. Where this is most pronounced, wind blast is killing the tussocks of *Poa foliosa* which together with the under-

TABLE 20.

Maritime Community (Continued)

Species	Sand and shingle beaches	Peat patches at edge of beaches	Sand pockets amongst coastal rocks	*Poa foliosa* association altered by wind blown sand
Cotula plumosa	VR	D	D	VR
Callitriche antarctica		C		VR
Ranunculus biternatus		VR		O
Puccinellia macquariensis			VR	
Stilbocarpa polaris				O
Poa foliosa				D
Poa annua				A
Agrostis magellanica				F
Cerastium triviale				C
Stellaria media				C
Epilobium linnaeoides				O
Stellaria decipiens				O
Epilobium nerterioides				C
Cardamine corymbosa				O
Acaena anserifolia				O
Colobanthus crassifolius				O
Percentage cover	Nil-½	95	95	100

D = Dominant. A = Abundant. C = Common. R = Rare.

F = Frequent. O = Occasional. VR = Very Rare.

lying peat are then rapidly removed under the influence of gravity. Where the effect of the sand blast is less severe an open community dominated by *Poa foliosa* tussocks is formed. Here the individual tussocks are separated by distances up to 3 yards and the intervening ground is well covered by smaller species. The soil beneath this community may consist of three feet or more of sand overlying a layer of peat.

SUMMARY OF THE FACTORS AFFECTING THE *POA FOLIOSA* ALLIANCE

The occurrence of the *Poa foliosa* association is limited by several factors.

1. *Sea Spray.* Coastal *Poa foliosa* communities receive a good deal of sea spray which prevents the growth of the climax associations. If the area near the shore line is flat or gently sloping the zone affected may be up to 50 yards broad, but if it is protected by large rocks or steep slopes it is much narrower.

2. *Wind exposure.* The effect of topography greatly alters the local wind velocity. Thus the velocity of winds over the highlands is far greater than over the lowlands, and considerably greater than at the same height above open sea. In places where the wind velocity is high *Poa foliosa* association is unable to develop. The limiting effect of wind is due to its increasing the transpiration rate. Very high wind velocities by themselves have little mechanical effect on the *Poa foliosa* alliance, though sand blast and more rarely snow blast may prove to be factors in limiting the spread of the alliance.

3. *High water tables.* In most areas with a high water table, even though sea spray and wind do not appear to be limiting factors, *Poa foliosa* alliance is unable to grow. Thus when the ground water table is less than 18 inches below the surface, *Poa foliosa* alliance is replaced by *Pleurophyllum hookeri* alliance, except when the high water table is due to the proximity of a stream. It appears that the *Poa foliosa* alliance is unable to compete successfully with *Pleurophyllum hookeri* alliance owing to the lessened aeration of such sites.

4. *Depth of peat.* *Poa foliosa* alliance is unable to grow on bare slip slopes, rocks, etc. even though no other limiting factors are present until a depth of from 4 to 6 inches of peat has been formed.

HERBFIELD (SUB-GLACIAL)
PLEUROPHYLLUM HOOKERI ALLIANCE

The *Pleurophyllum hookeri* alliance consists of five associations. The cccurrence of a particular association depends partly on the presence or absence of material carried down by soil slips, and partly on the chance availability of seeds of *Carex trifida.*

The associations are listed below. Floristic lists and frequencies are given in Table 21.

1. *Pleurophyllum hookeri* association.

2. *Pleurophyllum hookeri—Festuca erecta* association.

3. *Festuca erecta* association.

4. *Carex trifida* association.

5. *Pleurophyllum hookeri—Carex trifida* association.

1. *Pleurophyllum hookeri* association. This association consists of three sub-associations:

(a) *Pleurophyllum hookeri: Cerastium triviale* sub-association.

(b) *Pleurophyllum hookeri: Stilbocarpa polaris* sub-association.

(c) *Pleurophyllum hookeri: Coprosma repens* sub-association.

The *Pleurophyllum hookeri* association covers far the greatest area of the alliance, the other four associations being confined to small areas on the raised beach terrace.

(a) *Pleurophyllum hookeri: Cerastium triviale* sub-association. This community is completely dominated by regularly spaced, tall growing plants of *Pleurophyllum hookeri.* Here the leaves of each rosette grow vertically for 6 inches before spreading out horizontally. The spacing depends on the vigour of the individual plants, but normally they are about one foot apart. Where the water table lies very close to the surface they may be only 6 inches apart and are smaller, with their leaves closely appressed to the surface of the ground.

The closed canopy of leaves does not permit lower growing species to enter, and these are represented only by a few scattered etiolated plants.

This community is found only in low level areas which have a high water table, 18 inches-½ inch below the surface, and which are well protected from wind and not subject to additions of mineral material by soil slips from above. At the present day the only such area is the river flat of Finch Creek. Suitable sites exist in one or two river valleys further south but here rabbits have destroyed the original vegetation.

(b) *Pleurophyllum hookeri: Stilbocarpa polaris* sub-association. This is the usual expression of the association and of the alliance. The dominating plants of *Pleurophyllum hookeri* are scattered at random throughout the community with individual plants being spaced about 2 feet apart. The size of the leaves of the flat rosettes varies from 5 to

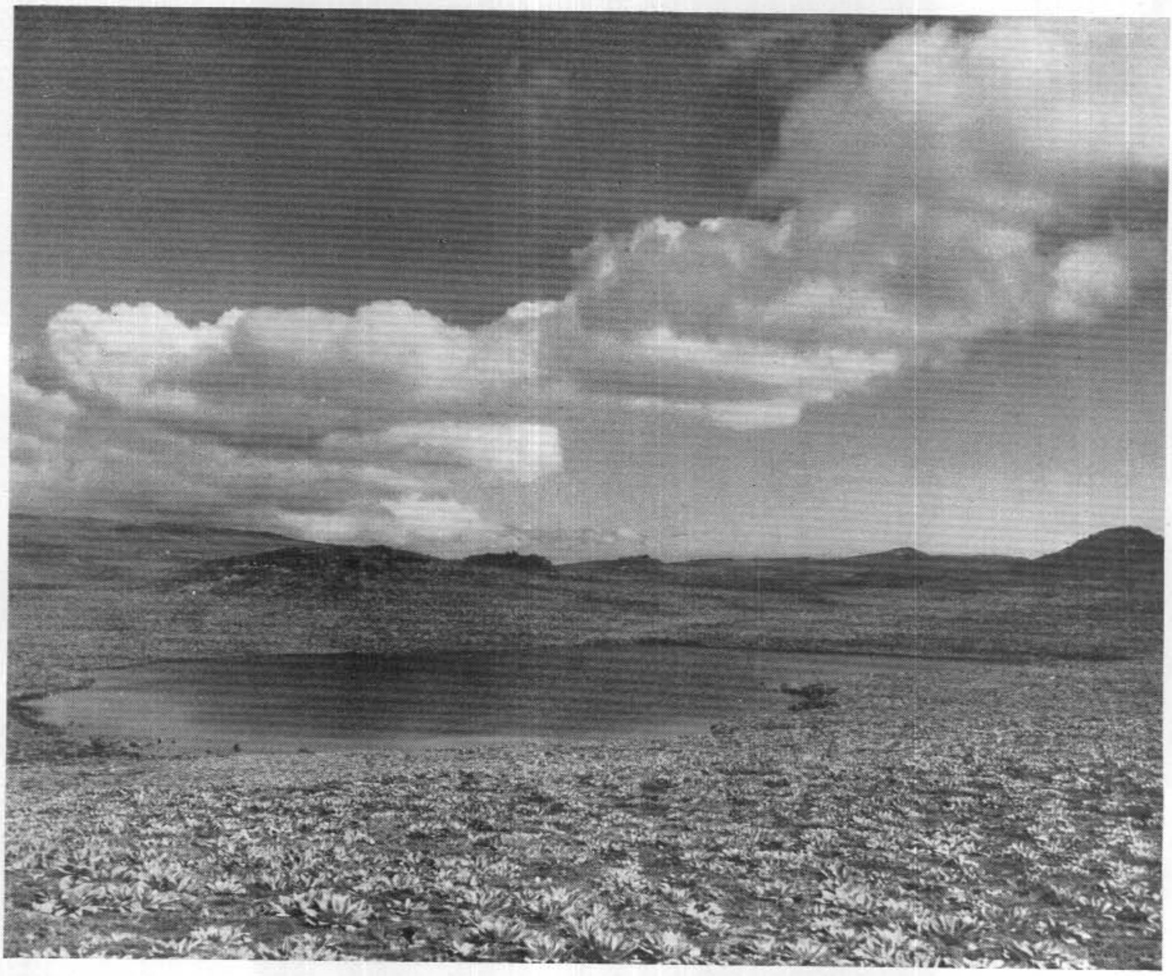

Plate 11. *Pleurophyllum hookeri*: *Stilbocarpa polaris* sub-association at 600 feet elevation. Soil—rich fen peat. (Photo, N. Laird).

20 inches, but normally they are about 9 inches in length and 3 inches in breadth. The intervening ground is completely covered by a mat of low growing vegetation, the most conspicuous species of which are *Stilbocarpa polaris* and various grasses and sedges. The plants of *Stilbocarpa polaris* in this community are much reduced in size with leaves rarely more than 4 inches in diameter growing close to the ground surface.

The community occurs on flats and slight slopes at all levels, where the water table is between 1 inch and 18 inches below the ground surface and there is only moderate wind exposure.

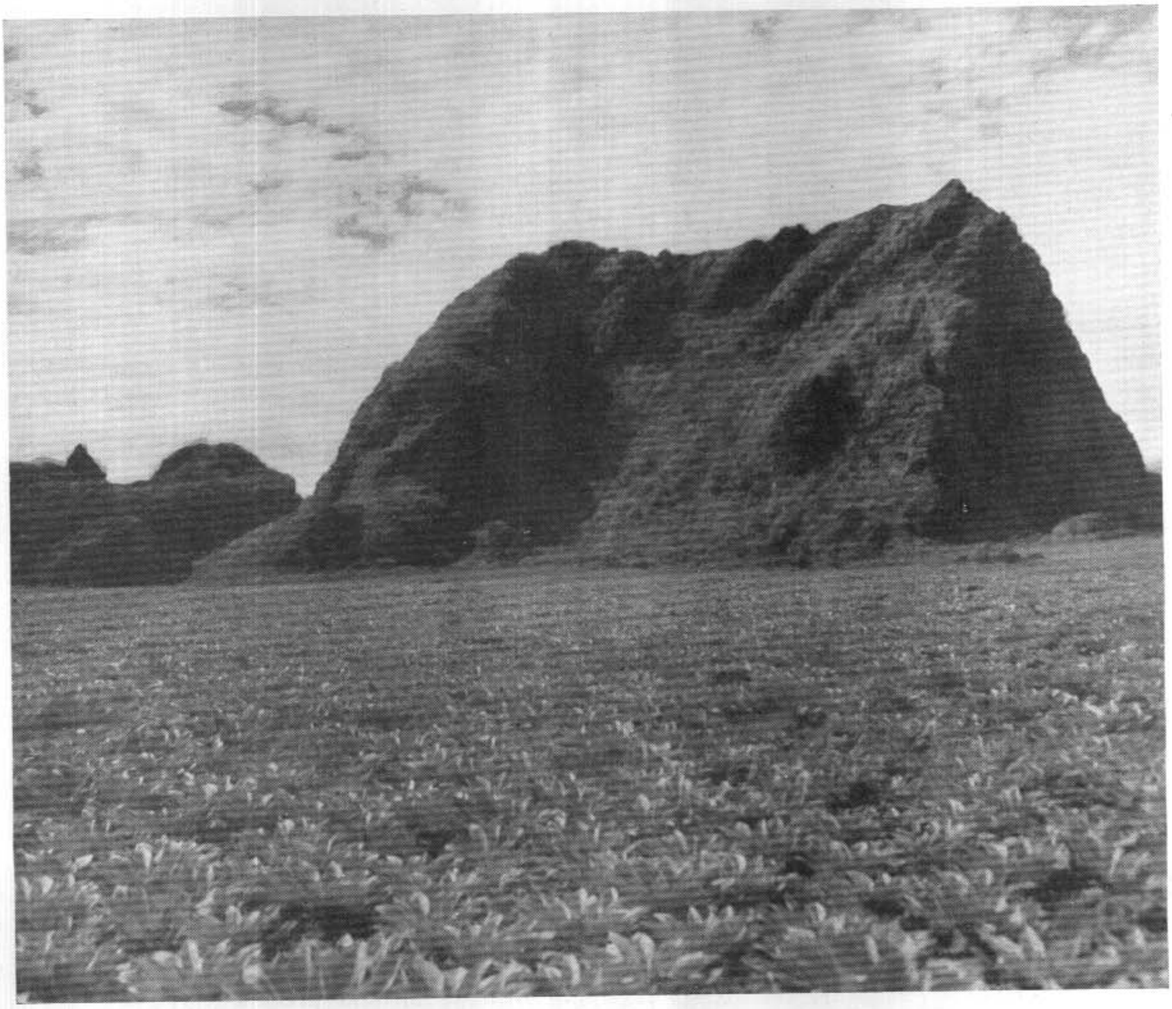

Plate 12. *Pleurophyllum hookeri*: *Stilbocarpa polaris* sub-association in foreground growing on the raised beach terrace. Soil—poor fen peat. In background an old sea stack covered by *Poa foliosa* association. Soil—highmoor peat. (Photo, N. Laird).

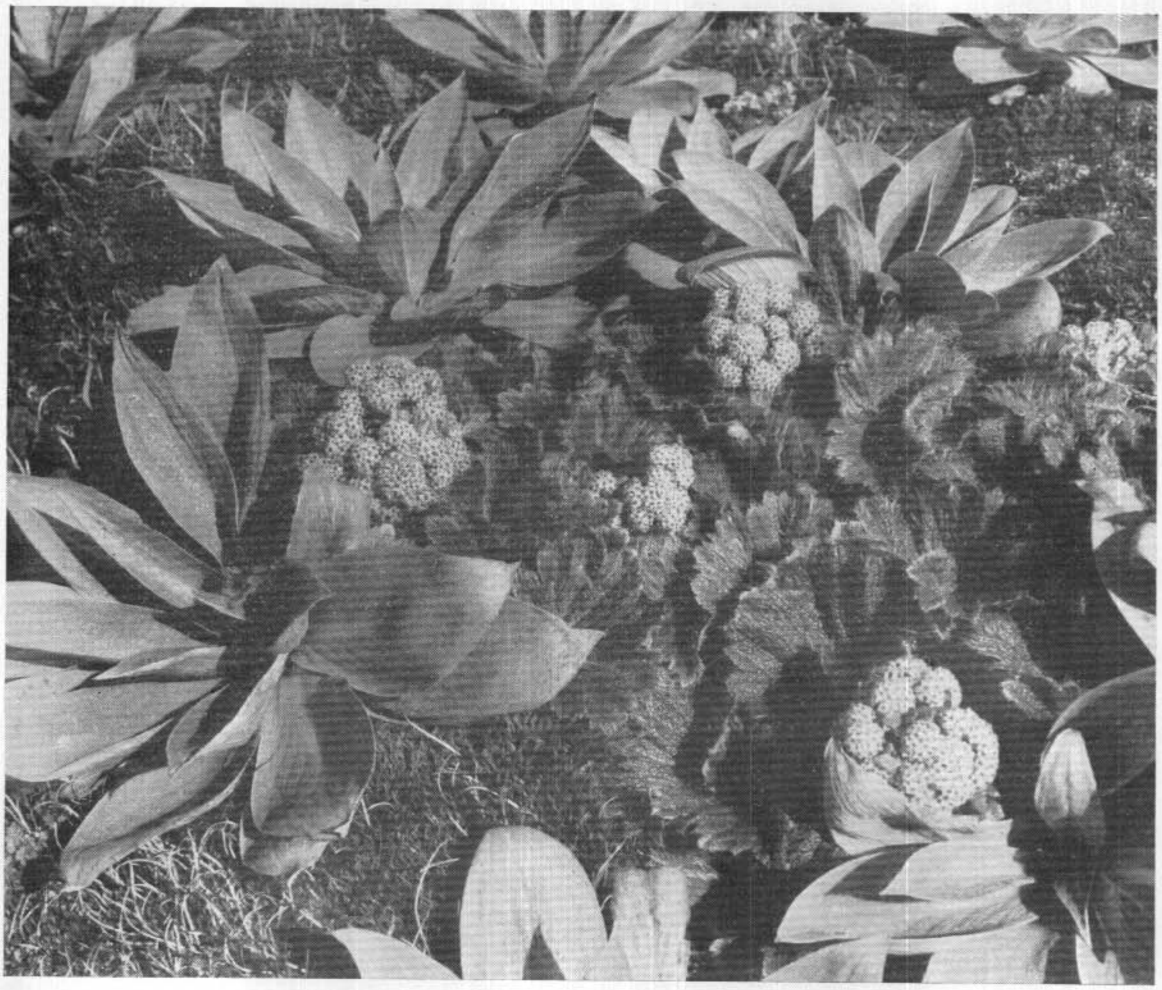

Plate 13. *Pleurophyllum hookeri*: *Stilbocarpa polaris* sub-association. (Photo, N. Laird).

In a small area of Handspike Point on the raised beach terrace, large tussocks of *Festuca erecta* grow in the midst of the sub-association. These tussocks are very large, 2 feet 6 inches to 3 feet in height and a yard in diameter, but only a dozen very scattered tussocks are found on the whole island and all of these are at Handspike Point.

The plants of *Festuca erecta* comprising these tussocks are morphologically identical with the plants of *Festuca erecta* in the surrounding community but are many times larger. Their appearance does not seem to correspond with any ecological factor and is probably due to some genetic difference.

(c) *Pleurophyllum hookeri: Coprosma repens* sub-association. In this community the dominating plants of *Pleurophyllum hookeri* are well scattered as in the *Stilbocarpa polaris* sub-association but are generally slightly smaller. The leaves of the rosette average 6 inches in length. The intervening carpet of vegetation is dominated by mat-forming species viz. *Coprosma repens* and *Acaena anserifolia*. The typical community occurs on slopes without a high water table but with moderate wind exposure. The exposure to wind of sites occupied by this community is intermediate between those of sites occupied by the *Poa foliosa* alliance and the *Azorella selago* alliance.

2. *Pleurophyllum hookeri—Festuca erecta* association. This association is dominated by scattered rosettes of *Pleurophyllum hookeri* with the intervening ground dominated by *Festuca erecta*. The association represents an intermediate stage between the *Pleurophyllum hookeri: Stilbocarpa polaris* sub-association, and the *Festuca erecta* association. The majority of the elements of the *Stilbocarpa polaris* sub-association are replaced by *Festuca erecta* which is fairly tall, growing 9 inches high.

3. *Festuca erecta* association. In this association *Festuca erecta* is completely dominant over all other elements of the *Pleurophyllum hookeri* alliance. Scattered rosettes of *Pleurophyllum hookeri* occur but are overshadowed by the taller growing *Festuca erecta*, which grows up to 18 inches high. The frequencies of most species which are in common with the *Pleurophyllum hookeri* association are reduced, *Stilbocarpa polaris* being almost absent. A few species, notably *Acaena adscendens* are more common than in the *Pleurophyllum hookeri* association.

4. *Carex trifida* association. This community is completely dominated by the tall, closely growing sedge, *Carex trifida*. The individual plants are roughly uniform in height from 2 feet to 2 feet 6 inches and their leaves form a continuous canopy. Under this canopy only rare plants of a few small species grow, even though there is a good deal of bare ground between the upright stems of the individual plants of *Carex trifida*. The association is extremely limited in extent, for apart from a few scattered sites on Handspike Point, only one stand about 50 yards long by 10 yards wide is known from Macquarie Island. The soil is poor fen peat with a water table 2 inches below the surface.

5. *Pleurophyllum hookeri—Carex trifida* association. This association is dominated by scattered plants of *Pleurophyllum hookeri* and *Carex trifida*. The individual plants of *Carex trifida* are well separated but smaller than plants growing in the *Carex trifida* association, averaging only 18 inches in height. Apart from this change in dominance the association is essentially similar to the *Stilbocarpa polaris* sub-association of the *Pleurophyllum hookeri* association. It is found only in a few scattered sites on the raised beach terrace at Handspike Point.

TABLE 21.

The *Pleurophyllum hookeri* Alliance.

	Pleurophyllum hookeri association		*Coprosma pumila* sub-association	*Pleurophyllum hookeri*—*Festuca erecta* association	*Festuca erecta* association	*Carex trifida* association	*Pleurophyllum hookeri*—*Carex trifida* association
	Cerastium triviale sub-association	*Stilbocarpa polaris* sub-association					
VASCULAR PLANTS							
Pleurophyllum hookeri	D	D	D	Co-D	F		Co-D
Stilbocarpa polaris		A	O	C	O		C
Festuca erecta		A	O	Co-D	D		F
Agrostis magellanica		A	O	F	F		F
Luzula campestris		F	O	F	C		F
Coprosma pumila		O	A	O	R		O
Acaena anserifolia		O	F	O	R		R
Acaena adscendens		C		F	A		C
Carex trifida						D	Co-D
Juncus scheuchzerioides		C		O	R		C
Uncinia riparia		C	C	O	R		C
Blechnum penna-marina		(L) A	(L) A				
Montia fontana		C	R	O	O		O
Ranunculus biternatus		C	C	C	O	VR	C
Epilobium nerterioides		C	F	C	O		C
Epilobium linnaeoides		O	C	O	R		O
Deschampsia chapmani		D					D
Cardamine corymbosa		O	C	O	R	VA	O
Stellaria decipiens		R	C	O	O	VR	R
Stellaria media	R	VR					
Poa annua		O	R	VR		VR	O
Cerastium triviale	O	R	VR	VR			
Callitriche antarctica		R		VR			VR
Colobanthus crassifolius		R		VR			R
Hydrocotyle sp.		(L) C					
Cotula plumosa		(L) O					

Azorella selago		(L) VR					
LICHENS		O	F	O	O		
LIVERWORTS		O	F	O	O		
MOSSES							
Dicranoloma robustum		A		C	C		
Brutelia pendula		F	C	O	O		
Brutelia elongata		C					
Thuidium furfurosum		F	O	O	O		O
Drepanocladus aduncus		O	C	C	O		O
Pottia c.f. heimii		O	R	R	VR		O
Brachythecium salabrosum		O	R	O	O		
Rhacomitrium crispulum		O	C				
Rhacomitrium lanuginosum		R	R				R
Ptychomnion aciculare		O					
Bryum laevigatum		O					R
Distichium capillaceum		O		R			O
Bartramia papillata		O					O
Poganatum alpinum		R	O				O
Amblystegium serpens		R					C
Rhacocarpus humboltii		R					
Lembophyllum							O
clandestinum		R	R	R	R		O
Pterygophyllum dentatum			R				

D = Dominant. A = Abundant. C = Common. R = Rare. Co-D = Co-Dominant. F = Frequent. O = Occasional. VR = Very Rare.

It will be seen from the table that several species are of local occurrence only. This may be due first to the more strictly defined tolerance of species to a particular factor than to the community as a whole, and secondly to the limited distribution of species even in favourable habitats. Thus *Blechum penna-marina* is found only in isolated patches in the valleys and slopes. Here however, it may completely dominate the ground layer of vegetation. *Hydrocotyle sp.* is found only in the *Pleurophyllum hookeri* association when the community lies alongside a bog community in which *Hydrocotyle sp.* is abundant. *Azorella selago* has been noted only in one place in the *Pleurophyllum hookeri* association, well out of its normal habitat requirements. Its success there must be regarded as accidental.

Seasonal aspects of the Pleurophyllum hookeri alliance. All species of the various associations show a marked regrowth in spring and a gradual dying down in autumn and winter. Most species commence flowering early in the spring and at the end of summer all seeds are ripe and have been shed. However, fruits of *Luzula campestris* are frequently retained in the inflorescence till the following spring.

This seasonal variation is most marked in the case of *Pleurophyllum hookeri.* At the end of summer the large leaves forming the base of the rosette decay and only the smaller central leaves remain. With the coming of the next spring these grow rapidly and are in turn replaced by newly formed leaves. In the spring long flowering spikes grow vertically from the axils of leaves in the rosette and die off at the end of summer. The dead spikes may persist till the next spring but are generally blown over and soon decay.

Plants of *Carex trifida* are greener and the leaves slightly longer in spring but the fruiting inflorescence persists from spring till late in the following winter.

Factors affecting the Pleurophyllum hookeri alliance. The spread of the alliance on Macquarie Island is restricted by its inability to compete with the *Poa foliosa* alliance (due to the shading of the higher growing plants of *Poa foliosa*) and by severe wind exposure which prevents it from growing or at any rate from competing with the *Azorella selago* alliance. The alliance occupies all sites from which *Poa foliosa* is precluded and where wind is not too severe, viz. those with a high water table and moderate wind conditions. The difference in wind tolerance of the *Pleurophyllum hookeri* and the *Poa foliosa* alliances is not very great, so that on a slope with gradually increasing wind exposure *Poa foliosa* alliance is replaced by only a narrow band, of 100 feet vertical height, of *Pleurophyllum hookeri* alliance before this alliance is replaced by the more wind-resistant *Azorella selago* alliance.

Within the alliance various factors determine the resultant community. A high water table, with no loss or additions of soil material by slipping and only slight wind exposure, results in a community of the *Cerastium triviale* sub-association of the *Pleurophyllum hookeri* alliance. With slightly more wind exposure a community of the *Stilbocarpa polaris* sub-association is formed, and with still more, the *Coprosma repens* sub-association.

The *Festuca erecta* association and the *Festuca erecta—Pleurophyllum hookeri* association occur on sites with moderate wind exposure and a fairly high water table which are subject to additions of materials by soil slips.

The formation of the *Carex trifida* association and the *Carex trifida—Pleurophyllum hookeri* association depends mainly on the chance availability of seeds of *Carex trifida,* but conditions of moderate wind exposure and a water table 2 to 4 inches below the surface are necessary.

Seral communities leading to a climax of Pleurophyllum hookeri *alliance.* Various seres occur on bare areas culminating in one or other society of the *Pleurophyllum hookeri* alliance—hydroseres, lithoseres and a sere on the abandoned "bog holes" of sea elephants.

The hydrosere constitutes first an aquatic community belonging to the *Ranunculus biternatus* association; then a bog association, followed by a mosaic of bog and *Pleurophyllum hookeri* associations; and finally the climax, the *Pleurophyllum hookeri: Stilbocarpa polaris* sub-association. Despite the frequency of small pools and streams on the island, the number of places where this sere is advancing is very small.

The lithosere culminates in the *Pleurophyllum hookeri: Coprosma pumila* sub-association. It is very similar to the early stages of the lithosere culminating in *Poa foliosa* alliance, though due to greater wind exposure cushions of *Azorella selago* may appear in the earliest stages of the succession.

"Bog holes" abandoned by sea elephants are rapidly recolonised by plants. Only a few stages in the succession have been observed, but these are enough to trace the probable path of the sere. "Bog holes" are flat areas several feet below the surrounding ground level so that an abandoned "bog hole" is easy to recognise.

At first the surface consists of several feet of semi-liquid peat. *Callitriche antarctica* is the first coloniser, followed fairly soon by *Poa annua* and *Ranunculus biternatus*. These spread over the greater part of the area of the "bog hole" leaving only a few channels. Their roots bind the surface a little and a few other species enter, probably in this order: *Montia fontana, Agrostis magellanica,* various moss species, *Juncus scheuchzerioides, Colobanthus crassifolius, Stilbocarpa polaris, Pleurophyllum hookeri.* A few observed stages in this sere are given in Table 21. Final stages in the succession were never seen but probably the last example in Table 22 would soon develop into the *Stilbocarpa polaris* sub-association of the *Pleurophyllum hookeri* association. In stage IV the ground could easily support the weight of a man, in stage III it could be walked across only with extreme caution, while in stage I of course, this would be impossible.

TABLE 22.

Stages in Sere on Sea Elephant "Bog Holes".

	Stages actually observed			
	I	II	III	IV
VASCULAR PLANTS	R	A	A	
Callitriche antarctica	VR	A	A	R
Poa annua	R	C	O	R
Ranunculus biternatus			F	O
Montia fontana			C	O
Agrostis magellanica				F
Juncus scheuchzerioides				A
Colobanthus crassifolius				O
Stilbocarpa polaris				A
Pleurophyllum hookeri				O
MOSSES				O
Percentage cover	1	20	90	100

A = Abundant. C = Common. R = Rare. F = Frequent. O = Occasional.
VR = Very Rare.

FEN

JUNCUS SCHEUCHZERIOIDES ALLIANCE

Four associations of the *Juncus scheuchzerioides* alliance are recognised. These are:—

I. *Juncus scheuchzerioides* association.

II. *Juncus scheuchzerioides—Scirpus aucklandicus* association.

III. *Scirpus aucklandicus* association.

IV. *Juncus scheuchzerioides—Scirpus aucklandicus—Deschampsia penicillata* association.

The occurrence of a particular association is dependent on the exposure to wind, the limited distribution of *Scirpus aucklandicus,* and the depth of water in which the community grows. Floristic lists and frequencies are shown in Table 23.

I. *Juncus scheuchzerioides* association. This community is dominated by the leaves of *Juncus scheuchzerioides* which project from three to six inches above the surface water table. The growth is very dense but as the leaves grow vertically a continuous canopy is not formed and a few species comprise a continuous lower layer. These species comprise several mosses, *Montia fontana,* with a few scattered representatives of other species, notably *Acaena adscendens.*

II. *Juncus scheuchzerioides—Scirpus aucklandicus* association. The dominant layer in this community consists mostly of *Juncus scheuchzerioides* growing similarly to the first association together with a smaller percentage of plants of *Scirpus aucklandicus.* The outward appearance of the two associations is very similar but in the lower layer of vegetation in the *Juncus scheuchzerioides—Scirpus aucklandicus* association, *Colobanthus crassifolius* also occurs either as small plants growing in moss, or as large cushions or mats.

III. *Scirpus aucklandicus* association. This is a single layered community consisting solely of *Scirpus aucklandicus* in a fairly dense stand with no associated species.

These three associations grow in all sites with a surface water table where the wind exposure is not severe. The *Juncus scheuchzerioides* association occurs in all such sites except those on the raised beach terrace of the west coast where it is replaced by the *Juncus scheuchzerioides—Scirpus aucklandicus* association. The difference between these two communities is due to the presence in the latter of *Scirpus aucklandicus* which grows only on the poor fen peats of raised beach terrace and whose seeds are therefore not readily available to the upland communities, and *Colobanthus crassifolius* whose occurrence is probably correlated with the different soil conditions. The *Juncus scheuchzerioides* association grows on rich fen peat while the *Juncus scheuchzerioides—Scirpus aucklandicus* association grows on poor fen peat.

The *Scirpus aucklandicus* association grows only on the edge of a water pool surrounded by the *Juncus scheuchzerioides—Scirpus aucklandicus* association and its occurrence is due to the elimination of *Juncus scheuchzerioides* with increasing depth of water.

Juncus scheuchzerioides association occupies large areas in upland valley bottoms. In a single valley a continuous stand of the association may extend for a half mile or more along the valley and be up to 200 yards wide. The permanence of these areas depends on their drainage systems.

Juncus scheuchzerioides—Scirpus aucklandicus association is found only on the raised beach terrace in patches up to a maximum size of 100 yards by 20 yards. They are presumably a permanent feature in this locality but an alteration in the water relations of the area, either by further formation of peat or by an alteration in drainage, results in the reversion of one patch to *Pleurophyllum hookeri* association and another patch previously covered by *Pleurophyllum hookeri* association to *Juncus scheuchzerioides—Scirpus aucklandicus* association. In the only soil profile dug through one of these swamps this was the case. At two feet the peat had obviously been formed by *Pleurophyllum hookeri* association.

The *Scirpus aucklandicus* association is found only in areas of very limited extent (one or two square yards).

Only rarely are elements of the *Pleurophyllum hookeri* alliance found growing amongst fen communities representing an ecotone between the two alliances.

IV. *Juncus scheuchzerioides—Agrostis magellanica—Deschampsia penicillata* association. The three dominants of this association occur in all seven possible combinations either singly, in pairs, or all three together. The dominants are scattered, rarely forming more than 10% cover, and are low-growing, always less than three inches high. The only species associated with these communities are *Ranunculus biternatus,* which here has only its leaves above the soil surface; *Callitriche antarctica;* and a few rather rare species of moss. The particular combination of dominants seems dependent only on chance.

Seasonal differences in this association are slight. Very little growth takes place in winter or summer and the *Agrostic magellanica* and *Deschampsia penicillata* plants growing in this community have never been observed to fruit, while the *Juncus scheuchzerioides* plants have only been observed fruiting rarely.

The association grows only in sites with a water table at ground level or slightly above it and exposed to severe winds. It occurs on the highlands of the island alongside lakes or streams, or in the small soaks which occur fairly frequently amongst the feldmark formation. The areas of the individual stands are generally less than 10 yards square and frequently less than one yard square.

TABLE 23.

Fen Formation.

Juncus Scheuchzerioides Alliance.

	Juncus scheuch-zerioides association	*Juncus scheuch-zerioides Scirpus aucklandicus* association	*Scirpus aucklandicus* association	*Juncus scheuch-zerioides Agrostis magellonica Deschampsia penicillata* association
VASCULAR PLANTS				
Juncus scheuchzerioides	D	D		Co-D
Scirpus aucklandicus		F	D	
Montia fontana	A	A		
Colobanthus crassifolius		F		
Callitriche antarctica	VR	R		VR
Cardamine corymbosa	VR	O		
Ranunculus biternatus	VR	O		O
Hydrocotyle sp.	(L) VR	R		
Agrostis magellanica	VR	VR		Co-D
Deschampsia penicillata				Co-D
Acaena adscendens	O	O		R
LICHENS	R	R		
LIVERWORTS	O	C		
MOSSES	F	A		R
Percentage cover	100	100	50	10

D = Dominant. A = Abundant. C = Common. R = Rare. Co-D = Co-dominant. F = Frequent. O = Occasional. VR = Very Rare. (L) = Local.

BOG

Large areas of bog are found in a few scattered regions of the west coast raised beach terrace. Small patches are found scattered in the herbfield formation, growing on wet flats at all elevations.

Plate 14. Patches of bog formation, Handspike Point. Soil—bog peat. (Photo, N. Laird).

The formation is characterized by a continuous carpet composed of many moss species, or of vascular species with a very similar life form. Other vascular species are also found scattered throughout the community. The water table is generally at the surface of the moss carpet, or immediately above or below. Bogs are only normally found where this ground water is derived directly from rain water with an extremely low proportion of water previously in contact with mineral soils. As a consequence the ground water is low in dissolved nutrients.

Three subdivisions of the formation have been recognised:—

1. The *Breutelia pendula* alliance.

2. The *Sphagnum falcatulum* alliance.

3. The *Colobanthus muscoides* alliance.

The Breutelia pendula alliance. This alliance consists of a large number of communities dominated by various combinations of moss species and of *Colobanthus crassifolius.* The most important mosses of the alliance are *Breutelia pendula, Breutelia elongata, Drepanocladus aduncus, Dicranoloma robustum, Brachythecium salabrosum* and *Ptychomnion aciculare.*

Colobanthus crassifolius, a vascular species, occasionally dominates small areas of bog, forming a dense flat mat. It also occurs commonly as scattered plants in the moss carpet.

Other vascular species growing in bogs are generally well scattered. They may be divided into three groups:—

(a) Species growing amongst the dense mass of moss stems, e.g. *Montia fontana, Cardamine corymbosa,* and *Callitriche antarctica.*

(b) Species with their leaves flush on the surface of the moss carpet, e.g. *Ranunculus biternatus, Hydrocotyle sp. Epilobium nerterioides* and *Epilobium linnaeoides.*

(c) Taller species (never above 4 inches) : *Juncus scheuchzerioides, Scirpus aucklandicus, Agrostis magellanica, Festuca erecta,* and *Uncinia riparia.*

The alliance occurs as a large stand in only a few areas, notably on the raised beach at Handspike Point where it covers areas up to several hundred yards in diameter. These develop on large flat areas with a surface water table but receiving no water by lateral drainage.

The alliance also occurs as scattered patches, up to one square yard in area, scattered throughout the herbfield formation growing on large moist flats throughout the island. The occurrence of these patches must be determined by the local topography of the peat. They always occur in small depressions and though they appear to be a permanent feature of the areas, an examination of the underlying peat indicates the previous presence of herbfield. Differing growth rates of the vegetation in these areas, with the subsequent changes in surface topography of the peat, must result in changes in the water table level and the appearance or disappearance of bog communities.

The composition of these patches differs considerably from that of the large stands of bog both in moss and vascular species.

The transition zone between the large stands of bog and the herbfield formation is marked by the occurrence of a "Wind Line" complex. Here herbfield occurs as long, thin slightly-raised lines, roughly 1 foot wide and up to 100 yards long. These are separated by shallow depressions of similar dimensions covered by the *Breutelia pendula* alliance or occasionally by a pure community of *Coprosma repens*. The lines are roughly parallel to the prevailing direction of the local winds. In the Handspike Point area the winds are particularly strong and, with the approach of bog conditions, they must play the deciding part in the survival of the herbfield formation.

Sphagnum falcatulum association. This association occurs in small patches rarely more than a few square yards in area. It is found in old pond sites and drainage channels at all elevations, but it is not of common occurrence. The association may occur as a pure community or with a few scattered vascular species, notably *Juncus scheuchzerioides* and on the west coast *Scirpus aucklandicus.*

Colobanthus muscoides association. This association is found only on the west coast raised beach terrace. Several large stands 200 yards by 20 yards, are known as well as many small patches. The association is always surrounded by the *Breutelia pendula* alliance. It is always completely dominated by the mat of *Colobanthus muscoides* which closely resembles the mat of moss of the *Breutelia pendula* alliance, although slightly more tightly packed. Other vascular species are not frequent and moss species are rare. The mat surface is much convoluted and roughly follows a surface drainage pattern.

Floristic lists and frequencies of the various bog communities are given in Table 24.

TABLE 24

Bog Formation

	Species	*Breutelia pendula alliance* Large Stands	*Breutelia pendula alliance* Small Patches	*Sphagnum falcatulum* association	*Colobanthus muscoides* association
Dominant layer of mat plants	*MOSSES*				
	Breutelia pendula	A	A		VR
	Drepanocladus aduncus	A	A		VR
	Bryum laevigatum	A	F		VR
	Ptychomnoin aciculare	A	F		
	Thuidium furfurosum	F	F		
	Dicranoloma robustum	F	A		
	Distichium capillaceum	C	O		
	Bartramia papillata	C	C		
	Lembophyllum clandestinum	O			
	Breutelia elongata		A		
	Brachythecium salebrosum		A		
	Rhacomitrium crispulum		C		
	Rhacocarpus humboldtii		C		
	Amblystegium serpens		O		
	Rhacomitrium lanuginosum		R		
	Poganatum alpinum		R		
	Sphagnum falcatulum			D	
	VASCULAR PLANTS				
	Colobanthus crassifolius	F	C		O
	Colobanthus muscoides	VR			D
Other Layers	*Juncus scheuchzerioides*	F	C	C	O
	Scirpus aucklandicus	C	R(L)	C(L)	O
	Epilobium nerterioides	R	O		
	Epilobium linnaeoides	R	O		
	Agrostis magellanica	C	C	O	R
	Festuca erecta	O	R		
	Uncinia riparia	R	C		
	Ranunculus biternatus	C	C	R	O
	Hydrocotyle sp.	C			
	Montia fontana	O	O	O	VR
	Cardamine corymbosa	C	O	O	
	Callitriche antarctica	R		VR	
	LIVERWORTS	C	C		R
	LICHENS	C	C		R

D = Dominant. C = Common. VR = Very Rare.
A = Abundant. O = Occasional. (L) = Local.
F = Frequent. R = Rare.

FRESH WATER COMMUNITIES

Various characteristic communities, as described below, grow in the numerous fresh water lakes, ponds, pools and streams on the island:—

Myriophyllum elatinoides association. This association consists generally of *Myriophyllum elatinoides* without any other species. The association grows in most of the plateau lakes in depths of water ranging from 1 to 8 feet, in large fast flowing streams, and in one small pond of 4 inches depth. The plants have stems creeping along the stream or lake bed which send up numerous vertical shoots which may reach and float on the surface of the water.

In some cases the community may be modified by the invasion of fresh water algae which densely clothe the ascending stems and kill them. The only seasonal change observed was the formation of *hibernaculae* in late summer from which new shoots presumably grew the following spring. These buds are usually apical, as the ascending shoot rarely branches. No aerial shoots, flowers or fruit were formed in the year 1950/51.

Algal associations. Communities of many different fresh water algae occur. The species are as yet unidentified.

They occur in the following localities:—

(a) Pools in peaty soils. These are very common on the raised beach terrace, upland valleys and in areas damaged by sea elephants. Algal communities will rapidly colonise any newly formed pool, e.g. a soil pit.

(b) Lakes and ponds. In well formed large lakes, algal communities occur but are generally not conspicuous.

(c) Streams. Algal communities are rare in streams, being found only in small, slow-moving streams.

(d) Rocks, and bare, moist ground.

Ranunculus biternatus association. *Ranunculus biternatus* often grows completely or partly submerged in the water of small streams, ponds or pools. It may grow by itself or together with one or more of several grasses, *Poa annua, Agrostis magellanica* or *Deschampsia penicillata*. *Poa annua* or *Agrostis magellanica* frequently grow alone or together, especially in pools amongst the wet tussock formation.

Ranunculus biternatus occasionally forms a continuous carpet around the edges of small ponds. Only one occurrence of *Deschampsia penicillata* in a fresh water community is known. Here it is surrounded by a mat of *Ranunculus biternatus* and forms a pure community a few feet square floating on the water's surface.

All plants from these communities show an increase in vegetative size over the terrestrial forms and, though flowers and fruits are formed, these are always borne above water and occur only rarely.

This association is not a natural group but the term serves to unite the various combinations of the species already mentioned e.g. *Ranunculus*

Plate 15. *Ranunculus biternatus* association growing in a small pond. Fen community of *Juncus scheuchzeriodies* association at right background. (Photo, N. Laird).

biternatus, Poa annua, Agrostis magellanica, and *Deschampsia penicillata.*

Callitriche antarctica association. Callitriche antarctica frequently grows in small pools in peat at low elevations. It is generally rooted to the peat bottom but occasionally a mat is formed floating on the surface of the pool. Under this mat a whole mass of roots is formed below water level, the majority of the shoots being above water level.

When the roots penetrate the peat sides or bottom of the pool the growth of the plants is not so dense. The shoots, however, may reach and float on the surface of the pool. The community is frequently continuous with a sward of terrestrial *Callitriche antarctica* on the moist peat leading down to the pool's edge.

Spring and summer result in much vegetative growth of this community, but no male flowers have ever been seen and only one female flower.

Bartramia papillata-Bryum laevigatum association. This association consists of scattered moss plants growing around the shores of the lakes, generally amongst small scattered rocks. It occurs in water from 1 inch to 1 foot in depth and the small patches of moss grow to three inches in length. These mosses are frequently covered by a layer of fine clay.

All the fresh water communities mentioned must be able to withstand the effects of freezing. At all elevations pools, lakes and streams are frozen for periods of up to three weeks each winter. Small pools are frozen solid, the edges of lakes are frozen to a depth of 2 feet and even the centres of large lakes have an inch or more of ice. In addition, the temperature of the water reaches freezing point many times at all seasons of the year. However, no major differences were noted in communities observed before and after a long cold period. Individual plants may die but the majority appear unharmed.

FELDMARK

Two alliances occurring in the feldmark formation have been recognised — the *Azorella selago* alliance and the *Dicronoweisia antarctica* alliance.

1. *Azorella selago* alliance. The *Azorella selago* alliance consists of three associations which are determined by their degree of exposure to the wind.

A. *Azorella selago* association.

B. *Azorella selago-Rhacomitrium crispulum* association.

C. *Rhacomitrium crispulum* association.

A. *Azorella selago* association. This association is dominated by the cushions of *Azorella selago,* the remaining species of the association growing in or on the cushions, or more rarely in the shelter of the cushions. These cushions consist of closely packed, freely branching shoots of *Azorella selago.* The shoots are of equal size, thus forming a smooth surface of cushion, and are densely clothed with dead scale-like leaves. So densely packed are the shoots that it is impossible to withdraw a single shoot without destroying the cushion. A cushion can often support the weight of a man without significant compression. However, a very heavy boot mark may leave an impression which is retained for periods as long as six months.

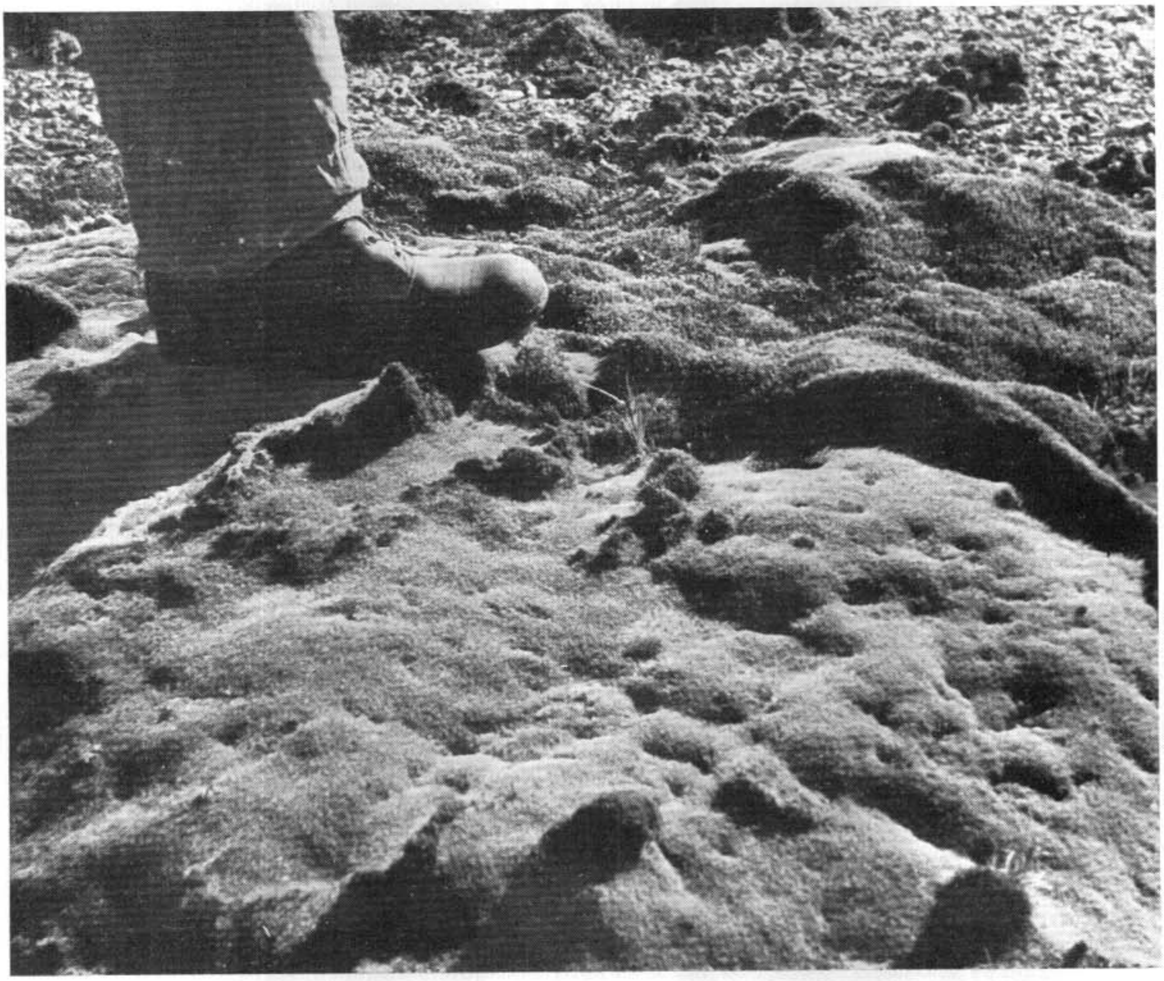

Plate 16. *Azorella selago* association. Bare gravel surface in background. (Photo, N. Laird).

The scattered plants of other species may grow in amongst the shoots of *Azorella selago* or the mat plants may trail over the surface of the cushion. The roots of these plants are entwined with the shoot of *Azorella selago,* rarely reaching down to the underlying soil.

The association covers most of the area of the *Azorella selago* alliance. In the lee sites of the peculiar terraces of the area and in more sheltered places it forms a continuous cover. With increasing wind-exposure isolated cushions may be formed and finally the association is replaced by the *Azorella selago-Rhacomitrium crispulum* association when the mosses already present in the *Azorella selago* community assume co-dominance. Isolated cushions of *Azorella selago* also occur on bare rocks exposed to severe winds, generally only in areas higher than 300 feet above sea level, but in one instance where the winds were particularly violent due to the topography of the area, a cushion of *Azorella selago* was observed growing on a rock near sea level, though not exposed to sea spray.

The depth of the growth of *Azorella selago* varies from 18 inches in isolated cushions to 2 inches in the most exposed mats on the terraces. These terraces are fully discussed under the descriptions of the soils of the island and are of two types — those on windward slopes and those on lee slopes. Their height varies from 2 feet vertical to 20 feet, but averages 4 feet. On windward slopes the sloping face of the terrace is exposed to the wind and on lee slopes the terrace flat is exposed, and these may be either bare of vegetation or covered with *Dicranoweisia antarctica*.

On lee slopes, the sloping face of the terrace is covered with *Azorella selago* association extending for long distances in a narrow band a few yards in width and several hundred yards long, generally running along the contour. On windward slopes in the terrace flat the patches of *Azorella selago* association rarely exceed 10 yards in length. Isolated cushions are normally only a yard in diameter. In areas protected from severe wind the *Azorella selago* association may be continuous for a hundred yards square, with one or more isolated bare patches.

The bare patches are covered by a continuous layer of fragmented basalt. The layer varies from ¼ of an inch to 6 inches in depth, averaging 2 inches. This layer on the immediate surface consists solely of pieces of undecomposed rock averaging 1 to 2 inches in length with no fine particles visible. Underneath the surface the layer of stones is admixed with a small percentage of finer particles. Under this surface layer of stones there is an organic soil of varying depth.

All species growing in this association show marked reduction in size compared with their growth in other alliances. Thus the leaves of the *Pleurophyllum hookeri* rosette rarely exceed 4 inches in length, mature plants of *Luzula campestris, Agrostis magellanica, Festuca erecta,* never exceed 4 inches in height and frequently a plant with mature fruit is only ½ an inch high. Elsewhere these species reach heights of a foot or more. *Stilbocarpa polaris* leaves never exceed 3 inches in diameter and the petioles never exceed 2 inches.

Most species are able to flower and fruit, though every plant does not flower each year. This is especially the case with *Stilbocarpa polaris* and *Pleurophyllum hookeri.* However, certain very rare species, which are stragglers from other associations and which are found occasionally in the *Azorella selago* association, never flower or fruit. This is the case with the two species of *Colobanthus*.

Seasonal aspects of the Azorella selago alliance. Spring and summer are associated with the flowering and fruiting of most species, as elsewhere on the island. However, *Azorella selago* itself rarely flowers, though flowers may be very common over small areas probably associated with favourable conditions and the age of the plant.

The most conspicuous seasonal change of the association is the gradual death of the small leaves of *Azorella selago* in March and April and the formation of new leaves from August to October. Thus in winter, the association is dark brown in colour and in summer a dark green. The leaves commence to die in patches. Thus yellowish patches in the continuous mat of green herald the approach of winter. The new leaves formed each spring add ¼ of an inch to the height of the cushion. Beneath this the leaves are dark brown and may be hardly decomposed for some depth. However, the growth of the cushions is so dense that in summer these dead leaves cannot be seen.

The growth of new leaves of *Pleurophyllum hookeri* each spring makes it impossible for other plants to grow beneath them. Thus in winter *Pleurophyllum hookeri* plants are surrounded by a bare star-shaped area, where the leaves of the last summer covered the area, killing any plants which were growing there. The lichens growing on top of the *Azorella selago* cushions are frequently very conspicuous, forming large fluffy masses.

B. *Azorella selago-Rhacomitrium crispulum* association. This occurs in areas which are even more exposed to wind than those where the *Azorella selago* association occurs. The mosses normally associated with the *Azorella selago* association assume a position of co-dominance mainly due to a reduction in vigour of *Azorella selago*. The association is found only as a mat on terraces towards the top of an exposed hill or mountain.

The plants of *Azorella selago* are always small and the mat of dead shoots rarely exceeds 4 inches in depth. The mosses grow vigorously, densely packed and up to 4 inches in height.

Other species enter the association but these are not nearly as numerous nor as frequent as in the *Azorella selago* association. The plants of these species are always very small and slightly smaller than the average size of the same species in the *Azorella selago* association. The additional wind exposure to which the association is exposed greatly restricts the development of vascular plants, though all species present are capable of flowering. The species of the dominant mosses, however, rarely develop spores anywhere in the various plant alliances on the island.

Plate 17. *Azorella selago—Rhaeomitrium crispulum* association. (Photo, N. Laird).

Seasonal aspects are much the same as in the *Azorella selago* association but the dominant mosses show little change from one season to another.

C. *Rhacomitrium crispulum* association. This association is completely dominated by the mosses common to the previous two associations which grow lightly packed, never more than 3 inches high. The association never has more than 10% ground cover, the remaining ground being covered by a layer of stones. It frequently grows in small strips, several feet long and a few inches wide, parallel to the wind direction. The plants on the windward edge of each strip slowly die off while fresh growth forms on the lee edge.

Most species growing in the *Azorella selago-Rhacomitrium crispulum* association grow in this association too, but with an even smaller average size. Small buttons of *Azorella selago* also occur rarely. Seasonal aspects of the association are essentially similar to the *Azorella selago-Rhacomitrium crispulum* association.

The association grows only in areas exposed to the most severe winds — on mountain tops, saddles, and other exposed sites. It occasionally invades the flats of lee-slope terraces which are normally covered only by the *Dicranoweisia antarctica* association, a community even more wind-resistant than *Rhacomitrium crispulum* association.

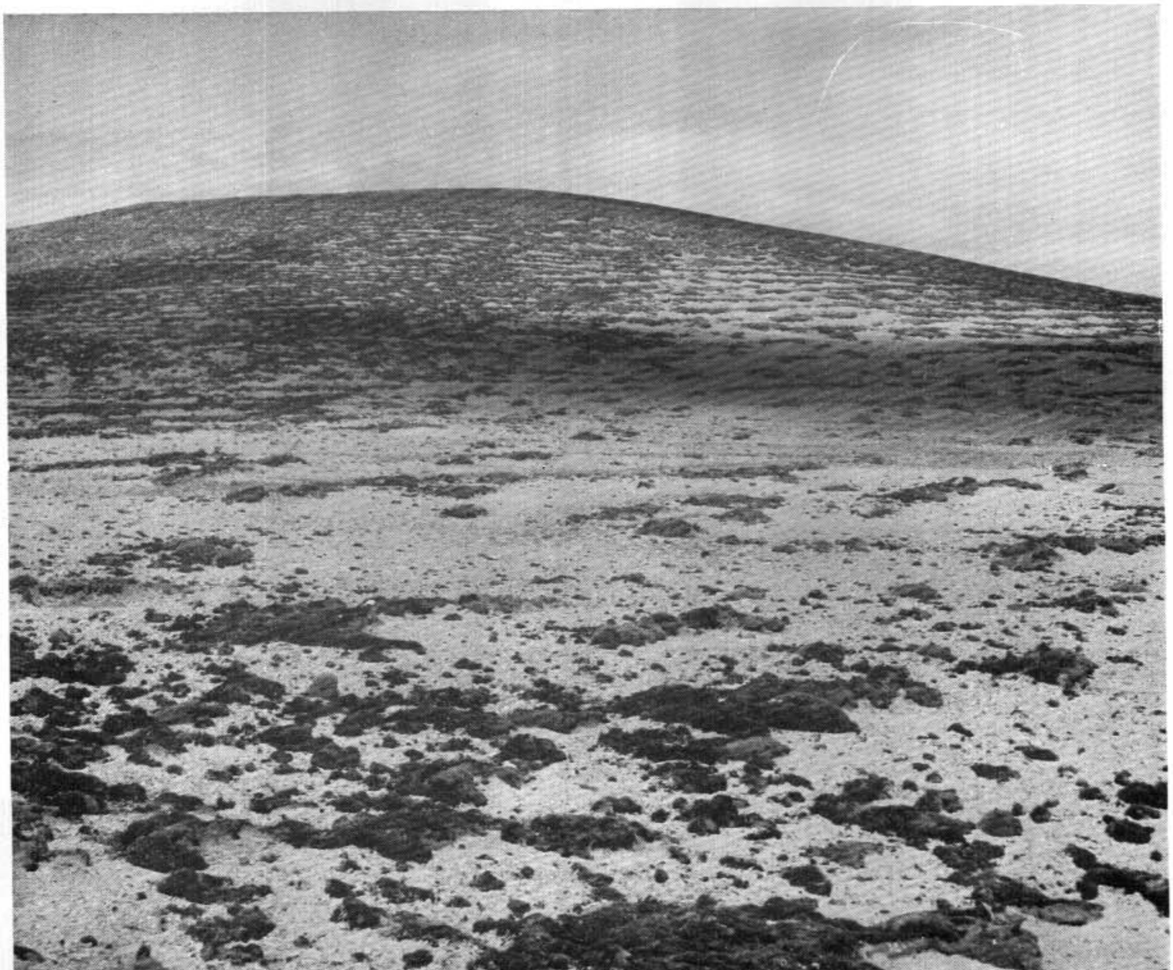

Plate 18. *Rhacomitrium crispulum* association growing on a wind-swept saddle in foreground. Windward terraces bearing *Azorella selago* association in background. Soil—dry tundra. (Photo, N. Laird).

TABLE 25

Feldmark Formation
Azorella selago Alliance
Floristic List
Feldmark Formation

Species	*Azorella selago* association.	Occurrence of species in various sites in the *Azorella selago* association.			*Azorella selago* — *Rhacomitrium crispulum* association	*Rhacomitrium crispulum* association.
		Species growing in *Azorella selago* cushions.	Species on top of *Azorella selago* cushions.	Species growing in pockets in the *Azorella selago* cushions.		
VASCULAR PLANTS						
Azorella selago	D				Co-D	R
Pleurophyllum hookeri	F			A	R	
Stilbocorpa polaris	C			F	R	
Agrostis magellanica	F	F		F	F	C
Festuca erecta	F	F		F	C	O
Luzula campestris	C	C		C	C	O
Uncinia riparia	C	R		C	O	R
Polypodium billardieri	C	F		R	R	VR
Coprosma pumila	C		C	O	R	VR
Ranunculus biternatus	O	O		R		
Cardamine corymbosa	R		VR	R		
Stellaria decipiens	VR			VR		
Epilobium nerterioides	VR			VR		
Epilobium linnaeoides	VR			VR		
Poa annua	VR			VR		
Cerastium triviale	VR			VR		
Acaena adscendens	VR			VR		
Montia fontana	VR			VR		
Callitriche antarctica	VR			VR		
Colobanthus crassifolius	VR	VR				
Colobanthus muscoides	VR	VR				
Lycopodium saururus	VR	VR		VR		
Acaena anserifolia	C		C	O	R	VR
LICHENS	F	F	F	F	C	C
LIVERWORTS	R			R		
MOSSES						
Rhacomitrium crispulum	F				Co-D	D
Dicranoloma robustum	C				F	F
Thuidium furfurosum	C				C	C
Rhacomitrium lanuginosum	O				O	C
Rhacocarpus humboldtii	O				O	C
Campylopus clavatus	O				R	
Bartramia papillata	O				O	C
Drepanocladus aduncus	C				O	O
Pogonatum alpinum	C					
Breutelia elongata	R				O	R
Conostomum australe	R					

D = Dominant.
Co-D = Co-dominant.
A = Abundant.
F = Frequent.
C = Common.
O = Occassional.
R = Rare.
VR = Very Rare.

DICRANOWEISIA ANTARCTICA ALLIANCE

Only one association is recognised from this alliance, the *Dicranoweisia antarctica* association.

Dicranoweisia antarctica association. This association is an open community consisting solely of a few species of moss growing in densely packed buttons or very small cushions. The only vascular species which occurs in the association is *Azorella selago*. It appears rarely in small buttons of 1 inch diameter and it never flowers or fruits.

TABLE 26

Feldmark Formation

Dicranoweisia antarctica association.

Dicranoweisia antarctica	F	F = Frequent
Andreaea acutifolia	C	C = Common
Rhacomitrium crispulum	O	O = Occasional
Pogonatum alpinum	R	R = Rare
Azorella selago	O	

The buttons of mosses vary in size, reaching a maximum of 6 inches. They tend to be spherical in shape, though the surface resting on the ground is always flat. A cross section of a button shows a layer of living and dead moss and a central core of a fine organic soil which is composed of fine mineral matter caught by the growing moss, together with unrecognisable decomposed organic matter.

All the various species of moss appear to grow very slowly showing little outward change with the seasons. Fruiting capsules are frequently developed on all species in spring or summer and the empty capsules may be retained all the next winter. Each button normally consists of only one species of moss.

The association is found only on sites which are permanently bare. It occurs on the bare flats of slope terraces, on rocks and in a few exposed saddles but it does not occur on the bare slopes of windward terraces as these terraces slowly move uphill, and their surfaces are unstable.

The buttons grow on the surface layer of stones and are easily removed. Roots never penetrate the underlying soil so that the button is an independent unit.

Factors affecting the feldmark formation. Wind exposure and probably mean temperature determine whether or not feldmark occurs in a

Plate 19. *Rhacomitrium crispulum* association.

given area. Owing to the topography of the island the highlands are subjected to very much greater wind velocities than the lowlands. This factor then, determines whether *Poa foliosa*, *Pleurophyllum hookeri* or *Azorella selago* alliances grow. If either of the first two alliances develop, then the *Azorella selago* alliance is unable to compete. Normally *Azorella selago* alliance does not grow below 600 feet but in places it is found as low as 200 feet above sea level. Such places are always associated with a very high wind velocity due to the peculiar nature of the local topography e.g. a ridge at a very low altitude due east of the very low saddle separating Finch and Stoney Creeks. Temperature must also have some effect since an area of the raised beach at Handspike Point is exposed to violent winds sweeping round to Hasselborough Bay but the area is covered by a modification of the *Pleurophyllum hookeri* alliance. Similarly a few other sites at low elevations are exposed to winds comparable to those at some of the more protected sites in the feldmark formation.

The few readings of temperature which have been taken on the highlands show a drop from corresponding temperatures taken at sea level. For 1,100 feet this drop is 6 or 7°F. It is probable that the mean temperature at 600 feet, above which point feldmark is common, is 3 or 4°F. lower than at sea level. This would place the mean only 3 or 4°F. above freezing point and would imply greatly restricted plant activity. In conjunction with high winds this would tend to prevent the development of the *Poa foliosa* or *Pleurophyllum hookeri* alliances.

Within the formation, increasing wind exposure successively favours the various associations, *Azorella selago, Azorella selago-Rhacomitrium crispulum, Rhacomitrium crispulum* and *Dicranoweisia antarctica* association in that order.

Ecotone between the Azorella selago and Pleurophyllum hookeri alliances: The Azorella selago-Pleurophyllum hookeri association. Normally the transition area between these two alliances is very short but in a few sites a well marked transition community is formed, the *Azorella selago-Pleurophyllum hookeri* association.

In this community the *Pleurophyllum hookeri* plants are vigorous, tall and frequent, with the intervening ground completely covered by a mat of *Azorella selago.* The floristics of the community are identical with the *Azorella selago* association apart from the dominant position of *Pleurophyllum hookeri.*

The habitat of the area represents an intermediate stage in wind exposure between the two alliances. The community may cover an area where the shape of old feldmark lee slope terraces can clearly be seen and is probably formed from an original community of *Azorella selago* association by local alleviation of one or more growth factors.

EFFECT OF ANIMALS AND MAN ON THE VEGETATION

Macquarie Island is the natural home of a large number of animals distributed over an area of sea estimated to be as large as Australia. They all obtain their food directly or indirectly from the sea, either from fish or small marine organisms or by preying on one another. During the breeding season myriads of birds and seals inhabit the island, all having some effect on the vegetation. A great deal of seal and bird excreta, animal corpses and moulted feathers are deposited on land, predominantly near the coast.

In addition, man has greatly altered the vegetation, partly by mechanical movement and the introduction of a few new species of plants, but mainly indirectly through the introduction of several animals, notably rabbits.

SEALS

The seals found on Macquarie Island are elephant seals, leopard seals, fur seals, and occasional Weddell seals and sea lions.

Only the elephant seals *Macrorhinus proboscideus,* are of any importance in their effect on the vegetation. Their number has been estimated at more than 80,000 and their average stay on the island each year is at least two months. The remaining species of seal are found only singly or in small numbers and furthermore they all keep to the beaches or rocky points.

The sea elephants, though congregating on the beaches, also wander on to the coastal flats and raised beach terraces and may proceed a little way up creek beds. They are very large animals. An adult cow may be twelve feet long and weigh one ton while an old bull may be twenty feet long and weigh as much as five tons.

Prior to the extermination of the fur seals in 1815, the sea elephants were probably not nearly as numerous, but with the removal of competition from the fur seals, the herds increased. The sealers then transferred their attention to the sea elephants which were slaughtered for their oil till as late at 1918. Since then they have undergone a rapid increase in numbers and have probably now reached a stable figure. However, their effect on the vegetation has not reached a stable point. During one year, 1950-51, notable extensions of completely bare areas were observed and many new regions suffered lesser damage. This damage was due solely to seals moving through the vegetation or basking for long periods in particular spots.

The sea elephant effects the vegetation in three ways. First, it causes a general flattening of the plants in its path. A *Poa foliosa* tussock is able to recover unless the damage is too frequent. This flattening results in a decrease in the density of tussock and an opening up of the previously continuous canopy of leaves. Secondly, as a result of the compression of

Plate 20. Sick bull sea elephant amongst flattened tussocks of *Poa foliosa*. (ANARE Photo).

the surface peat, pools are formed in depressions between tussocks. These pools are permanent even though there is generally no water table in the underlying peat. Lastly, a certain amount of nitrogenous material is added to the soil.

As a result of one or more of these processes additional species are able to enter the community, forming a biotic sub-climax community — the *Poa foliosa*: *Cotula plumosa* sub-association. This is the case for most coastal flats, especially on the east coast where there are more beaches suitable for seals to come ashore.

The sea elephants usually have wallowing sites amongst the great masses of kelp washed on to the beaches, but they may also be found a little inland on the coastal flats. Here the vegetation is rapidly removed, though the original surface contour of the tussock stools is at first retained. Such bare areas may form rapidly; for example, during the year 1950-51 an increase of 100 yards in length of one of these wallowing sites was noted. If the mechanical damage is then discontinued, *Cotula plumosa* is able to become established, forming a continuous carpet. However, if the wallowing is continued, water pools appear and the underlying peat is converted into a "mush" which is easily transported by water and "bog holes" are formed. These "bog holes" may be as big as 50 by 20 yards, they are several feet below the surrounding ground level and they extend laterally by undercutting their banks. The bottom of a "bog hole" is usually several feet of mush in which the elephants continue to wallow, thus preventing any effective regeneration.

Plate 21. Sea elephant "bog" hole. Young seal in middle. (ANARE photo).

The effect of the sea elephants on the tussock flats at Bauer Bay on the west coast has left a community of unusual structure. As the area has very low valleys behind, it is subject to strong winds. It is traversed by three large creeks. The sub-soil is sea-worn sand (fragmented basalt) formed under water. After the ice age, as the raised beach was formed, this sand was elevated above the sea and some of it was blown a little way inland. *Poa foliosa* association then covered the area and a surface layer of peat was formed.

Now, however, the sand is exposed with isolated tussocks growing up from the general level of the sand. These tussocks bear a dense growth of *Poa foliosa* on top of a stool which consists of a layer of peat over

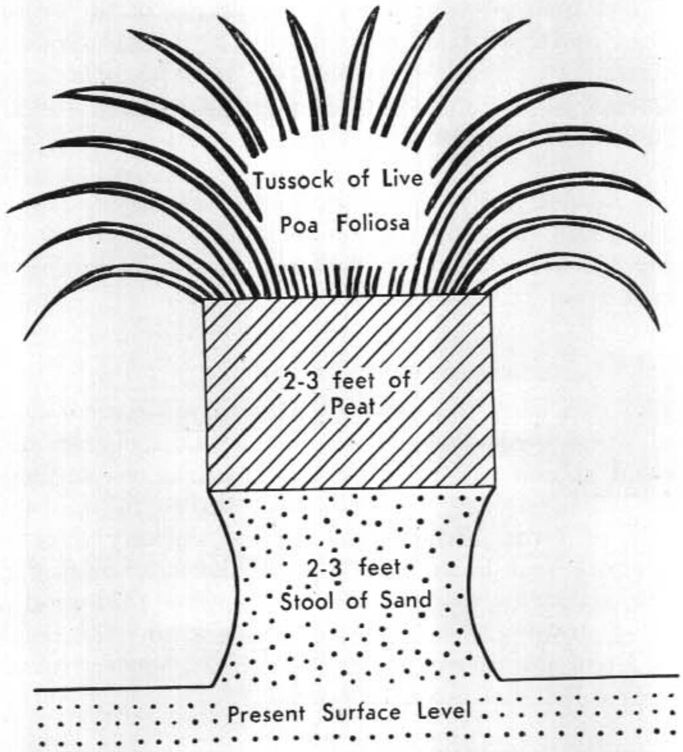

Fig. 7. Cross Section of Poa foliosa Stool, Bauer Bay.

another layer of sand, slightly undercut by wind and water. The stool is generally between 5 and 6 feet high, with the leaves of *Poa foliosa* extending several feet above that, and with a diameter from 5 to 10 feet. Each stool is well separated from its nearest neighbour often by as much as 30 yards.

It seems that this area was once covered by a continuous layer of *Poa foliosa* and of peat. Sea elephants then killed off the majority of the *Poa foliosa* tussocks, exposing the bare ground to the action of wind and water. As a result the peat and a good deal of the underlying sand were removed, leaving only the stools protected by the surviving *Poa foliosa*. No mention of this area was made in the A.A.E. Geological Report

(Mawson, 1943) though another less extensive sand deposit was noted. Presumably this area was covered by *Poa foliosa* in 1913 and the denudation has occurred since. The change is probably associated with the increase in numbers of the sea elephants since 1922.

The only portion of the *Pleurophyllum hookeri* alliance within the range of sea elephants is that on the raised beach terrace. Here the seals generally restrict themselves to the various stages of the ecotone between the *Poa foliosa* and *Pleurophyllum hookeri* alliances. Their movements are readily seen by a trail of broken *Stilbocarpa polaris* petioles and flattened *Pleurophyllum hookeri* rosettes and flowering stalks. Moreover, "bog holes" are more frequent and of greater extent.

The seals do not arrive until the end of summer, after the plants' growing period, and thus the vegetation is able to recover. Any damage caused during the year is not in evidence at the beginning of the next summer, apart from the permanent "bog holes".

BIRDS

(a) *Royal and king penguins* (*Eudyptes schlegeli and Aptenodytes patagonica*). These birds form dense, permanent rookeries on the coastal flats, slopes and upland valleys. In a rookery area the surface vegetation and the soil have been completely removed due to the movements of the great numbers of birds. The surface of the rookery area is thus very rocky and up to 8 feet below the level of the surrounding ground. Invariably these rookeries are formed in the *Poa foliosa* alliance which occupies all well drained sites protected from wind. The largest of these rookeries, at Hurd Point, covers an area of 16 acres with a population estimated at over 600,000 birds (Mawson, 1943).

Though the rookery is vacant for six months each year, the great density of the birds during spring and summer prevents any regeneration of the vegetation in the area.

Large quantities of manure are deposited by the birds in the rookery. This manure is generally washed straight into the sea by rain water each year, but in the Nuggets Creek area many rookeries are on the hillsides with no creek draining them. Here there is a considerable lateral drainage of rain wash from the bare rookeries which carries with it the manure. Many small channels are excavated in the peat between tussock stools, and *Poa foliosa* is to a large extent replaced by *Poa hamiltoni*. This is in evidence near other rookeries but on a smaller scale.

This region in Nuggets Creek is the only extensive area where penguin manure is not washed straight into the sea and is the only place where an extensive area of the *Poa foliosa-Poa hamiltoni* association occurs. Other small areas bearing this association are found in the immediate vicinity of the rookeries of royal or rockhopper penguins or elsewhere where these birds congregate. The occurrence of *Poa hamiltoni* has never been noted away from such areas nor has it been noted in conjunction with gentoo penguins whose rookeries are not permanently established.

(b) *Rockhopper penguins* (*Eudyptes cristatus*). These birds form rookeries very rarely more than 100 feet above sea level. The rookeries are generally in rocky places and thus always within the maritime region of the *Poa foliosa* alliances. The birds largely destroy the vegetation between the rocks but do not seriously affect the lithosere on the rocks.

(c) *Gentoo penguins* (*Pygoscelis papua*). These birds form rookeries, of a semi-permanent nature on coastal rocks, flats and slopes. A comparison of the writer's records with notes and photographs taken in 1948 shows that since then some gentoo rookery sites have been abandoned and new sites colonised. The penguins very rarely wander inland or higher than 300 feet above sea level. Their rookeries are generally formed in the *Poa foliosa* alliance, rarely in the *Pleurophyllum hookeri* alliance, and the individual nests in a rookery are well separated.

The formation of a rookery results in a considerable thinning out of the tussocks of *Poa foliosa*, but is never continued to the local extinction of the vegetation. Thinning out takes place partly because of the mechanical action of the moving birds which occurs in all penguin rookeries, but also because of the habit these birds have of building their nests on top of tussocks or using the leaves of *Poa foliosa* in making their nests.

In some cases, determined by local topography, the increased run-off from the barer areas of the rookery results in pools forming between the tussocks on flats below the rookery. This may be further modified by the movement of penguins, making the ground very boggy and the leaf canopy open.

In gentoo rookeries very little recolonisation of these bare areas occurs while the rookery is still occupied. Species that may enter the community are *Poa annua* and *Stellaria media*. However, considerable re-growth takes place each year on rocks amongst rockhopper rookeries. As previously mentioned, no re-growth takes place in royal or king penguin rookeries. Two rookeries are known to have become extinct due to the depredations of the sealers. The first, a large royal penguin rookery in Caroline Creek, was flourishing in 1911 (Mawson, 1943) but no sign of the rookery could be seen in 1951. Vegetation has covered the area, obliterating in less than 40 years, all traces of the rookery. In the second case, an immense king penguin rookery on the Isthmus was abandoned, due to the extermination of all the birds occupying it. This occurred probably around 1850 (Mawson, 1943). No sign of the old rookery could be seen in 1951, nor could any trace be seen in photographs of the area taken in 1911.

Thus when the rookery area is deserted by the penguins, the vegetation seems able to revert to the climax in a very short time. Moreover, mature soil conditions are rapidly formed.

King and rockhopper penguins have rookeries which abut on to the sea or beach so that their passage from the sea has little effect on the vegetation. Gentoo rookeries are generally some little distance from the sea. However, these birds rarely follow well defined trails and the trampling of the vegetation only occasionally is noticeable in a slight opening up of the community.

Royal penguin rookeries, though generally abutting on to the sea, are occasionally a mile or more inland. Moreover, the birds travel in groups along well defined trails, one trail to each rookery, as a protection against attacks by skuas and giant petrels. As a rule these inland rookeries are on a stream and the trail follows the stream bed in a few inches of water. Occasionally the trail may leave the stream and a track, rather like a narrow footpath, is formed. It is sometimes bridged over by peat giving evidence of the permanence of the trail. On one occasion a section of one of these stream-bed trails was observed to have been made redundant by stream capture. The penguins completely ignored the new stream bed which was a shorter route to the sea and followed the old course which they kept clear of vegetation.

(d) *Giant petrels* (*Macronectes giganteus*). These birds form large semi-permanent rookeries, sometimes comprising as many as 200 nests, at heights ranging up to 1,000 feet above sea level. Occasionally birds build isolated nests away from the rookeries, but these are frequently abandoned after a year's use.

The nests (about 2 feet in diameter) are made from plant material. Vegetation is completely killed off for a foot or more around each nest and there is much degeneration of the surrounding vegetation, whether it be the *Azorella selago* alliance, which is most common, or the *Pleurophyllum hookeri* or *Poa foliosa* alliances. In addition to rookeries, the birds have semi-permanent sites for sleeping in groups at night and resting-places near the more popular lakes for swimming. All stages in the degeneration of the plant communities up to complete extinction are observable in such sites.

(e) *Southern skuas* (*Catharacta skua lonnbergi*). These birds build small, well-isolated nests all over the island though the greatest number are built in the *Pleurophyllum hookeri* alliance. The nests are small (about

1 foot in diameter) and there is little effect on the vegetation even in the immediate vicinity of the nests. Moreover, the nests are used for one breeding season only.

Southern skuas and giant petrels are often seen swimming in lakes or streams. They are, then, probably responsible for the widespread distribution of the aquatic *Myriophyllum elatinoides* on the island, carrying vegetative parts from one valley system to the next. As no flowers or fruits of this species are ever formed on the island, this is the only possible method of dissemination. The birds most likely effect a similar distribution of fresh water algae.

(f) *Dominican gulls* (*Larus dominicanus*) *and Macquarie Island cormorants* (*Phalacrocorax albiventer*). These birds nest on coastal rocks where they greatly suppress the development of the lithosere.

(g) *Burrowing birds* (*petrels, prions, etc.*). Five bird species make burrows in the peat of the highlands. The burrows may be quite long (6 feet or more) and up to 1 foot wide, but with a narrow entrance. However, these burrows are only prevalent in the central and southern sections of the island and so their effect on vegetation is masked by the effect of the rabbit populations there. Undoubtedly, they must cause some improvement in aeration and drainage.

(h) *Light-mantled sooty albatrosses* (*Phoebetria palpebrata*). These build isolated nests on very steep slopes. These nests are widely distributed on the island but are relatively few in number. Death of the vegetation is caused by continual movement of the birds for a yard or more around each nest.

(i) *Black browed albatrosses* (*Thalassarche melanophrys*). These birds have one small rookery on the island on a steep slope. There is a small bare area around each nest.

(j) *Snowy or wandering albatrosses* (*Diomeda exulans*). The albatrosses nest individually or in widely scattered rookeries. Their nests are mounds of peat or plant material, between 2 and 3 feet in diameter. Each year birds rear single chicks which remain on the nest for eight months. At five months they leave the nest for short periods and trample the surrounding vegetation, having a serious effect for only a few feet around each nest. After the chicks leave the nests, and if the parent birds do not return, the surrounding areas rapidly return to normal. The nests themselves are rapidly recolonised, notably by *Poa annua*, though the shapes of the nests persist for several years under their cover of vegetation.

(k) *Grey ducks* (*Anas superciliosa*). These are relatively rare on the island, numbering about 100 birds. They were often to be observed feeding in pools on the raised beach terrace, but they are particularly timid and their nests were never found. However, they must have some effect in suppressing the hydrosere in the lakes they frequent.

LOWER ORGANISMS

Worms, caterpillars, moths, snails and other small organisms were frequently seen. They obtain their food in some measure from the terrestrial vegetation but their effects cannot readily be gauged. The moths appear in great numbers at the commencement of the flowering season and may be agents for pollinating some of the flowering plants.

EFFECTS OF MAN

Macquarie Island was discovered in 1810 by a sealing captain. From 1810 till 1922 the island was continually visited by sealing ships with land parties on shore for many years. Huts and boiling-down factories were erected at one time or another at many points, e.g. Caroline Cove, Lusitania Bay, Hurd Point, Sandy Bay, the Nuggets and the Isthmus. In addition, the island was visited by many Antarctic Expeditions though only two of these, the A.A.E. and A.N.A.R.E., established bases on the island.

Man has had an effect on the vegetation in three ways: (a) by mechanical damage around his settlements, (b) by the introduction of weed species, (c) by the introduction of various animals.

(a) *Mechanical damage*. The vegetation around old sealing settlements has now recovered or the damage has been masked by the effects of sea elephants. The position of the old huts is now marked only by scattered timber or ironware. However, a large area of tussock around the A.N.A.R.E. station 1947-51 has been destroyed mainly by the movements of tractors.

(b) *Plant introduction*. Three plant species were accidentally introduced by the sealers, probably in packing. Of these, *Poa annua* is very widespread and abundant, *Stellaria media* is abundant but only within a radius of ½ a mile from old settlements, while *Cerastium triviale* though not very common is fairly widespread on the island.

These three species are found growing in climax communities but are much more frequent as colonisers of bare ground, land slips, etc. or where the plant communities have been altered by rabbit grazing.

No species has ever been purposely established on the island. Seedlings of snow gum when once planted outside, quickly died. Vegetables could not be raised even when grown in a specially prepared garden plot.

(c) *Introduced animals.* (i) Sheep and goats. Since 1947 sheep and goats have been kept and successfully raised on the island, averaging in number 15 sheep, 20 goats. These have been confined to the small area of Wireless Hill, though for the first year the sheep were let loose on the Isthmus and wandered as far afield as the raised beach terrace. In 1950 there was no observed effect on the vegetation of the Isthmus or the raised beach, but there was a considerable effect on Wireless Hill. The goats were therefore subsequently shot.

Only a portion of the small total area of Wireless Hill is grazed, the animals preferring to remain on the upland flat and slighter slopes, resulting in fairly intense grazing in these areas.

The steeper slopes have a large number of soil slips. Some of these are of natural occurrence but probably the greater proportion is due to the grazing on the slighter slopes and flats above, which has caused an increased run-off of rain water. Individual tussocks of *Poa foliosa* sometimes show a marked effect of grazing but never to the extent of seriously diminishing the plants' vigour. Small patches of *Stilbocarpa polaris* have been extensively damaged or even killed, but this is due mainly to trampling by the animals. The small area of *Pleurophyllum hookeri* alliance on the hill flat, though extensively grazed, shows no basic changes.

(ii) *Dogs, cats, mice and rats.* Dogs and cats were introduced as pets by the sealers or swam ashore from shipwrecked vessels. The dogs at one time roamed the island in bands, but are now extinct. Cats are still very numerous over the whole island. Rats and mice which were accidental introductions are now widespread.

These animals effect the vegetation only indirectly, through their reduction of the rabbit and bird populations. Cats, especially, are a potent factor in preventing greater increases in the rabbit population. This as a rule is a benefit to the vegetation. However, the extinction by cats and dogs of the ground parrakeet has probably resulted in a decreased dissemination of the berries of *Coprosma repens.* Rats and mice eat the seeds of many species and may aid their dissemination.

(iii) "*Weka*" (*Gallirallus fuseus*). This flightless bird was introduced around 1880 to be used as food for the sealers. It is now abundantly naturalised all round the island, predominantly near the coast but occasionally inland as high as 600 feet.

Though occasionally seen attacking wounded rabbits or dead seals, the weka's main food is small animal organisms such as the kelp fly which occurs abundantly in the large rotting piles of kelp which strew the beaches. These birds have little effect on the vegetation. However, inland in boggy ground they pull out mosses and small plants with their beaks to extract worms, caterpillars, etc. Such operations are carried out systematically, a square yard or more being the work of individual birds or small family groups. Occasional patches of 20 yards square which are the work of many birds occur in particularly boggy areas. Thus wekas have a considerable effect in suppressing the development of the hydrosere.

In rabbit-grazed areas where boggy ground is more extensive this effect is even more noticeable. In addition wekas tear up the stools of *Poa foliosa* tussocks, laid bare by rabbit grazing, in their search for food. They probably have a considerable effect in reducing this hillock-hollow formation to a flat surface.

Wekas build well-concealed nests in a burrow hollowed out into tussock stools. This must have some effect on the health of the tussocks.

(iv) *Rabbits.* Rabbits were introduced on the island around 1880 by sealing gangs. It was hoped that they would provide a source of fresh meat more acceptable than penguin or seal.

Accounts of their subsequent history are fragmentary. They have slowly increased their area of grazing, with a proportional increase in numbers. This latter increase has been subject to many periodic fluctuations.

The point of introduction in the 1880's was at Lusitania Bay. During the stay of the Australasian Antarctic Expedition, 1911-13, their severe effect on the vegetation was only too easily seen. Numerous rabbits were reported at all points on the east coast, although the severely grazed area extended only three miles north of Lusitania Bay to Waterfall Bay. No rabbits were observed anywhere on the west coast (Mawson, 1943).

The B.A.N.Z.A.R. Expedition of 1930 spent only a few days on the island, mainly at the north end. It is probable that the grazed area then extended to Green Gorge, four miles north of Waterfall Bay; no information is available of numbers on the west coast.

In April 1950, when the writer arrived, the severely grazed area included the whole island south of a line five miles from the north end of the island. This line ran from Sandy Bay on the east coast, to Bauer Bay on the west coast, and roughly followed Finch and Stony Creeks. North of this line only isolated pockets of rabbit grazing could be observed, notably in two small areas, one a little south of Island Lake, the other at 400 feet elevation, east of Mount Elder. Elsewhere the vegetation was in its natural state though even as far north as the Isthmus evidence of rabbits was occasionally noticed. The line separating grazed and ungrazed areas was frequently very sharp during the winter of 1950, especially when a creek constituted a temporary barrier. It was frequently observed that the southern bank was eaten bare whilst the north bank supported untouched vegetation, which was as tall as 3 feet, the separating creek being often less than a yard in width.

During the following spring and summer, however, the rabbit-grazed area was extended northwards by as much as half a mile. During the whole year (1950), the rabbits in this area were in plague proportions, though elsewhere in the rabbit-grazed areas the rabbit density was very much lower. In the plague area whole hillsides appeared as a moving mass of rabbits, whilst elsewhere only a few rabbits could be seen at one time. However, reports from subsequent A.N.A.R.E. parties indicate this concentration of rabbits in the Sandy Bay-Bauer Bay area was not permanent. In 1948 the greatest concentration was in the Lusitania-Waterfall Bay area (Laird, verbal), in 1949, Green Gorge (Gwynn, verbal), and in 1951 Flat Creek (Bunt, verbal). In 1951, the great population of rabbits in the Sandy Bay area dropped to the normal population for grazed areas. In this region approximately 1,000 rabbits were shot for food and population studies by A.N.A.R.E. biologist, E. Shipp in 1950. However, the drop was equally great around Bauer Bay where none was shot.

Investigations carried out by Shipp (unpublished) show that on Macquarie Island the rabbits breed for only a short season each year, and that the number of their progeny is correlated with the food available. The natural vegetation in winter and summer has a huge reserve of edible plants but long-grazed areas have no reserve to carry the rabbit population over winter, when plant growth is limited. Thus the borders of the grazed areas tend to support a large slowly advancing population, whilst areas long grazed support only a small population, though if these latter areas build up a food reserve the population could increase sharply and then decrease once more.

Effect on plant communities. The natural vegetation of long-grazed areas in the south of the island has frequently to be inferred, with the exception of the relatively unaltered feldmark formation. This inference has been done by comparison with identical sites which support natural or little grazed vegetation. The resultant communities now growing on a once uniform vegetation type are extremely varied and seem to depend on both past and present severity of grazing.

(a) *Grassland (wet tussock)*. The slopes and flats originally covered by this formation show all stages of degeneration from almost untouched areas to areas completely bare and from which the peat layer of soil has been removed by accelerated erosion.

The rabbits do not move far when grazing and normally strip a small area completely before moving on. They may leave patches of greater or less extent untouched, whilst the surrounding area has been grazed to the ground.

The most palatable plant in this formation is *Stilbocarpa polaris*. Its thick fleshy leaves are eaten first, but as food becomes scarcer, petioles and even the rhizomes are eaten. *Poa foliosa* is also highly favoured. Many tussocks of this grass are eaten down to soil level and the fate of the community is then dependent on the steepness of slope. Slopes above 25°, which constitute the greater part of the area of the formation, are denuded of the peat layer by soil slipping. Frequently only a thin unstable layer of peat is left covering the mineral sub-soil. Where tussocks of *Poa foliosa* are not completely eaten the plant dies leaving a pile of straw which may reshoot the following spring, but under continued grazing *Poa foliosa* entirely disappears.

Plate 22. *Poa foliosa* association after 1-2 years rabbit grazing. (Compare Plates 4 and 6, Brothers Creek). (ANARE Photo).

Plate 23. Recently grazed *Poa foliosa—Stilbocarpa polaris* association in Sawyer Creek. Soil slipping commencing. (Compare Plate 5). (Photo, N. Laird).

On the lesser slopes and flats soil slipping does not occur. If grazing is very severe only a scattered carpet of algae and mosses grow, but usually a continuous mat of low growing species is found. The composition of the mat varies greatly. At first species previously present in the formation are most common, seedlings of *Stilbocarpa polaris* being frequent. If grazing is discontinued the area reverts within a year or two to its natural state.

Under continuous grazing, however, other species soon dominate the area, *Luzula campestris*, *Acaena anserifolia*, *Agrostis magellanica* and many moss species are the most important. *Polystichum vestitum* is only rarely eaten by rabbits. It frequently remains barely touched whilst surrounding vegetation is eaten almost to ground level. However, in long grazed areas it finally dies and the survival of this species on the island is now threatened.

Plate 24. Small stand of *Polystichum vestitum* untouched by rabbits. Surrounding *Poa foliosa* association eaten almost bare. (Photo, N. Laird).

Species list and frequencies for actual areas under different grazing conditions are given in Table 27.

TABLE 27

Floristic Composition of Rabbit Grazed Areas of the *Poa Foliosa* Alliance

Original Community	*Poa foliosa* association	*Poa foliosa* association	*Poa foliosa-Stilbocarpa polaris* association	*Poa foliosa* association	*Poa foliosa* alliance	*Poa foliosa* alliance
Severity of Grazing	Very light	Severe	Severe then Light	Light	Moderate	Very Severe
Period of Grazing	Several years	3 months	6 months	Long continued	Long continued	2 months
Habitat	Plateau slope	Coastal slope	Coastal slope	Coastal flats	Slopes	All slopes and flats
Percentage Cover	95	30	100	100	100	0-5
VASCULAR PLANTS						
Poa foliosa	D	C				
Stellaria decipiens		R	O	VR	O	
Stellaria media		R	D		O(L)	
Poa annua		C	F	D	VR	
Luzula campestris	C	R	R		A	
Agrostis magellanica	C		R		A	
Acaena anserifolia	O	O	O	F	A	
Callitriche antarctica					C	O
Ranunculus biternatus	R	R	C	O	C	VR
Montia fontana			R	C	R	
Festuca erecta					F	
Epilobium linnaeoides	C	VR	O	R	C	
Epilobium nerterioides	VR	VR	VR	R	C	
Cardamine corymbosa	O	C	O	O	O	
MOSSES	O	O	F	C	F	R
LIVERWORTS		R	R		O	
TERRESTRIAL ALGAE	R	R				C

D = Dominant, A = Abundant, F = Frequent, C = Common, O = Occassional, R = Rare, VR = Very Rare.

(b) *Herbfield.* As this formation is not found on steep slopes it is not subject to soil slip even under the most severe grazing and consequently complete cover of vegetation is always maintained.

The dominant plant in this formation, *Pleurophyllum hookeri,* is well favoured by rabbits, particularly during winter when food is scarce. Its rosette of leaves is eaten down to the base but it is able to reshoot again in spring when other food for the rabbits is plentiful. However, no seedling is ever allowed to mature under grazing, and the plant disappears from the community with the gradual death of the older plants. South of the newly grazed areas, the frequency of *Pleurophyllum hookeri* gradually decreases

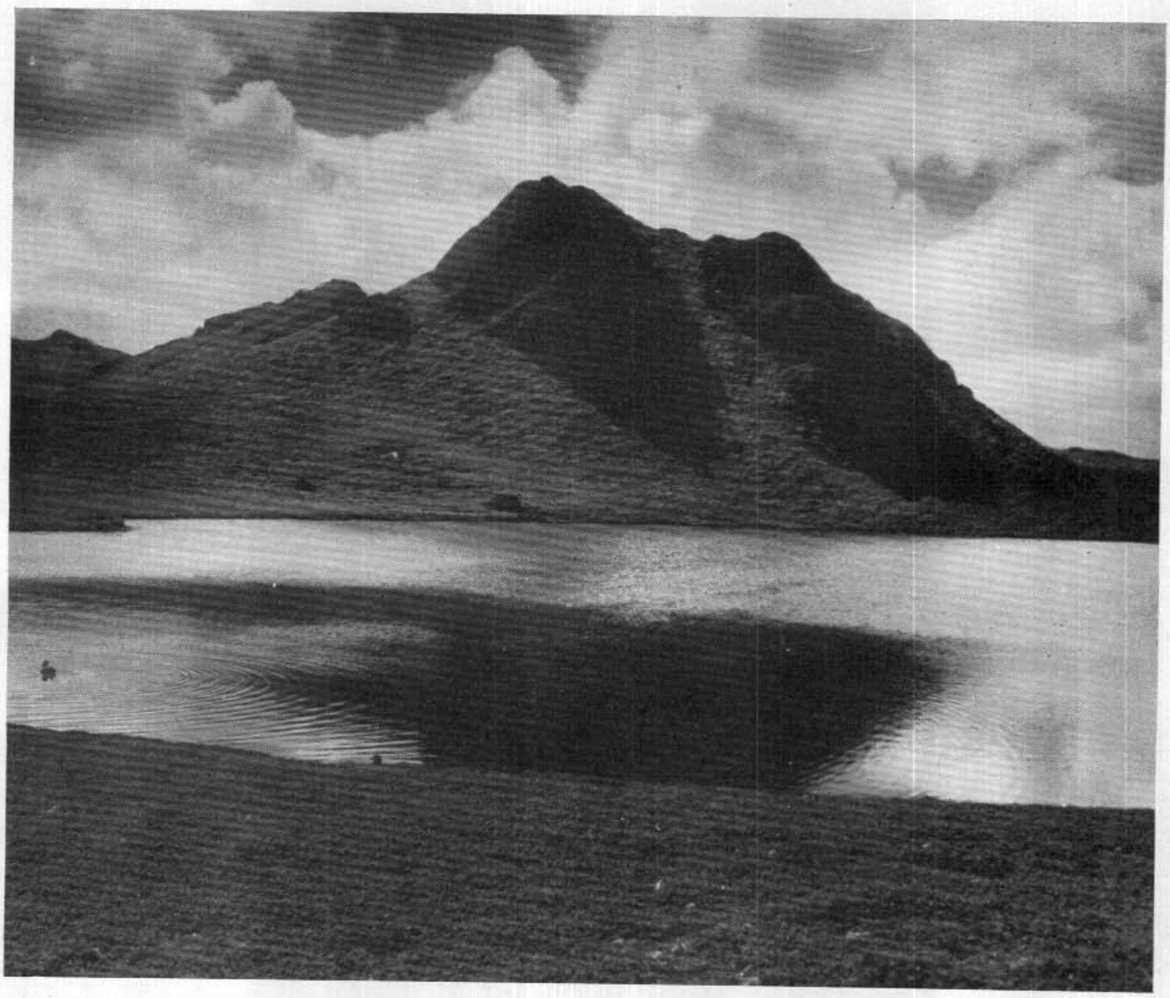

Plate 25. Rabbit grazed herbfield. (Compare with Plate 11 taken in a similar but ungrazed site). Original vegetation replaced by a society of *Acaena adscendens.* (Photo, N. Laird).

till at Green Gorge and farther south none is to be found in the herbfield formation. The one exception is an island in a plateau lake, well separated from the shore, which was seen to be covered by natural *Pleurophyllum hookeri* association.

Other more palatable species, notably *Stilbocarpa polaris,* disappear much more rapidly and may disappear completely within one year. These are replaced by species which can withstand rabbit grazing and a fairly stable community is formed.

The most severely grazed area of herbfield is on the raised beach terrace, south of Bauer Bay. In this area in the winter of 1950 there was not a single plant over a centimeter in height, the only species surviving being such species as *Hydrocotyle sp., Ranunculus biternatus* and *Agrostis magellanica,* which can grow closely appressed to the soil surface. In addition, the water table had risen in the soil and boggy patches were much more frequent.. In identical but ungrazed areas, walking conditions were quite fair but in the grazed area the numerous unsuspected bogs made walking unpleasant and somewhat dangerous.

Floristic list and frequencies of some typical areas of grazed herbfield are given in Table 28.

(c) *Feldmark.* The dominant species of this formation are most unpalatable to rabbits and are never eaten. All other species found in the formation, with the exception of *Stilbocarpa polaris* and *Pleurophyllum hookeri,* are either extremely small or very dry and unpalatable (or both), and are rarely eaten.

Pleurophyllum hookeri growing in the feldmark formation is very frequently grazed, but its position in the community is never seriously threatened. *Stilbocarpa polaris,* however, has been exterminated from large areas of feldmark except for very rare seedlings. *Lycopodium saururus,* which is rare in ungrazed areas, has only been reported once from a grazed area.

The only other rabbit-caused damage is the result of the rabbits' digging "squats" for wind protection. These are always dug in cushions of

TABLE 28

Rabbit-grazed Areas of the *Pleurophyllum hookeri* Alliance

Severity of Grazing	Severe	Severe	Stable societies now under moderate to severe grazing			Very severe
Period of Grazing	1 year		2-15 years			3-10 years
Distribution	Uplands	Uplands	Wetter areas of uplands	Extensive areas of uplands	Small upland societies	Raised beach terrace
VASCULAR PLANTS						
Pleurophyllum hookeri	D	C				
Luzula campestris	O	A	VR	D or A	VR	F
Agrostis magellanica	O	A	R	D or A	C	
Deschampsia chapmani		R			D	
Festuca erecta		C		C		
Juncus scheuchzerioides	O	C	C	R	O	O
Ranunculus biternatus	C	C	O	O	C	F
Epilobium linnaeoides		C		O	O	
Epilobium nerterioides		O		O		
Acaena adscendens		C	D	C	O	
Acaena anserifolia		O		O		
Montia fontana	O	C	C	O		C
Coprosma pumila		R		R		
Uncinia riparia	R	O	O	O	R	
Blechnum penna-marina		VR		VR		
Cardamine corymbosa	O	C	O	R	O	R
Stellaria decipiens		R		VR		
Cerastium triviale		VR		VR		
Hydrocotyle sp.						F
Colobanthus crassifolius						O
MOSSES	A	A	F	F	F	A

D = Dominant, A = Abundant, F = Frequent, C = Common, O = Occassional, R = Rare, VR = Very Rare.

Azorella selago which are much softer than the surrounding gravelly, dry, tundra soils. These "squats" are most conspicuous, but are not common.

(d) *Bog and fen.* These formations growing on very wet areas are only rarely grazed by rabbits and their composition is unaltered.

SOIL EROSION CAUSED BY RABBITS

I. *Highmoor peats.* As already mentioned, these support vegetation of wet tussock grassland and are frequently subject to soil slips after the vegetation is removed by grazing. In freshly grazed areas large soil slips are very frequent after heavy rains. To date, more than half of the steeper slopes in long grazed areas have been denuded of their layer of highmoor peat, exposing the mineral sub-soil or leaving only a relatively thin, unstable layer.

II. *Fen and bog peats.* Since these occur on lesser slopes and flats, they are not subject to soil slips but large gullies have formed in three areas, viz. Finch Creek, Stony Creek, and Sawyer Creek(1). The longest gully is over 400 yards long; the height of the gullies may be as great as 7 feet; their average width is 20 yards; and they are continually extending in area.

III. *Dry tundra soils.* These soils, supporting the unpalatable feldmark formation, show no signs of accelerated erosion.

Future effects of rabbits. Although rabbits have been naturalised on Macquarie Island for 70 years, they have not yet reached any sort of balance with the vegetation. There is still a small area at the north end of the island clad with natural vegetation. It seems most likely that another 20 years will see this last area destroyed unless the rabbits are checked by man.

The vegetation of the subantarctic islands is unique, being formed under a cold, ocanic climate, and as such constitutes one of the major vegetation types of the world. Moreover, each island is affected by a unique combination of factors with minor climatic, and major biotic

(1) These creeks are the main creeks draining into Sandy Bay, Bauer Bay and Green Gorge respectively.

differences. The destruction of the vegetation of any one of these is an irreplaceable loss. The larger islands of the Kerguelen Group have already suffered this fate, but here numerous smaller islands preserve an untouched vegetation. No such fortunate chance can preserve the vegetation of Macquarie Island, whose outlying islands are but scantily-vegetated rocks.

Two species appear to be facing extinction on the island. These are the rare *Lycopodium saururus,* and *Carex trifida,* of which only a few small stands are known. Moreover, the great reduction in numbers of such species as *Poa foliosa,* the endemic *Poa hamiltoni, Stilbocarpa polaris,* and *Polystichum vestitum* must affect their future survival. Fortunately, the other two endemic species, *Puccinellia macquariensis* and *Deschampsia penicillata,* are not adversely affected by rabbit grazing.

Methods of control. The habitat of Macquarie Island is distinctly unfavourable for rabbits, as is shown by their very slow spread (12-14 miles since 1880). Their increase in numbers must have been slow, and it should not be difficult to reverse this trend and bring the population down to a small figure, although total extermination may be difficult. It may be possible that the shooting of rabbits by expedition personnel will prevent any further increase, but as yet the effect has not been determined.

The virus myxomatosis which has been used on a spectacular scale in Australia may well prove useless on Macquarie Island owing to the lack of insect vectors. There are no mosquitoes on the island, though the possibility of other vectors could well be investigated. Wholesale shooting could only be effective in plague areas, for elsewhere the rabbits could not be approached at all closely. Poison trails could be of use during winter when food is scarce but would constitute a serious menace to the native fauna.

Trapping was tried on a small scale in 1950-51, and this was quite effective. Extensive trapping would result in the death of large numbers of the introduced "wekas", but it should have no effect on the native fauna. If this trapping could be done on a large scale within a single season, without causing a similar reduction in the number of cats, the rabbit population would probably be reduced to very small figures. The main food of the cats is rabbits and as the rabbit numbers decrease the proportion killed by cats should rapidly increase.

AUTOECOLOGY OF THE VASCULAR FLORA

RANUNCULACAE

Ranunculus biternatus Smith

Distribution. Macquarie I., Tierra del Fuego, Patagonia, Falkland Is., South Georgia, Iles de Kerguelen, Marion I., Prince Edward I., Iles Crozet, Ile Amsterdam. It also possibly occurs at Tristan da Cunha.

Habitat. Ranunculus biternatus prefers moist, peaty sheltered sites, but has a wide range of tolerance. Its main limiting factor is wind. It grows in sand, peat and water; also on very alkaline rock floors. It is never found on the bare surface of dry tundra soils, but this is more likely due to wind exposure than to unfavourable soil conditions.

Communities.

(i) *Poa foliosa* alliance. *Ranunculus biternatus* grows between the stools of *Poa foliosa* or under the leaves of *Stilbocarpa polaris.* It is also frequently found in maritime communities either in cushions of *Colobanthus muscoides* or on dry fibrous peat.

(ii) *Pleurophyllum hookeri* alliance. It grows amongst the mass of grasses and sedges separating the dominant plants of *Pleurophyllum hookeri* but favours the wetter sites.

(iii) *Juncus scheuchzerioides* association. It is found commonly in this association.

(iv) It grows with bog and fen communities at all heights.

(v) *Azorella selago* alliance. It is found very occasionally, generally growing in the cushion of *Azorella selago,* more rarely amongst mosses. It is found in streams, ponds and pools at all heights and is also frequent in all seres.

Effect of biotic factors. Normally *Ranunculus biternatus* increases in frequency under rabbit grazing because of its ability to grow as a mat close to the ground. It is also favoured by the increase in water-table level and the destruction of higher growing plants usually associated with rabbit grazing. The plants are relatively unaffected though reduced in density in some areas, due to mechanical damage by sea elephants.

Gregariousness, performance. The plants are usually well scattered, but under aquatic conditions they may form dense mats. Their usual habitat is very moist peat where their leaves grow 3 or 4 inches in diameter with petioles 4 inches long. The plants are largest in wet, sheltered conditions in bog communities, and smallest in cushion plants and on

Plate 26. *Ranunculus biternatus* growing on unstable scree slope in spring. (Photo, N. Laird).

almost bare scree slopes. They are little affected by changing climatic conditions, and aquatic plants are capable of withstanding complete freezing over.

Morphology. Life form: Geophyte, sometimes hydrophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 452.

Amendments to description. Petioles are from $\frac{1}{4}$ inch to 11 inches long and leaves from 1/3 inch to 2 inches in diameter. Petals are yellow and rapidly drop off. Achenes are usually green or yellow, but sometimes purple.

Phenology. It flowers from October to March, most prolifically in January and February, and its fruits are ripe from December to September. Most growth is in spring and early summer.

Floral biology. Seeds are produced in all habitats. In acquatic plants they are always borne above water level. Seed dispersal is probably by wind and water. The seeds are roughly spherical, with a small hook $1\frac{1}{2}$ mm. in diameter. The hook is $\frac{1}{2}$ mm. long. Effective reproduction is by seeds and locally by rhizomes.

CRUCIFERAE

Cardamine corymbosa Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Tierra del Fuego, Patagonia, Falkland Is. It also possibly occurs on the New Zealand mainland.

Habitat. This species is found at all elevations up to a maximum of 1,200 feet. Its limiting factor on Macquarie Island is wind exposure. It grows in peat, sand, and water pools.
Communities.

(i) *Poa foliosa* alliance. *Cardamine corymbosa* is common throughout, growing between the stools of *Poa foliosa* or under the leaves of *Stilbocarpa polaris*.

(ii) *Pleurophyllum hookeri* alliance. It occasionally occurs in wet sites where the growth of taller species is lessened, and on small bare areas.

(iii) *Juncus scheuchzerioides* association. It occurs occasionally in the *Juncus scheuchzerioides* association, much etiolated but always overshadowed by the taller-growing dominants.

(iv) It is occasionally found in bog communities.

(v) *Azorella selago* alliance. It is of rare occurrence; it grows with mosses, but never in or on *Azorella selago* cushions.

Effect of biotic factors. Though eaten by rabbits, it is capable of low mat growth so that under very severe rabbit grazing it is actually favoured at the expense of taller-growing species.

It is relatively unaffected by native animals, but is an early coloniser of abandoned birds' nests and is injured to some extent by mechanical damage from sea elephants.

Gregariousness, performance. The plants never form clumps. They are fairly uniform in size, greatest under *Stilbocarpa polaris* leaves, where their petioles may be 6 inches long. In the *Azorella selago* alliance, petioles are as small as ½ an inch. No damage by frost was observed on the plants.

Morphology. Life form: Hemicryptophyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 467.

Amendments to description. The leaves are few, petiolate, and from ¼ to 6 inches long. The number of leaflets varies from 1 to 6, the terminal leaflet being up to 1 inch in diameter. The lateral leaflets are usually remote, sometimes opposite, and frequently entirely absent. The silique is from ¼ to ¾ inch long.

Phenology. It flowers from October to April, and its fruits are ripe from November to June.

Floral biology. Seeds are produced in a silique which is borne vertically and dehisces. The seeds are disc-shaped, 1 mm. in diameter and 1/3 mm. deep. They are easily transported short distances by wind.

Reproduction is by seeds and locally by rhizomes.

Plate 27. Small plants of *Cardamine corymbosa* growing in wind-blown sand. (Photo, N. Laird).

CARDAMINE GLACILIS D.C.

Var. *subcarnosa* O. R. Schultz

This species has only been recorded from Macquarie I. by T. Kirk, apparently on the authority of A. Hamilton's collection of 1880, though it was not noted by A. Hamilton himself.

The only specimens seen that could possibly be called *Cardamine glacilis* were leaves of *Cardamine corymbosa* with five remote lateral leaflets. However, leaves occurred on the same plant with fewer and even without lateral leaflets, and these are only variations of *Cardamine corymbosa*. Kirk possibly based his determination on such a leaf. As a very careful watch was kept for *Cardamine glacilis* and none was found it is most probable that Kirk's determination was in error and *Cardamine glacilis* should be removed from the list of Macquarie Island species, as suggested by Cheeseman (1919).

CARYOPHYLLACEAE

Stellaria decipiens Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I. (var. *angustala,* Antipodes Is.).

Habitat. Its limiting factors are high wind exposure and wet soil conditions. The plants grow on sand and relatively dry peat.
Communities.

(i) *Poa foliosa* alliance. *Stellaria decipiens* is fairly common throughout this alliance, growing on fibrous peat or dead *Poa foliosa* leaves. It also grows under the large leaves of *Stilbocarpa polaris* and is common on coastal rock communities.

(ii) *Pleurophyllum hookeri* alliance. It is found only in the drier areas, generally growing on top of other plants or on small bare patches.

(iii) *Azorella selago* alliance. It is of rare occurrence, growing amongst dry mosses. The species is absent from fen, bog and aquatic communities.

Effect of biotic factors. It forms a low-growing mat but does not appear to flourish under severe rabbit grazing, as do most other low-growing species. It suffers mechanical damage from all native fauna.

Gregariousness, performance. It is slightly gregarious, due to vegetative reproduction by continued growth and death, but dense patches never form. There is very little difference in performance of plants growing in various habitats.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 421.

Amendments to description. The capsules are as long to twice as long, as sepals. The peduncles are frequently one-flowered and are smaller than the leaves.

Phenology. It flowers from September to April and its fruits are ripe from October to June. New leaves are developed in spring and summer. The old leaves and stem die off at all times of the year, but mainly in winter. The plant is perennial.

Floral biology. Seeds are produced in a capsule, which dehisces, allowing the seeds to be slowly shaken out by the wind. Seeds 1 mm. x 4/5 mm. x 3/6 mm. are much convoluted, and are probably dispersed by wind on the island.

Effective reproduction is by seeds and also vegetatively, by growth of creeping stems, with the death of older portions.

Stellaria media (Linn.)

Distribution. Stellaria media was originally a North Temperate plant but has now been widely spread accidentally by man. It was introduced to Macquarie Island prior to 1880, probably as seeds in the packing material of food or machinery. It prefers cool, damp climates. In the sub-antarctic zone it is now found in all the New Zealand sub-antarctic islands, Iles de Kerguelen, Marion I., Prince Edward I., Ile Amsterdam, Ile St. Paul, South Georgia, Falkland Is., Tierra del Fuego, Patagonia.

Habitat. It is never found above 400 feet elevation, nor in very wet areas, nor far from old settlements. It is probably limited by wind exposure, a high water table and lack of time to make its dissemination complete. The plant prefers alkaline sites, scree, sand, gravel, etc., but will also grow well on drier peats.

Communities.

(i) *Poa foliosa* alliance. It is found growing on fibrous peat between the tussocks of *Poa foliosa*. It is common near old sealing settlements, but very rare elsewhere. It prefers plant communities subject to soil slips or the marked action of native or introduced animals. It is a frequent coloniser of bare ground within the area of the alliance and within $\frac{3}{4}$ of a mile of old settlements. It is not found in any other alliance.

Effect of biotic factors. It is eaten by rabbits, but during the growing period of spring and summer it rapidly colonises areas denuded by rabbits where seeds are available. It frequently colonises sites denuded by seals, birds and penguins.

Gregariousness, performance. In severely rabbit-grazed areas it may dominate the vegetation for up to one hundred yards, forming a dense carpet, but it is generally found in small patches of a square foot or less.

In climax communities, and in seral communities on bare ground, the plants are relatively small, but in severely rabbit-grazed areas it reaches its greatest size and is very succulent.

Morphology. Life form: Chamaephyte. Leaf type: Nanophyll. Described by Kirk (1899), p. 57.

Phenology. It flowers from September to June and its fruits are ripe all the year round. Its greatest growth takes place in early spring.

Floral biology. Seeds are produced in capsules which dehisce, allowing the seeds to be shaken out by the wind. Seeds are 1-1/5 mm. by 1-1/5 mm. x 4/5 mm., rounded and much convoluted, and are probably dispersed by wind. Effective reproduction is by seeds and by vegetative growth of the creeping stems.

Cerastium triviale Link.

Distribution. Cerastium triviale was spread by man from the northern hemisphere to the southern. The species was introduced accidentally by sealers prior to 1880, probably in packing material. Though infrequent, it is now widespread, being found on the west coast and the plateau far distant from any sealing base. Its present sub-antarctic distribution is: Macquarie I., Auckland I., Campbell I., Iles de Kerguelen, Marion I., Prince Edward I., Iles Crozet, Tristan da Cunha, Gough I.

Habitat. It is widespread over the island up to an elevation of 900 feet. Its limiting factors are very severe winds, dense shading and a water table near the surface. It grows in the drier peats, sand, scree and all other alkaline substrata.

Communities.

(i) *Poa foliosa* alliance. It is only found very occasionally in the more open communities.

(ii) *Pleurophyllum hookeri* alliance. *Cerastium triviale* is found occasionally in this alliance, particularly in low-lying areas, but also, more rarely, in the upland valleys.

(iii) *Azorella selago* alliance. It is of rare occurrence in the lower elevations of this alliance. The species is absent from bog, fen and aquatic communities.

Effect of biotic factors. It is eaten by rabbits but is not greatly favoured. The plants are capable of low mat growth and are slightly more frequent in rabbit-grazed areas.

Gregariousness, performance. The plants are not gregarious, but may form large mats, 18 inches in diameter, from a single rootstock. Individual plants are well scattered but are more common in a few small areas. Generally, the leaves are dry and the lowermost dead. On scree slopes and rock flour the leaves and stems are rather small. Under the close canopy of *Pleurophyllum hookeri* in the *Pleurophyllum hookeri* association the leaves are succulent and large and the plant etiolated.

Morphology. Life form: Chamaephyte. Leaf type: Nanophyll. Described by Kirk (1897), p. 56.

Phenology. It flowers from October to July and its fruits are ripe all the year round.

Floral biology. The seeds are borne in capsules which are shaken out by the wind. Seeds are 3/5 mm. x 3/5 mm. x 1/3 mm., rounded and convoluted, and are disseminated by wind. Effective reproduction is by seeds.

Colobanthus muscoides Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., the Snares.

Habitat. Cushions of this species are abundant along the whole shoreline and are common in bogs, though they are rarely found in other sites. They are limited by competition from other species and are only able to compete where taller growing species are excluded by sea spray or by very wet bog conditions. They grow in very wet fibrous peat, in dry peat, and on bare rock.

Communities.

(i) Maritime communities. It is the most conspicuous species growing on coastal rocks, accounting for up to 10 per cent. of the total cover.

(ii) *Poa foliosa* alliance. It is very rarely found in this alliance. It occasionally appears high up on the tussock-clad slopes of extremely exposed cliffs subject to sea spray.

(iii) *Azorella selago* alliance. Extremely rare single plants are found growing in *Azorella selago* cushions.

(iv) Bog communities. The plants dominate large areas of bog on the west coast terrace.

(v) Cushions of the plant grow on the many old sea stacks, which may be up to half a mile from the sea.

Effect of biotic factors. The plants are never eaten by rabbits. They do not gain by the reduction in competition in bog communities and are never affected by competition on coastal rocks so they are totally unaffected by rabbit grazing. The plants are damaged by the mechanical movements of royal and rockhopper penquins which frequent the areas where they grow. Cushions growing near penguin rookeries show a marked decrease in vigour. Many scratches from the birds' claws are visible and the plants are spattered by penguin excreta. The plants support large populations of small lower animals.

Gregariousness, performance. In coastal rock, bog and sea stack communities, the plant forms dense cushions or mats. On rocks these cushions may be up to 2 feet in diameter and 9 inches thick. Below the immediate surface, all leaves are dead and flaccid. The stems and old leaves are extremely tightly packed, much more so than in the *Azorella selago* cushions. The whole cushion is saturated with water, which can easily be squeezed out.

Under laboratory conditions at a temperature of 20°C. isolated cushions grow extremely rapidly while supplied with water. Individual shoots are markedly phototropic.

In bog communities the plant forms a dense deep mat, with a slightly convoluted surface which may be 50 yards long.

In the *Poa foliosa* association, exposed to sea spray, the plants form small buttons never more than 2 inches in diameter. In all the foregoing communities, flowers and seeds are regularly formed. No flowers are produced by the single plants growing in *Azorella selago* cushions. Small cushions up to 4 inches in diameter occasionally grow in pools near the sea but these are usually only loosely packed.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 423.

Amendments to description. The flowers are up to 1/10 inch long. Cheeseman's description is accurate for the normal form but where a loose cushion is formed as in a water pool or bog, or on scree slopes, the leaves may be quite linear, up to 2/5 inch long with fruiting peduncles up to $\frac{1}{2}$ inch long.

Frequently a layer of blue-green algae, $\frac{1}{8}$ inch thick is formed about 1/5 inch from the surface of a cushion growing on coastal rocks. These algae belong to ten or more genera but have not been specifically identified. Many vascular plants occasionally grow epiphytically on the plant. These are *Cotula plumosa, Puccinellia macquariensis, Crassula moschata, Poa foliosa, Ranunculus biternatus.*

Phenology. Colobanthus muscoides flowers from September to March and its fruits are ripe from October to May. A fresh growth of leaves at the surface of the cushion takes place slowly during spring and summer. Old leaves gradually die in all seasons. During autumn and winter the surface of the cushion, although green, is tinged with yellow which quickly disappears with the growth of fresh leaves in spring.

Floral biology. The capsule is borne at the surface of the cushion and this dehisces when the seeds are ripe, exposing them to wind and rain which gradually remove them. Seeds are kidney shaped, 2/5 mm. x 2/5 mm. x 1/3 mm., and are easily disseminated by wind. Effective reproduction is by sseds and by the lateral growth of cushions and mats.

Colobanthus crassifolius Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Chatham Is., New Zealand, Marion I., Prince Edward I., South Georgia, Falkland Is., Tierra del Fuego, Graham Land to 68°S. Cheeseman (1925) follows Dr. Shottsberg in uniting the New Zealand and Macquarie I. plants with the South American *Colobanthus crassifolius* and considers it distinct from Australian plants of the same genus. However, after an examination of Macquarie I. specimens, the Melbourne Herbarium considers that the latter statement is open to doubt and that the Macquarie I. *Colobanthus crassifolius* may prove to be identical with the Australian *Colobanthus apetala.*

Habitat. It is found at all elevations up to a maximum of 1000 feet. Plants are restricted by high wind velocities and by taller growing species. They grow in moist to very wet peat and in *Azorella selago* cushions.

Communities.

(i) Bog communities. *Colobanthus crassifolius* may be dominant for several square yards.

(ii) Seral communities. It is a very frequent member of seral communities on slip slopes, growing frequently on moist peat either alone or with mosses.

(iii) *Pleurophyllum hookeri* alliance. It occurs only very occasionally in the wetter sites.

(iv) *Azorella selago* alliance. It is very rare, growing in *Azorella selago* cushions.

Effect of biotic factors. It is hardly ever eaten by rabbits and increases slightly in cover under rabbit grazing. It is scarcely affected at all by the native fauna.

Gregariousness, performance. It forms dense patches in bog communities but elsewhere it occurs only as single plants. In bog communities the plants are much larger in all parts than elsewhere. Flowers and fruits are developed in all sites except in the *Azorella selago* alliance.

Morphology. Life form: Hemicryptophyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 424.

Amendments to description. The leaves are from ¼ to 1½ inches long, the peduncles are from 1/10 to 1 inch long and the flowers are from 1/10 to 1/8 inch long.

Phenology. It flowers from late July to March and its seeds are ripe from September to May.

Floral biology. The seeds are carried aloft in the capsule, which dehisces and permits the wind to shake the seeds out. Seeds are kidney shaped, 2/3 mm. x 2/5 mm. x 1/6 mm., and are easily disseminated by wind. Effective reproduction is by seeds.

PORTULACACENE

Montia fontana Linn.

Distribution. Montia fontana is widely distributed in the North and South Temperate Zones, including Australia, New Zealand, Auckland I., Campbell I., Antipodes Is., Macquarie I., Iles de Kerguelen, Marion I., Prince Edward I., Iles Crozet, Falkland Is., Tierra del Fuego. It is absent from Cape Colony, Africa. It is used as a salad in the northern hemisphere (Willis, 1948).

Habitat. It is found in wet sites at all elevations, its distribution being mainly limited by the water supply, to some extent by taller growing and by high wind velocities. It grows in very moist to very wet peat and gravels.

Communities.

(i) *Juncus scheuchzerioides* association. It frequently attains almost complete cover in this association under the taller growing *Juncus scheuchzerioides.*

(ii) Seral communities. It is frequently found in wet areas of seral communities on slip slopes, screes, etc.

(iii) *Pleurophyllum hookeri* alliance. Scattered plants are common in this alliance, generally growing amongst moss, but also entwined with grasses, sedges, etc.

(iv) *Montia fontana* also grows in small wet patches at all elevations.

Gregariousness, performance. In wetter areas it may form a continuous sward and reach a height of 9 inches; elsewhere it is much smaller and frequently occurs as single plants.

Effect of biotic factors. In rabbit-grazed areas the tallest growths have disappeared, but individual plants are slightly more frequent due to wetter conditions in these areas.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 418.

Amendments to description. *Montia fontana* often occurs at Macquarie I. as single plants. The stems are up to 9 inches high and the leaves are between 1/5 to 1/3 inch long but never longer.

Phenology. It flowers from November to April and its fruits are ripe from December to May. The species is an annual in more temperate regions but is a perennial on Macquarie I.

Floral biology. Seeds are produced in a capsule which bursts suddenly, discharging the seeds. Seeds are very small, $\frac{3}{4}$ mm. in diameter. Effective reproduction is by seeds.

ROSACEAE

Acaena adscendens Vahl.

Distribution. Macquarie I., Iles de Kerguelen, South Georgia, Iles Crozet, Falkland Is., Patagonia, Tierra del Fuego, Marion I., Prince Edward I.

Habitat. Acaena adscendens is found at all heights, but only in wet sites. It is limited to some extent by wind but mainly by its requirement of a high water table. It grows in wet to very wet peat and gravel.
Communities.

(i) *Pleurophyllum hookeri* alliance. It is of common occurrence in most communities of this alliance, favouring wetter sites and areas subject to additions of gravel by slips from nearby slopes.

(ii) Fen communities. It occurs occasionally in the fen communities at low levels, particularly in areas where the water table is not above the ground surface. Here it may constitute the greatest part of the subdominant cover. It is rarely found in fen communities above 600 feet.

(iii) *Azorella selago* alliance. It is very rare in this alliance, being found only in small moss patches.

(iv) Seral communities. Dense mats are occasionally formed, particularly on the gravels of creek fans.

Effect of biotic factors. Whole areas of dead *Acaena adscendens* are observable in severely rabbit-grazed areas. Its fruit is adapted for distribution by the fur of rabbits and the plant quickly germinates and regenerates each spring, with the result that the species plays an important part in rabbit-grazed communities.

Generally it is more frequent in occurrence near birds' nests, due to the wet conditions prevailing there and the adaptability of the seed to carriage by birds' feathers.

Gregariousness, performance. Acaena adscendens may occur as single plants, but also forms mats several yards in diameter. It reaches its greatest size in these mats and its smallest size in upland fen communities. It forms fruits in all habitats but they are much more prolific in areas where mats are formed, particularly on creek gravels.

Morphology. Life form: Chamaephyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 507.

Amendments to description. The stems are up to 3 feet or more in length, woody, and up to $\frac{1}{4}$ inch in diameter. The leaves are from $\frac{3}{4}$ to 4 inches or more in length with 11, 13 or 15 leaflets. The largest leaflet of the leaf is from 1/5 to 3/4 inch long, the scape is from 2 to 6½ inches long and the seed heads are from 1/3 to 3/4 inch in diameter.

Phenology. It flowers from September to February and its fruits are ripe from November to May. Many leaves and stems are very purplish in spring.

Plate 28. Flowers of *Acaena adscendens* in early spring. (Photo, N. Laird).

Floral biology. The fruits are well adapted for carriage by animals, having four barbed spines which are difficult to remove from wool or fur. The fruits are conical in shape and 4 mm. long. Spines are 4 mm. long with barbs ½ to 1 mm. long. Effective reproduction is by seeds or locally by lateral growth of the creeping stems.

Acaena anserifolia

Var. *minor* Hook. f.

Species called *Acaena sanguisorbae* by Cheeseman (1925), but *Acaena anserifolia* in Biblio. Britt Vol. 89 (1914-21), p. 718.

Distribution. Australia, New Zealand, Macquarie I., Auckland I., Campbell I., Antipodes Is., Ile Amsterdam, Ile St. Paul, Tristan da Cunha, South Georgia.

The species has been divided into three species, separating the Amsterdam Group plants as *Acaena insularis* and those from Tristan da Cunha and South Georgia as *Acaena sarmentosa,* leaving the remainder as *Acaena anserifolia.*

Var. *minor* is confined to Macquarie I., Auckland I., Campbell I., and Antipodes Is.

Habitat. It occurs at all elevations on the island. It is limited by wet conditions and by shading from taller species. It grows in dry to very moist peat and gravel.

Communities.

(i) *Pleurophyllum hookeri* alliance. It occurs commonly but prefers the drier areas, where it forms large mats.

(ii) Ecotone between *Pleurophyllum hookeri* and *Poa foliosa* alliance. It is quite common in dry sites in the various ecotone communities, particularly those on very high slopes.

(iii) *Azorella selago alliance.* It occurs as scattered plants growing with mosses, or on top of *Azorella selago* cushions. It is common at low elevations but very rare in areas subject to the severest wind velocities.

(iv) Seral communities. It is common in seral communities, particularly on coastal rocks and elsewhere where the soil conditions are relatively dry.

Effect of biotic factors. The plants are eaten by rabbits but the fruits are also distributed by rabbits as with *Acaena adscendens.* The species plays a very important part in the drier parts of rabbit-grazed areas.

Gregariousness, performance. It sometimes forms mats but more frequently occurs as single plants. Its fruits are formed in all habitats. The greatest growth occurs in moist gravelly sites, the smallest in sites exposed to very high winds.

Morphology. Life form: Chamaephyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 509.

Amendments to description. The leaves are from 1/5 to 7 inches long. The number of leaflets are 11, or 13, with very rarely less. The largest leaflets are from $\frac{1}{4}$ to 1 inch long and the scape from $\frac{3}{4}$ to 4 inches long. The anthers are occasionally reddish. Old stems which are $\frac{1}{4}$ inch in diameter are woody.

Phenology. It flowers from September to January and its fruits are ripe from January to April.

Floral biology. The fruits are dispersed like *Acaena adscendens.* The fruit is $3\frac{1}{2}$ mm. long and the spines are 5 mm. long. The fruit is very woolly.

CRASSULACEAE

Crassula moschata D.C.

The genus described by C. H. Ostenfeld, Dansk Botanisk ARKW, Band 2, No. 8, p. 39, 1918, was called *Tillaea* by Cheeseman (1925) but now it is generally accepted as *Crassula.*

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., Chatham Is., New Zealand, Iles de Kerguelen, Marion I., Prince Edward I., Iles Crozet, Falkland Is., Tierra del Fuego, Patagonia.

Habitat. Crassula moschata is found on coastal rocks, rarely inland. Its distribution is limited, presumably by competition, to areas subject to sea spray. It grows in very shallow, fibrous peat but rarely in moist peat. It also is found on cushions of *Colobanthus muscoides.*

Communities.

(i) Coastal rock communities. It forms small mats on coastal rocks, up to 1 foot in diameter, and occasionally grows in cushions of *Colobanthus muscoides*.

(ii) Very occasionally it grows on moist peat in the shade of overhanging rocks near the sea.

Effect of biotic factors. It is not eaten by rabbits. Presumably it is not unpalatable, but the areas where it grows have little cover of vegetation and are unattractive to rabbits.

Gregariousness, performance. This species is occasionally observed growing as single plants under overhanging rocks. Here the plants are larger and etiolated with little red colouration. Elsewhere the plants grow in dense mats on shallow peat, and have very red stems. The peat is always less than 2 inches thick, and is mostly made up from dead plants of *Crassula moschata*. It is easily recognized, being very black and very fibrous. In the sites most exposed to sea spray, the stems and leaves are very small and lie flat. With less exposure to spray the plants are larger, and have a more upright growth. Occasional mats grow close to fresh water pools and are subject to flooding. These are more luxuriant than usual.

Its distribution round the island is sporadic. It is only found in scattered areas, yet where it does occur mats are very frequent. Its absence does not seem to depend on external factors and must be due to the availability of seeds. This may possibly be due to the relatively recent immigration of the species. It has been recorded from many points along both east and west coasts in great abundance, yet none could be found during dozens of trips from Buckles Bay to Sandy Bay, a distance of four miles containing abundant habitats which would appear suitable.

Morphology. Life form: Chamaephyte. Leaf type: Septophyll. Described by Cheeseman (1925), p. 479.

Amendment to description. The leaves are 1/15 to 1/3 inch long. The leaf of the Macquarie plant is never longer.

Phenology. In 1948-49 the species was observed in flower by N. Laird from early in January. However, in 1950-51, despite a careful search, no flowers were seen till March. Fruiting commences in April.

Floral biology. The seeds are very small, ½ mm. in diameter, and are dispersed by wind.

HALAGORAGAE

Myriophyllum elatinoides

New record for Macquarie I.

The specimens collected were submitted to Mr. J. Willis of the Melbourne National Herbarium. The species does not bear fruits, flowers or aerial shoots on Macquarie Island, so that its identification can not be absolutely certain, but it was considered to be morphologically identical to specimens bearing flowers and fruits of *Myriophyllum elatinoides*.

Distribution. Widespread in the southern hemisphere including South America, Tierra del Fuego, Australia, New Zealand, Falkland Is. It has not been recorded from the remaining sub-antarctic islands.

Habitat. It grows in lakes, pools and streams, but is never found below 300 feet elevation. Its growth is limited by very swiftly flowing water. It occurs in organic loam, gravel and rock flour.

Communities.

Myriophyllum elatinoides association. This community occurs in the majority of the plateau lakes, in water from 1 foot to 8 feet deep, in a few streams, and in one small pond with water 4 to 6 inches deep. This latter pool is a moraine-dammed pond and is fed by water washed down over bare cliffs of boulder clay. The bed of the pool consists of a deposit of clay and the plants also are covered by a fairly thick layer. Some plants have been killed but the remainder appear healthy, though only 4 inches high.

Effect of biotic factors. The plants are sometimes covered by a layer of filamentous green algae which results in death. The species is probably aided in dissemination by birds, which frequently swim in lakes and pools, carrying whole pieces of plant from one valley system to the next.

Gregariousness, performance. The plants generally grow in large communities on the edges of deep lakes and may almost cover the bottoms of shallow lakes. They reach their greatest size in 4 feet of still water, becoming smaller with increasing or decreasing depth. They are smallest in very shallow or swiftly flowing water.

Phenology. During winter the lakes are regularly frozen over for several periods each year and may remain frozen for up to a month at a time. The ice may be at least 18 inches thick at the banks, though only 1 inch or less in the centre. Small pools are frozen solid.

The plants were not noted till September so the effect of freezing could not be observed. However, the amount of growth seen then indicated that the plants had survived the winter relatively untouched.

No serial shoots, flowers or fruits were formed during 1950-51, but as it is known that these organs are not formed on the plant in the Falkland Islands, it is quite probable that they never form on Macquarie.

Hibernacula were formed during late summer and autumn, generally at the apex of the shoot.

Floral biology. Wave action and probably ice action result in stems being uprooted and floating downstream at all periods of the year. These or hibernacula are the only methods of reproduction of the plant on Macquarie Island.

HALAGORAGEAE

Callitriche antarctica Engilm.

Callitriche antarctica is regarded by some botanists as merely a variety of a widely divergent species, *Callitriche verna.* The differences between these two species are that the fruits of *Callitriche antarctica* are not winged, with obtuse instead of keeled edges, whilst the plant is smaller and terrestrial; *Callitriche verna* is aquatic.

Both terrestrial and aquatic forms occur on Macquarie Island. Whether these are well marked varieties, let alone different species, is *doubtful.* It is probably that they are merely plants of the one species growing in different habitats. The stems of the aquatic form are much larger but the differences in leaves are very slight.

The terrestrial form is often seen as a sward leading down into a water pool. The plants growing in water and on the moist peat are typical vegetatively of *Callitriche verna* and *Callitriche antarctica* respectively, whilst those at the water surface are intermediate. However, fruits of both forms fit the description of *Callitriche antarctica.* It would seem, therefore, that though the plants on Macquarie can be classed as *Callitriche antarctica* they include forms which are very close to *Callitriche verna* if a specific difference is maintained. It seems, however, that *Callitriche antarctica* should be included in the wide-ranging *Callitriche verna.*

Distribution. Callitriche antarctica. Macquarie I., Auckland I., Campbell I., Snares, Antipodes Is., Iles de Kerguelen, Marion I., Iles Crozet, Heard I., Falkland Is., Tierra del Fuego, Patagonia.

Callitriche verna. Australia, New Zealand and most large land areas of the world.

Habitat. The species grows in very wet soils but is very rare at high elevations. It is limited by low water availability, high wind velocities and by competition from taller growing species. It grows in water, very moist to very wet peat, gravel, loam and sand.

Communities.

(i) *Poa foliosa* alliance. It is of common occurrence in the *Poa foliosa*: *Cotula plumosa* sub-association and also appears occasionally under the leaves of *Stilbocarpa polaris* throughout the alliance.

(ii) Aquatic communities. It is quite common in communities with a water table at the surface at all heights and is also found in pools at low elevations. It is very rare in fen communities.

Effect of biotic factors. It is eaten by rabbits, but it can grow as a low mat. In those areas of the raised beach terrace which are severely grazed by rabbits and as a result have a water table nearly on the surface, it is the predominant vascular species. Elsewhere in rabbit-grazed areas it has increased greatly in frequency.

It is damaged by the mechanical movements of seals and other animals, but it frequently benefits from their opening up a closed community and by the formation of pools. This is especially the case around the coast in the *Poa foliosa*: *Cotula plumosa* sub-association. In addition, the "bog-holes" formed by sea elephants are rapidly colonised by the species, though the holes are frequently churned up each year, towards the end of summer, by the returning seals.

Gregariousness, performance. The plant forms swards on open ground, which is its normal habitat, but in a closed community only a few scattered plants occur together. The aquatic form may root to the bottom of a pool when the various stems are separated. In rare cases a mat is formed floating on the water surface with stems and roots intertwined. This surface mat may be several feet in diameter and 6 inches thick. Below the water surface there is a mass of roots and above it a mass of stems and leaves.

Morphology. Life form: Chamaephyte, hydrophyte. Leaf type: Leptophyl. Described by Cheeseman (1925), p. 545. The leaves of both forms are from 1/16 to ½ an inch long. Stems of the terrestrial form are from 1 to 9 inches long and of the aquatic form are up to 18 inches long with the nodes much further apart.

Apart from the greater size of the stems of aquatic plants, both forms fit Cheeseman's (1925) description of *Callitriche antarctica.*

Phenology. It flowers from September to March.

Parasites. An unidentified green gall was observed on several occasions growing on aquatic plants.

ONAGRACEAE

Epilobium linnaeiodes Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., New Zealand (on mountains).

Habitat. It occurs at all elevations up to a maximum of 1,000 feet, but generally only in the wetter areas. It is limited by very high wind velocities, dry conditions, and by competition from taller species. It grows in very moist to wet peat, sand, mosses and gravel.

Communities.

(i) *Pleurophyllum hookeri* alliance. It occurs occasionally in this alliance, notably in areas where there are few tall-growing species.

(ii) *Azorella selago* alliance. It grows very occasionally on mosses or bare dry peat in the lowest elevations of this alliance.

(iii) Seral communities. It is common in seral communities on steep slopes, growing with mosses, and disappears on the advent of taller species.

Effect of biotic factors. It is eaten by rabbits but it can grow as a low mat and can quickly regrow in spring. It is one of the more important plants in rabbit-grazed areas of the *Pleurophyllum hookeri* alliance and is greatly increasing in these areas.

Gregariousness, performance. It occasionally forms mats, particularly in rabbit-grazed areas, where it reaches its most luxuriant state. Its smallest size is in the *Azorella selago* alliance. Fruits are formed in all habitats. Under undisturbed conditions it will form a mat on bare ground but normally occurs as scattered plants.

Morphology. Life form: Chamaephyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 609.

Amendments to description. The leaves may be as small as 1/5 of an inch in length. They are normally green but occasionally purplish. Its capsules are $\frac{3}{4}$ to $1\frac{1}{2}$ inches long.

Phenology. It flowers from October to April and ripe fruits are found from November to June.

Floral biology. The seeds are borne aloft in a long silique which on splitting liberates them. The seeds are $\frac{3}{4}$ mm. x $\frac{1}{4}$ mm. x $\frac{1}{4}$ mm. and have a dense mass of silky hairs at one end. These hairs are 4 mm. long by 0.01 mm. wide and facilitate wind dispersal and possibly dispersal by the fur of rabbits and the feathers of birds.

Epilobium nerterioides A. Cunn.

Distribution. Macquarie I., Auckland I., Campbell I., Chatham Is., New Zealand (sea level to 3,000 ft.).

Habitat and Communities. As for *Epilobium linnaeoides*, but under natural conditions it is of more common occurrence in all sites.

Effect of biotic factors. It is affected by rabbits similarly to *Epilobium linnaeoides.* Although of far greater frequency in rabbit-grazed areas than under natural conditions, it is not nearly as frequent as *Epilobium linnaeoides.* No reason could be seen for the preponderance of *Epilobium linnaeoides* in rabbit-grazed areas, and *Epilobium nerterioides* in areas untouched by rabbits.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 611.

Amendments to description. The stem is from 1 to 12 inches long and the leaves measure up to 2/5 of an inch in diameter. Capsules are 2 inches and peduncles from 1 to 2 inches long. Seeds are very similar to *Epilobium linnaeoides.*

Parasites. An infection by an unidentified ascomycete was occasionally noted.

UMBELLIFERAE

Hydrocotyle sp.

New record for Macquarie Island.

Identification. All specimens collected were submitted to Mr. J. Willis of the Melbourne National Herbarium who reported, "This seems to be undescribed. Comparable material occurs under alpine conditions in New Zealand, and Cheeseman (1925), p. 647, refers it erroneously to *Hydrocotyle microphylla* A. Cunn.—a very different plant with much smaller sharply-keeled mericarps. It seems nearest to *Hydrocotyle novaezealandiae* D.C., but differs in having smaller, thicker leaves which are *totally glabrous* (above the petiole); the flowers also are fewer and on more conspicuous pedicels".

Habitat. It is found predominantly between 15 and 40 feet above sea level, although in one locality it occurs as high as 300 feet. It is limited by moderate wind velocities and by a water table dropping far below the surface. Its occurrence is limited to the west coast raised beach terrace and one creek flat on the uplands, just above the raised beach terrace. It does not grow in other identical habitats elsewhere on the island.
Communities.

(i) Bog formation. It is of common occurrence in the large stands of *Breutelia pendula* alliance on the raised beach terrace where it grows with its leaves flush on the moss surface. Elsewhere in the formation it is of strictly limited occurrence, being rarely found in the small patches of bog scattered amongst the herbfield and then only on the raised beach terrace.

(ii) *Pleurophyllum hookeri* association. It is of common occurrence in areas of this association fringing large stands of bog formation. However it rarely occurs in the association farther than 10 to 20 yards away from bog communities.

Effect of biotic factors. It is not eaten by rabbits in bog communities because of its low growth. The section of the raised beach terrace south of Bauer Bay has been subject to severe rabbit-grazing. Here the plant is very much more frequent, partly due to its immunity to rabbit-grazing and partly due to the far greater prevalence of bog conditions following on rabbit-grazing.

Gregariousness, performance. In bog communities the plants' rhizomes are entwined below the surface and the leaves are an inch or less apart. These leaves are borne flat on the surface. When growing with the *Pleurophyllum hookeri* association where the water table is 2-4 inches below the surface, the creeping rhizomes are on the surface and the petioles are very much longer. Its leaves are larger in such sites and are smaller where the water table is above the surface. Rhizomes are widest in bog communities with the water table ½ an inch below the surface.

Phenology. It flowers from December to March. Ripe fruits are shed from February to June.

UMBELLIFERAE

Azorella selago Hook. f.

Distribution. Macquarie I., Iles de Kerguelen, Marion I., Iles Crozet, Heard I., Falkland Is., Tierra del Fuego, Patagonia.

Habitat. It is found in sites exposed to very high wind velocities. It rarely occurs below 400 feet elevation. Its growth is limited by competition from taller species, by a very high water table, and by the most extreme wind velocities. It grows in organic loam, dry peat, and rock.

Communities.

(i) Feldmark formation. It is the dominant plant in the feldmark formation, which covers half the area of the island and which includes almost all areas above 600 feet elevation.

(ii) *Pleurophyllum hookeri* association. One single plant was observed growing in this association at an elevation of 500 feet where the water table was only six inches below the surface.

(iii) Rock communities. Cushions of *Azorella selago* occur on rocks in all areas exposed to high winds. In one exceptional case a cushion grew on a rock only 40 feet above sea-level.

Gregariousness, performance. The plant always grows in mats, cushions or buttons. Mats of the plant may stretch for many hundreds of yards, but in the most exposed areas only small buttons an inch in diameter are formed. In most areas the cushions or mats are tightly packed and the leaves small; in a few favourable sites the cushions are loosely packed with larger leaves.

Effect of biotic factors. It is probably not eaten by rabbits. However, in some areas it suffers mechanical damage, the stems of the cushion being torn up and scattered, probably through the rabbits digging squats for protection from the wind.

Large giant petrel rookeries frequently occur in the feldmark formation. All *Azorella selago* plants in the area are killed or their growth is greatly retarded.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 649.

Amendments to description. The leaves, with petioles, are from $\frac{1}{8}$ to $\frac{3}{4}$ of an inch long or more. The petiole is normally as long as the leaf blade but in the largest leaves it may be twice as long. The stem is from 1 to 18 inches long. *Azorella selago* may form continuous mats for hundreds of yards. Large cushions have a surface rootstock, many yards long, $\frac{1}{4}$ of an inch wide.

Phenology. It flowers from December to February and ripe seeds are shed from January to April. Green leaves are formed from September, and by October no brown leaves are visible. Leaves begin dying late in March and no green leaves are visible by May.

Floral biology. Its seeds are 1 mm. in diameter.

Epiphytes. Many lichens, mosses and higher plants (listed Table 25) grow epiphytically on *Azorella selago* cushions. Cushions in wetter localities sometimes have a layer, $\frac{1}{4}$ of an inch in depth, of blue-green algae growing $\frac{1}{4}$ of an inch below the cushion surface.

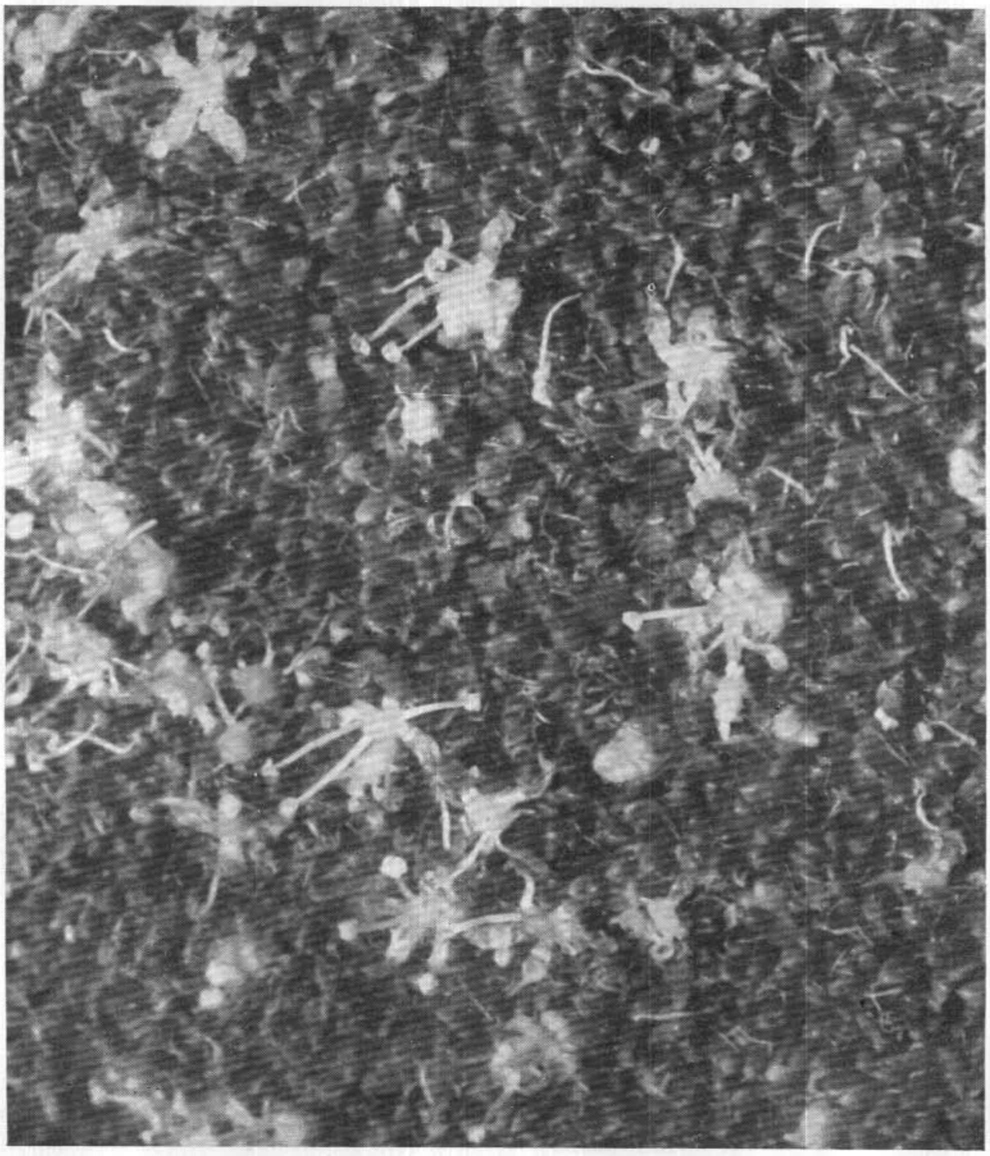

Plate 29. Surface of cushion of *Azorella selago*, late spring. (Photo, N. Laird).

ARALIACAE

Stilbocarpa polaris A. Gray

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is.

Stilbocarpa polaris is the "Macquarie Island Cabbage" used by the sealers of the nineteenth century as an anti-scorbutic.[1]

Habitat. It is found at almost all elevations, its growth being limited by very wet conditions and by extreme wind velocities. It grows in dry to wet peat.

Communities.

(i) *Poa foliosa* alliance. It occurs as a co-dominant over the greater part of this alliance.

(ii) *Pleurophyllum hookeri* alliance. It occurs as the most frequent species in the ground layer within the greater part of this alliance.

(iii) *Azorella selago alliance.* It is quite common except in the most exposed sites.

(iv) Seral communities. It is frequently a dominant in the final stages of many seres.

Effect of biotic factors. It is the favourite food of rabbits, which eat the leaves, petioles and even the fleshy rhizome. When exposed to severe rabbit-grazing it is eradicated within a few months. Rabbits have even removed it entirely from large areas of the feldmark formation where other food is infrequent and where few rabbits venture.

It is also the favourite food of the sheep and goats which graze on Wireless Hill, although these eat only the leaves. Small patches show mechanical damage, however, and death may result. Even the rhizome is sometimes destroyed by trampling.

The stomach contents of penguins have been found to include scraps of *Stilbocarpa polaris* leaves, but they eat the plant very infrequently and no effect of grazing can be seen even in the immediate rookery areas. Occasional trampling by penguins causes damage.

The movements of sea elephants are probably responsible for the absence of the plant from large flat areas near the coast, as the brittle

(1) The petioles taste like celery when cooked; pickled rhizomes like turnips; and leaves when cooked like wet blotting paper.

nature of the petioles makes it extremely susceptible to mechanical damage.

Gregariousness, performance. In the *Poa foliosa* alliance the plant forms large stands with very big leaves and petioles. The leaves are rarely smaller than 9 inches in diameter and the petioles are always 18 inches long or longer. In the herbfield and feldmark formations the plants occur singly and are greatly reduced in size, the leaves rarely exceeding 6

Plate 30. *Stilbocarpa polaris* in early summer. (Photo, N. Laird).

inches in diameter and the petioles rarely exceeding 6 inches in length. Frequently both are much smaller.

Morphology. Life form: Hemicryptophyte. Leaf type: Macrophyll. Described by Cheeseman (1925), p. 632.

Amendments to description. The stems are rarely branched. The mature leaves are from 1 to 18 inches in diameter and mature petioles are from 1 to 30 inches long. The fruit is black.

Phenology. It flowers from November to April and fruits are shed from January to August.

Floral biology. The fruits are borne on a large umbel, which may be as large as 1 foot in diameter. This umbel is normally carried slightly higher than the leaves and when the fruits are ripe it slowly droops to the ground. The seeds are dispersed by gravity or water movements. It is likely that in the past the plant was distributed by the now extinct ground parrakeet. The fruit is from 4 to 5 mm. in diameter. It is almost spherical in shape and very hard.

RUBIACEAE

Coprosma pumila Hook. f.

Called *Coprosma repens* by Cheeeseman (1925), but species split into two by W. R. B. Oliver in "The Genus *Coprosma*", Bernice Bishop Mus. Bull. Vol. 132, p. 33, 1935.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes I., New Zealand (mountain districts), Australia (mountain districts).

Habitat. It occurs at all elevations and in most soil water conditions. Its growth is limited by a water table at the ground surface or above, by competition from taller growing species and by the highest wind velocities. It grows in very wet to dry peat, and in mosses and *Azorella selago* cushions.

Communities.

(i) *Pleurophyllum hookeri* alliance. It is common in most communities especially where the growth of the taller grasses and sedges is restricted by unfavourable conditions.

(ii) *Azorella selago* alliance. It is common, and forms a close-growing mat over other vegetation or directly on the layer of peaty soil.

(iii) *Seral communities.* It is occasionally found in the middle stages of the lithosere at all elevations.

Effect of biotic factors. The plants are eaten by rabbits but not particularly favoured and are untouched in large areas of the feldmark formation from which *Stilbocarpa polaris* has been completely eradicated by rabbit-grazing. It is capable of growing as a low mat but seems unable to survive severe rabbit-grazing, and has disappeared completely from many areas formerly covered by the *Pleurophyllum hookeri* alliance.

Gregariousness, performance. The plant forms mats up to several square yards in extent, probably by vegetative growth from a single plant. The size of the creeping stems is reduced with increasing wind exposure but the leaves show little variation.

A small society of *Coprosma pumila* was snow covered for two months during winter. After thawing it was noted that many fruit had ripened under the snow.

Morphology. Life form: Chamaephyte. Leaf type: Leptophyll. Described by Cheeseman (1925), p. 876.

Amendments to description. Its bark is brown or grey. It usually has four stamens, though sometimes there are only three. The plant is frequently (possibly always) monoecious, not diecious, as are all other members of the species found elsewhere.

Phenology. It flowers from December to April and ripe fruit are shed all the year round.

Floral biology. Three or four seeds, 4 x 2 x ½ mm., are borne in a red fleshy berry 1 cm. long x 7 mm. in diameter. The fruit is sticky when drying and is dispersed by rolling, possibly by the introduced weka. It was probably distributed in the past by the now extinct ground parrakeet.

COMPOSITAE

Pleurophyllum hookeri Buck.

Distribution. Auckland I. and Campbell I. (upland meadows usually above 500 feet and ascending to over 1,000 feet), Macquarie I.

Habitat. It is found at all elevations on the island. Its growth is limited by a surface water table, the most severe wind exposures, and by taller-growing species. It grows in dry to very wet peat and sand.

Plate 31. Mat of *Coprosma repens* with red succulent berries. *Luzula compestris* at top right. *Agrostis magellanica* at top left. Sand grains caught by the plant leaves. (Photo, N. Laird).

Communities.

(i) *Pleurophyllum hookeri* alliance. It is the sole dominant over by far the greatest area covered by this alliance.

(ii) *Azorella selago* alliance. It occurs frequently in this alliance, and is absent from only the most exposed sites. It is nearly as tolerant of high winds as *Azorella selago*.

(iii) *Seral communities*. It occurs in the closing stages of seres on rocks and slopes, but less frequently in the maritime zone.

Effect of biotic factors. It is a highly favoured food of rabbits, which may eat the leaves right down to the rootstock. However, during spring when food for the rabbits is abundant, the plant can regrow normally, to be eaten again the following winter. Between 5 and 20 years of such grazing results in the extinction of the species, although this may be due to the prevention of seedling development by the rabbits, rather than through early death of the adult plant. However, in feldmark communities, the plant is little touched by rabbits and seems well able to endure rabbit-grazing which in these areas is less severe.

It is damaged by mechanical movements of sea elephants, penguins and other birds but never to any marked extent.

Gregariousness, performance. It is normally scattered throughout the community but occasionally it is found in clumps of up to a dozen plants or in large stands. It reaches its greatest size in very moist, well drained, sheltered areas, decreasing in leaf size with exposure to wind and with less or more soil moisture.

Morphology. Life form: Hemicryptophyte. Leaf type: Mesophyll. Described by Cheeseman (1925), p. 931.

Amendments to description. Mature leaves are from 5 to 20 inches long and from 1 to 5 inches broad. There are 8 to 16 main nerves. Flowering stalks have 1 to 4 or more bracts, and are from 6 to 24 inches high.

Phenology. It flowers from late September to December, and ripe fruits are shed from December to March. Rapid development of young leaves occurs in spring; death of the old leaves is most marked in autumn. Fruits are borne in heads on upright flowering stalks. The fruits are 5 mm. long, 1 mm. in diameter, and have a dense mass of pappus hairs at the top. The pappus hairs are 8 mm. long and are very thin and bristly. Effective reproduction is by seeds only.

Cotula plumosa Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., Iles de Kerguelen, Marion I., Iles Crozet.

Habitat. It is generally found close to the sea and always in areas

Plate 32. *Pleurophyllum hookeri* in winter. Lower leaves dead. (Photo, N. Laird).

influenced by sea spray or animal dung. Its development is limited by taller-growing species. It grows in dry to very wet peat, sand, gravel and in *Colobanthus muscoides* cushions.

Communities.

(i) Maritime communities. It is very common, especially in areas affected by animal manure. It is a primary coloniser of wind-blown sand.

(ii) *Poa foliosa* alliance. It is only found in the *Poa foliosa*: *Cotula plumosa* sub-association of this alliance.

(iii) *Pleurophyllum hookeri* alliance. It is only seen on the raised beach terrace in those rare areas frequently visited by sea elephants.

(iv) It occurs extremely rarely in the *Azorella selago* alliance.

Effect of biotic factors. It is eaten by rabbits but is not particularly favoured. It is affected greatly by seals, penguins and also by man. A moderate concentration of penguins and seals stimulates growth of the plant, but a heavy concentration such as a seal wallow or a penguin moulting site results in mechanical damage and death of the plant, though soil conditions are made suitable for the plant's growth next spring.

Gregariousness, performance. The plant reaches its greatest size in sand patches in sheltered positions; it is of intermediate size on moist peat and is smallest on the very dry peat of coastal rocks or in *Colobanthus muscoides* cushions. It may grow as single rosettes but more frequently it is found in small patches up to several yards in diameter.

Morphology. Life form: Hemicryptophyte. Leaf type: Microphyll. Described by Cheeseman (1925), p. 994.

Amendments to description. Petioles are from 1 to 4½ inches long, and leaf blades from ¼ to 5½ inches long. The flower head is from ¼ to 1/3 of an inch in diameter and the rhizome is up to 12 inches long and ¼ of an inch in width.

Phenology. It flowers from November to March and ripe fruits are shed from February to May.

Floral biology. Its fruit is elliptical, 3 mm. by 1 mm. Effective reproduction is by seeds and creeping rhizome.

JUNCACEAE

Juncus scheuchzerioides Gaud.

Distribution. Macquarie I., Auckland I., Campbell I., New Zealand (lake district, alpine), Argentina to Tierra del Fuego, Falkland Is., Iles de Kerguelen, South Georgia.

Habitat. It occurs at all elevations up to 1,000 feet, generally limited to very wet sites. It grows in free water and in very wet to very moist peat.

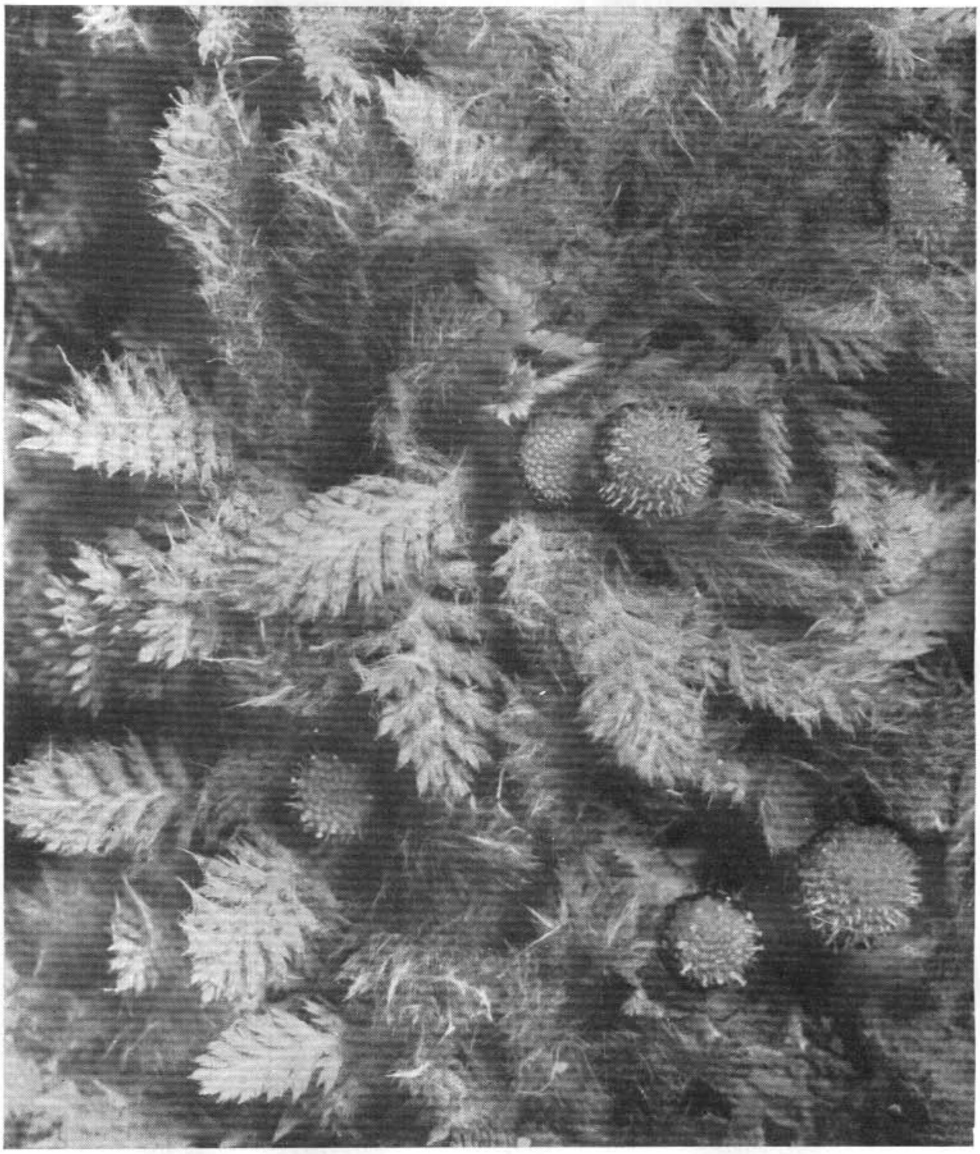

Plate 33. *Cotula plumosa* in spring. (Photo, N. Laird).

Communities.

(i) Fen communities. It is the dominant plant over the greatest area of the fen communities.

(ii) Bog communities. It is common in bog communities.

(ii) *Pleurophyllum hookeri* alliance. It occurs occasionally in wetter sites throughout the alliance.

Effect of biotic factors. It is hardly ever eaten by rabbits, probably because of the physical characteristics of the areas in which it grows. It is somewhat favoured by the increased run-off associated with rabbit-grazing.

Gregariousness, performance. It forms large stands in fen communities. Elsewhere it occurs as scattered plants. It reaches its maximum size in small pools at low elevations, and is reduced in size as the water table drops and also as wind exposure increases.

Morphology. Life form: Helophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 299.

Amendment to description. The leaves are from ½ to 8 inches long.

Phenology. It flowers from December to April and ripe fruits are shed from February to July.

Floral biology. The fruit is 4 mm. x 2 mm.; seeds are 3/5 mm. x 1/5 mm.

Luzula campestris D.C.

var. *crinata* Buch.

Distribution. South America, New Zealand and other temperate regions; var. *crinata,* Macquarie I., Auckland I., Campbell I.

Habitat. It occurs at all elevations. Its growth is limited by the most severe wind exposure, extremely high water table and by taller growing species. It grows in dry to very moist peat, *Azorella selago* cushions and sand.

Communities.

(i) *Pleurophyllum hookeri* alliance. It is very common throughout this alliance.

(ii) *Azorella selago* alliance. It is common except in the more exposed *Dicranoweisia antarctica* association.

(iii) Seral communities. It is common in the intermediate stages of seres on slopes and rocks.

Effect of biotic factors. It is eaten by rabbits, but not favoured. Under the most severe grazing it disappears from the community as it cannot grow as a low mat. Under moderate grazing it is frequently a dominant plant even in a long grazed community.

Gregariousness, performance. It never forms mats—individual plants are generally well scattered. It reaches its greatest size on well-drained, sheltered slopes, decreasing in size with decreasing water table and with increasing wind exposure.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 305.

Amendments to description. The leaves of smallest plants frequently overlap the culm. The culm is from ½ to 20 inches long and the leaves from ½ to 32 inches long, 1/25 to 1/5 of an inch broad but never more. The inflorescence is 3/10 to 1 inch long.

Phenology. It flowers from October to January and ripe fruits are shed from January to October and probably even till the next January.

Floral biology. Effective reproduction is by wind blown seeds. Seeds are 1 mm. x 3/5 mm.

CYPERACEAE

Scirpus aucklandicus Boeck.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., New Zealand, Tasmania, Ile Amsterdam.

Habitat. It is only found on the west coast raised beach terrace in very wet sites. Its growth is limited by a sub-surface water table. No reason can be seen for its confinement to this area. It grows in water pools and in very wet to wet peat and mosses.

Cheeseman (1919), p. 24, notes *Scirpus aucklandicus* as being common on wet gravelly beaches. It was never seen on any beach on Macquarie Island. This error was probably due to a specimen of *Scirpus aucklandicus* growing with *Colobanthus muscoides* collected from a bog community, not from a beach.

Communities.

(i) Fen communities. It is only found in fen communities on the raised beach terrace, but it is common there.

(ii) Bog communities. It appears occasionally in bog communities on the raised beach terrace.

Effect of biotic factors. In the area of the raised beach terrace invaded by rabbits, grazing has been very severe and *Scirpus aucklandicus* has almost disappeared.

Gregariousness, performance. Generally the plants are scattered or in small stands but occasionally dense buttons are formed. The plants are slightly larger in pools, and smaller in dense buttons on drier ground.

Morphology. Life form: Helophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 221.

Amendments to description. It occasionally forms dense buttons. Its leaves are always rigid and its spikelets never green. The stems are from 1 to 4 inches long, and the leaves from 1 to 5 inches long.

Phenology. It flowers from December to February and ripe fruits are shed from March to September.

Floral biology. Reproduction is by very small seeds. The fruits are 2 mm. x 3/5 mm. Seeds are 1 mm. x 3/5 mm., and angled.

Uncinia riparia R. Br.

var. *hookeri* Kukenth.

Distribution. New Guinea, New Zealand, Australia, Lord Howe I. var. *hookeri*: Macquarie I., Auckland I., Campbell I., Antipodes Is.

Habitat. It is found at all elevations but its growth is limited by a water table 1 inch below the ground surface, or higher, and by very high wind velocities and taller-growing species. It grows in dry to wet peat or mosses and in *Azorella selago* cushions.

Communities.

(i) *Pleurophyllum hookeri* alliance. It is fairly common throughout this alliance but more frequent in the upland valley flats.

(ii) *Azorella selago* alliance. It occasionally occurs in the less exposed communities. In both alliances the occurrence of *Uncinia riparia* tends to be more common in a few scattered areas and less frequent or rare in other comparable sites.

Effect of biotic factors. It is eaten by rabbits, but generally it is not touched when growing in feldmark communities. Elsewhere the plant is able to continue growth under moderate grazing but with very severe grazing it disappears completely from the community. When rabbit grazing results in an increased run off and a higher water table the frequency of the plant is reduced.

Gregariousness, performance. It is not gregarious and shoots generally grow well separated amongst a mass of mosses, grasses, *Azorella selago* or sedges. There is a slight reduction in the size of the plant with increasing wind exposure.

Morphology. Life form: Geophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 248.

Amendment to description. The spikes are from ½ to 1 inch long.

Phenology. It flowers from November to December and ripe fruits are shed from January to April.

Floral biology. The fruit is 4 mm. long and has a long barbed utricle. The utricle is 5 mm. long, the barb 2 mm. This would appear suitable for transport by birds' feathers. The seed is 2 mm. x 1 mm. and angled.

Carex trifida

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., the Snares, New Zealand, South America (from Chile to Tierra del Fuego), Falkland Is.

Habitat. It is extremely local in occurrence, being found only at Handspike Point at an elevation between 25 and 40 feet. The water table is from 2 to 4 inches below the surface. The plant is quite successful in this area and there would appear to be many more suitable sites for growth. Its local occurrence may be due to the short space of time since the species reached the island.

Communities.

Pleurophyllum hookeri alliance. It has formed one large stand and elsewhere on Handspike Point it occurs as a co-dominant of the *Pleurophyllum hookeri* alliance or together with *Poa foliosa.*

Effect of biotic factors. It has not come under rabbit grazing yet, and is seldom visited by seals. A gentoo penguin rookery is found at Handspike Point but the birds do not approach *Carex trifida,* preferring to walk or squat amongst the lower-growing associations of the *Pleurophyllum hookeri* alliance.

Morphology. Life form: Hemicryptophyte. Leaf type: Mesophyll. Described by Cheeseman (1925), p. 276.

Amendments to description. It never forms a tussock on Macquarie Island. The leaves are from 1 to 3 feet long and from 1/3 to 3/5 of an inch broad. Culms are from $1\frac{1}{2}$ to 3 feet high and spikelets from 1 to $3\frac{1}{2}$ inches long.

Phenology. It flowers from November to January, and ripe fruits are shed from April to July.

Floral biology. Effective reproduction is by seeds. Fruits are 4 mm. long and $1\frac{1}{2}$ mm. in diameter, with a three-pointed tip.

Plate 34. Small stand of *Corex trifida* 3 feet high. *Pleurophyllum hookeri, Stilbocarpa polaris* and *Juncus scheuchzerioides* in background. (Photo, N. Laird).

GRAMINEAE

Agrostis magellanica Lam.

Distribution. Macquarie I., Auckland I., Campbell I., New Zealand, Antipodes Is., Chile, Tierra del Fuego, Patagonia, Falkland Is., Iles Crozet, Marion I., Iles de Kerguelen, Heard I.

Habitat. It is found at all elevations and at all positions of the water table. Its growth is only limited by taller-growing species. It grows in dry to very wet peat, sand, free water, mosses, *Colobanthus muscoides* and *Azorella selago* cushions.

Communities.

(i) *Pleurophyllum hookeri* alliance. It commonly occurs throughout this alliance.

(ii) *Azorella selago* alliance. It is common throughout this alliance except in the most exposed sites.

(iii) Fen communities. It is quite rare and very small when growing in its *Juncus scheuchzerioides* association, probably because of the taller growth of the dominants. In the fen communities at high levels, where the *Juncus scheuchzerioides* and other dominants are much smaller, it occurs frequently as a co-dominant.

(iv) Aquatic communities. It is fairly frequent in pools and streams.

(v) Seral communities. It is common in the intermediate and primary stages of many seres, including seres or slopes, lithoseres and hydroseres.

Effect of biotic factors. It is eaten by rabbits, but regenerates very well and plays a very important part in the more stable communities under rabbit-grazing. It can grow as a small mat and survives even under the most intense grazing.

Gregariousness, performance. It shows great variation in size. It is smallest in very dry positions exposed to very high winds or sea spray. The leaves are best developed in aquatic communities, and culms are best developed on well-drained gravel slopes protected from the wind.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 153.

Amendments to description. Culms are from ½ to 24 inches long and leaves from $\frac{1}{2}$ to 12 inches long and $\frac{1}{4}$ to 1/5 of an inch broad. Panicles are from $\frac{1}{4}$ to 5 inches long.

Phenology. It flowers from late November to March and ripe fruits are shed from March to December.

Floral biology. The fruits are 4 mm. x 1 mm. with numerous short hairs. Seeds are 1 mm. x 2/5 mm. in diameter.

Deschampsia chapmani Petrie

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., New Zealand.

Habitat. It is found from sea-level to 800 feet. Its growth is limited by wind, very high water table and by taller-growing species. It grows in moist to wet peat.

Communities.

(i) *Pleurophyllum hookeri* alliance. It occurs occasionally in most communities but is rather localised in distribution.

(ii) Seral communities. It is found occasionally in seral communities on slopes.

Effect of biotic factors. It is eaten by rabbits but its seeds are probably distributed in the rabbits' fur. The species is very much more frequent in rabbit-grazed areas, where it may be locally dominant.

Gregariousness, performance. Wherever the plant occurs it is generally not far distant from its nearest neighbour but it never forms clumps or dense mats. The plant is fairly uniform in size, but grows best in sheltered, moist, yet well-drained sites. It is smallest in rabbit-grazed or very wet areas.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 166.

Amendments to description. Culms are from $2\frac{1}{2}$ to 15 inches long and panicles from $1\frac{1}{2}$ to $4\frac{1}{2}$ inches long.

Phenology. It flowers from December to March and ripe fruits are shed from March to May.

Floral biology. The fruits are $2\frac{1}{2}$ mm. x $\frac{1}{2}$ mm. with many small hairs and bristles.

Deschampsia penicillata T. Kirk

Distribution. Macquarie I. (Endemic).

Habitat. It is found at an elevation from 500 to 1,000 feet. Its growth is limited by a water table falling below the ground surface, and by competition from taller-growing species. It grows in very wet peat or peaty loam.

Communities.

(i) *Juncus scheuchzerioides-Agrostis megellanica-Deschampsia penicillata* association. It is practically confined to this association which occurs on small soaks with a surface water table in regions of the island exposed to very severe winds.

(ii) *Pleurophyllum hookeri* alliance. It is found growing in one site only. This site is where a stream flowing through the feldmark formation enters the *Pleurophyllum hookeri* alliance.

Effect of biotic factors. It is very rarely eaten by rabbits.

Gregariousness, performance. Individual plants are always separated by two or more inches. In fen communities the plant has never been observed to flower or fruit and the plants show little variation. In the one instance noted of the plant growing in the *Pleurophyllum hookeri* alliance, it was much larger and almost every plant bore a spike with flowers and nearly mature seeds.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 168. Description based on two specimens collected by A. Hamilton in 1880.

Amendments to description. Culms measure up to 12 inches in length, and spikes up to 3 inches. Leaf blades are from $\frac{3}{4}$ to $1\frac{3}{4}$ inches long.

Phenology. No observable changes occurred in the plants in the fen communities, either in winter or summer. In February flowers and immature seed were noted in the *Pleurophyllum hookeri* alliance. These plants were only seen in one site, and on only one occasion.

Puccinellia macquariensis (Cheeseman) All. and Jan.

Originally assigned by Cheeseman (1919) to the genus *Triodia,* the species was assigned to *Puccinellia* by Allard and Jansen in Trans. Roy. Soc. N.Z., Vol. 69, p. 268, September, 1937.

Distribution. Macquarie I. (Endemic).

Habitat. It is found on coastal rocks or cliffs. Its growth is limited by competition with other species. It grows in shallow, fibrous peat or bare rocks. This peat is formed by *Puccinellia macquariensis* or by *Colobanthus muscoides.* Less frequently, it grows in cushions of *Colobanthus muscoides.*

Communities.

(i) Maritime communities. It is only found on rocks subject to sea spray or occasional waves. It is a primary coloniser in such localities.

Gregariousness, performance. It is very gregarious and is always found in dense patches a few square inches to a square foot in area. Occasionally a patch may surround a *Colobanthus muscoides* cushion. It varies slightly in size, increasing with a better supply of rainwater draining from the surrounding bare rock. There is very little decrease in size with increasing depth of peat or exposure to spray.

Effect of biotic factors. It is not eaten by rabbits, probably as the area in which it grows offers little attraction, being very rocky and bare. Sometimes it is weakened by trampling by penguins, but otherwise it is unaffected.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 183.

Amendments to description. Culms are from $1\frac{3}{4}$ to 5 inches long, panicles from $\frac{3}{4}$ to $2\frac{1}{2}$ inches long. Definitely perennial.

Phenology. It flowers from November to June, and ripe fruits are shed from January to January.

Floral biology. The fruits are very bristly, 2 mm. x $\frac{1}{2}$ mm.

Poa foliosa Hook. f.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., the Snares. It is also found on a few small islands off Stewart Island (New Zealand) and on one cape of Stewart Island itself.

Habitat. It is found at all elevations up to 1,200 feet. Its growth is limited by sea spray, high wind velocities and a waterlogged soil, where the water table is within 12 inches of the surface. It grows in moist to very moist peat, also in or alongside running streams and in *Colobanthus muscoides* and *Azorella selago* cushions.

Communities.

(i) *Poa foliosa* alliance. It is the dominant plant in all communities of this alliance, except the *Stilbocarpa polaris* association. It occurs on all the steep slopes fringing the upland plateau, in creek valleys and on coastal flats with a low water table.

(ii) *Azorella selago* alliance. It appears very rarely growing in *Azorella selago* cushions.

Effect of biotic factors. It suffers extinction under the very severe rabbit-grazing conditions that prevail over the greater part of the south of the island. Rabbits apparently eat below the ligule, killing the leaves which are left as a pile of straw. The plant may reshoot next spring but generally it soon dies.

Sea elephants, by their movements over coastal flats, flatten the tussocks of *Poa foliosa* and all stages are observable from untouched areas to completely bare areas where all the *Poa foliosa* has been killed by the movement of seals.

Penguins, by their movement and manure, cause a decline in vigour of the plant and it is sometimes replaced by *Poa hamiltoni.*

Gregariousness, performance. Under conditions of moderate wind exposure the plant forms large tussocks of densely-packed shoots. The stool, together with the grass on top, may approach six feet in height. At higher elevations with higher wind exposures, tussocks are no longer formed and the plant covers the ground as a dense mat no more than one foot in height. The smallest plants are found on maritime rocks growing in cushions of *Colobanthus muscoides.*

Morphology. Life form: Hemicryptophyte. Leaf type: Mesophyll. Described by Cheeseman (1925), p. 187.

Amendments to description. Mature leaves are as small as 3 inches long and from 1/3 to ½ an inch broad but never broader. Panicles are from 1½ to 8 inches long and from ¾ to 2½ inches broad. Culms are never broader than ½ an inch.

Phenology. It flowers from October to January, and ripe fruits are shed from February to May.

Floral biology. The fruits are shed from the tall panicles and blown small distances by wind. The fruits are 4 mm. x 1 mm. and very hairy.

Fossil record. A leaf was found in a deposit of fossil peat laid down in the closing stages of the last ice age.

Poa hamiltoni T. Kirk

Distribution. Macquarie I. (Endemic).

Habitat. It is found on slopes and flats up to 500 feet elevation, but only in areas enriched by excreta. Its growth is limited by the same factors as *Poa foliosa,* but it is unable to compete except where influenced by penguin excreta. It grows in moist to wet peat, and in *Colobanthus muscoides* cushions.

Communities.

(i) *Poa foliosa-Poa hamiltoni* association. It consists of up to 50 per cent. of the cover of this association and is never found in any other community.

Gregariousness, performance. It forms tussocks similar to *Poa foliosa* but they are slightly smaller. The plants are smallest when subject to mechanical damage by penguins or when growing in *Colobanthus muscoides* cushions on maritime rocks.

Effect of biotic factors. It is able to compete with *Poa foliosa* when receiving penguin excreta, but when excreta is deposited directly on the plant and mechanical damage is greater, the plants are much smaller. It is probably eaten by rabbits in the same way as *Poa foliosa.*

Morphology. Life form: Hemicryptophyte. Leaf type: Microphyll. It is very similar in external appearance to smaller specimens of *Poa foliosa.* Described by Cheeseman (1925), p. 188.

Amendments to description. Panicles measure up to 5½ inches long and leaves up to 2 feet long.

Phenology. It flowers from November to February, and ripe fruits are shed from late May to September.

Floral biology. Fruits are 5 mm. by 1 mm. and very hairy.

Poa annua Linn.

Distribution. Originating in Europe and Temperate Asia, *Poa annua* is now naturalised in most regions of the world. In the sub-antarctic zone it is established on all the New Zealand sub-antarctic islands, Iles de Kerguelen, Marion I., Gough I., Falkland Is., Tierra del Fuego, Chile, Patagonia and probably many other localities. It was introduced accidentally to Macquarie Island by the sealers prior to 1880, probably in packing material. It is now widespread, occurring only slightly more frequently near old sealing settlements.

Habitat. It is found from sea level to 1,000 feet. Its growth is limited by high wind velocities and by taller species. It grows in dry to very wet peat, free water, sand, gravel and rock flour.

Communities.

(i) *Poa foliosa alliance.* It occurs only rarely except where the community has been altered by sea elephant movements, when it is very common.

(ii) *Pleurophyllum hookeri* alliance. It is occasionally found at low elevations, but rarely above 400 feet elevation.

(iii) *Azorella selago* alliance. It is very rare in this alliance.

(iv) Aquatic communities. It is common in pools at low elevations.

(v) Seral communities. It is common in the early stages of seral communities on slopes, but is rarely found on rocks.

Effect of biotic factors. It is eaten by rabbits but is abundant under very severe grazing as it soon forms a low-growing mat. Under moderate grazing it is slightly more frequent than normal.

It is damaged by mechanical movements of seals, penguins, and flying birds, but rapidly colonises ground laid bare by these animals.

Gregariousness, performance. In undisturbed communities *Poa annua* normally occurs as scattered individuals but in areas subject to sea elephant movements it may form a dense sward 20 yards square or more. It is smallest under very dry conditions or where it is subject to much competition from taller species. Leaves and culms are very large when growing in water pools.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Culms are from 1 to 26 inches long, panicles from $\frac{1}{2}$ to 4 inches long and leaf blades from 1/3 to 6 inches long.

Phenology. On Macquarie Island the plant is a perennial, not an annual. Similarly it is known to be a perennial in arctic regions.

It flowers from September to June and ripe fruits are not produced in the first year of growth.

Floral biology. The fruits are very hairy, 2 mm. x 1 mm.

Festuca erecta D'Urv.

Distribution. Macquarie I., Iles de Kerguelen, South Georgia, Falkland Is., Tierra del Fuego, Patagonia.

Habitat. It is found at all elevations. Its growth is limited by the most extreme wind velocities, by a water table one inch from the surface or higher, by competition from taller species, and by sea spray. It grows in dry to wet peat.

Communities.

(i) *Pleurophyllum hookeri* alliance. It is abundant throughout this alliance. In small areas on the raised beach terrace it occurs os a dominant or co-dominant.

(ii) *Azorella selago* alliance. It is common throughout, except in the most exposed *Dicranoweisia antarctica* association.

(iii) Seral communities. It is common in the intermediate stages of seres on slopes and rocks.

Effect of biotic factors. It is eaten by rabbits. Under moderate grazing it is not exterminated, but is reduced in frequency, even when growing in the lightly-grazed feldmark formation. Under severe grazing it disappears entirely.

Gregariousness, performance. It normally grows as scattered individual plants. However, a dozen or more scattered tussocks grow at Handspike Point in poor fen peat. These tussocks are a yard in diameter and consist of a closely-packed growth of culms from 20 to 26 inches in height. The variation of these plants from the norm may be due to some genetic difference or to the more acid nature of the ground water. The latter explanation seems unlikely, however, as the tussocks are sometimes surrounded by individual plants of normal size growing in the *Pleurophyllum hookeri* association.

Elsewhere the plant reaches its maximum size of 20 inches in wet but well-drained slopes, or flats, where slips have added mineral matter to the peat. The size of the plant decreases with a high water table, or dry peat, and reaches its smallest size in sites exposed to very high winds.

Morphology. Life form: Hemicryptophyte. Leaf type: Nanophyll. Described by Cheeseman (1925), p. 207.

Amendments to description. The stems are branched below. Culms are from 1½ to 36 inches long and panicles from 1 to 5 inches long. The width of the leaf blade is 1/10 of an inch or less.

Phenology. It flowers from October to January and ripe fruits are shed from February to October.

FILICES

Blechnum penna-marina Kuhn.

Distribution. Macquarie I., Antipodes Is., New Zealand, Australia, Iles de Kerguelen, Marion I., Iles Crozet, Ile Amsterdam, Ile St. Paul, Tristan da Cunha, Falkland Is., South America from Chile to Tierra del Fuego, Islas Juan Fernandez.

Habitat. It occurs from sea level to 600 feet in sheltered valleys. Its growth is limited by high winds and very wet or very dry soils. It grows in very moist peat and is extremely sporadic in occurrence.

Communities.

(i) *Pleurophyllum hookeri* alliance. It is locally abundant in a few scattered localities, and may dominate the growth between the taller plants of *Pleurophyllum hookeri.*

Plate 35. Dense stand of *Blechnum penna-marina,* fronds 5 inches long. Grass is *Festuca erecta.* (Photo, N. Laird).

(ii) *Poa foliosa* alliance. It was only noted in one locality, growing abundantly between stools of *Poa foliosa*. This area was adjacent to a river flat covered by the *Pleurophyllum hookeri* association in which the *Blechnum penna-marina* was abundant.

Effect of biotic factors. It is probably eaten by rabbits during food shortages. In rabbit-grazed areas the plant is very rare and stunted.

Gregariousness, performance. It is always found as a loose mat. The plant decreases in size with increasing wind exposure.

Morphology. Described by Cheeseman (1925), p. 58.

Amendments to description. Stipes are from ¼ to 5 inches long and fronds (with stipes) are from 1 to 9 inches long, never larger. Pinna are from 1/5 to ½ an inch long. The sporangia are scattered on pinna.

Phenology. The sporangia are formed infrequently and were only noted in January when ripe and unripe spores had developed.

Polystichum vestitum Presl.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., Chatham Is., New Zealand, Australia, Tierra del Fuego, Islas Juan Fernandez.

Habitat. It occurs on slopes and valley flats up to 400 feet elevation. Its growth is limited by moderate wind velocities, by a high water table, and by immature soil conditions. It grows in moist to wet peat.

Communities.

(i) *Poa foliosa* alliance. It occurs as a co-dominant in the alliance in more sheltered localities. It is somewhat local in occurrence, found only on eastern slopes or valleys south of the Nuggets, and is never found in other communities.

Effect of biotic factors. It is killed by prolonged rabbit grazing. Only a few scattered plants germinate under even moderate rabbit grazing and these never attain any size.

Gregariousness, performance. It shows little variation in size in the areas where it grows. It generally occurs scattered amongst tussocks of *Poa foliosa* but occasionally occurs in small stands.

Morphology. Described by Cheeseman (1925), p. 28.

Amendments to description. Stipes are from 4 to 15 inches long and fronds (without stipes) from 2 to 24 inches long. Pinna are from 1 to 3 inches long. The sporangia occasionally cover the whole of the pinnule.

Phenology. Sporangia are developed from November to February and spores are ripe in the sporangia from January to December.

Fossil record. Remains were found in fossil peat laid down in the closing stages of the ice age. These remains consisted of pieces of caudex and pinna.

Polypodium billardieri R. Br.

Distribution. Macquarie I., Auckland I., Campbell I., Antipodes Is., New Zealand, Iles de Kerguelen, Iles Crozet, Falkland Is., Tierra del Fuego, Patagonia.

Habitat. Polypodium billardieri is found at all elevations above 300 feet. Its growth is limited by taller-growing species, by the most extreme wind velocities, and by high water tables. It grows in *Azorella selago* cushions and occasionally in mosses. It is very rarely in contact with the soil itself.

Communities.

(i) *Azorella selago* alliance. It is quite common but its frequency varies greatly from place to place for no apparent reason. It does not grow in any other community.

Effect of biotic factors. It is never eaten by rabbits. The plants are occasionally killed when growing in giant petrel rookeries.

Gregariousness, performance. The plants are always more or less separate, and are very sporadic in occurrence. Very little variation in size occurs, but plants growing in mosses are slightly larger.

Morphology. Described by Cheeseman (1925), p. 80.

Amendments to description. The Macquarie Island plants are very small. Fronds are from 1/5 to $\frac{3}{4}$ of an inch long, never longer, and from 1/20 to $\frac{1}{8}$ of an inch wide. The rhizome is never more than 3 inches long. Only one sori is formed on each frond, at the centre near the top of the frond. It is almost invariably an epiphyte.

Phenology. Spores are produced from October to April.

LYCOPODIACEAE

Lycopodium saururus Lamk.

The Macquarie Island species of *Lycopodium* was identified by Cheeseman (1919) as *Lycopodium varium.* Holloway (1919) quotes a letter from Cheeseman expressing his uncertainty in this identification. Specimens have been examined by the Australian National Herbarium and are considered identical with the Kerguelen *Lycopodium saururus.*

Distribution. Macquarie I., Iles de Kerguelen, Marion I., St. Helena, Tristan da Cunha, Chile, Peru, South Africa, East Africa.

Habitat. Lycopodium saururus is found in areas of high wind exposure, at 600 to 1,000 feet elevation. Its growth is limited by very high wind velocities, higher-growing vegetation, and by a high water table. It grows in dry to moist peat, in moss and in *Azorella selago* cushions.

Communities.

(i) *Azorella selago* alliance. It is of very rare occurrence, growing only in the more sheltered sites in this alliance, occasionally close to a small stream. It is never found in other communities.

Effect of biotic factors. It was never observed in areas grazed by rabbits, where it probably has been exterminated.

Gregariousness, performance. It was only observed in a dozen localities on the island. Where it does grow, two or more plants are generally close together. Of 100 plants seen in the whole of 1950-51, over half were in a small area a few yards in diameter.

Morphology. Described by Cheeseman (1925), p. 100.

Amendments to description. It is from 1 to 4 inches in height, and the leaves are never larger than 1/3 of an inch in diameter. Effective reproduction is by gemmae and spores.

One piece of stem was observed being blown over the highlands, and such transport probably facilitates dissemination.

TRANSIENT SPECIES

Under this heading, several groups of species which are not established members of the flora have been placed. The first, *Avenea fatua*, was accidentally introduced by man; the second, several species of Australian snow gums, were purposely introduced; the third, an unidentified seed, reached the island by natural means.

I. *Avena fatua* Linn.

Innumerable seeds of *Avenea fatua*, wild oats, were included in packing material of A.N.A.R.E. stores and were widely distributed in the vicinity of the A.N.A.R.E. Station. During spring and early summer of 1950 many hundreds of these germinated but none grew larger than 3 inches before succumbing to a frost.

However, a small dense patch which germinated in 1949 grew to 18 inches and set seed. This patch was in a particularly favourable site. It grew in a small plot which had been fenced and manured in an unsuccessful attempt to grow vegetables in 1948. The soil was beach sand and the manuring included limeing.

Although climatically Macquarie Island is within the range of *Avenea fatua*, this plant requires more favourable soil conditions than it has yet encountered under natural conditions to compensate for the severity of the climate. It is most unlikely that this species will ever become established on Macquarie Island, as it has done on islands slightly farther north.

II. *Snow gums.*

Seeds of several Australian species of snow gums were brought to the island for germination tests. These seeds included *Eucalyptus pauciflora* Sieb. and *Eucalyptus coccifera* Hook. f. which had been collected from trees growing near the tree line in Tasmania, Victoria and New South Wales. These seeds were supplied by courtesy of Mr. D. Martin, C.S.I.R.O. Plant Industry, Hobart.

Seeds were planted on the surface and at shallow depths in several pots of different island soils and were kept well watered and drained for a period of four months in spring and summer. After this time there was no sign of germination in pots placed in protected sites at island temperature. One large pot which had been placed in a warm hut, 65°F., rapidly produced vigorous seedlings, but when these were 3 inches high they were placed outside. No further growth took place, and the plants died after the first frost which occurred a few days later.

Two large snow gum seedlings, details of which are not available, were brought to the island with the first A.N.A.R.E. party and planted, and these, too, soon died.

It would seem that at least one of the factors preventing the growth of trees on Macquarie Island is the lack of any warm period sufficient to permit germination of seeds and establishment of seedlings, although it may be possible that trees from other regions could be established.

III. *Unidentified seed.*

A seed was found on the shores of Waterfall Lake by the biologists of the 1951-52 A.N.A.R.E. Party, Bunt and Lindholm. This seed bears no resemblance whatever to the seeds of any species recorded from the island.

This seed was given to Miss Myers, of the Seed Testing Laboratory, N.S.W. Department of Agriculture, who reported as follows:—

"A description of the seed would be as follows: 5.1 mm. long; 3.3 mm. wide in the broadest part; surface smooth and shining; colour tawny; two sides meet in a well-defined central ridge, the third side convex; hilum in conspicuous basal scar, depressed.

"I have sent this description, together with one of the photographs, to Miss Cowen, Research Officer, Palmerston North Seed Testing Laboratory in New Zealand, but she can't identify the seed either, at least from the material given her.

"The seed to me looks as though it belongs to the Convolvulaceae, except for the smooth surface, which is atypical, as far as I know.

"It is still under test for germination, though suitable temperatures are only guessed at—alternations of 20°C. and 32°C. are being used at present (for 16 and 8 hours daily) after unsuccessfully trying 20°C. constant. The seed is still firm and free from moulds typical of hard seeds or of other kinds of dormancy, and, I think, indicating that it is alive; otherwise, it should become moudly."

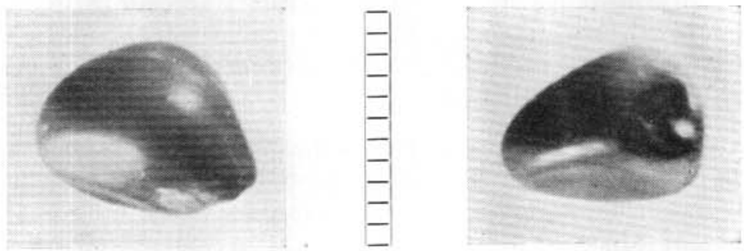

Plate 36.
Unidentified seed, scale units in millimetres. (N.S.W. Dept. of Agriculture Photo).

Further efforts will be made to germinate the seed, and it is proposed to approach South American seed experts regarding identification.

The area in which the seed was found had not been visited by man for more than 6 months, and the possibility that it was accidentally dropped by a previous party can be ruled out. The seed must either belong to a species present, but not recorded from the island, or it has been transported to the island over a great distance, presumably by birds.

Neither possibility can be ruled out, but the fact that Macquarie has now been extremely closely explored botanically makes the first explanation less probable. Moreover, a careful search has been made of the Waterfall Lake area and no new species or further seed has been found.

Wind and sea currents can be ruled out as a method of transport, as the seed is too large to be carried far by wind and was found on a lake bank 600 feet above the sea. However, this position lends weight to the theory that it was transported by birds. It was found within a foot of the water's edge on a gently-sloping, sandy bank and must have been washed ashore from the lake, which is the most popular site for swimming by giant petrels. Whenever the lake was approached a large number of these birds, estimated at 600, was seen swimming in the lake or resting on shore.

SOILS

Introduction. The various soil types occurring on Macquarie Island have been classified into the great soil groups according to the system of Glinka (1928), with some modifications following the classification of Hallsworth and Costin (1950). The groups identified are highmoor peats, fen peats, bog peats, and dry tundra soils.

However, it may be stated that the Macquarie soils differ considerably from soils of these groups described elsewhere. Particularly is this the case with the dry tundra soils. The reason for these differences is that the climate of Macquarie Island is oceanic in the extreme whilst soils previously described from these groups are all formed under continental climates.

The factors affecting the formation are discussed in detail under each soil type. Broadly speaking the following generalization may be made: where wind velocities are not very high and the rate of plant growth is not slowed down a peat soil is formed. The type of peat formed varies with the absence or presence of a permanent water table in the peat profile and the nature of the ground water. Where wind velocity is very high and the plant growth rate greatly retarded, then dry tundra soils are formed.

The effect of organic matter generally masks the effect of parent material. Indeed, with only one exception, the various types of parent material result in only very slight differences in the soils formed on them. The rocks of the island are all basic; weathering of different rocks in situ gives very similar soils and subsoils. However, soils formed on transported material, e.g., glacial till, sea and wind deposited sands, though all derived from basic rocks, may result in distinctly different soil profiles.

Owing to the influence of type and amount of organic matter and also to the same factors influencing both, there is a very high correlation between vegetation and the soil on which it grows. Thus the vegetation map could serve as a soil map if the area of the feldmark formation was designated dry tundra soil complex, the sub-glacial herbfield called fen and bog peat, and the wet tussock grassland called highmoor peat.

As funds were limited this report could not be extended to a full analysis of the factors affecting soil formation. The report must therefore be taken mainly as a field description backed by only a small amount of analytical data.

Field techniques. Over 500 soil samples were collected from 60 profiles and the soils were examined, but not collected, in many other sites. The samples varied in weight from 5 to 12 pounds, of which frequently 80 per cent. was gravel or water. More samples would probably have been collected but it was necessary to carry them on foot for distances of several miles. The relatively small number of profiles collected means that the descriptions of some soil types may not be typical, especially in the lower horizons. Samples from 10 profiles from the southern end of the island, where the rock types are slightly different, were not available for analysis during the preparation of this report. These, unfortunately, were left on the island following the wreck of a D.U.K.W. (amphibious truck) which was to have brought them off.

All samples were taken from soil pits, dug with pick and shovel, and in a few instances from the sides of naturally occurring cuttings. Soil augers could not penetrate the very gravelly dry tundra soils and the work involved in cleaning the cold metal parts of the auger working in a peat soil was not worth while. However, for a small percentage of profiles, auger samples were taken for the last foot.

Soil pits were continued till bedrock was encountered, or until it was thought that the work involved would be prohibitive. In some cases the rapid influx of water into deep pits made further digging almost impossible. The average profile was four to five feet in depth, but many were much deeper, up to a maximum of twelve feet. Natural cuttings were used in a few places to extend the depth of sampling.

The position of each sample was checked by careful cross reference to a 50-foot contour map. Slopes were determined by an Abney level.

Method of analysis. pH. pH was determined on the sticky point of air-dry soils by the glass electrode, following the methods of Hallsworth (1947). In addition, the pH of many soils was determined within a day of sampling. This was done colorimetrically using a Lovibond comparator on a 1: 10 suspension, cleared with barium sulphate. Unless specifically mentioned all pH values quoted are figures obtained by the glass electrode on air-dry soils.

Gravel. Air-dry soils were sieved through a 2 mm. sieve and the amount of gravel was expressed as a percentage of the fine earth on an oven-dry basis. Stones and rocks above 2 inches in diameter were not included in this figure, as they were generally discarded during sampling. All the results from the following analysis have been expressed in terms of the oven-dry soil after removing the gravel.

Silt and clay. The soils were dispersed following the method of Hallsworth (1947) and estimated by the Hydrometer Method. In all cases it was necessary to add large quantities of hydrogen peroxide to destroy the organic matter.

Loss at 105°*C.* Before leaving the island all samples were dried in a small, heated hut and packed for transport in airtight containers. As the hut was packed full of soil samples and the drying rate was very slow, the samples were not evenly dried. Little significance can be attached to the percentage of water in these samples. They represent more the effect of differential drying than the water-holding capacity of the soil. The method followed is that of Hallsworth (1947). All other analysis is expressed in terms of this oven-dry weight.

Loss at 400°*C.* The method followed is that of Hallsworth (1947). This loss includes the water of hydration of clay, and part of the CO_2 of any carbonates, as well as the organic matter. However, when the amount of organic matter is high (above 10 per cent.), its effects mask other losses and the figure can be used as a good guide to organic content. This is especially the case with peat soils.

Organic carbon. This was determined by the Walkley and Black Rapid Titration Method, as outlined in Piper (1947). It gives a fairly reliable index of organic content, especially for soils where the percentage of loss on ignition is low and unreliable.

Chloride. This was determined by the Best Electrometric Titration Method, as outlined in Piper (1947). Drift of the end point was frequently observed in peat soils with a high chloride content. However, final readings were taken after a standard time and should be quite comparable.

Phosphate. Phosphate was extracted by a dilute acid solution of ammonium fluoride as outlined in Diagnostic Techniques. This was estimated colorimetrically.

CLASSIFICATION OF SOILS

1. *Peat Soils.*

Three main types of peat soils occur on Macquarie Island. These are (a) highmore peats, (b) fen peats, (c) bog peats. Highmore peats are formed by the decomposition of organic matter under aerobic conditions, i.e., when no permanent water table is present in the peat profile. Fen and bog peats are formed by anaerobic decomposition of organic matter, i.e., where a water table is high in the peat profile. In fen soils this water has a percentage of mineral salts dissolved, in bog soils the water is almost free of dissolved salts.

The occurrence of all three types is normally determined by topography, which controls the rate of drainage, and also the presence or absence of drainage water in the profile that has come in contact with mineral matter. However, in the case of the highmoor peat formed on marine deposits of the raised beach, the highly permeable nature of the subsoil has prevented the formation of a permanent water table and thus prevented the formation of fen or bog peats.

(a) Highmoor peats.

These soils support vegetation of all communities of the *Poa foliosa* alliance and also the *Pleurophyllum hookeri*: *Coprosma repens* sub-association.

Occurrence. Wherever the two plant types mentioned above occur, highmoor peats occur. Thus their distribution can be seen from the vege-

Plate 37. Natural erosion of highmoor peat, Wireless Hill. (Photo, N. Laird).

tation map. All areas marked as wet tussock grassland, and those areas of the sub-glacial herbfield formed on slopes of over 20°, support highmoor peats. They occur on all slopes above 20° where wind velocities are not too high and also on coastal flats where the subsoils consist of rapidly drained marine deposits of sand and gravel.

Substrata. Highmoor peat overlies a variety of substrata. These are: gravelly loams, often of great depth, formed by the weathering of various rocks in situ, e.g., basalts, diorites, gabbros and occasionally serpentine; gravels, deposited by creeks or soil slips; wave-worn gravels and sands and, more rarely, wind-deposited sands. Under immature soils formed on steep cliffs, old sea stacks or boulders, the peat may rest directly on rock that has been little decomposed by weathering.

Profile characteristics. The peat profile may be up to 6 feet deep, averaging from 3 to 4 feet. In mature soils the top few feet are very fibrous brown peat, changing fairly sharply into dark brown amorphous peat which contains very few fibres. The peat profile may be almost pure organic matter, but generally contains a small amount of wind-blown sand and in many areas contains gravel and other mineral matter carried down by soil slips.

The appearance of the peat, especially the fibrous layer, varies considerably, depending on the type of plant community forming it. Thus peat formed from *Poa foliosa* is lighter in colour and much more fibrous than peat formed from *Stilbocarpa polaris.*

Under deep, mature highmoor peats, a thin iron pan is formed overlaying the mineral subsoil. This pan may be up to ¼ of an inch thick.

Where the mineral subsoil is formed from rock weathered in situ, a zone of illuvial organic matter and sesquioxides is frequently found. This horizon is generally yellowish or orange in colour and varies in depth with the amount of water draining down the profile. At the bottom of a small slope, 100 feet high, this horizon was less than 2 feet in depth. On the slopes fringing the plateau, where all excess precipitation drains laterally through the soil profile, the mineral subsoil has been examined for 7 feet without leaving the zone of illuviation.

Where the amount of drainage water is less, a layer of well decomposed rock has been observed under the illuviation horizon. This layer is a gravelly loam, the colour of which varies from green to ash grey, depending on the type of parent rock, and continues to some depth.

These mineral subsoils have a fair content of silt and clay, which indicates that the temperatures at Macquarie Island are sufficiently high to permit of chemical weathering.

Where the mineral subsoil is formed from sands and gravel it is much more permeable to water and the zone of illuviation is much deeper, though the amount of clay and organic matter held is much less.

A typical highmoor peat, with a subsoil of weathered rock in situ, is described in Table 29.

TABLE 29

Highmoor Peat.

Profile No. K.

Vegetation: *Poa foliosa* association.

Location: 350′ elevation. North Head facing plateau slope, Hasselborough Bay. Slope 35°.

Parent material of mineral subsoil: Basic, igneous rock in situ.

Sample No.	Depth in Inches	Field Description	pH	% Silt	% Clay	% Loss 105°C.	% Loss 400°C.	% Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
K1	0-9	Very fibrous peat. Leaves and roots barely decomposed.	5.4			15.4	89.3		.090	3.80
K2	9-17	Very fibrous peat. Plant remains easily distinguished.	4.4			24.1	84.3		.047	6.08
K3	17-27	Dark brown fibrous peat. Occasional large rocks to 1 ft. diameter.	4.2			53.1	79.9		.047	.67
K4	27-34	Brown peat, few fibres, margins fairly sharp.	4.4			17.5	80.0		.040	.67
K5	34-47	Dark brown amorphous peat. Occasional decomposing pebbles to 2 in. diameter.	4.5			22.1	89.5		.031	.09
K6	47-58	As K5, slightly darker colour.	4.2			21.3	90.0	41.0	.047	.57
K7	58-60	Very dark brown peaty loam, with many decomposing pebbles.	4.5	24	48	10.5	24.2	10.19	.017	5.63
K8	60-70	Brown loam with little peat.	4.4	15	45	27.3	27.4	10.7	.015	14.7
K9	70-76	Yellow gravelly loam, with many brown mottlings.	4.7	28	28	4.2	18.4	6.0	.011	16.1
K10	76-80	As K9 Gravel content	4.5	16	36	23.1	20.7	8.1	.011	15.1
K11	80-84	As K9 increasing	5.0	15	26	18.2	15.0	5.4	0.10	13.9
K12	84-90	As K9 with	4.8	13	17	9.7	14.4	4.6	.014	12.2
K13	90-94	As K9 depth	6.0	9	13	13.3	14.7	4.8	.006	2.2

Water relations. The peat layer may be fully saturated following a period of heavy rain and is moist at all times. No free water surface ever forms in pits dug into the profile though water oozes out from all sides, notably through the uphill face of the pits. The mineral subsoil is always moist and may contain a permanent water table.

Factors affecting the formation of highmoor peats.

(i) *Climate*. The climate of Macquarie Island is such that the rate of decomposition of organic matter is extremely slow. The most potent factor is the lack of even a short period of warm temperatures. On the other hand the climate is such that plant growth is still fairly rapid. Thus, unless plant growth is limited by exposure to wind, organic remains accumulate.

Plate 38. Section through beach gravels, ANARE Station, the Isthmus. (ANARE Photo).

(ii) *Topography*. The topographical position is important in two ways. First it determines the degree of exposure to wind and thus whether peat can be accumulated. Secondly it influences the drainage rate and on steep slopes prevents the formation of a permanent water table, thus determining whether highmoor, fen or bog peats are formed.

The degree of slope and the position below mineral soils and rocks largely determines the amount of mineral matter incorporated in the peat. The proximity to the coastal beaches determines the amount of wind-blown sand incorporated.

(iii) *Biotic factors.* The various plant associations responsible for the organic deposits have a strong influence on the amount of fibre in the resultant peat.

(iv) *Time.* Increasing time results in an accumulation of highmoor peat which has two effects. (a) On the steep slopes the peat becomes unstable and slips down in small or large slides. These slides occur after a rainy period, when the soil is saturated and at its heaviest. Normally the mineral layer is unaffected by slipping. A smooth surface of the iron pan covering the mineral soil is frequently exposed. Such slips are relatively infrequent; only two occurred during the period 1948-1952 at the northern end of the island, where rabbits were few. (b) On coastal flats increasing depth of peat with time impedes drainage, till finally a permanent water table forms, and highmoor peats are no longer produced.

(*b*) *Fen peats.*

Fen peats are peats formed on flats or lesser slopes in which a permanent water table, containing dissolved mineral salts, is present in the peat profile.

There are two distinct types of fen peats formed on Macquarie Island: rich fen peats, where the ground water is high in dissolved salts; and poor fen peats, in which ground water is low in dissolved salts (Hallsworth and Costin, 1950).

Rich fen peats. These peats support all communities of the *Pleurophyllum hookeri* association, excepting the *Coprosma repens* sub-association, and the *Juncus scheuchzeroides* association.

Occurrence. The actual areas covered by these peats can be seen from the vegetation maps. They cover the area mapped as sub-glacial herbfield, except on the coastal flats and on slopes of over 20°.

Substrata. Various types of mineral substrata occur, including decomposing rock in situ, various types of glacial till, and lake sediments. These were rarely examined to any depth because of the rapidity with which soil pits filled with water. No differences of the overlying peat could be associated with the various types of substrata.

Profile characteristics. The top two inches of the peat profile consist of almost black, very fibrous peat and plant roots. This is sharply bounded from the underlying peat which is very dark brown in colour, mainly amorphous with the percentage of fibres and roots rapidly decreasing with depth.

Where the substrata is weathered rock or glacial till, the transition from peat to mineral subsoil is sharp, but on sites of old lakes or ponds the transition from pure peat to sand and silt is very slow.

The subsoils formed from weathered rocks are always very gravelly, compact, and green in colour. On drying, the colour changes to yellow brown, probably due to oxidation of ferrous iron. No iron pan was ever noted.

TABLE 30
Rich Fen Peat.

Profile No. 12.

Vegetation: *Pleurophyllum hookeri*: *Stilbocarpa polaris* sub-association.

Location: 500′ elevation. Gentle creek slope, overlooking Half Moon Bay. Slope 5°.

Permanent water table at 3 inches.

Substrata: Shallow pond sediments overlying decomposing rock.

Sample No.	Depth in Inches	Field Description	pH	Gravel	% Loss 105°C.	% Loss 400°C.	% Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
12A	0-1	Black fibrous peat and roots, tightly interwoven.	3.9	0	10.9	89.6	39.3	.158	1.29
12B	1-5	Dark brown peat, fairly fibrous many roots.	3.9	0		90.0	39.0	.183	
12C	5-16	Mottled brown and blackish peat, few roots and fibres. Groups of bird-dropped, rounded pebbles.	3.9	.1	14.0	91.7	36.3	.116	.61
12D	16-21	Very dark brown amorphous peat, very few roots or fibres.	3.8	0	32.4	95.2	43.6	.028	.38
12E	21-29	Brown amorphous peat.	3.4	0	12.9	92.7	39.8	.042	.38
12F	29-33	Brown amorphous peat.	3.7	0	14.5	94.2	37.2	.034	1.77
12G	33-39	Very dark brown amorphous peat.	3.7	0	20.1	77.3	36.3	.054	.93
12H	39-45	Brownish green peaty sand, with recognisable plant remains.	4.2	.5	8.0	18.0	8.0	.011	.99
12I	45-55	Greenish brown sandy peat, with recognisable plant remains.	4.2	3	8.3	19.7	9.4	.024	2.91
12J	55-67	Green gravelly loam, with many large pieces of barely decomposed rock.	4.5	55	6.3	10.2	3.9	.005	.91

The depth of peat is normally between 3 and 5 feet. It was never noted less than 2 feet thick but some sites have been examined to a depth of 8 feet without reaching mineral subsoil, or lake deposits.

Mineral material from soil slips is rarely added to these peats. Practically the only mineral matter added is wind-blown sand, which can be observed caught in plant leaves at all elevations.

A typical rich fen peat formed on decomposing rock in situ, is described in Table 30.

Water relations. A permanent water table is present in the peat profiles, normally somewhere between 0 and 18 inches from the surface, the actual height depending on the degree of slope and other factors affecting drainage. In any one site the water table level remains very constant throughout the year.

Plate 39. 7 feet soil pit in rich fen peat, one day after digging. (ANARE Photo).

Poor fen peats. All communities of the herbfield and fen formations, which grow on the raised beach terrace, occur on these soils. These include most communities of the *Pleurophyllum hookeri* and *Juncus scheuchzerioides* alliances.

Occurrence. The actual areas covered by these soils can be seen from the vegetation maps. They occupy those areas of the coastal flats mapped as herbfield, excepting a small area at Handspike Point, which is covered by bog soils.

Substrata. The mineral subsoils of these peats have never been examined. Geographical evidence is irrefutable that they are marine-deposited sands and gravels (Mawson, 1943). A study of plant succession strongly points to the fact that these marine deposits are covered by up to 5 feet of what originally was highmoor peat. This observation was confirmed by Bunt 1952. He found what was originally a highmoor peat underlying poor fen peat near the border of the area of poor fen soils.

Profile characteristics. The depth of the peat layer was estimated as being fairly uniform at 15 to 20 feet. Wherever examined it was at least 8 feet deep, but pits could not be dug deeper, because of the extremely rapid influx of water.

These peats are markedly different from rich fen peats. The rate of decomposition is slower and throughout the depths of peat examined, plant remains were readily identified. At a depth of 5 feet woody stems of *Acaena* spp. were easily recognised. The peat appears fibrous, but the fibres have no strength whatever; once the surface vegetation is removed pits can be easily dug using a steel bucket only. This type of peat has been called pseudofibrous. On air drying, however, it becomes very tough and resistant.

Other differences between rich and poor fen peats are that rich fen peats are very sticky and adhere to clothes, skin, tools, etc., while poor fen peats do not adhere at all. Further, the rate of movement of water into a soil pit in a poor fen is very rapid (at least ten times faster than in a rich fen).

The main differences observed in the peat of a poor fen profile are due to the differences in the various plant communities forming the peat, the particular plant community present at a given time being dependent on the minor topography causing minor fluctuations in the level of the water table. This minor topography is itself controlled by the different rates of peat accumulation of the different communities. Thus a poor fen profile shows unmistakeable evidence of the succession of many different plant communities in the past.

Small patches of red crystals which are presumed to be bird excreta are frequently seen in these peats. In addition, small patches of rounded gravel are frequent in rich fen peat and it is assumed that they are also left by birds. The surface 5 feet of a typical poor fen peat are described in Table 31.

TABLE 31

Poor Fen Peat.

Profile No. 16.

Vegetation: *Juncus scheuchzerioides-Scirpus aucklandicus* association.

Location: 30′ elevation. Raised beach terrace 300 yards from sea, Half Moon Bay. Slope almost nil.

Permanent water table at 1 inch.

Sample No.	Depth in Inches		pH	% Loss 105°C.	% Loss 400°C.	% Chloride	mgms. PO_4 per 100 gms.
16A	0-4	Light brown pseudo-fibrous peat derived from a fen community.	4.5	13.4	90.1	.219	3.35
16B	4-12	Brown pseudo-fibrous peat, many plant roots.	4.6	16.2	93.5	.190	1.12
16C	12-20	Dark brown pseudo-fibrous peat derived from *Pleurophyllum hookeri* community.	4.6	15.4	93.1	.253	.24
16D	20-28	Brown pseudo-fibrous peat derived from *Pleurophyllum hookeri* community, few live roots.	4.6	18.6	89.9	.250	.27
16E	28-40	Brown pseudo-fibrous peat, derived from *Pleurophyllum hookeri* community. *Stilbocorpa polaris* very frequent.	4.5	19.9	84.6	.239	.36
16F	40-48	Dark browi pseudo-fibrous peat, derived from a *Pleurophyllum hookeri* community.	4.4	16.4	92.3	.335	.31
16G	48-52	Very dark brown pseudo-fibrous peat, derived from a society of *Acena* sp.	4.6	13.5	88.7	.242	1.04
16H	52-	As 16G.	4.8	14.2	91.2	.254	1.55

Factors affecting the formation of fen peats.

(i) *Climate.* Similar effect to that operating on highmoor peats.

(ii) *Topography.* This is the deciding factor which differentiates fen peats from bog and most highmoor peats. It is also the deciding factor influencing the formation of rich or poor fen peats.

Fen and bog peats are differentiated from highmoor peats through the presence of a water table in the peat profile, the presence or absence of which is largely determined by the influence of topography on drainage.

Fen peats are differentiated from bog peats by the presence of a high content of dissolved salts in the ground water. Thus fen peats form in areas where at least part of the ground water has previously flowed through mineral soil or subsoil by lateral drainage from the surrounding slopes. The mineral soils of the island, being derived from basic rocks, are all high in soluble salts.

Rich and poor fen peats are differentiated by the proportion of direct rain water and drainage water in the soil. A relatively high proportion of drainage water results in the formation of a rich fen; a low proportion in the formation of a poor fen peat. This proportion is determined by the topography. Only on the intensive flats of the raised beach terrace does the proportion of drainage water drop low enough to permit the formation of poor fen peats.

(iii) *Biotic factors.* The plant communities are responsible for the deposition of plant remains and micro-organisms for their conversion to peat. However, the various plant communities have no significant effect on the type of fen peat formed, though superficially, differences in the appearances of poor fen peats do occur.

(iv) *Time.* It is most probable that the depths of fen peats are still increasing. This is certainly the case with the extensive deposits of poor fen peats where the decomposition rate is very low.

(v) *Parent material.* The available parent materials show no differences in their overlying peats, but only differences in the mineral subsoil.

(*c*) *Bog peats.*

Bog peats are peats formed on flats or very slight slopes, with a permanent water table in the profile, which has never been in contact with mineral soil, and is consequently very low in dissolved nutrient salts.

Vegetation. The vegetation growing on these soils consists of a whole range of bog communities dominated by mosses, or in a few instances by *Colobanthus muscoides.*

Occurrence. Bog soils are found on Macquarie Island only on the largest points of the west coast terrace. Here they are entirely unaffected by drainage water from the steep plateau slopes, receiving water only as rain falling directly on the area.

Profile characteristics. Unfortunately, these soils were examined superficially and never sampled. They appear very similar to poor fen peats, but having a slower rate of decomposition there is a very gradual change from living to dead material and thence to peat. The water table level approximates the surface only occasionally being an inch above or below it. The surface in this instance is taken as the flat top of the living moss carpet, which may be as much as 1 foot above true peat. The depth of these peats has been estimated to be as least as great as the poor fen peats (15 to 20 feet).

Factors affecting the formation of bog peats.

All factors, excepting topography, have a similar effect to those operating on poor fen peats. The soils are limited to those areas where topography determines that all ground water comes from rain and none from drainage through mineral soils.

2. MINERAL SOILS

The dry tundra soil complex. These soils are gravelly loams with a high percentage of organic matter. The formation of a peat soil is prevented by the very slow growth rate, due to high wind velocities, of the plant communities growing in the area. This is so even though the soils are subject to lower temperatures than those prevailing in most areas supporting peat soils, and thus have a lower decomposition rate. These soils have been called dry tundras and have many points of similarity with the dry tundra soils of the Northern Hemisphere which have been formed under a continental climate. However these show many points of difference, notably in the absence of a glei horizon and of perpetually frozen subsoils.

The soils of the complex show marked differences in different topographical positions and with differing parent material. The major differences are correlated with the presence or absence of a permanent water table in the soil profile, with surface cover and surface contours, associated with wind effects, and with depth and texture associated with different parent materials.

The major division of the complex is between the widespread types, which have a high water table for only short periods, and those types receiving drainage water from surrounding slopes, which have a permanent water table near the soil surface.

Occurrence. The areas occupied by soils of this complex can be seen accurately on the vegetation map. The boundaries of the dry tundra soils correspond exactly with the boundaries of the feldmark formation. Where other plant communities can grow, their growth rate is much more rapid and peat soils are formed. Thus dry tundra soils occur on the higher flats and ridges of the island where wind velocities are very high.

Well-drained soils of the dry tundra complex. These soils have been further subdivided into several types mainly on the nature of their surfaces, on the amount and permanency of plant cover or of a wind resistant layer of rock fragments (the latter is correlated with the amount of organic matter throughout the profile), and on the presence or absence of a peaty layer at the soil surface. They also show differences in surface contours. One of the most noticeable facts about the whole area covered by the complex is the well-marked terracing, which is discussed in detail below.

The well-drained soils also show marked differences with different parent materials, notably with different types of glacial till and with rock in situ. All these types grade into one another.

Type 1—Well-drained soils with a continuous plant cover.

Vegetation. Azorella selago or *Azorella selago-Pleurophyllum hookeri* association.

Occurrence. It is found very infrequently in the most sheltered areas of the complex, where wind velocities are just too great to permit the formation of highmoor peats. These soils are commonly found at the lower borders of the complex, but occur occasionally at higher elevations, notably at the very top of a steep slope leading down from a flat wind-swept ridge. The sudden change in topography results in a relatively wind-free area for up to 100 feet.

Parent materials. These are the same as all dry tundra soils, and include rock in situ together with a wide variety of glacial tills. All parent materials, however, are very similar in chemical composition.

Profile characteristics. The surface is completely covered by a mat of living plants. Below this there is a layer of a few inches which may approach very closely to a peat but below this the amount of organic matter rapidly decreases. These lower layers are characteristically very gravelly, silty loams. When formed from rock in situ, the soil is shallow and the gravel angular. Glacial till, however, permits of much greater penetration of weathering and weathered soil merges gradually with unaltered till, which may, in extreme cases, be several hundred feet in depth.

There is no uniform sequence of texture down a profile, owing to the masking effects of different types of glacial till. Two processes, however, seem to be occurring: First, clay and silt are slowly formed by weathering which is more rapid as the surface is approached; secondly, some clay and silt are removed by the excess of precipitation.

Water relations. These dry tundra soils are well drained because of the high percentage of rock, gravel and sand which they contain and also because of the steepness of the slopes on which they occur. After a period of heavy rain a water table may be formed in the profile, but this generally drains away within a few days.

No running creeks pass through the area of the complex, though a few commence just within its borders. Water was very rarely observed running over the surface of any soil of the complex, even on steep slopes during heavy rain. This was due to the rapid infiltration rate and to the fact that the surfaces consisted of either highly absorptive cushion plants, or large gravel fragments, bare mineral soil being never exposed.

Type II—Well-drained dry tundra soils with a discontinuous plant cover.

This soil type constitutes the bulk of the soil of the complex and includes soils formed on slight slopes and flats, and on the steeper slopes, the latter position being generally associated with terrace formation.

Vegetation. Three plant associations grow on these soils: *Azorella selago; Azorella selago-Rhacomitrium crispulum; Rhacomitrium crispulum* associations; these replace each other with increased wind velocities. The vegetation on the greater part of this area is moving slowly downwind owing to death on the windward side and regrowth on the lee. However, owing to the nature of the terraces on leeward slopes, the vegetated areas here are stable in position.

Profile characteristics. The amount of organic matter in the profile is less than in Type I, the amount present being dependent on whether or not plants are growing on the immediate surface or not; but even under a gravel surface the amount of organic matter is high. This is due partly to the fact that most bare areas were once vegetated and also to a movement of organic matter in solution.

The organic content decreases regularly with depth but in porous soils it may still be appreciable at 6 feet.

Where no plants are growing, the soil surface is always covered by a layer of gravel with no silt or clay visible. The minimum size of gravel exposed is uniform for an area and increases with increasing wind exposure. The gravel consists of angular fragments (sometimes glacially rounded) of the basic rocks of the island and is always greyish in colour.

Beneath the surface the soils vary widely in gravel content and mechanical constitution, depending on the composition of the original glacial till. Where the soils are formed on weathered rock in situ the true soil may be only 6 inches to 1 foot in depth. Description of a typical soil, formed on glacial till, is given in Table 32.

TABLE 32

Well-drained Dry Tundra Soils (Type II)

Profile No. 7.

Vegetation: 10 per cent. cover of *Rhacomitrium crispulum* association.

Location: 825′ elevation. Flat ridge top, North End. Slope 0°-1°.

Glacially rounded boulders up to 18 inches in diameter frequent throughout the whole profile. Soil quite moist below 7 inches depth.

Sample No.	Depth in Inches	Field Description	pH	% Gravel	% Silt	% Clay	% Loss 105°C.	% Loss 400°C.	% Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
7A	0-½	Rock fragments, angular and rounded. Size range ¼ in.-½ in.									
7B	½-4	Dark brown, gravelly, peaty loam, few plant roots. Most gravel under ¼ in. diameter.	5.1	120	17	7.5	6.3	19.3	5.15	.005	1.53
7C	4-7	Dark brown, gravelly, peaty loam, very few plant roots.	5.0	150	9.5	20	12.0	15.0	4.34	.006	1.47
7D	7-12	Yellow brown, gravelly loam.	5.2	70	14	15	9.3	12.9	3.46	.006	.44
7E	12-18	Reddish brown, fine gravelly loam.	5.3	70	12.5	11.5	13.5	10.6	2.98	.005	2.23
7F	23-25	Reddish brown gravel.	5.4	600			13.4	11.1	2.45	.006	3.04
7E	18-23	Reddish brown, very gravelly loam.	5.3	250	7	5	5.9	10.7	1.84	.002	1.88
7G	25-32	Light reddish brown, very gravelly loam.	5.5	250	8	19	9.6	7.4	1.58	.006	.83
7H	32-46	Light yellow brown, very gravelly loam.	5.4	250	10	18	6.0	4.1	1.00	.004	1.64
7I	46-60	As 7H.	5.5	300	13	12	4.7	4.8	.92	.004	1.04
7J	60-72	As 7H.	5.6	250	7	8	4.1	3.9	.66	.002	2.12

Factors affecting the formation of well-drained dry tundra soils.

(i) *Climate.* The local climate prevents peat formation by the suppression of plant growth by wind. However, temperatures are so low that the decomposition of organic matter is very slow and most soils have a high content of organic matter.

The soils are subject all the year round to much freezing and thawing. This probably has a churning effect on the soil, besides contributing to mechanical division of the soil with a tendency to form silt. The churning effect on bare grounds results in a certain amount of gravel and fine soil being brought to the surface and exposed to the action of the strong winds. Wind and water washing then removes all fine material from the soil surface, leaving only a wind resistant layer of gravel.

(ii) *Topography.* The main effect of topography is its influence on the local climate, mainly in the intensity of wind exposure but also on drainage.

There is a certain amount of soil creep due to freezing, thawing and solifluction. As a result the depth of soil is often less on the tops of ridges and increases down the slopes.

(iii) *Biotic factors.* Differences due to different plant communities supplying the soil organic matter are very slight. The main effect is due to the different growth rate of various communities which is in itself dependent on local climate and results in differences in organic content.

(iv) *Parent material.* This, as previously mentioned, results in major differences in texture, depth of weathering, etc., of the resultant soils.

Poorly-drained soils of the dry tundra complex.

Soils of the dry tundra complex where a permanent water table is present high in the profile as a result of drainage from the surrounding slopes have been placed in this group.

Vegetation. Plant cover varies from 0-10 per cent., consisting of scattered cushions of the *Azorella selago* association.

Occurrence. It is very rare, and is formed only in almost flat basins surrounded by steeper slopes where the wind velocity prevents the growth of peat-forming plant associations.

Parent material. This consists of glacial till and soil brought down by creep from the surrounding slopes.

Profile characteristics. (i) Surface features. The vegetation cover never exceeds 10 per cent., the remainder of the ground being covered by angular rock fragments overlying a gravelly loam.

The surface contours of both gravel and loam are most peculiar. All the gravel surface is thrown up in a series of waves, 6 to 12 inches from crest to crest depending on the slope of the area, with the long axis of the waves always running downhill. When this gravel is removed it can be seen that the wave shape is even more accentuated in the surface of the gravelly loam. The troughs in the loam are all filled with gravel with no finer material at all, and thus a series of channels is formed, 3 to 6 inches

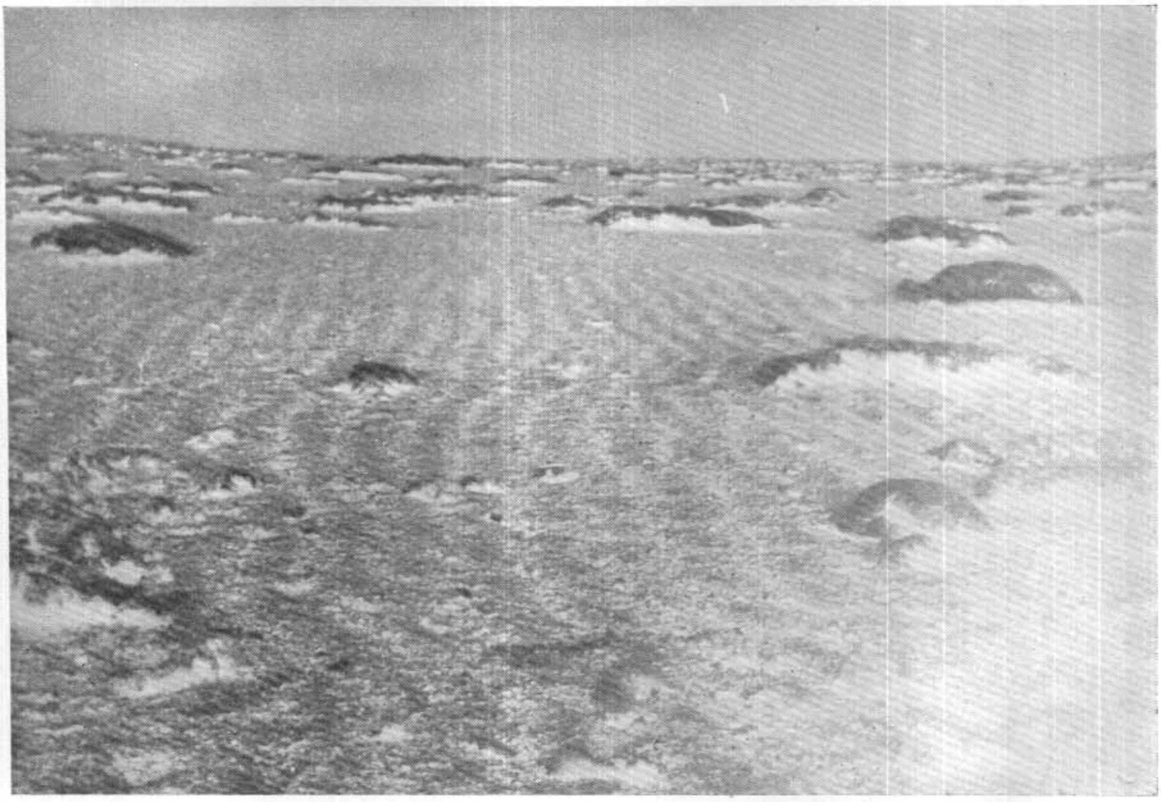

Plate 40. "Drainage channels" in poorly drained dry tundra soils. Channel crests 10 inches apart. Note the channels curving round the cushion of *Azorella selago*, middle right. (ANARE Photo).

deep, which have been followed down a gentle slope for a hundred yards or more. These channels follow the natural drainage pattern of the area, and where this narrows, individual channels coalesce, deepen and become narrower, finally to disappear into a small creek at the very edge of the dry tundra complex.

The slopes down which these channels flow are generally very slight, from 0-5°. The channels tend to swing round any surface obstacle, such as a cushion of *Azorella selago*. These cushions are slowly moving downwind, as a result of death on the windward side and regrowth on the lee. It follows that the curvature of the channels round these obstructions is also moving uphill, and that the structure of the channels is still being modified.

Plate 41. Commencement of soil profile No. 20 in poorly drained dry tundra soils. Channels visible in foreground. Windward type terraces on slope in background. (ANARE Photo).

(ii) Profile features. Underneath the wave-like gravel surface the gravelly loam may extend to a depth of 1 foot or more. Beneath this there is a horizon 1 to 3 inches deep bright orange to brick red in colour due to the deposition of sesquioxides. Below this deposition horizon there may be a little weathered till or, more rarely, weathered rock in situ.

Water relations. These soils are characterised by a high permanent water table. On almost imperceptible slopes, this table remains almost constantly at the very bottom of gravel filled channels; any rise subsequent to a period of heavy rain is rapidly drained down the channels.

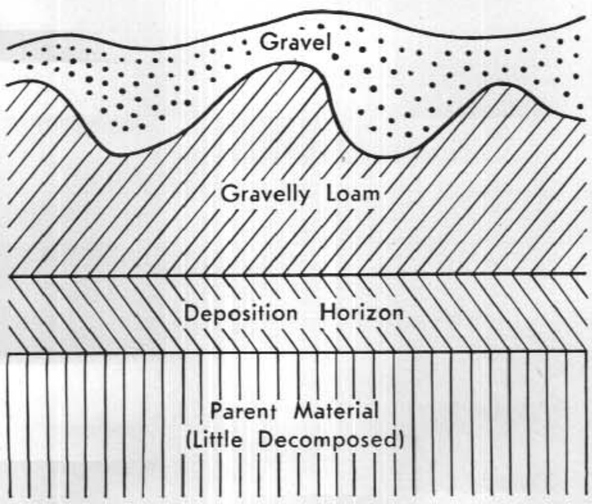

Fig. 8. Vertical Section through Poorly Drained Dry Tundra Soil.

Description of a typical profile is given in Table 33.

Factors affecting the formation of poorly drained dry tundra soils.

Factors affecting these soils are very similar to the rest of the dry tundra soils, but the surface corrugations and the deposition horizon deserve special mention.

TABLE 33

Poorly-drained Dry Tundra Soil.

Profile No. 20.

Vegetation: *Azorella selago* association 5 per cent. cover.

Location: 800′ elevation. Windward side of North Mountain(1) in a small basin. Slope: 1°-2°.

Water table 3 inches from surface.

Surface corrugated, wave crests 10 inches apart, 80 yards long. Gravel channels 3 inches deep. Profile taken from a wave crest. This profile passes through an old pond site.

Sample No.	Depth in Inches	Field Description	pH	% Gravel	% Silt	% Clay	% Loss 105°C.	% Loss 400°C.	% Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
20A	0-¼	Gravel layer.									
20B	¼-3	Brown gravelly clay loam.	5.3	15	10	30	7.3	5.9	1.15	.008	3.6
20C	3-6	Orange brown gravelly clay loam.	5.9	15	21	25	11.0	5.8	.31		
20D	6-8	Red, gravelly loam.	6.0	25	14	24	16.8	6.5	.18		
20E	8-11	Brown silty loam, little gravel.	5.9	8	13	20	7.4	5.7	.21		
20F	11-14	Yellow brown clay loam.	6.1	35	24	24	7.2	4.5	.11		
20G	14-15	Bright orange silty clay.	5.8	.1	26	30	14.6	5.2	.30		
20H	15-22	Very compact brown silty clay with mottling of decomposing pebbles. Old pond deposit.	5.8	.2	30	39	9.0	6.6	.56	.006	1.2
20I	22-30	Green gravelly loam of decomposing rock in situ.	6.0	2	12	15	11.2	3.2	.05		

(i) *Formation of corrugated surface.* The only agency which could cause the expansion necessary to throw the surface into waves appears to be freezing and thawing of the ground water. Wetting and drying with a subsequent expansion is ruled out as the soils are always very moist even at the immediate surface.

Once these surface waves are formed, gravel deposited in the troughs is kept clear of finer material because the waves operate as channels for the draining off of excess water.

(1) A peak at the north-east corner of the plateau.

The process of uplift is still continuing. This is borne out by the fact that channels curve round cushion plants (which are moving slowly) and the changes in the height of the wave crests can be observed from time to time following a freeze.

(ii) *Deposition horizons.* The soil profile is receiving water which has drained through the soils of the surrounding slopes. This water passes rapidly through the soils on the slope and may stand for long periods on the basin flat, apparently picking up and redepositing sesquioxides.

It is interesting to note that the sesquioxides deposited have a bright orange colour indicating a high percentage of iron in the ferric state, though they may be deposited as much as 12 inches below a permanent water table. This may be due to the fact that the water is rapidly replaced and is well aerated.

Terracing in the dry tundra complex.

Well-marked terraces are a distinctive feature of the highlands of Macquarie Island. Their occurrence is strictly limited to the area of the dry tundra soils. Three main types occur, all on slopes, and these may be classified without exception by their relationship to the prevailing wind: (a) terraces of east-facing slopes (leeward), (b) terraces of west-facing slopes (windward), (c) terraces of north or south-facing slopes.

(*a*) *Lee slope terraces.*

Occurrence. This terrace system occurs in sharply delineated areas of the dry tundra complex. The terraces are only found on east-facing slopes, which are in the lee of the prevailing westerly wind. As the main ridge of the island runs north and south, at right angles to the prevailing wind, such east-facing slopes are very common. So dependent is the formation of the characteristic lee terrace on the wind effects operating on a lee slope, that its occurrence has been used as a rough, but infallible, guide to direction even in the densest mists.

Description. The terraces have sharply defined slopes and flats and run along the contour for distances of up to a mile or more. A series of terraces runs up a lee slope, giving the effect of a giant stairway. The steepness of the terrace slope approximates 25°. Other dimensions are very variable; the vertical height of each terrace averages from 4 to 5 feet but may be anything from 2 to 20 feet; the width of slopes and flats also vary but average 10 and 15 feet respectively. The height of each terrace, and also the widths of slope and flat, seem to be dependent on the steepness of the slopes on which they are formed; with steepening of the topography, terrace height and slope width increase, terrace flat width decreases.

The arrangement of vegetation is characteristic. The slopes of the terraces are always completely covered by vegetation of the *Azorella selago* association, while the terrace flat may be bare of vegetation, or with a sparse cover of *Dicranoweisia antarctica* association. The ground unprotected by vegetation is, like all bare dry tundra soils, covered by a continuous gravel layer.

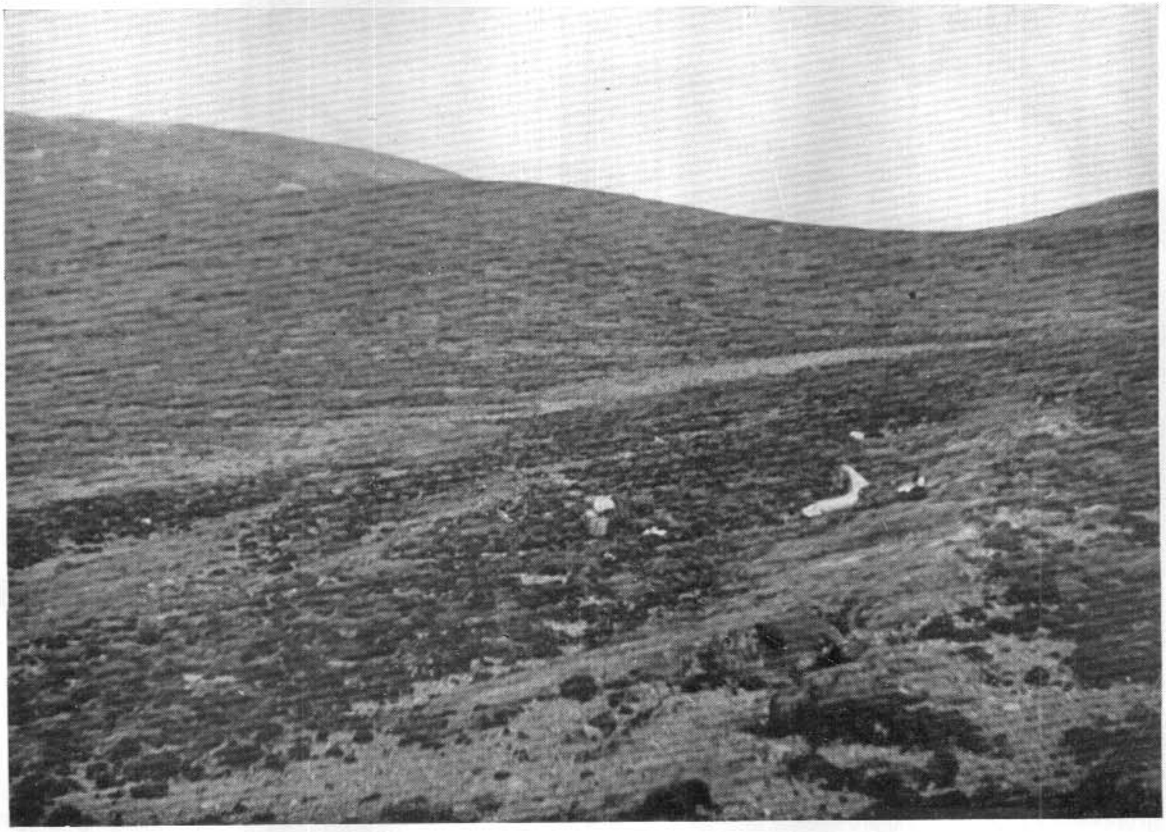

Plate 42. Lee slope terraces. Terrace slope covered by *Azorella selago* association. Terrace flat covered by an unusually dense stand of *Dicranoweisia antarctica* association. (ANARE Photo).

The soil profiles under the terrace slope and flat are similar to those under vegetated and bare areas respectively, found elsewhere in the dry tundra complex. However, owing to their general occurrence on fairly steep slopes, the parent material is seldom glacial till but generally weathered rock in situ, together with material carried downward by soil creep. As a result, the proportion of gravel is relatively small, and the soils shallow. The transition to bed-rock is frequently sharp and the rock tends to follow the surface contour of the terrace. This indicates that the size, shape, and position of tne terraces are relatively permanent. No sign that the vegetation or bare areas were moving was ever observed.

Water relations. As with the typical dry tundra soils, a water table forms only after a period of heavy rain and rapidly drains away. However, this water table drains away most rapidly from the top of a terrace slope and least rapidly on the terrace flat nearest the foot of a slope, indicating that the drainage is directly down the slope.

A description of the soil found under a lee slope terrace is given in Table 34 and a diagram of a vertical section through a terrace in Figure 7.

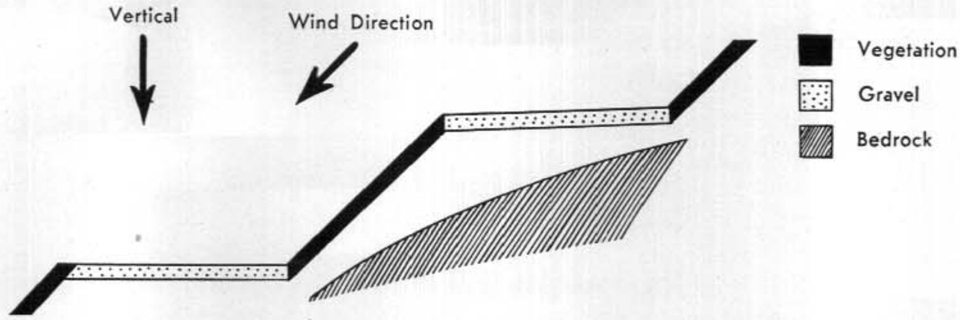

Fig. 9. Cross Section of Leeward Terrace, Macquarie Island.

TABLE 34

Soils under a Lee Slope Terrace, Dry Tundra.

Profile No. N and No. Q.

Location: 650′ elevation. Eastern slope of North Mountain. Overall slope 15°. Profile N from terrace slope, profile Q from terrace flat.

Vegetation: Profile N, 100 per cent. cover of *Azorella selago* association. Profile Q 2 per cent. cover of *Dicranoweisia antarctica* association.

Parent Material: Rock in situ, and material deposited by soil creep.

Sample No.	Depth in Inches	Field Description	pH	% Gravel	% Silt	Clay	% Loss 105°C.	% Loss 400°C.	% Chloride	mgms. PO_4 per 100 gm.
		PROFILE N								
N1	0-2	**Mat of Azorella selago.**								
N2	2-10	Brown peaty, gravelly loam.	4.7	40	25	45	12.7	25.1	.020	1.27
N3	10-14	Brown, very gravelly loam.	4.9	300	12	32	7.5	11.5	.012	4.03
		PROFILE Q								
Q1	0-½	Surface layer of angular gravel.								
Q2	½-3	Brown gravelly loam.								
Q3	3-11	Reddish brown, very gravelly loam.	4.7 4.7	25 300	8 12	40 44	6.9 10.0	14.6 11.4	.013 .018	1.95 .75

(*b*) *Windward slope terraces.*

Occurrence. These terraces are found only on windward slopes in the area of the dry tundra complex. However, they cannot form on the steeper slopes.

Description. The major difference between this type of terrace and terraces on lee slopes is that here the terrace slope is bare, not vegetated, while the flat is fully vegetated, not bare.

Since the terrace slope is bare of vegetation, it cannot form at such a steep angle as the lee type; consequently steeper slopes are never terraced. The vegetated flat is constantly being eroded at its downhill end, leaving a sheer bare face of peaty soil, which may be one foot in height. The slope is continually creeping onto the vegetated flat, and the vegetation is slowly advancing on the uphill end; as a result the whole terrace is moving slowly uphill.

The terraces are not as well formed as lee terraces. They run along the contour but rarely exceed 15 yards in length. The vertical height averages 4 feet, the terrace flat 5 feet in width, and the slope from 8 to 15 feet in width.

Windward terraces, never being formed on very steep slopes, are generally formed on glacial till and their soil profiles are normal for dry tundra soils.

The terrace flats are covered completely by vegetation of the *Azorella selago* association or the *Azorella selago-Rhacomitrium crispulum* associa-

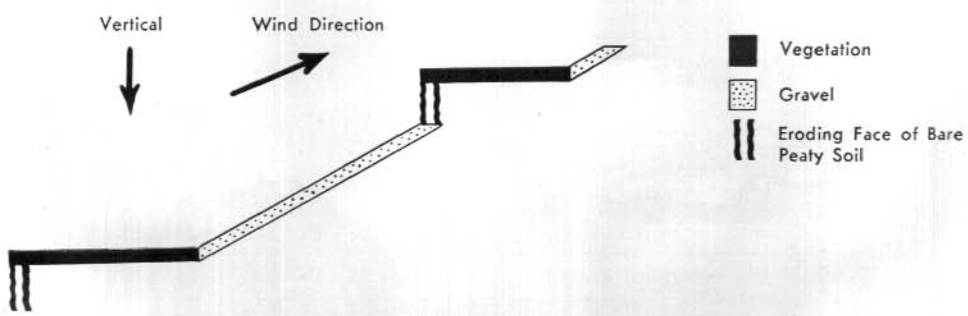

Fig. 10. Cross Section of Windward Terrace, Macquarie Island.

tion. Unlike the lee terraces, no vegetation ever grows on the gravel surface, probably because this is on a slope and the surface is thus unstable.

Water relations. The temporary water table rapidly drains away, but as with the lee terraces, it disappears more quickly under the terrace slopes. However, the soil is generally fairly moist and water very slowly oozes out of the uphill sides of soil pits.

Profile descriptions are given in Table 35 under a terrace flat, and Table 36 under a terrace slope. A diagram of a vertical cross section is shown in Figure 8.

TABLE 35

Soils under a Windward Terrace Flat, Dry Tundra.

Profile No. X.

Location: 875′ elevation. Western slope of North Mountain terrace flat.

Vegetation: *Azorella selago-Rhacomitrium crispulum* association.

Sample No.	Depth in Inches	Field Description	pH	% Gravel	% Silt	% Clay	% Loss 105°C.	% Loss 400°C.	Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
1	0-4	Gravelly dark brown peaty loam. Gravel generally under ½ in. in diameter.	5.2	25	16	7	5.9	14.4	4.30	.005	1.53
2	4-9	Very gravelly, brown peaty loam. Many plant roots.	5.2	150	18	10	6.4	11.9	3.69		
3	9-16	Very gravelly yellow loam, occasional plant roots.	5.0	150	17	12	6.4	6.9	.74		
4	16-24	Very gravelly, yellow brown loam with large pieces of decomposing rock.	5.3	150	18	14	6.4	7.5	.56		
5	24-36	Very gravelly, yellow brown loam, with green and red mottlings of decomposed rock.	5.6	150	21	16	8.6	5.9	.20		
6	36-48	As 5, but more gravel.	5.5	200	21	16	8.1	5.9	.16		
7	48-58	As 5, with still more gravel.	5.7	400	24	22	8.1	6.0	.14		

TABLE 36

Soil Formed under Windward Terrace Slope, Dry Tundra.

Location: 800′ elevation. Western slope of North Mountain.

Vegetation: Immediate surface bare. Surrounding vegetation *Azorella selago* association.

Sample No.	Depth in Inches	Field Description	pH	% Gravel	% Loss 105°C.	% Loss 400°C.	% Silt	% Clay	% Organ. Carbon	% Chloride	mgms. PO_4 per 100 gms.
1	0-½	Angular grey gravel. ½ in. in diameter.									
2	½-2	Dark brown loam with much gravel to 1/3 in. in diameter.	5.0	150	5.3	11.2	13	20	2.86	.005	.55
3	2-6	Brown gravelly loam.	5.2	40	7.4	10.2	19	12	2.22		
4	6-12	Grey brown gravelly loam.	5.0	70	8.5	6.1	18	10	.71		
5	12-24	Compact yellow brown gravelly loam. Large masses of decomposing rock.	4.9	70	7.2	4.3	22	13	.17		
6	24-36	As 5.	5.5	70	8.3	5.1	14	14	.12		
7	36-48	As 5.	5.2	100	10.2	5.3	30	17	.08		
8	48-57	As 5.	5.5	150	7.2	5.0	12	14	.12		

(*c*) *Terraces on north and south-facing slopes.*

Occurrence. Special terraces form on a few slopes in the area of dry tundra soils where the slopes are facing nearly north or south. Such slopes are relatively rare on the island, for the main ridge of the island runs north and south.

Description. These terraces somewhat resemble lee slope terraces, but are never formed along the contour. They tend to run down the slope and may be at an angle of 70° from the contour. The alternating strips of gravel-covered and vegetated areas of the terraces may curve but are always so orientated that the gravel surface is exposed to the wind, which on these slopes tends to be horizontal along the slope, whilst the vegetated areas are protected.

The bare areas are generally completely free of vegetation or may have a sparse cover of *Dicranoweisia antarctica* association. The vegetated area is completely covered by *Azorella selago* association.

Factors affecting terrace formation.

All three types of terraces are so arranged that the plants growing on them are protected from the prevailing wind. On looking downwind

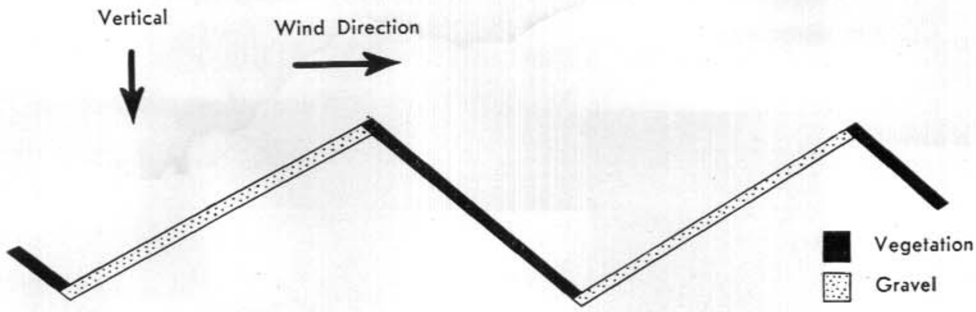

Fig. 11. Cross Section of North Slope Terrace.

in any terrace system little vegetation can be seen, the exposed surfaces being almost entirely gravel. Looking upwind little gravel can be seen and these protected surfaces are almost entirely covered by vegetation.

It is apparent that little or no vegetation can grow exposed to the full blast of the wind.

Lee type terraces, as already stated, are presumed to be fairly stable in position and shape. Here, terrace formation probably follows the establishment of a few scattered cushion plants growing in the most favourable sites. Soil creep then deposits material on the upper side of the cushions which protects them from the full effect of the wind and permits downhill and lateral growth until a series of small terraces are formed, which slowly expand laterally and coalesce.

Any difference in level between the two small terraces would cause turbulence of the wind, with death of the plants at the higher level and a redistribution of soil material by creep. The terraces would then be linked up in long bands at right angles to the wind direction which in this case would be along the contour.

Even though the wind direction is not quite parallel to the slope, redistribution of material by soil creep would tend to make the terraces still follow the contour. In the case of terraces on north or south-facing slopes, however, redistribution is over-ridden by the direction of the prevailing wind being nearly along the contour. It is interesting to note that terraces on such slopes do not form straight lines, but are curved wherever local topography changes the wind direction, the terraces always being at right angles to wind direction.

Windward terraces are formed similarly to lee types, but here the whole terrace is slowly moving uphill and adjacent terraces have not been able to link up.

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On his return to Australia, the author finished this work in the Botany Department, Sydney University. He wishes to record his indebtedness to Professor N. A. Burges for his advice and encouragement and also for the use of the facilities of the Department, and to all members of the staff of the Department. A particular debt is due to Dr. N. C. W. Beadle under whose supervision this report was written and who was always ready with advice and criticism on all aspects of the work, and also to Honorary Professor L. G. M. Baas-Becking for his advice and interest, notably in the section of the report dealing with the origin of the island's flora.

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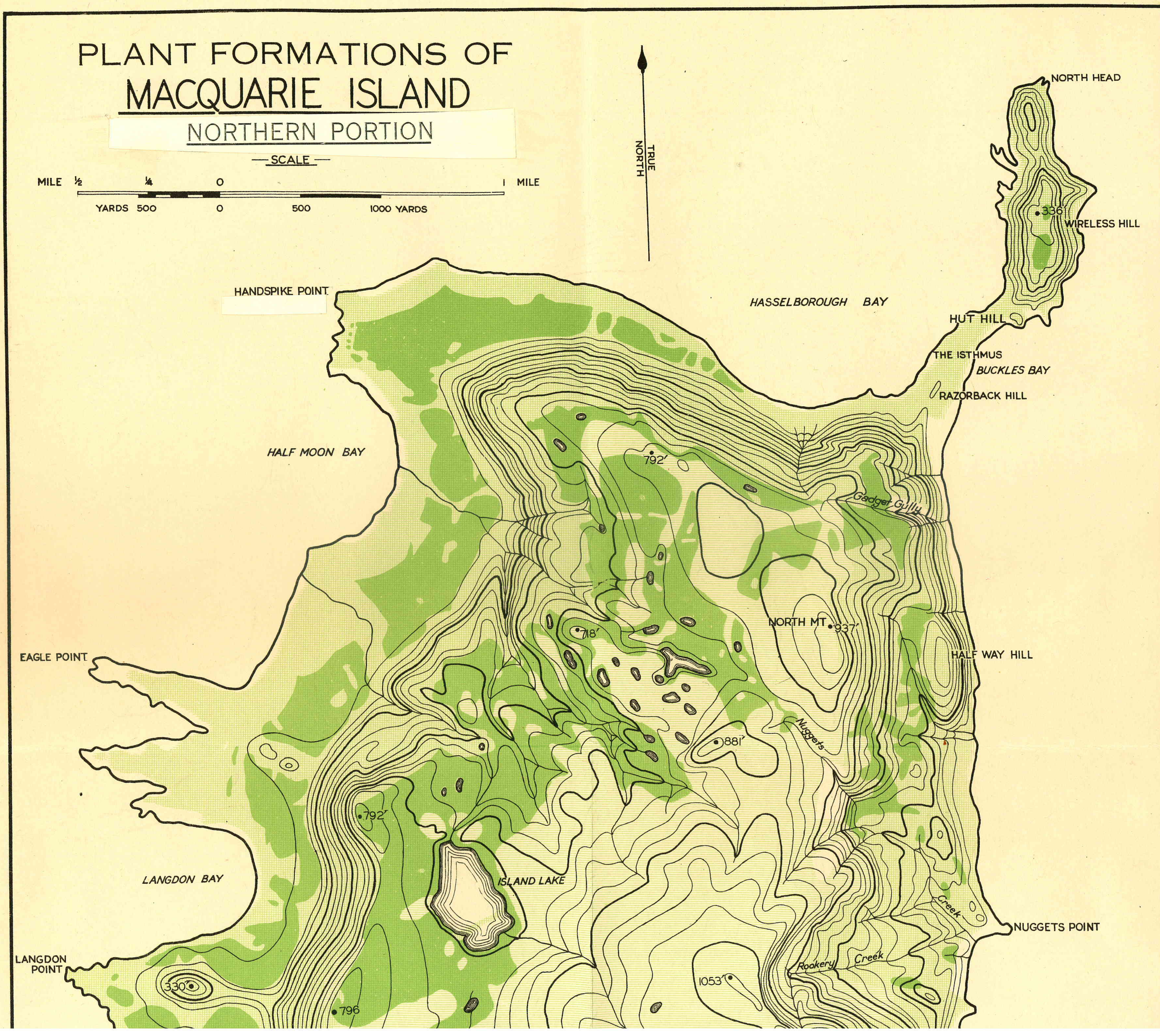
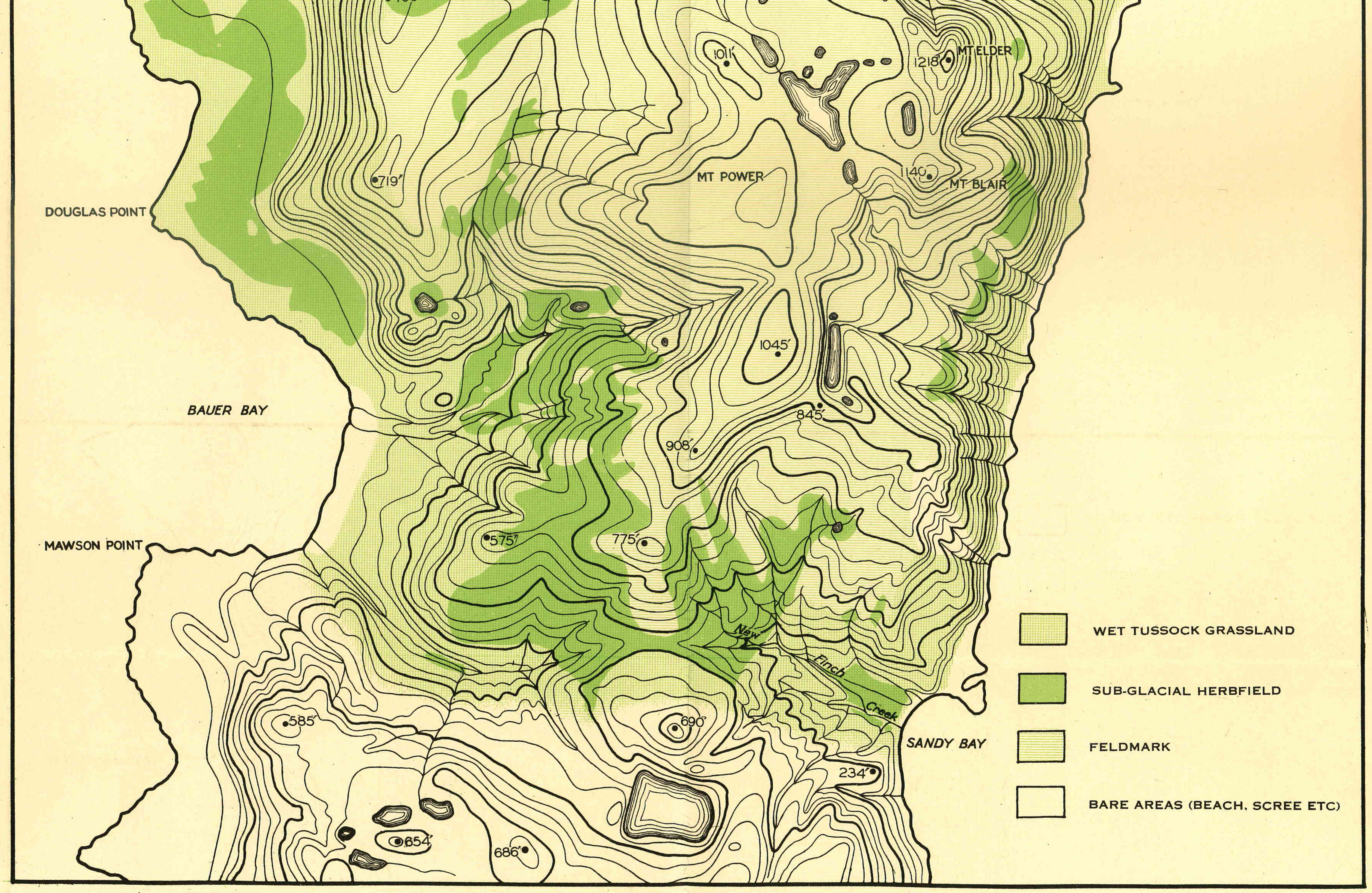
PLANT FORMATIONS OF
MACQUARIE ISLAND
NORTHERN PORTION

—SCALE—

MILE ½ ¼ 0 1 MILE

YARDS 500 0 500 1000 YARDS





AHQ/A6-12/0232


ELLIOTT
REEF
NORTH HEAD
Hasselborough
20
Bay
WIRELESS HILL
LORD NELSON REEF
HANDSPIKE PT.
Half Moon Bay
Buckles' Bay
Gadget Gully
HALF WAY HILL
EAGLE PT.
Nuggets Ck.
Langdon Bay
Island L.
LANGDON PT
NUGGETS PT
Rookery Ck.
MT ELDER
MT BLAIR
MT POWER
DOUGLAS PT
Bauer Bay
MAWSON PT
Scoria Ck.
Finch Ck.
Sandy Bay
Flat Ck.
MT TULLOCK
BROTHERS PT
MT HARRISSON
Prion L.
MT EITEL
AURORA PT.
MT. IFOULD
GREEN GORGE
MT STRAHAN
MT WAITE
Sawyer Ck.
Flynn L.
MT BLAKE
PYRAMID PK
DAVIS PT.
VICTORIA PT.
Sandell Bay
Waterfall Bay

PLANT FORMATIONS OF MACQUARIE ISLAND

SCALE

0 1 2 3 MILES

STATUTE

CONTOUR INTERVAL 200 FEET

WET TUSSOCK GRASSLAND

SUB GLACIAL HERBFIELD

FELDMARK

AHQ/A6-12/0231