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A STUDY OF ECOLOGICAL INTERACTION  
BETWEEN INTRODUCED AND INDIGENOUS PLANT SPECIES  
IN THE MANAWATU DISTRICT, NORTH ISLAND, NEW ZEALAND.

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J. A. CARNAHAN.

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#### NOTE.

The writer is a member of the teaching staff of Massey Agricultural College, Palmerston North, enrolled as a "staff candidate" for Ph.D., under the supervision of Dr. J.S. Yeates. The major part of the field work was carried out in 1954, during a year's leave from teaching duties.

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## INTRODUCTION.

The object of the present work has been to investigate, for one district of New Zealand, the sociological relations between the indigenous plant species and those introduced to the country by man.

The result of the invasion of New Zealand by people of European origin, and by the plants and animals that they introduced, has been well described by Clark (1949: v) as "a revolutionary change in the character of a region, which occurred in a period of less than two centuries". From the botanical point of view, Cockayne (1928: 361) has said of the present situation: "There are two distinct areas, the one dominated by primitive New Zealand conditions and the other by such as approximate to those of Europe, while between these extremes is a gradual range of intermediates". Allan (1940: 7) has pointed out that: "A new flora and a new vegetation have come into being alongside of, intermingled with, or in place of the indigenous flora and vegetation".

Cockayne's "two distinct areas" have been studied in some detail by New Zealand botanists. A great deal has been written about the indigenous communities on the one hand, and about the artificial (economic) communities of introduced plants on the other. However, much less attention seems to have been paid to the consequences of the contact between the two floras and the two vegetations.

Darwin (1859: 172-73) and Hooker (1867: 757) touched briefly upon the subject when they inferred from the alleged "superiority" of the plant species introduced into New Zealand from Europe that, in the "struggle for existence", these species were capable of displacing the indigenous species without man's aid. Travers (1869: 312), Kirk (1878: 362-63), and Cheeseman (1882: 272-74) were influenced by Darwin's views on natural selection into expressing similar opinions (which were qualified somewhat in the cases of Kirk and Cheeseman). Since Travers, Kirk, and Cheeseman are included among New Zealand's most important botanical explorers, it would seem that a preconceived idea led them to underestim-

ate the role of human activities in the replacement of native species by aliens.

The comprehensive studies of the vegetation of New Zealand by Cockayne (1921a), and of the introduced flora by Thomson (1922) involved a closer consideration of the contact between the alien and the indigenous species. This led Cockayne (1921a: 283) and Thomson (1922: ch. XIV) to oppose the views of earlier workers on the aggressiveness of the alien flora. Cockayne claimed that no exotic species has gained a foothold in New Zealand without the assistance of man or his introduced animals, and this view has been supported by Allan (1936: 191). (Wulff (1943: ch. VII), dealing with the relationship of man's activities to world plant distribution, has cited evidence from various countries, including Allan's New Zealand paper, to show the error of the view formerly held that aliens may crowd out an indigenous vegetation without man's aid).

Cockayne devoted 10 pages to a section on "The New Vegetation" (originally entitled "Displacement and Replacement of Associations and Species") in the first edition of his monumental work (Cockayne 1921a: 283-292) and 18 pages in the second edition (Cockayne (1928: 355-372)). The latter version stresses (p. 356) "the far greater aggressiveness - in their native land - of the New Zealand indigenous species themselves". Cockayne's observations on the "new vegetation" have been amplified in a paper by Cockayne, Simpson, and Scott-Thomson (1932).

In recent years, the role of the introduced species has been referred to in a number of studies of areas of predominantly indigenous vegetation, particularly in studies of successional communities (e.g. Allan (1926); Croker (1953); Williamson (1953)). Further, interaction is directly involved in those studies of pasture establishment (notably the classical work of Levy (1923) and of Guthrie-Smith (1926: ch. XIX)) that treat the regeneration of indigenous communities as an agricultural problem. However, the paper by Allan (1936) on competition between indigenous and alien plant species appears to be the only modern contribution on the vegetation of New Zealand, besides those by Cockayne (and his co-workers) and by Thomson, that is concerned with the subject of interaction as such.

As Smith (1957: 135) has pointed out: "Whether botanists wish it or not, the proper study of the native botanist now is the study of that amalgam of indigene and alian ... that covers now mainly all of New Zealand except fully and intensively cultivated areas on the one hand, and large tracts of National Parks and Scenic Reserves on the other". It would appear that the few workers who have given specific attention to this subject of interaction have tended to make general observations covering the country as a whole. In the present work, it was proposed to cover a more limited area in greater detail.

## I. INTRODUCED AND INDIGENOUS SPECIES

### (1) DEFINITIONS

Introduced species are defined for this study as those that have been imported into New Zealand by man, whether deliberately or accidentally. It would seem that very few of these were introduced by Polynesians (?950-1350 A.D.); some were introduced by European explorers (1769 onwards), sealers, whalers, and traders (1792 onwards), and missionaries (1814 onwards); and most have been introduced since organized European settlement began in 1840 (Thomson (1922: part III); Healy (1949: 160-62)).

Indigenous species are defined as those that were present in New Zealand prior to the arrival of men, an event which probably occurred about 1000 years ago (Te Rangi Hiroa (1950: 4-21); Duff (1956)). It is not impossible for some species to have arrived since then through agencies other than man and his activities, but the present geographical isolation of New Zealand must be a barrier to natural distribution.

### (2) CRITERIA FOR DISTINCTION

Cheeseman (1925) separated the introduced and indigenous vascular floras almost completely, and there have been very few subsequent corrections of his allocations. (These corrections are referred to later). He did not give a specific account of his criteria for distinction. They were probably similar to those suggested below. The criteria given are not inconsistent with Cheeseman's views on the aggressiveness of the introduced flora. From the point of view of more recent workers, another criterion for regarding a species as introduced has been that "it has never been found in really virgin country" (Cockayne and Allan (1926a: 65)).

(i) There is no doubt about the allocation of the endemic species, nor about the economic species that have been imported deliberately by Polynesian or European settlers. (The few del-

iberate introductions by the Maoris are well authenticated (Thomson (1922: part III); Te Rangi Hiroa (1950: 89-91)). In the case of the highly compound Festuca rubra L., certain economic varieties have definitely been introduced by Europeans, but some wild varieties may possibly have been represented in the indigenous flora). For the rest, there is adequate evidence in the case of all but a few species.

(ii) Botanical explorers began to study the vegetation and flora of New Zealand in 1769. Organized European settlement began only in 1840. From the locality records made by visiting botanists before 1840 and by resident botanists since 1840, it has been possible to build up some sort of picture of the distribution of nearly every plant species in different periods, and roughly to determine the correlation of that distribution with the distribution of areas of European settlement in the same periods. A species with a consistently high correlation with areas of European settlement may fairly safely be regarded as introduced, and one with a consistently low correlation may be regarded as indigenous. Indigenous species which have become weeds in European settlements may be distinguished as indigenous because of an initially low correlation with settlement. (A few species which are well known as cosmopolitan weeds of arable land were recorded by the earliest botanical explorers. Healy (1949: 160) has suggested that these may well have been species accidentally introduced by the Maoris rather than indigenous species).

(iii) Cheeseman (1925: xiv) pointed out that, of the 1763 vascular species that he regarded as indigenous, only 434 are found elsewhere, of which 369 extend to Australia and 112 to temperate South America. Of the 369 also found in Australia, 82 extend to temperate South America, some being tropical as well, and 35 to tropical but not temperate South America, while 35 species are found in New Zealand and in some country other than Australia or South America. In the case of those non-cultivated species

that he regarded as introduced, Cheeseman (1925: 1053) stated that 463 had come from the north temperate regions, 45 from tropical regions, 21 from South Africa, 20 from South America, and 28 from Australia. Therefore, if a species cannot be classified adequately in terms of (ii) above, a record of the countries in which that species appears to be indigenous may give some suggestion of the category to which it belongs.

Thus, the principal criteria for allocating a species to the introduced or to the indigenous flora would appear to be: (i) Is it an endemic or a known introduction? (ii) If neither, how does its distribution at different periods compare with the distribution of European settlements at the same periods? (iii) In what countries does it appear to be indigenous?

### (3) PUBLICATIONS ON THE NEW ZEALAND FLORA

The basic manuals of the New Zealand flora used in the present study have been those by Cheeseman (1925) for indigenous vascular species, and Allan (1940) for introduced species. New editions of both are becoming necessary. There have been many taxonomic alterations, and additions of species to the flora, in both cases. In the case of the indigenous flora these are spread over many publications. (See "List of Species"). In the case of the introduced flora they are largely concentrated in a series of papers by Healy (1943, 1944, 1946, 1948, 1953a, 1953b, 1954).

There has been little disagreement with Cheeseman's allocations of species to the indigenous or to the introduced flora. The principal corrections and comments are those by Cockayne and Allan (1926a), while a few more have been made by Allan (1940) and by Healy (1943-54). Reference is made to these at the appropriate points in the "List of Species", notably in section iii. (This section ("Species of Doubtful Status") covers the few cases where there is doubt or disagreement over the status of a species, or where a species appears to contain both introduced and indigenous elements, and these are not readily distinguishable).

The last manual of the indigenous flora that included non-vascular cryptogams was that of Hooker (1867). There have been many publications since then dealing with sections of the indigenous non-vascular cryptogamic flora. The most recent manual of the mosses is that of Sainsbury (1955).

Allan (1940: 314) has made brief reference to the introduced non-vascular cryptogams, about which little is known. His manual mentions five species of Musci that may be introduced in part, and one that appears to be introduced only, while of the Fungi "there are probably many" introduced species, as in the case of the rusts, of which 33 species, or about 23%, are introduced.

#### (4) HYBRIDIZATION

In addition to those species, the allocation of which is in doubt, there is the other special category of hybrids between introduced and indigenous species. This has been mentioned by Cockayne and Allan (1934), who have pointed out that at least 8 such species hybrids exist.

Intraspecific crosses must also be considered. It is possible that some species in the "doubtful" category have both indigenous and introduced sections. In such cases there may or may not be interbreeding between these sections.

## II. THE STUDY AREA

### (1) CHOICE OF AREA

It was intended to work from Palmerston North as base. One practical factor in determining the limits of the study area about this centre was the amount of ground that could be studied adequately by one person. On this count, it seemed that the Manawatu district, as described below, would be a convenient area for investigation.

The portion of the catchment of the Manawatu River that lies to the west of the crest of the Tararua-Ruahine Range was chosen as the basis of the study area (fig. 1). This area forms the central part of Wellington Province and corresponds roughly to the social geographer's concept of "the Manawatu district" (Pownall (1953)). Historically, this district is the region of European settlement that first was opened up by scattered pioneers along the Manawatu River and subsequently developed from Palmerston North as centre. In terms of the present day, it is the tributary district of the town of Palmerston North, with the qualification that motor transport and sealed roads have brought an area on the eastern side of the mountains into the tributary district (Pownall (1953: 12)).

It was decided to exclude certain specialized habitats from the study area. These were : the subpolar region, namely the land above 4000 feet or 1200 metres (Zotov (1938a: 264-66)); the coastal sand-dune country; and the swamps near the mouth of the Manawatu River. The last two exclusions were largely achieved by eliminating the true right catchment of the Manawatu River between its mouth and the entry of the Oroua River, and the true right catchment of the Oroua River above that point, together with the true left catchment of the Manawatu River between its mouth and Shannon. A wide range of plant habitat remained after the exclusion of the specialized habitats. (This range was not reduced by the exclusion (in the eliminated catchments) of some areas that are not occupied by sand or swamp).

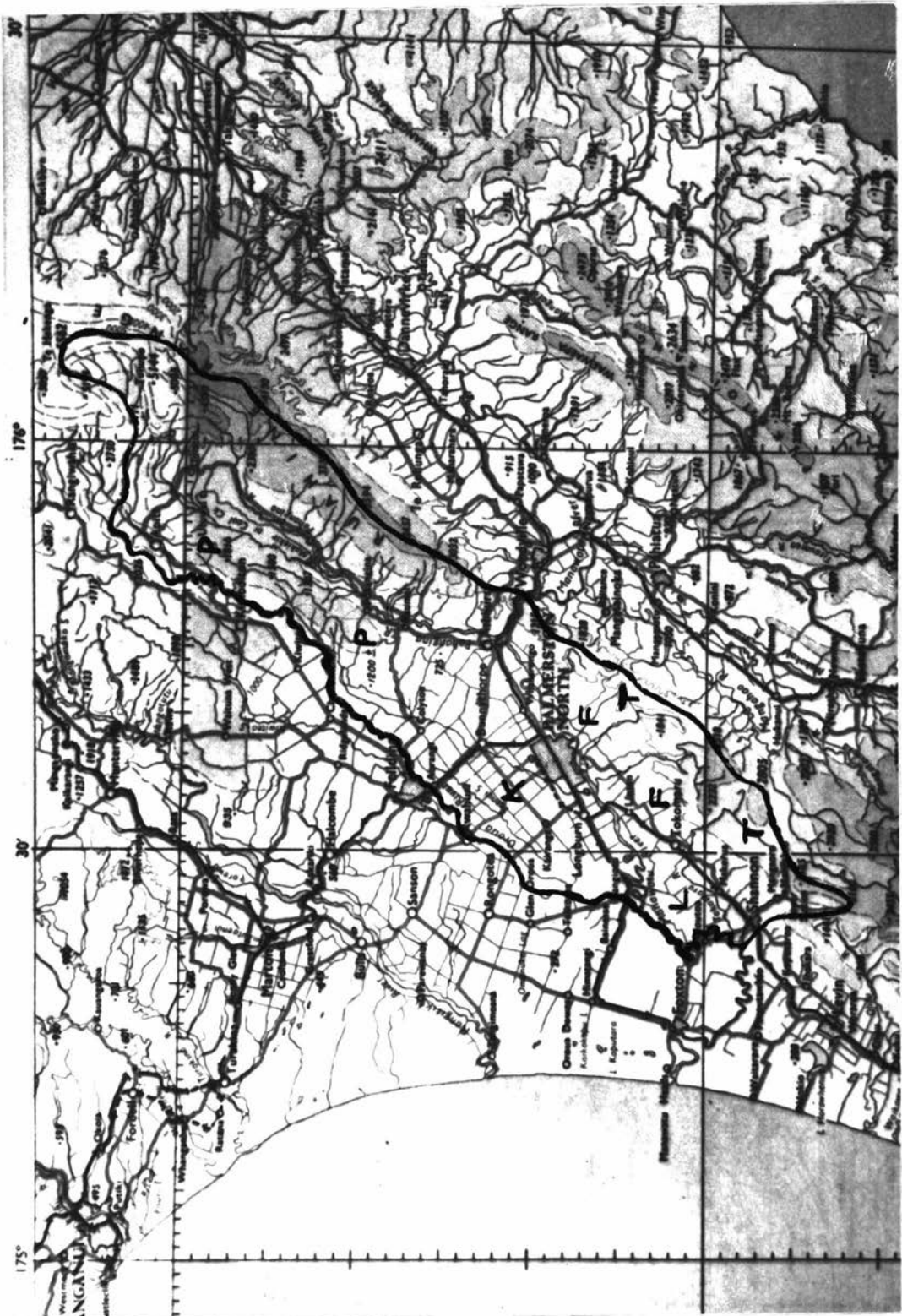
The study area thus arrived at (fig. 1) covers about 600 square miles (1550 sq. km.). (Much of the relevant previous work by others, and in particular the Surveys of New Zealand, which were used in the field work, has employed the English system of linear measurement. This system has therefore been retained by the present writer. However, at least the first reference to any English unit is accompanied by the metric equivalent).

(2) PHYSIOGRAPHY (fig. 1).

The main physiographic features of the study area are the Range, the Pohangina Plain (P), the Fitzherbert Plain (F), the Kairanga Plain (K), and the lower floodplain of the Manawatu River (L). (The "Plains" are named by the present writer after the districts to which they correspond).

(i) The Range

The Range runs approximately N.N.E.-S.S.W. It takes the form of two elongated domes, the southern dome being the Tararua Range (T) and the northern the Ruahine Range (Wellman (1948: 124)). According to the latest maps, the highest trig. stations of the Tararua Range just exceed 5000 ft. (1500m.), and those of the Ruahine Range just exceed 5500 ft. The lowest part of the saddle between the Tararua and Ruahine Ranges is about 1000 ft. above sea level, while the altitude of the bottom of the Manawatu Gorge (in which the Manawatu River flows westward through the saddle into the study area) is about 200 ft. The dome of the Tararua Range is dissected into a complex rectangular pattern of longitudinal and transverse ridges (Adkin (1949: 264)), and the Ruahine Range has a similar form. The country may be described as steep, the sides of most of the valleys having slopes of  $30^{\circ}$  or more, and the ridge-tops being narrow. The steepest slopes tend to occur on the sides of the transverse ridges. (As Adkin has pointed out, the transverse reaches of the streams usually run in narrow gorges). The rocks of the Range are indurated sandstones and mudstones (grey-wackes), which are probably of lower Mesozoic age (Wellman (1948: 123)).



**FIG. 1.      PHYSICAL MAP OF STUDY AREA (FROM NZMS 19A)**

Lambert Conformal Conic Projection. Palmerston North is located at  $40^{\circ}22'S$ ,  $175^{\circ}37'E$ . Scale about 11 miles to the inch.

Boundary of study area \_\_\_\_\_

(North of the Manawatu Gorge, in the sag between the Tararua and Ruahine Ranges, the greywacke is overlain by an arch of softer Tertiary rocks (Lillie (1953: 66 & maps)), similar to those of the northern part of the Pohangina Plain). The eastern boundary of the study area runs along the main divide of the Range, crossing the Manawatu River in the Manawatu Gorge just below Te Apiti railway station.

(ii) The Pohangina Plain

The Ruahine Range is flanked to the west by a plain that slopes downwards to the S.S.W. (that is, parallel to the Range). It has an altitude of about 2200 ft. towards the northern boundary of the study area, and about 200 ft. where it merges into the Kairanga Plain. The surface of the Pohangina Plain has been much dissected by tributaries of the Manawatu River, owing to regional uplift in late Pleistocene times, very little of the original surface being left (Greenall and Hamilton (unpub.: 16-17); Speight and Wild (1924: 222)). (The principal tributaries involved are the Oroua and Pohangina Rivers, which arise in the Ruahine Range, and flow roughly S.S.W. through the Pohangina Plain. The eastern tributary, the Pohangina River, enters the Manawatu River at the western end of the Manawatu Gorge). While downcutting by rivers and streams has produced many gorges and cliffs, wide terraces have also been formed, and there are broad rolling ridges as well as those that are narrow and steep. The Pohangina Plain proper consists of Pleistocene gravels, sands, and clays in the south-west, and Upper Pliocene sands, siltstones, mudstones, and conglomerates in the north and east, while the river terraces consist of Upper Pleistocene and Recent gravels and alluvium (Greenall and Hamilton (unpub.: 7-14)).

(iii) The Fitzherbert Plain

The Tararua Range is flanked to the west by a plain that slopes down in a north-west direction (that is, roughly at right angles to the Range) towards the Kairanga Plain (except at the southern end,

where it slopes down towards the lower floodplain of the Manawatu River). There is also a slight slope to the south-west, the highest part of the plain (about 800 ft.) being near the north-east corner. As with the Pohangina Plain, the Fitzherbert Plain has undergone a considerable degree of dissection, and some steep valley walls and terrace faces are to be found. However, many of the divides are wide and more or less flat-topped, particularly at lower altitudes. These represent little-modified remnants of the former surface (Adkin (1919: 108-11)). The Fitzherbert Plain has been described by Adkin (1910: 507, 520) as consisting of Pleistocene to Recent sandstone and clay.

(iv) The Kairanga Plain

The Kairanga Plain is a triangular area that lies roughly south-west of the Pohangina Plain and north-west of the Fitzherbert Plain. It is bounded to the west by the coastal dunes and by the low hills to the west of the Oroua River (both of which regions have been excluded from the study area). It slopes evenly downwards from about 200 ft. at the north-east edge to about 25 ft. at the south-west corner. The surface of the plain is virtually flat. According to Mr. C.C. Rich of Victoria College, Wellington, (private comm.), the Kairanga Plain, which consists of Recent alluvium, may represent a former joint estuary of the Manawatu and Oroua Rivers, which has been filled in by their deposits. These rivers now flow along the south-east and western edges respectively of the plain, below the surface of which their present floodplains are slightly entrenched. Palmerston North lies near the eastern corner of the Kairanga Plain.

(v) The Lower Floodplain

The Oroua River enters the Manawatu at about the south-west corner of the Kairanga Plain. Below this junction, the floodplain of the Manawatu River is about four miles wide. It is bounded to the west by the coastal dunes (through which the river finally passes to the sea), and to the south-east by the Fitzherbert Plain. The height

of this floodplain above sea level ranges from 25 feet down to about ten feet or less. Until it was drained and stop-banked, most of the floodplain was swampy. A low-lying portion of this floodplain to the east of the river (that is, within the study area) is still called the Mākerua "Swamp", although of its former 14,000 acres (56.7 sq.km.) (Miller (1917: 25)), all but about 500 acres have been reclaimed.

### (3) CLIMATE

Most of the available information on the climate of the study area is based on the daily records of the climatological stations of the New Zealand Meteorological Service. There are two stations within the study area, both being in Palmerston North, one at the Grasslands Division of the Department of Scientific and Industrial Research and one at the Boys' High School. Besides these stations, which carry on a full recording service, there are about 20 rainfall stations within the study area, of which five use non-standard gauges. The year's records from both classes of station are published in "Meteorological Observations", the annual publication of the New Zealand Meteorological Service. (The most recent number available is that for the year 1950 (published in 1953)). Apart from the work of these stations, the only regular observations on the weather in the study area appear to have been some made on wind and fog in 1932 and 1933 by Zotov (1938a: 260-62).

Recording began at the Climatological Station at the Grasslands Division in April 1928. The observations from that date to April 1953 have been analysed by Schwass (1953).

#### (i) Temperature

Schwass's figures show that the mean air temperature at Grasslands is 54.6°F. (12.6°C), the warmest month being January, with a mean of 62.4°, and the coldest July (46.1°). The mean minimum grass temperature is 40.2°, the warmest month again being January (47.4°), and the coldest July (32.3°). The equivalent air temperatures for higher parts of the study area may be estimated by subtracting 2.74°F.

for every added 1000 ft. ( $5^{\circ}\text{C}$  for every 1000m.) (Kidson (1931: 142)). (This correction has been accepted by Zotov (1938b: 477) and by Garnier (1950: 88-89) as a practical basis for climatic studies). According to the rough maps of Kidson (1932), the number of frosts is low except on the Range, where they occur on 25-75 days in the year, while ground frosts occur on 50-100 days over most of the study area.

(ii) Rainfall

The mean annual rainfall at Grasslands is 39.44 in. (100 cm.) (Schwass (1953)). This rainfall is spread fairly evenly through the year, the wettest month being June with a mean of 4.38 in., and the driest months March (2.41 in.) and September (2.38 in.). However, there is great variation in the rainfall for each month. The greatest monthly rainfall recorded in 25 years is 10.34 in. (June 1947), and the lowest 0.45 in. (February 1939). According to Greenall and Hamilton (unpub.: 24-26), there is a similar pattern of distribution, and a similar variation in monthly rainfall, in the northern part of the study area.

The mean number of days with rain per year at Grasslands is 173.5, while the monthly means range from 17.0 days in June to 10.3 in March. Here again there is wide variation, the difference between maximum and minimum values for each month being of the order of 15 days.

"Meteorological Observations for 1950" gives the mean annual rainfall (and, in most cases, the mean number of days with rain) for 13 of the 19 rainfall stations within the study area, and for six stations just outside the boundaries of the area. (These are listed in table I. Stations outside the study area are marked \*.) Although the records are insufficient to give a clear-cut correlation of increase in rainfall with altitude or with nearness to the Range, the tendencies are obvious.

Seelye (1940) has calculated that the percentage variability in the annual rainfall for the stations in the Manawatu district ranges from 10% to 14%.

(iii) Snow and Hail

According to the rough maps of Kidson (1932), snow falls in the study area on less than one day in the year below about 1000 ft. The number of days with snow increases with altitude to 15-30 days above about 3000 ft. Days with hail are rarer. The range is from 2.5-5.0 days near sea level to more than 7.5 days above about 1000 ft.

(iv) Sunshine

The mean annual number of hours of bright sunshine at Grasslands is 1845, while monthly means range from 208 hours in January to 100 in June. The maximum value recorded for a month in 25 years is 300 hours (December 1934), while the minimum is 59 hours (June 1947).

(v) Wind

The mean 24-hourly wind run at Grasslands is 150 miles (241 km.), the highest monthly mean being 176 miles in January and the lowest 118 miles in June. As Zotov (1938a: 260) has pointed out, wind velocities must be much higher in the mountains.

According to Schwass, westerly and north-west winds predominate at Grasslands in spring and summer, but in autumn and winter, winds from an easterly or south-east direction are of nearly equal frequency to those from the west and north-west. Zotov (1938a: 260-62) has recorded a similar seasonal variation in wind direction in the northern part of the Tararua Range.

A south-east wind of abnormal velocity on February 2, 1936, has been described by Zotov (1938a: 270). In two hours it caused great damage within the study area, and in particular levelled whole hill-sides of indigenous forest.

(vi) Fog

There is frequent cloud formation in the air-gap between the Tararua and Ruahine domes. This has been mentioned by Elder (1949: 4) in connection with the vegetation of the southern end of the Ruahine Range, while Zotov (1938a: 261) has claimed that the northern end of

TABLE I. RAINFALL STATIONS IN THE MANAWATU DISTRICT.

Station	Mean annual rainfall (inches)	Mean no. of rain days	Altitude (feet)	Shortest distance from main divide (miles)
* Foxton	33	119	10	15
Kairanga	35	120	51	10
* Glen Oroua	36	109	63	16
* Feilding	36	159	235	14
Palmerston North (average of 5 stations)	38	162	136	7
Linton	40	156	155	7
Colyton	40	140	800	10
* Palaka	41	not stated	10	8
Tiritea	47	165	272	3
Mangaore	50	180	360	3
Apiti	51	201	1500	10
Komako	52	147	600	5
Arapeti	88	not stated	1190	1
* Mangahao Dams (average of 2 stations)	124	225 (1 station)	1185	1

the Tararua Range may be fog-bound as frequently (200 days a year) as is the higher central part of the range.

#### (4) SOILS

The soils of the study area have been surveyed by the New Zealand Soil Bureau in the course of a general survey of the soils of the North Island.

The results of this survey are depicted on a map on the scale of four miles to the inch, which was published in sections between 1945 and 1948. The introduction to the bulletin describing the soils (N.Z. Soil Bureau (1954: 12)) gives warning that the information has been published with many imperfections, in order to make it available without delay.

The list that follows contains the code numbers and names of the soil types of the study area, as given in the bulletin and map (fig. 2), together with the location of each soil type within the area.

##### (i) Recent Soils from Alluvium

1. Manawatu loam, sandy loam, silt loam, and clay loam.

The principal soil of the present floodplains of the rivers.

- 1c. Tukituki sandy loam, stony gravel, etc. On stony flats along the rivers.

2. Kairanga silt loam and clay loam. The principal soil of the Kairanga Plain.

- 2a. Kairanga loam etc. - strongly gleyed. Its principal location is the lower floodplain of the Manawatu River.

- 2b. Opiki complex (peaty loams). A belt of this soil encircles the Makerua "Swamp", and there is another example near the southern end of the Kairanga Plain.

##### (ii) Organic Soils

107. Makerua peaty loam. The soil of the Makerua "Swamp".

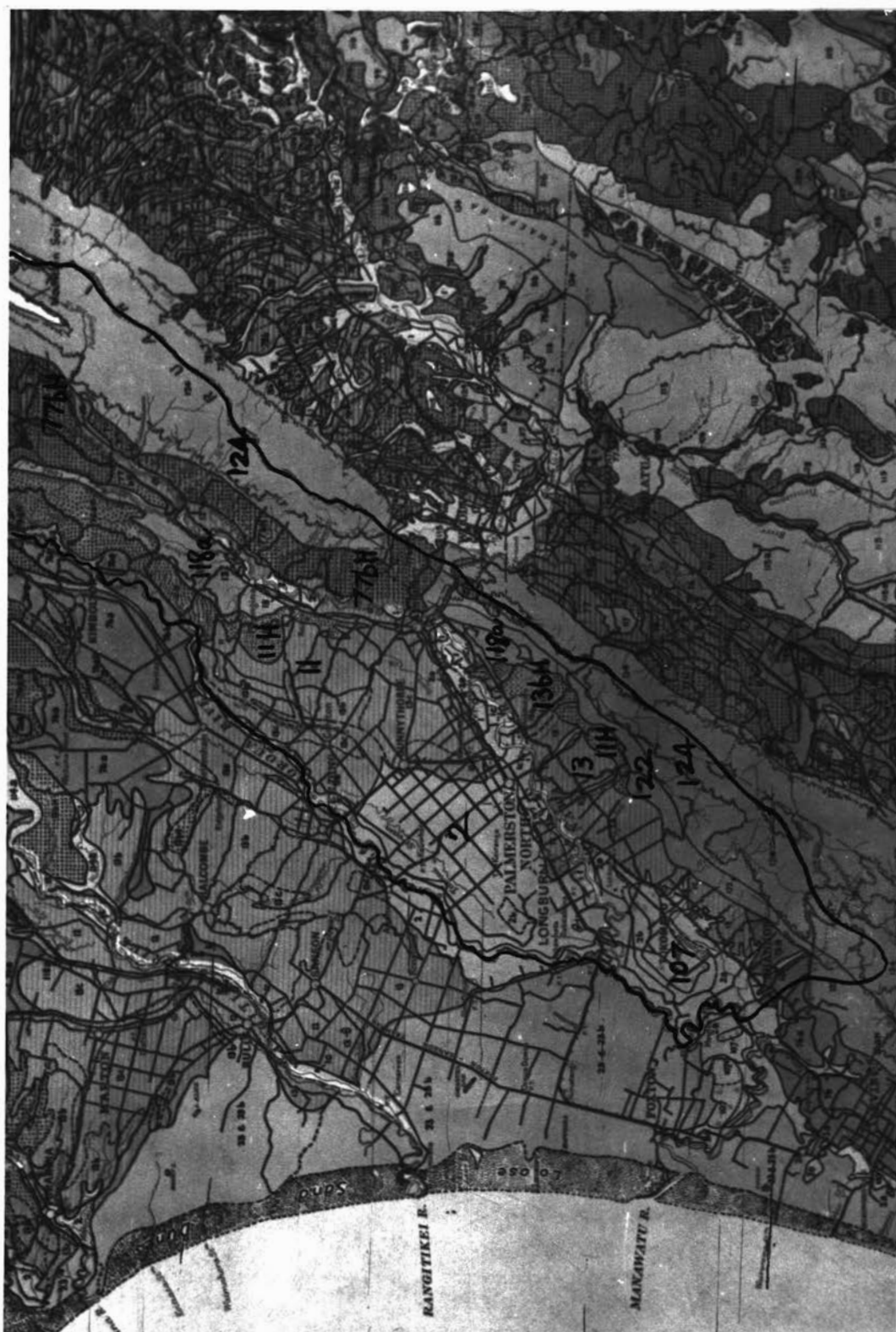


FIG. 2. SOIL MAP OF STUDY AREA (N.Z. SOIL BUREAU)

Scale about 8 miles to the inch.

Boundary of study area \_\_\_\_\_

(iii) Yellow-grey Soils

(There appears to be a correlation between these soils and the Pleistocene sediments of the study area).

11. Raumai sandy loam. On the southern part of the Pohangina Plain.

11H. Raumai sandy loam - hill soil. This occurs on steeper ground than does 11. There is an area of this soil towards the middle of the Pohangina Plain, and a strip along the eastern edge of the central part of the Fitzherbert Plain.

12. Ohakea loam. The soil of most of the terraces in the immediate vicinity of the Manawatu and Pohangina Rivers.

13. Tokomaru silt loam. The principal soil of the Fitzherbert Plain.

13a. Milson silt loam. At the southern extremity of the Pohangina Plain.

13b. Halcombe silt loam. On the southern part of the Pohangina Plain. Also on the northern part of the Fitzherbert Plain (except for the north-east corner).

13bH. Halcombe silt loam - hill soil. On the northern part of the Fitzherbert Plain, to the east of the area of 13b.

13c. Marton loam. On the southern part of the Pohangina Plain.

(iv) Secondary Podzolic Soils

29H. Atua silt loam - hill soil. A wedge of this soil lies towards the northern end of the Pohangina Plain.

(v) Brown Loams. Subgroup Yellow-brown Loams

(Within the study area these soils appear to be correlated with Tertiary sediments).

76a. Kiwitea loam. At the southern extremity of the Fitzherbert Plain and on terraces in the northern part of the Pohangina Plain.

76aH. Kiwitea loam - hill soil. The principal soil (other than on the terraces) of the north-west part of the Pohangina Plain.

76b. Kawhatau stony silt loam. On some terraces in the middle of the Pohangina Plain.

77b. Matamau heavy silt loam. On the crest of the Tararua Range for about two miles southward from the Manawatu Gorge.

77bH. Matamau heavy silt loam - hill soil. On the arch of Tertiary rocks just north of the Manawatu Gorge; also the soil of most of the eastern part of the Pohangina Plain.

(vi) Skeletal Soils (of steep hillsides)

(These are more influenced by the parent material and less by climate and vegetation than are the soils on easier slopes. The parent material of 118a is soft sandstone (late Pliocene or early Pleistocene), while that of 122 and 124 is greywacke).

118a. Pohangina sandy loam. The principal occurrence of this soil is in the middle of the Pohangina Plain. It also occurs in the north-east corner of the Fitzherbert Plain.

122. Makara stony loam. Developed under rainfall 40-60 in. This soil occupies a belt 1-2 miles wide along the western edge of the Tararua Range behind the Fitzherbert Plain.

124. Ruahine stony silt loam. Developed under rainfall 50-100 in. The soil of the Tararua and Ruahine Ranges, up to about 3500 feet, above which altitude are "mountain soils".

(A soil map of New Zealand, on the scale of 32 miles to the inch, was published by the New Zealand Soil Bureau in 1948, that is, after the four miles to the inch maps but before the bulletin that describes the same. Because of the smaller scale of the 1948 map, it only shows major categories (e.g. "Recent soils from alluvium"). The classification of these categories differs in some respects from that used for the four miles to the inch map. An appendix to the bulletin (N.Z. Soil Bureau (1954: 275)) compares the two classifications.

### III. THE ORIGINAL VEGETATION

#### (1) FOREST

It would seem that in pre-human times there was forest over the whole of the study area, with certain exceptions that are discussed later.

Most of the study area below about 2000 ft. is now in pasture, but it is clear from the historical record of Buick (1903) that the early European explorers and settlers found the district to be covered by dense forest, with the exception of the clearings made by the Maoris alongside the rivers. Further, Cockayne (1928: 148) has stated certain conditions of the physical environment that appear to govern the occurrence of indigenous forest below about 800 m. (2700 ft.), and these conditions are fulfilled in the study area.

The nature of the former forest cover below about 2000 ft. may be deduced from forest reserves and forest remnants. The problem of reconstruction is relatively much easier in the case of the vegetation above about 2000 ft., most of which is still in a roughly primeval condition. There are two forest reserves below 2000 ft., namely Totara Reserve, an area of over 600 acres alongside the lower course of the Pohangina River, and Tiritea Reserve, an area of about 8000 acres on the Tararua Range. In addition to these reserves, forest remnants of various sizes occur below 2000 ft. throughout the study area, mostly on private property. (Many of these latter areas are not protected from domestic grazing animals, while all forest areas in the district are liable to have been modified since the arrival of Europeans by wild herbivorous mammals, and, in many cases, by fire as well. (See (IV) Historical). The cyclone of 1936 also modified the remaining forests in certain areas).

The reconstruction that follows is based on descriptions of some of these surviving forest areas by Zotov (1938a), Greenwood (1949), Greenall and Hamilton (unpub.: 27-31), Allan (1924), and Cockayne (1928: 176), together with observations made by the present writer in the course

of an extensive reconnaissance of the vegetation of the district.

The principal type of forest was that described by Cockayne (1928: 161 ff.) as "podocarp-broadleaved dicotyledonous forest of dry ground". The dominant podocarp was Darydium cupressinum. (Podocarpus totara, P. hallii, P. dacrydioides, P. ferrugineus, and P. spicatus were all present, but of less importance than Darydium cupressinum). The principal dicotyledonous species were Boisschmidia tawa (especially below about 1000 ft.), Weinmannia racemosa (especially above about 1000 ft.), and Metrosideros robusta. Knightia excelsa, Elaeocarpus dentatus, and Alectryon excelsum were prominent in places, and there was a great variety of other trees. (Cockayne (1928: 148) has listed 108 species of trees for the lowland-lower hills' forest of New Zealand). Tree-ferns were also important, especially Cyathea medullaris (or, at higher altitudes, C. smithii).

The floodplains (including the drier part of the swamp country) and the lower-lying part of the Kairanga Plain were occupied by "semi-swamp forest" (Cockayne (1928: 174-75)), dominated by Podocarpus dacrydioides and Laurelia novae-zelandiae. There was a gradual transition between semi-swamp forest and podocarp-dicotyledonous forest of dry ground. Drier river flats tended to be dominated by Podocarpus totara. Below about 1500 ft., the crests of ridges and spurs, and also faces with thin gravelly soil, were often occupied by a forest dominated by Nothofagus solandri. (N. solandri may have been confined to the Pohangina Plain and the northern end of the Fitzherbert Plain, which are the only places within the study area where it occurs today).

Above about 2700 ft., there tended to be a shift in dominance. Darydium cupressinum and Metrosideros robusta fell out. The principal species included Weinmannia racemosa, Griselinia littoralis, Podocarpus hallii, Libocedrus bidwillii, and Phyllocladus alpinus. Certain species of Nothofagus were present above 2000 ft. in the extreme north and extreme south of the study area (see below) and were dominant in places.

(A notable feature of the study area is the absence, except at

its northern and southern extremities, of certain species of fagus (notably N. fusca), which elsewhere on the western side. Range are important constituents of the forests above about 2000 ft. According to Elder (1949: 4), the causative factor would appear to be the reduction in sunlight that is associated with the frequent formation of cloud in the air-gap between the Tararua and Ruahine domes).

Zotov (1938b) has observed that, in the latitude of the study area, 1200m. (4000 ft.) is a critical climatic level above which indigenous trees never grow. It is the start of his "subpolar" region, and the altitudinal limit of the study area.

## (2) MOUNTAIN SCRUB

The probable role of fog as a factor controlling the distribution of Nothofagus species has been referred to already. In some parts of the study area above about 2000 ft., it would appear that localized frequent fogs reduce the illumination below the lowest level required by any indigenous tree species (Zotov (1938a: 265)). It may be observed in the roughly primeval vegetation of the higher parts of the Tararua Range that in such cases scrub, usually dominated by Olearia colensoi, occurs between the timberline (upper limit of forest) and the 4000 ft. level (Zotov (1938b: 475-76)).

The average height of the timberline in the part of the Tararua Range that lies within the study area is about 2500 ft. In the southern Ruahine Range, the average height is about 3000 ft., but it is higher towards the northern limits of the study area. In the higher parts of the Ruahine Range, there is also scrub, usually dominated by Olearia colensoi, between the timberline and the 4000 ft. level.

## (3) SWAMP VEGETATION

Where permanent water was present within the limits of the original forest, not even semi-swamp forest would occur. The Makerua Swamp was in this category (Miller (1917: 28)). Such areas would be dominated by tall and medium sized monocotyledonous herbs such as Typha angustifolia, Phormium tenax, and Carex secta (Cookayne (1928:

197); Poole and Boyce (1949: 16)).

(4) MINOR COMMUNITIES

The other examples of non-forest communities within the original forest would be of little importance. One such group of communities would include those of watercourses, riverbanks, riverbeds, and cliffs. Another would consist of those in succession from bare ground to forest (as on the new subsoil exposed by the changing course of a river on a plain or by slips in hill country). Previous storms of the magnitude of the 1936 gale may have felled areas of forest and thus induced successional communities.

(5) ENVIRONMENT OF THE ORIGINAL VEGETATION

The general features of the climatic, edaphic, and physiographic environment of the study area have been discussed already. Perhaps the most important feature of the biotic environment of the original vegetation was the absence from pre-human New Zealand of any mammals other than two species of Chiroptera (Hutton and Drummond (1923: 38)).

#### IV. HISTORICAL

This is a brief account of past human activities within the study area in terms of their effect on the vegetation. With local variations, it is a well-known national story in New Zealand.

##### (1) POLYNESIANS

Maori traditions mentioned by Buick (1903: ch.I) indicate that the Manawatu district was inhabited at least from the time of the second Polynesian settlement period, that is, from about 1150 A.D. (Te Rangi Hiroa (1950: book I).

When the first Europeans reached the district, the Maori population was estimated at 3400 (Buick (1903: 153)). They lived in villages along the river banks. It appears from Buick's account (p. 161) that there were no villages on the Oroua River north of the Kairanga Plain, nor were there any on the Pohangina River.

Maori agriculture in New Zealand was limited to the cultivation of a few introduced Polynesian plant species. Of these species, it is probable that only kumara (Ipomoea batatas) was grown as far south as the study area (Te Rangi Hiroa (1950: 89)). Healy (1949: 160) suggested that such cosmopolitan weed species as Oxalis corniculata, Calystegia sepium, Solanum nigrum, and "Sonchus sp." may have entered New Zealand with the Maoris as "stowaways", perhaps in the soil about the roots of useful plants. (However, Guppy (1906: 29, 416-17, 539) considered that some of these weeds may have been spread through the Pacific by natural means).

More important as a source of food than the Polynesian introductions was the rhizome of the indigenous bracken (Pteridium esculentum) (Te Rangi Hiroa (1950: 93)). It would appear that the Maoris cleared areas of bush in order to induce the growth of this plant. According to Best (1942: 96), such areas were re-burned every 3-5 years to prev-

ent the succession from proceeding to scrub (and eventually forest).

It seems most probable that the vegetation of the district remained largely primeval until the coming of the Europeans. Since virgin New Zealand forest does not normally burn (Cockayne (1928: 353)), it is unlikely that fires set by the Maoris in preparing gardens or bracken grounds on the riverbanks spread far into the surrounding forest. In any case, great care was undoubtedly taken to prevent this from happening. Since the Maoris were a stone age people, relying largely for food and raw materials on naturally-occurring plants and animals, they had a strong tradition of conservation (Best (1942: 1-3)).

The only mammals that were introduced by the Maoris were a breed of dog (Canis familiaris) and a species of rat (Rattus exulans) (Te Rangi Hiroa (1950: 64)).

## (2) EUROPEANS

The principal record of European activities in the Manawatu district until about 1900 is that of Buick (1903). It appears that the first European residents were traders who established themselves in the Maori villages and exported timber and flax (Phormium tenax). By 1868 there were 32 European settlers in the neighbourhood of the Manawatu River between the mouth of the Oroua River and the Manawatu Gorge. Their agricultural activities were limited to subsistence cultivation and the rearing of a few cattle. 1871 saw the beginning of the first organized agricultural settlement of the district, and after a railway was built from the coast to Palmerston North in 1876 the district was rapidly settled in all directions from the railhead. Until about 1890 the timber industry was still the chief source of local wealth. However, the introduction of refrigeration in the 'eighties gave a great impetus to pastoral farming, and by 1903 Buick was able to say that, with one or two exceptions, the district was settled "to the best advantage".

These events represent a great change in the vegetation of the

Manawatu district. The principal effect of European settlement was the removal of most of the original forest covering below 2000 ft. by cutting and burning, and its replacement by a sown pasture of English grasses (Levy (1951: 203-10)). (At the same time, an alien flora of non-cultivated species was sown in the form of impurities in the imported "grass-seed". Allan (1940: 10) has estimated that at least 56% of the alien non-cultivated flora was imported into New Zealand, and further spread, in this way).

One important ecological aspect of this conversion to pasture concerns the changes in the soil that have been brought about by burning, fertilizing, and trampling by stock, and, in some places, by cultivation and draining, not to mention the effect on soil formation of the radical change in the type of vegetation. Much work remains to be done in this field. Some of these points have been studied by Miller, Stout, and Lee (1955), and some have been considered in the course of the soil survey of the North Island of New Zealand (N.Z. Soil Bureau (1954)). One gross effect, namely accelerated erosion, is discussed later in connection with the present vegetation.

Settlement also brought a new fauna, which included not only the sheep (Ovis aries) and cattle (Bos taurus) to graze the pastures, and such other domesticated animals as horses (Equus caballus), goats (Capra hircus), and pigs (Sus scrofa), but also a varied collection of wild mammals, notably red deer (Cervus elaphus) and opossums (Trichosurus vulpecula). The wild species were loosed deliberately into the native vegetation, into which some domestic animals also escaped. (According to Wodzicki (1950: 227-28), wild pigs in particular must have become established in the district at a very early date). The account by Zotov (1949) of the changes in the forests of the Tararua Range indicates the result. Rabbits (Oryctolagus cuniculus) and hares (Lepus europaeus) were also released, but did not spread into the forest (Zotov, (1938a: 280)).

Thus, the part of the original vegetative cover that survived

the establishment of pastoral farming was still modified and by man's activities. It was modified also by fires. Virginia land forest may not normally burn, but, in dry summers, fires laid to destroy scrub or felled forest, or else started accidentally, are quite liable to spread into damaged forest which has been opened up by timber extraction and/or by animals. Since dry summers are also the most suitable for burning felled forest, such fires were a feature of the settlement period. One notable example within the study area is the great fire of the dry summer of 1897-98 (Christensen (1950: 8); Lands and Survey Department (1898: 11)).

From its appearance, it is evident that much of the present standing forest of the study area has been affected by these fires. Many of the remaining forest areas consist largely of young trees, above which rise a few living survivors of the original canopy, among many standing skeletons.

## V. THE PRESENT VEGETATION

### (1) PREVIOUS WORK

#### (i) Vegetation

At the present time, sown pasture is the predominant vegetative cover of the Manawatu district. The principal kinds of pasture, and (in less detail) of other vegetation, have been described and mapped (on the scale of 16 miles to the inch) by Madden (1940) as part of a pasture survey of the North Island. In addition to this general survey, Suckling (1954) has studied the relation of management to pasture composition at Te Awa on the western side of the Pohangina Plain, while Merry (unpub.) working in the Manawatu district, has made an ecological study of rushes (Juncus species) in pasture. Greenall and Hamilton (unpub.: 32-34, 52-54) have given an account of the pastures of part of the Pohangina Plain.

#### (ii) Environment

Information on the environment may be obtained from several other sources besides the accounts of vegetation. Reference has been made already to publications that contribute to a knowledge of the physiography, lithology, climate, and soils of the study area. (Further, the soil survey of the North Island (N.Z. Soil Bureau (1954)) includes references to the average actual and possible stock-carrying capacity of each soil type). The question of accelerated soil erosion has been covered for the Manawatu district as a whole as part of a survey by Grange and Gibbs (1948). (Greenall and Hamilton (unpub.) have given special attention to soil erosion on the Pohangina Plain). Land-use and farming practices for the higher part of the Fitzherbert Plain, and the portion of the Tararua Range behind it, have been discussed by Gibson (unpub.). For the district as a whole, these last factors have been mentioned briefly in various national surveys of some aspect or aspects of primary production (e.g. Levy (1951), Department of Agriculture (1948), Belshaw et al. (1936)). Similarly, wild

mammals of the district have been mentioned by Wodzicki (1950) as part of the introduced fauna of New Zealand.

## (2) VEGETATION PATTERN AS A FUNCTION OF MAN'S ACTIVITIES

### (1) The pattern of Vegetation

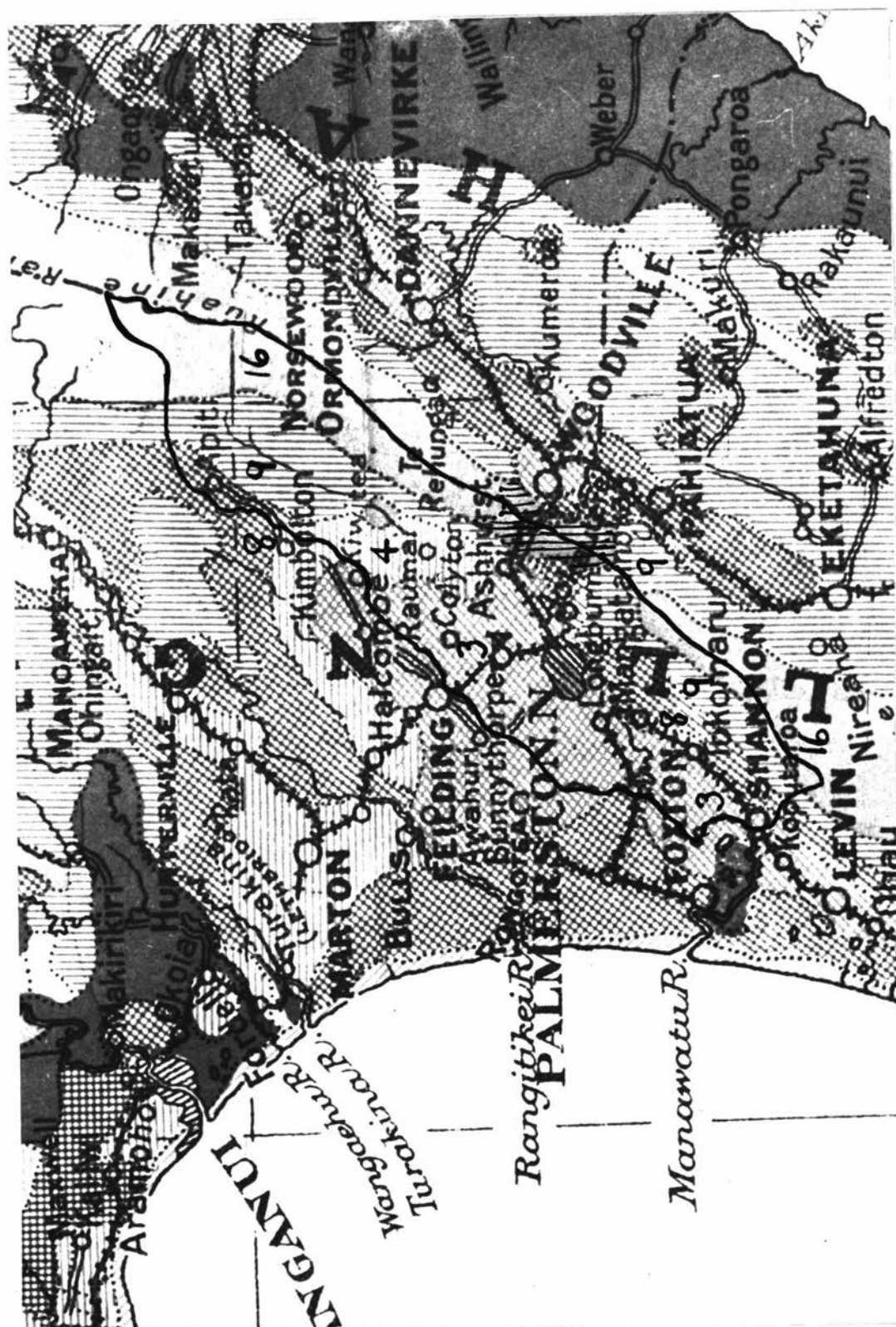
Although it deals primarily with pastures, the map made by Madden (1940) may also be regarded as a map of the present vegetation, as far as the Manawatu district is concerned (fig. 3).

The Kairanga Plain, together with the south-west part of the Pohangina Plain and the lower floodplain of the Manawatu River, is shown as occupied by a high-producing pasture (type 3 of Madden's classification), dominated by Lolium perenne, Trifolium repens, and Dactylis glomerata, with some to much Holcus lanatus, Cynosurus cristatus, Poa pratensis, and Trifolium dubium.

As the Pohangina Plain rises, type 3 is succeeded to the east and north-east by a zone of pasture (type 4) dominated by Dactylis glomerata and/or Cynosurus cristatus, with much Holcus lanatus and Trifolium repens, and some Lolium perenne, Poa pratensis, Trifolium dubium, and Anthoxanthum odoratum, also Agrostis tenuis and Danthonia spp., the last being indigenous. (Throughout the present text, a generic name followed by "spp." implies a particular superspecific taxon, which is described in the species list).

As the Kairanga Plain and the lower floodplain of the Manawatu River give way to the Fitzherbert Plain to the south-east, the type 3 pasture gives way to a lower-producing pasture (type 8), dominated by Danthonia spp. (indigenous) and/or Agrostis tenuis, but generally containing some better species such as Cynosurus cristatus, Dactylis glomerata, Trifolium dubium, Lotus uliginosus, Trifolium subterraneum, Lolium perenne, and Trifolium repens. Type 8 pastures are also found on the Pohangina Plain in the vicinity of the Oroua River.

Types 4 and 8 may be regarded as transitional pastures. They are succeeded on the higher parts of the Pohangina Plain and on the Range



**FIG. 3. PRESENT VEGETATION OF STUDY AREA (MADDEN)**

Scale about 11 miles to the inch.

Boundary of study area \_\_\_\_\_

by a low-producing hill-country pasture (type 9), dominated by Agrostis tenuis, with some Anthoxanthum odoratum, Holcus lanatus, Trifolium dubium, and Cynosurus cristatus. Danthonia spp. may very largely replace Agrostis tenuis on drier and warmer slopes. There are traces of Lolium perenne and Trifolium repens on stock camps and higher fertility areas.

Finally, the higher parts of the Range do not carry pasture. Above about 2000 ft., the Range is shown as occupied by type 16 (Forest, dense scrub, and eroded country). (The southern boundary of type 16 on the Ruahine Range has been corrected in fig. 3. It is actually at about the 2000 ft. contour, or about four miles north of the Manawatu Gorge. It does not extend across the Gorge as shown on Madden's original map).

#### (ii) Interpretation

The nature of the pasture at any place within the study area may be regarded as an indicator of the degree of human control over the vegetation that is permitted by the environment of that place. Thus, on the Kairanga Plain (and adjacent areas), the presence of high-producing pastures shows that a high degree of control is possible in that area. However, as the study area rises to the north and east, pasture changes show that limiting factors are reducing man's role towards the level where no pasture at all can be maintained. (Economic impracticability may of course establish a barrier before the environmental limits for the maintenance of pasture are reached).

The significance of several of these limiting factors may be considered separately for each factor. (In their origin and in their effects the factors are, of course, interrelated).

Climate. The increase in rainfall with altitude must tend to be a limiting factor in a region which was formerly in forest. The original bush-burns were less efficient in the higher rainfall areas, where they have left plenty of logs and stumps to protect the secondary growth of indigenous species (Levy (1951: 20, 22, 29)). Further,

the reduction in temperature with altitude may begin to have some effect on the length of the growing season of the pasture species at the higher levels.

Physiography. Physiography is largely responsible for controlling the degree of intensity of management. The flat to rolling ground of the lower-lying parts of the study area (and of the broader terraces of the Pohangina Plain) permits the optimum use of mechanization and subdivision (fig. 5). (Although many other practices besides actual cultivation are involved, it is convenient to symbolize such land as "ploughable"). With increasing altitude, the land tends to become steeper and more broken, thereby reducing the effectiveness of management (even though the situation has been improved since World War II by the use of aircraft for such purposes as spreading fertilizer, seeds, and weedkillers, and by the increased use of track-laying vehicles).

Natural Soil Fertility. (This has been defined (N.Z. Soil Bureau (1954: 62)) as the over-all content of plant nutrients). The lower natural fertility of the soils of the higher parts of the <sup>area</sup> study may also act as a limiting factor. The fertility of the recent and organic soils of the low country is high to very high, except for some of the peaty and stony soils, where fertility tends to be lower. The yellow-grey soils of the Fitzherbert Plain and the lower parts of the Pohangina Plain are of medium to high fertility. The brown loams of the upper Pohangina Plain and the skeletal soils of the Range (and of the steeper slopes of the Pohangina Plain), are in general medium in fertility. Ruahine stony silt loam (124), the least fertile of the skeletal soils, is low to medium in fertility. On this soil type, the vegetation grades from pasture into non-pasture (Madden's type 16). (To the extent that the present pattern of vegetation is determined by soil fertility, it is liable to be modified by the recent innovation of aerial top-dressing, with phosphatic fertilizers, but it must be stressed that soil fertility is only one of a complex of factors).

Soil Erosion. Erodibility of the soil must be considered as a limiting factor. Here again the flat to undulating ground of the study area is in the most favourable position, and the situation tends to deteriorate with altitude. The maps of Grange and Gibbs (1948) show no erosion of the recent soils of the flat country nor of the yellow-grey soils of the lower, least dissected, parts of the Pohangina and Fitzherbert Plains. However, some slips occur on the hill soils of the yellow-grey group, while some of the brown loams of the Pohangina Plain (together with the small area on the Tararua Range) exhibit slip or wind erosion. Finally, the skeletal soils of the Range, and of the steeper slopes of the Pohangina Plain, are shown as subject to slip erosion, much of it serious. (In the course of the field work, it was found that erosion seems to be less serious on the soils derived from greywacke than on those derived from unconsolidated rocks).

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Thus, the vegetation of the study area may be divided roughly into three categories in terms of land-use. "Ploughable" pasture occupies the land on which man can attain a relatively high degree of control over the vegetation. "Non-pasture" vegetation occupies the land on which it is impossible or impracticable to maintain pasture. Between these extremes, "unploughable" pasture occupies the land where the degree of human control will depend on the efficiency of management and the status of the limiting factors. At the first extreme, introduced economic species, and at the other extreme, indigenous species, may be expected to predominate; and interaction between indigenous and introduced species may be expected to be most intense in the region of unploughable pasture. (The role of introduced non-economic species may also be expected to be most significant in the unploughable pasture, where man's activities are not sufficiently intense to control them.)

There is one complicating factor in this assumption. In general, human efforts are directed towards maintaining economic pasture

species and suppressing non-economic species. Economic species in the study area are almost exclusively introduced, so that the policy is in effect one of maintaining introduced species (other than weeds) and suppressing indigenous species. However, it is important to note the role of the indigenous Danthonia spp., which has been adopted by European settlers as a pasture species and is now sown in some "seed-mixtures" (Levy (1951: 176-77)).

## VI. FIELD EXAMINATION OF THE PRESENT VEGETATION

### (1) BASIS

The methods used in the field examination of the present vegetation were based on the land-use interpretation of the vegetational pattern. The vegetation of the study area was divided into pasture and non-pasture. Any area on which man's activities are directed towards maintaining pasture was treated as pasture. Any area on which this is not the case was treated as non-pasture. (This latter is equivalent to Madden's type 16; it does not include examples of vegetation other than pasture that are under human control, such as plantations and gardens). In general, the distinction was clear because of adequate fencing. The whole of any paddock that is used for grazing was regarded as pasture for the purpose of this examination.

The pasture vegetation was regarded as consisting predominantly of introduced species. Examples of indigenous species were then sought for in pasture and the habitat of such examples was examined. Conversely, the non-pasture vegetation was regarded as consisting predominantly of indigenous species. Examples of introduced species were then sought for in non-pasture vegetation and their habitat was examined.

The nature of the actual methods for studying indigenous species in pasture and introduced species in non-pasture was affected by several practical considerations.

The first of these was the intensity of interaction between indigenous and introduced species. As indicated in the conclusion of the last section, this might be expected to be greatest in unploughable pasture. It was decided to make a systematic examination of unploughable pasture, since it seemed likely that such a method would produce enough positive records to justify the work involved. It seemed less likely that this would apply either where man had a relatively high degree of control over the vegetation or in the case of the non-pasture vegetation. In these cases a systematic examin-

ation would probably have meant a great deal of work to obtain very few positive records. It was therefore decided to cover these latter kinds of vegetation as thoroughly as possible, but not to a set plan.

Boundaries had to be set between the areas which it was proposed to examine systematically and those in which the examination would be extensive. First, it was assumed that cultivation would have been carried out, at some time nearly everywhere that it was practicable, so that a rough division into ploughable and unploughable pasture could be made on this basis. Therefore, towards the extreme at which man has a high degree of control, the distinction was made between land which appeared to have been ploughed or disced at some time and that which had not. (It was possible normally to make this distinction by inspection. Ground which has been cultivated at some time looks much smoother. In doubtful cases where it was suspected that an area had been cultivated at some time, a check with the occupier showed that it had been). To simplify matters, enclaves were merged with their surroundings so as to produce a continuous boundary, corresponding very roughly with the 500 foot contour.

Towards the extreme at which man has no direct control over the nature of the vegetation, the distinction, as mentioned earlier in this section, was often clear-cut, in that the boundary between pasture and non-pasture vegetation was a fence. Where no fence existed, the second practical consideration operated. This was freedom of movement. It was largely controlled by the nature of the vegetation and was another reason why a systematic examination was decided against for non-pasture vegetation. Where the vegetation graded through from pasture to non-pasture without a cultural boundary in the form of a fence, the apparent limit of penetration by domestic grazing animals (the presence of their dung being the principal criterion) was taken as the boundary. As with the other boundary, enclaves were abandoned so as to give a continuous line, corresponding very roughly with the 2000 foot contour.

Drawing these boundaries (figs. 4,5) divided the study area into three regions. The ploughable pasture region below the lower boundary (consisting of the Kairanga Plain, the lower floodplain of the Manawatu River, and the lower parts of the Fitzherbert and Pohangina Plains), and the non-pasture region above the upper boundary (consisting of most of the land above about 2000 ft., together with some forest reserves and remnants) were to be studied extensively. The unploughable pasture region between these boundaries (consisting of the higher parts of the Fitzherbert and Pohangina Plains, and the lower parts of the Range) was to be studied systematically. (The area that actually was examined systematically was further limited by other practical considerations. These are discussed in the account of this method).

The questions asked in the field examination were:-

- (a) What indigenous species occur in pasture? What introduced species occur in non-pasture?
- (b) Under what environmental conditions does each species occur?
- (c) What is the relative significance of each species within its range of environment?

## (2) EXTENSIVE EXAMINATION

The extensive examination referred to in the last section consisted of a note-taking reconnaissance. It was decided to include in this reconnaissance the area that it was proposed to examine systematically, in order to give an overall picture of the study area. (Further, since a portion of the area that it was proposed to examine systematically was in fact not so examined, the extensive record was needed for this section).

This reconnaissance therefore involved travelling by car, cycle, or foot, at least once over every road or track in the study area, except on the well-roaded Kairanga Plain, where about half the roads were covered. Further, air reconnaissances were made over the area

that subsequently was to be examined systematically. 35mm. photographs were made on these flights for reference purposes.

In the case of ploughable pasture, the results of the extensive examination were amplified by a small amount of more detailed work. This is referred to in the appropriate section of (VII) "Results of the Field Examination". Again, a certain amount of information on non-pasture vegetation was obtained during the systematic survey of unploughable pasture.

### (3) METHOD FOR STUDYING UNPLOUGHABLE PASTURE

#### (1) The Unit Area Method

The situation encountered in planning the systematic examination of the regions of unploughable pasture was fairly similar to that encountered by Greenall and Hamilton (unpub.: 78) when they set about collecting, recording, classifying, and interpreting physical facts related to land use and cultural erosion in Pohangina County. "At the outset it was apparent that, so many factors influenced land use and erosion, [that] special methods of symbolising, recording, and classifying these factors would be essential. An examination of relevant survey practice in New Zealand failed to discover a satisfactory precedent and so it was decided to modify a survey technique developed by the Soil Conservation Service U.S.D.A. to suit the conditions peculiar to this country. The technique used was the unit area method, the boundary being closed when any one factor mapped changed". (A later account (Greenall and Hamilton (1954)) includes a photograph showing the manner of subdividing an area of land into units).

As used by Greenall and Hamilton, the unit area method appears to lead to an adequate classification of the combinations of factors relevant to land use and erosion. It seemed, therefore, that it might also provide a suitable classification of the combinations of factors relevant to vegetation, or, in other words, of the kinds of plant habitat. If this method were to be used, the area under consid-

eration would be divided into units, within each of which the habitat appeared to be relatively uniform. (The expression "relatively uniform" is used advisedly. In determining the boundaries of such unit areas, there is the problem of deciding on the degree of subdivision of each factor. The decision as to what constitutes "change" in a factor which varies quantitatively must tend to be arbitrary and to be affected by expediency).

(ii) Transect Sampling of Units and of Vegetation of Same.

Greenall and Hamilton (unpub.) prepared a unit area map of the whole of their study area. However, it was felt that in the present study it would have been impracticable to carry out a similar 100% survey. Greenall and Hamilton's survey had required a team of workers. A 100% survey might have been practicable with a much-reduced area, but it was desired to cover as wide a range of habitat as possible. The question of sampling then arose.

It might have been possible to employ some scheme of random sampling to obtain unit areas for study. However, the amount of travel involved in a system of random sampling would probably have been far too great for practical purposes. It was decided, therefore, to use non-random sampling. This would detect, and locate accurately, various unit areas, the environmental characteristics and vegetation of which would be recorded. While such a system might have its limitations, it might be expected at least to indicate tendencies in the mutual relationships of introduced species, indigenous species, and environment.

The obvious system to use was line transecting, which would provide maximum (continuous) recording of information for the distance travelled. As the transect line was measured out, a record would be made when any environmental factor changed. In this way the positions of the unit areas through which the line passed would be fixed, and the environmental characteristics of those areas would be determined.

There remained the manner of investigating the vegetation of the unit areas thus detected. Some objective method was desirable. Separate sampling of the vegetation in each unit would require extra time and labour. Therefore, it was considered whether the transects used to detect the unit areas might be used also to sample the vegetation of the unit areas through which they passed.

If the transects were used in this way, it would mean that, in each such unit area, the vegetation would be sampled by one line transect, namely the portion of the general transect line that lay within the unit area. This line transect could be used to estimate the abundance of different species, in terms of the amount of cover provided by each species on the line. (It would be necessary to make the estimate of abundance in terms of cover, since preliminary field observations had made it clear that few of the plants in unploughable pasture could be treated as individuals, and that such individuals (mainly phanerophytes) tended to vary greatly in size, even within a species). A one-transect sample might not give an adequate account of the vegetation of the unit area in which it was taken, but a number of such samples, each from a different unit area of some given type, would be more likely to give a reasonable picture of the overall vegetation of their combined unit areas. The samples could be used to estimate frequency, in terms of the proportion of transects in which each species occurred, and also mean abundance, in terms of the mean cover provided by each species.

The method as described above bears some resemblance to a variation of the point method of analysis (Goodall (1952: 12-13)) that involves restricted randomization. Goodall's method is to sample the vegetation of a given area, by subdividing the total area into small plots of equal size, and taking a random one-point sample in each subdivision. The method that was proposed for the present work was to sample the vegetation of a given combination of unit areas by taking a single transect in each unit area.

It was not expected that the results would be particularly ac-

curate. The unit areas were not going to be of equal size, nor were the line transects going to be a given length and randomly placed in the unit areas. The sizes of the unit areas would be determined by the natural variations of the physical environment, and the placing of the transects would be determined by the arbitrary placing of the general transect lines of the survey. Further, it was obvious that the lengths of the transects within the units would vary considerably. However, it seemed probable that this last objection might be partly met by classifying the sampling transects into groups of similar length before deriving results from the samples. The probable accuracy of such results is discussed below in (vii) "Treatment of Sampling Data". (Of course, one way of achieving uniformity of transect length (although not random placing) would have been to use non-continuous recording of vegetation in the field method. This would have involved ignoring all unit areas in which the transect was of less than a given length, and recording only the given length of transect in each of the remaining unit areas. However, the whole point of the field method was to provide the maximum information for the distance travelled).

While this proposed method of vegetation sampling had its drawbacks, nevertheless it had the advantage that it would permit a large area to be covered. Further, it might be expected to give a more objective account of the vegetation than would the extensive survey. However, in view of some recognized deficiencies of the transecting scheme, separate sampling of the vegetation of certain selected unit areas was in fact carried out after the transecting had been completed, in order to amplify the information that had been obtained. (See (vi) below, "Point Analysis and Frequency Measurements").

It was further decided to attempt to obtain some indication of the relative intensity of grazing within each unit area, by using the transects to estimate the abundance of dung.

(iii) Maps Used in Systematic Examination

The 1:63,360 topographical map of New Zealand (Lands and Survey Department map series N.Z.M.S.1) was of great assistance in the systematic examination. This map is divided by the "National Grid" into squares covering 1000 yards by 1000 yards (about 900 m. by 900 m.). The transect lines of the systematic examination were laid down along the 5000 yard gridlines of the map. The use of this map meant that the position of locations of interest could be fixed by means of grid references. Further, the presence of contour lines meant that such environmental factors as slope, orientation, and local physiography could be checked on the map.

The 1:25,000 map of New Zealand (N.Z.M.S.2), with 50 ft. contours instead of the 100 ft. contours of N.Z.M.S.1, would have been even more useful, but the sheets covering the Manawatu district have not yet been prepared. However, aerial photographs or "mosaic maps" (N.Z.M.S.3), each equivalent to one sheet of N.Z.M.S.2, are available on the scale 1:15,840. They are "semicontrolled", in that the National Grid is superimposed. These maps of course show far more detail than N.Z.M.S.1, but have three disadvantages for field work, namely their high cost (£3 per sheet), the absence of contour lines, and some inevitable distortion. (It is noted on each sheet that grid references are subject to errors of 100-300 yards). These disadvantages do not occur with the "controlled" N.Z.M.S.2 sheets, but in the absence of this series it seemed preferable to use N.Z.M.S.1 rather than N.Z.M.S.3.

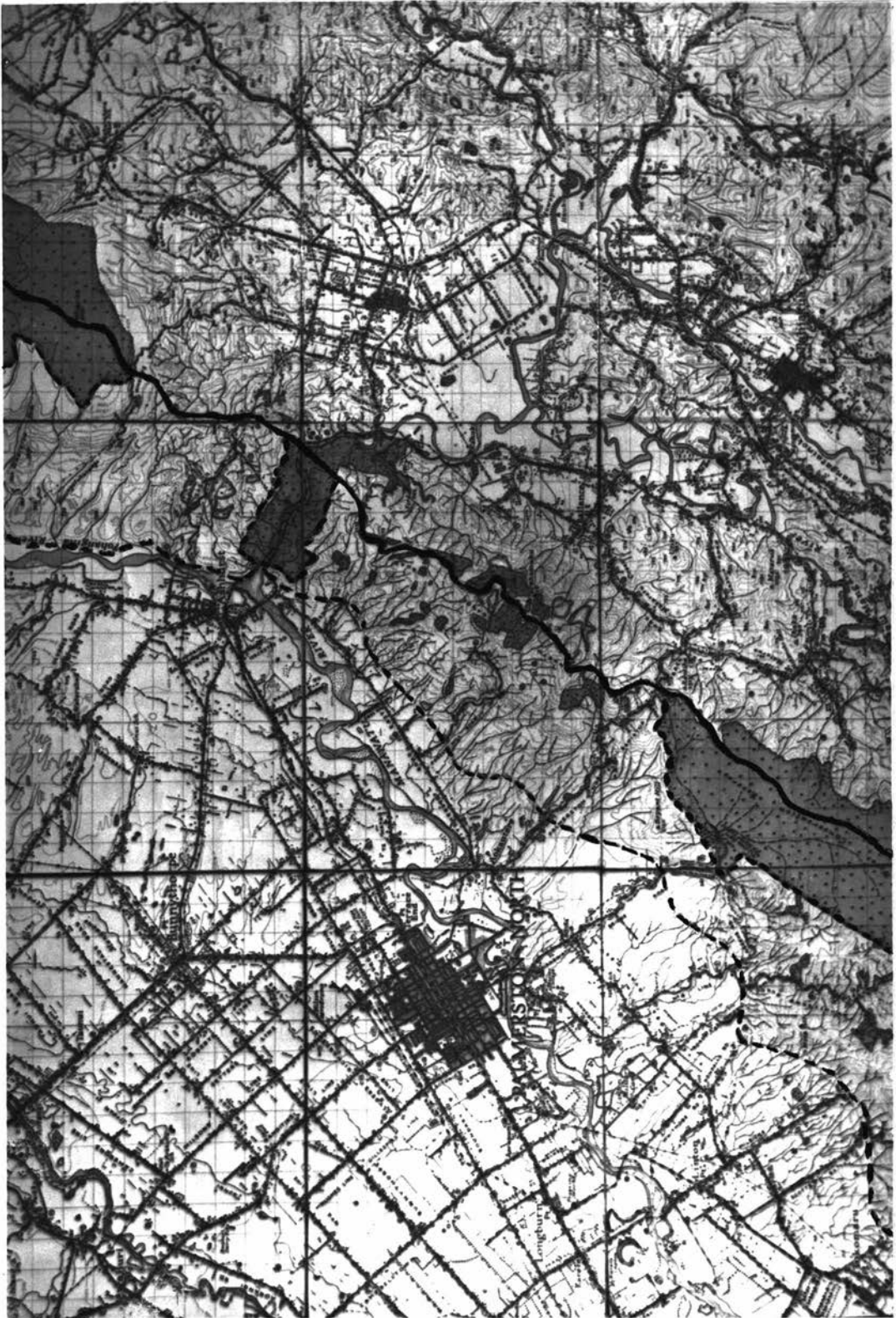
The Manawatu district has not yet been mapped completely even in the N.Z.M.S.1 series. This map is issued in sheets covering 30,000 yards (north-south) by 45,000 yards (east-west). (The sheets are oriented on true north). Some sheets have not yet been prepared, and others are incomplete, in that either they are not contoured at all or else the contours cover the lowlands (i.e. the ploughable country) only, and end between 200 and 500 ft. In fact, the only fully contoured sheets that were available in 1954 were the Palmer-

ston North (N.149) and Dannevirke (N145) sheets.

As far as the unploughable country of the study area is concerned, sheet N.149 (fig. 4) includes almost all of the upper Fitzherbert Plain, together with the portion of the Tararua Range to the east of the Plain. It also covers the southern end of the Ruahine Range for about five miles north from the Manawatu Gorge, together with the portion of the Pohangina Plain lying between this section of the Range and the Pohangina River. Although the upper Pohangina Plain and the rest of the Ruahine Range are not yet covered by N.Z.M.S.1, a large portion of Pohangina County between the Pohangina and Oroua Rivers has been mapped by Greenall and Hamilton (unpub. and 1954) on the scale 1:15,840. Their unit-area map of land classification and major existing erosion features is not contoured, but it is almost as useful as a mosaic map (being on the same scale as N.Z.M.S.3), and it is possible to achieve "semi-control" by superimposing the National Grid and the spot heights from the Ruahine map (N.Z.M.S. 74, a map on the scale 1:100,000, without contours, but showing roads and streams, and the 10,000 yard lines of the National Grid).

Because of the position with respect to maps, it was decided to restrict the systematic examination to the regions of un-ploughable pasture that are covered by the portion of N.149 that lies within the study area (figs. 4, 5), and by the Pohangina map of Greenall and Hamilton. (The small section of N.145 that is within the study area and in pasture was not sampled because a field examination had shown the area to be ploughable in many places).

The shortage of maps was one of the practical considerations referred to earlier as further limiting the area to be examined systematically. The other was that it took three months to cover even this limited area by transecting. The area of N.149 involved represents about 45 square miles, and the gridlines used represent a total length of about 38.5 miles. The area mapped by Greenall and Hamilton covers about 50 square miles. Because their map is less



**FIG. 4. NZMS 1, SHEET N.149 (PALMERSTON NORTH)**

Scale about three miles to the inch.

Boundary of study area                     

Boundary of area examined systematically

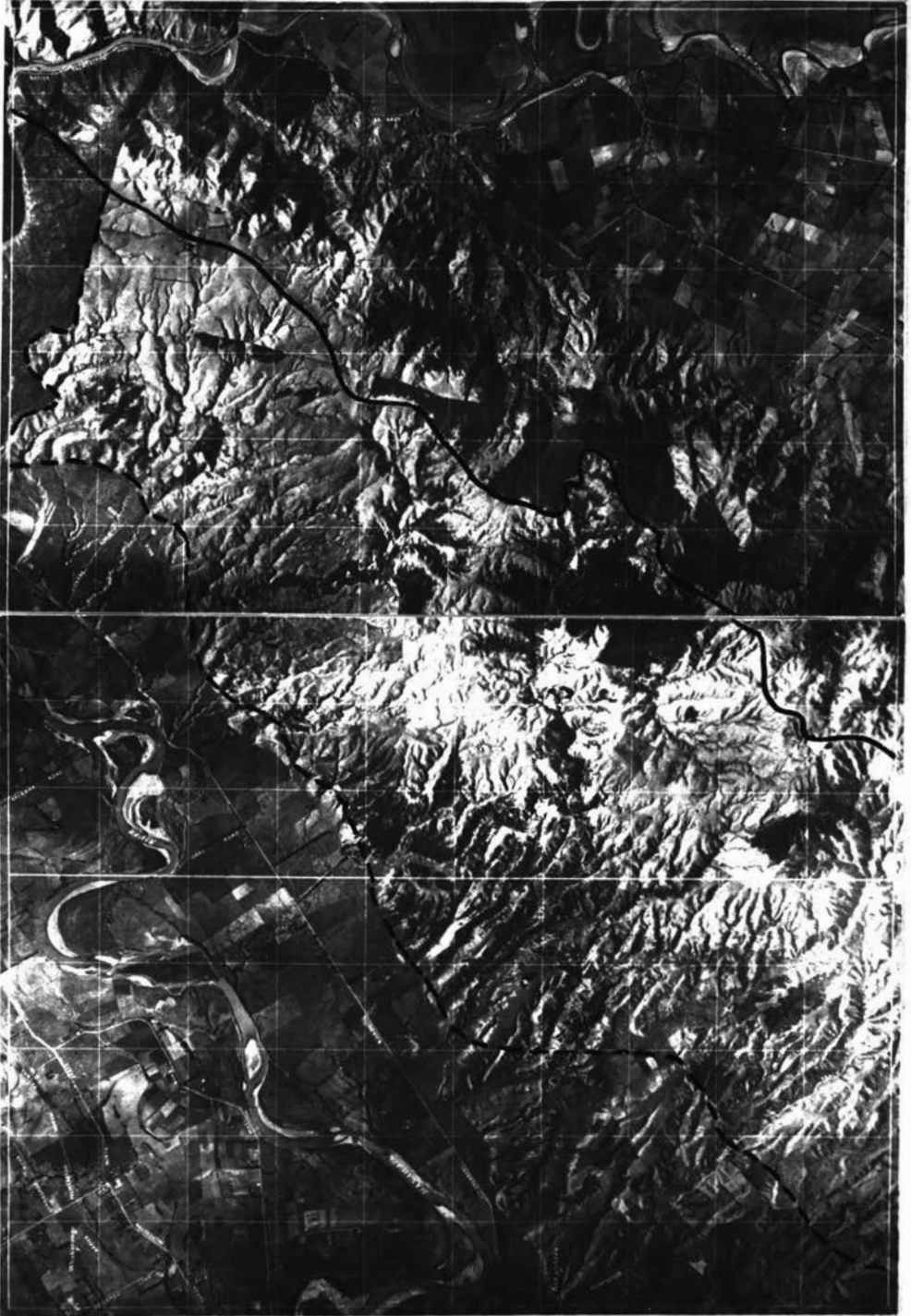


FIG. 5. NZMS 3, SHEET N.149/5 (WHAKARONGO)

Scale about one mile to the inch.

Boundary of study area \_\_\_\_\_

Boundary of area examined systematically - - - - -

accurate than N.Z.M.S.1, and was found to be less satisfactory to use in the field, the grid equivalent of only three miles was transected. (The grid line involved was the east-west line lying 10,000 yards north of the northern boundary of N.149).

N.Z.M.S.3, sheet N.149/5 (the central sheet of the nine, each covering 10,000 yards by 15,000 yards, that are equivalent to N.Z.M.S.1, sheet N.149), was purchased to amplify N.149, which is centred on unploughable country (figs. 4, 5).

(iv) Transecting Procedure

Each transect run along a gridline of the map was started from a recognizable landmark. The line was maintained by compass and landmarks. The transects were tied to the maps by giving the grid references of any mapped features (streams, roads etc.) that they crossed. A record was made of as many landmarks as possible (gates, strainer posts, distinctive plants, rock outcrops, waterfalls, etc.), on or near the line, to permit a recheck later where required. (It was obviously necessary to make as full a record as possible of the course of each line, since the position on the ground of each line was determined somewhat arbitrarily. The degree of accuracy in locating each gridline in the field was controlled by the fact that the principal map used is on the scale 1:63,360, so that, e.g., 0.06 inch on the map represents 100 yards in the field.)

The line was measured out by heel to toe pacing, or by a graduated measuring stick, whichever was the more appropriate at any place. The unit of measurement was the foot, namely the length of a boot (checked). (Preliminary trials had shown that the foot is short enough to separate out microhabitats (see below), while the yard (three feet) is not. Further, the trials had shown that the foot is sufficiently short to allow the dominant vegetation to be determined by eye without difficulty). The main difficulty was a tendency to underestimate distances, presumably because of failure to place the heel firmly against the toe of the other boot in pacing (especially in rough country), and similarly because of leaving gaps when measur-

uring with the stick. The total length of transect recorded was about 38 miles, although the distance covered as shown by the map was about 41.5 miles (without allowing for slope), so that the underestimation was of the order of at least 8%.

Where progress along the line was not possible, an accurate detour was laid off, and a note made of the nature of the obstruction. This refers essentially to cliffs and impenetrable thickets, both of which amount to non-pasture. A brief description of the non-pasture vegetation was noted in such cases, to amplify the results of the extensive examination. (The term "impenetrable" is used in a relative sense. It includes thickets through which a heavy cattle beast might be able to force its way, but which do not offer anything like freedom of movement).

The feet were counted off along the line (a mechanical counter being used for long runs) until a record was made. Each record was prefaced by the total number of feet since the previous record, the last foot of that total being that in which the record occurred. (Where the record was of a boundary between two unit areas, the foot in which the boundary occurred was allocated to the unit area that was being left).

For each foot of the transect (which was regarded as a fore and aft line (having no thickness) along the centre line of the boot or stick), records were made as follows.

Boundaries Based on Physical Environment. A record was made of any change in slope, orientation, soil type, or altitude. (Obviously these changes are often gradual, and the choice of the actual boundary-foot tended to be somewhat arbitrary in such cases).

The slope divisions were those which personal experience suggested would be convenient, namely: flat to gently rolling (up to about  $10^{\circ}$ ); strongly rolling to moderately steep (about  $10-30^{\circ}$ ); and steep (over about  $30^{\circ}$ ). (The N.Z. Soil Bureau (1954: 62) employs a similar classification). Categories of this magnitude can be estimated, and in many cases can be checked from the contour map. The

three slope divisions were symbolized as "0", "10", and "30" respectively.

Originally it was proposed that the orientation categories would be north-, south-, east-, and west-facing, while if the orientation of a unit area was almost exactly between two cardinal points it would be recorded as N.E., S.E., S.W., or N.W. (Owing to irregularities in the ground, it was found that it was not possible to determine the orientation of a unit area more closely than to the nearest sixteenth point. Thus such orientations as N.E. would actually cover an arc of about  $22.5^{\circ}$ ). However, it seemed probable that the important distinction would be between "sunny" and "shady" faces, that is, between north-facing and south-facing slopes. Therefore, the category "north-facing" was taken to include N.E. and N.W., and "south-facing" to include S.E. and S.W. (each of these major categories thus covering roughly  $112.5^{\circ}$ ). The east-facing and west-facing categories (each covering roughly  $67.5^{\circ}$ ) were pooled in a third group. This group consists in effect of the slopes that are in neither the "sunny" nor the "shady" category, but in a roughly intermediate position. This group is somewhat artificial, since while the light relations are similar for east-facing and for west-facing slopes, the period of maximum light is associated with higher temperatures in the case of the west-facing slopes. (For this reason, an alternative classification of orientation would have been into north-and-west and south-and-east). It was considered that the wind factor would not differ much between east-facing and west-facing slopes. (See "Climate"). A final group ("no orientation") contained the flat land (e.g. terrace tops and floodplains). The four orientations were symbolized as "N", "S", "EW", and "-" respectively.

(It was recognized that the general pattern of climate is liable to be modified by local physiography, an example being the reduction of light and of wind at any point by the shadowing effect of neighbouring ridges. However, it did not seem to be possible to combine

detailed estimates of these factors with this general survey).

Soil type boundaries were determined from the four miles to the inch soil map. This was done by projecting a colour slide of the soil map on to the N.Z.M.S.1. map, the projector being arranged so that the image of the soil map was four times natural size. Roads and rivers shown on both maps were used as guides in making the projected image and the contour map coincide. It was not possible to obtain a completely accurate register, because both in making and in projecting the photograph it would have been very difficult to make the object and the image truly parallel. (Further, the soil and the contour maps may have been drawn on slightly different projections). It was possible to make some check on the mapped soil boundaries if two adjacent soils were described as formed from different parent materials, or on different slopes, and the contact between these could be observed in the field. (Records of rocks exposed as outcrops or by erosion were of value in this connection). The soil types were symbolized by the code numbers referred to under "Soils".

The range of altitude was divided into 500 ft. belts. This division was partly arbitrary, but was partly derived from the claim of Zotov (1938b: 477) that in the indigenous vegetation of the Tararua Range each 300 m. (1000 ft.) contour represents an important level of floristic change. Altitude can be determined fairly accurately from the contoured N.Z.M.S.1, but less so from the spot heights of N.Z.M.S.74. The altitudinal belts were symbolized in terms of the lower boundary of each, that is, as "0", "5", "10", and "15" respectively.

Boundaries Based on Land-use. Fencelines were regarded as representing possible changes in environment (e.g. in grazing intensity), and therefore as boundaries, so that any fenceline crossed by the transect was recorded. (Relatively few fencelines were in fact recorded, since the areas of the paddocks are of the order of 100 acres or more). Natural features that are impassible to stock, such

as cliffs or impenetrable vegetation, may form part of the boundaries and thus be the equivalent of fencelines. Where natural features that were recorded by the line played the part of fencelines, this was indicated.

Unless otherwise stated, it was to be assumed from the record that the form of land-use was grazing on unploughable pasture. Therefore, whether or not they were marked by a fenceline, the boundaries were recorded of: ploughable land (that is, land which appeared to have been ploughed at some time); roads or farm tracks; plantations, homesteads, and stockyards; erosion features (as listed below); watercourses (including ditches) and stream beds; and stream banks (which were grouped with cliffs). (The vegetation was sampled in unploughable pasture only. In the case of the other categories, as with cliffs and impenetrable vegetation, a brief description of the vegetation was noted to amplify the results of the extensive examination).

The nature of each active or unhealed erosion feature was noted (e.g. slip, slump, mudflow, gully, wind erosion, scree). Where the subsoil was exposed, this was named (to amplify the soil record). Minor erosion features (those occupying isolated single feet) were not separated out from unploughable pasture, but were treated as microhabitat features. (See below).

Assessment of Management. The principal factor to be examined under this heading was the relative intensity of grazing within each unit area. In order to obtain some estimate of this factor, a record was made of the presence of any dung on each foot of line transect, and of the animal or animals involved. (For all practical purposes, this meant sheep and cattle). This technique was suggested by the "pellet count" method used by New Zealand wildlife investigators in estimating populations. (Riney (1956: 462-64) has described a form of pellet count method used in 1953 during a survey to assess the relative abundance of several species of grazing and browsing animals on different sections of a drainage system).

Certain deficiencies are obvious in the dung-count method used in the present work. The most serious lies in the attempt to classify unit areas in terms of grazing intensity by means of estimates based on single non-random sampling transects of varying length. Again, the correlation between dunging and grazing may be upset in the case of sheep by the animals camping on the high ground at night (Guthrie-Smith (1926: ch.XX)). There is also the problem of dung decaying at different rates in different environments. Further, while the dung count for any unit area will, presumably, be relatively constant through the year under set stocking, it may not be so under rotational or seasonal grazing. (Actually, both Greenall and Hamilton (unpub.: 60) and Gibson (unpub.) have pointed out that set stocking is usual but not universal in the areas that they covered). Another possible fault with the correlation is that different breeds of the same species, or different categories of the same breed, may differ in the efficiency of utilization of feed. The importance of this possible fault is lessened by the fact that most of the sheep of the area transected are breeding ewes (mainly Romney), and that most of the cattle are beef cattle (mainly Aberdeen Angus).

It was assumed that all unit areas were grazed both by sheep and by cattle. (In practice, this is largely, but not invariably, the case). On the basis of the transect sample, each unit area was then classified as being subjected to light or heavy sheep grazing and to light or heavy cattle grazing. Sheep grazing was arbitrarily regarded as heavy if sheep dung occurred in more than 10% of the feet in the sample, while cattle grazing was regarded as heavy if cattle dung occurred in more than 2.5% of the feet in the sample. In both cases, about 30% of the samples were in the "heavy grazing" category. (It was recognized that the percentages would vary in precision with the lengths of the transects on which they were based, so that the classification would be a very rough one). The term "heavy grazing" is rather relative, particularly in the case of cattle. Sheep, at the overall rate of one to two ewes per acre (plus young stock), are the predominant grazing animals, with one cattle beast

(the grazing equivalent of about five ewes) being carried, on a very rough average, for every 14 sheep (Gibson (unpub.); Greenall and Hamilton (unpub.: 55, 119)). Light and heavy sheep grazing were symbolized as "0" and "10.1" respectively, and light and heavy cattle grazing as "0" and "2.6" respectively.

The effects of horses, rabbits, and opossums were disregarded, since the dung of each of these species occurred only in about 1% of the transects, and then always at rates of less than 2.5%.

It did not seem possible to make any classification of unit areas on the basis of fertilizer treatment. Aerial distribution (and, to a much smaller extent, blower or spreader distribution) of phosphatic fertilizer (usually 2-3 cwt. of superphosphate per acre (250-375 kg. per hectare)) was a general practice in the unploughable country of the Manawatu district in the early part of 1954, and questioning of farmers on this country suggested that the use of phosphatic fertilizer had been very limited prior to that season. On an overall basis, the present work can be regarded as carried out at the onset of aerial topdressing in the Manawatu hill country, and therefore likely to lead to some interesting comparisons if repeated on the same area in the future.

A watch was kept for indications of spraying with herbicides, but the only observed signs of possible spraying were two or three individual plants of Ulex europaeus in a moribund condition.

Plant records. The vegetation was recorded in terms of the dominant vegetative cover on each foot of the line transect. (If the records of all the feet in a sampling transect of a unit area are combined, the result will not necessarily be quite as accurate as that obtained by measuring to the nearest foot the cover given by each species or category to the same transect. The latter method, however, would have been more laborious than the method of continuous recording that was used).

If bare ground occupied more than 50% of a foot of the transect

line, that foot was recorded as "bare". If more than 50% of the foot of transect was covered by one indigenous non-phanerophytic species, the species was recorded for that foot. If more than 50% of any foot was covered by one introduced non-phanerophytic species, the height of the leaves<sup>or shoots</sup> of which permanently exceeds 10 inches, the species was recorded for that foot. (The effective height of such species is above the lower level of phanerophytes, even though the highest perennating buds are not. It was felt that such species were in a different category from the introduced non-phanerophytes that occupied most of the "pasture" feet, as described below). In practice, the only species recorded in this way were Carex leporina and Juncus effusus. (The latter species is of doubtful status. The few species of doubtful status that were detected by the transecting were classed with the introduced species for sampling purposes).

If more than 50% of the foot was covered by non-phanerophytic vegetation that did not fulfill the above conditions (except in the case of co-dominance by two indigenous species, as described below), the vegetation of the foot was classified as "pasture". This was because reconnaissance in connection with the planning of the sampling method had indicated that such feet were usually dominated by introduced grasses and/or clovers, and also that it was unusual for any one of these introduced pasture species to show dominance, that is, cover more than 50%, in a foot. The latter observation was borne out when an amended sampling method was tried. (See (v) below, "Re-run of Some Transects").

If the ground layer (non-phanerophytes) was itself layered, "cover" in the above records was taken to mean "top cover". It was felt that there was no time for a more detailed examination during the transecting survey. ("Covered" implies that the ground (or lower layer) was concealed by the aerial parts of the plants involved). If the nature of the phanerophyte layer or layers prevented examination of the ground layer, this was indicated by the note "dense" (as part of the description of the phanerophyte layer(s)). Also phanerophyte

bases sometimes occupied more than 50% of a foot, and this was noted.

Where more than two out of all the above categories were present on a foot and none occupied more than 50% of the line, it was intended that the largest occupier (i.e. category) should be named, with an indication that it was in a minority. It was thought that, if the foot is a sufficiently small unit, this situation should not occur often, and in practice it was not encountered at all. Occasionally a foot was occupied by two vegetatively spreading indigenous species of similar life form, which were so intimately mixed that it was not possible to decide which was the dominant. In such a case, both species were recorded for the foot. (In assessing abundance, such a record for a species was rated with the records of sole dominance, that is, of occupation of more than 50% of the foot, thus giving totals of over 100% of ground cover for the sampling transects in which such records were made. However, since the calculations of abundance were only approximate at best, it was not thought that this treatment would result in serious error).

(The method of sampling the non-phanerophytic layer is biased in favour of those species that tend to occur in aggregations either because of vegetative reproduction or because of limited range of seed disposal. It seemed probable that some indigenous species might be quite prominent in the vegetation of the area transected although they rarely, if ever, dominated more than 50% of a foot or transect line. It was thought, however, that the role of such species, if truly important, would appear during the separate sampling of chosen units).

A record was made of all phanerophytic species (including introduced phanerophytes) that provided any cover to a foot of transect line (this being checked with a vertical stick). "Any" cover was specified in this case because the degree of cover could not be estimated as accurately as in the non-phanerophytic vegetation, which was trodden on. The phanerophytes were annotated N (nano-;

highest perennating bud 10-80 inches above the ground) or M (macro-; highest perennating bud more than 80 inches above the ground). (This is based on Raunkiaer's life forms (Braun-Blanquet (1932: ch.XII)). An interesting feature of this distinction is that the upper limit of the nanophanerophyte layer is comparable with the highest level that can be browsed by a large cattle beast on level ground). If the same species was represented by separate M and N plants in one foot of transect plane (the plane traced out by the vertical translation of one foot of the line transect) it was still recorded as N. Climbers also had the suffix C attached.

Microhabitat. For each foot, records were made of special features of the environment that might be relevant to the vegetation but were not indicated by the general record of environment. Thus, any foot that lay on waterlogged soil (that is, soil where the water lay on the surface or appeared in footprints) was noted as "swampy". Again, where phanerophytic vegetation was recorded for a foot, the note "shade" was added to the non-phanerophytic or ground record. (Where both M and N layers were present, the record of the latter was also annotated "shade").

Minor erosion features, classified in the same way as the larger features, were treated as microhabitat. A microhabitat record was also made for those feet where, instead of soil, the ground consisted of a rock outcrop or of stones (the rock being named in such cases to amplify the soil record), or where the ground was occupied by a tree-stump or a fallen log (either being recorded as "log").

The other records of microhabitat were those for which animals are responsible. These biotic microhabitats were not noted in the case of the "pasture" feet in the original transecting, but they were in the amended method. (See below). The most important category recorded was stock tracking, divided into track treads (recorded as "track") and uprights or risers. (The note "vertical" was used to cover any small vertical place but referred essentially to these uprights). The other categories were "shelf" (sleeping shelves being

areas trodden out on slopes by sheep; they are somewhat similar to tracks, but wider and not continuous); "stock trampling" (other than on tracks and shelves); and an occasional "burrow entrance".

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The date was noted on each day's transect record. Transecting was carried out in the three months February-April 1954 (late summer and autumn). It might have been desirable to make seasonal repetitions of the transects to cover possible variations in vegetation, and in the extent of swampy ground. However, by the time that the other surveys had been completed (see (v) and (vi) below), it was felt that this was out of the question in terms of time and labour. In any case, most of the species recorded were perennials.

(v) Re-run of Some Transects

An amended method of sampling was devised after the original transects had been recorded. Mainly because the introduced pasture species did not appear likely to lend themselves to the method, the emphasis in the original transecting was on native species in pasture. It was intended that the role of the introduced non-phanerophytic species would be determined later when the vegetation of selected units was sampled separately. However, it was felt subsequently that a fuller account of the vegetation and its environment might have been obtained from the original transects if all non-phanerophytic vegetation had been recorded. The features in which the amended method differed from the original were as follows.

If more than 50% of any foot was covered by one non-phanerophytic species (indigenous or introduced), the species was recorded. If more than 50% of any foot was covered by non-phanerophytic vegetation that did not fulfil this condition (with the exception of co-dominance by two species, as in the original transecting); (a) the foot was recorded as "f" (forbs) if species other than grasses and/or clovers covered more than 50% of the foot; (b) the vegetation was classified as "pasture" if grasses and/or clovers covered more than 50% of the foot.

The recording of microhabitat was also amended to give a more complete record. Biotic microhabitat was recorded for all feet, including "pasture" feet, except that, to save time, the uprights of stock tracks were not recorded where these were in "pasture" feet, their presence on steep slopes being inferred from the records of the treads.

Some sections of the original transect lines, comprising about a third of the total length, were re-run in terms of these amendments in October-December 1954 (spring and early summer). The original records were carried, and it was normally possible to keep to the line of the original transects by using the landmarks that had been noted. (It should therefore be possible to re-run the transects at some time in the future, if desired, in order to look for evidence of changes in the vegetation). The method of recording was to note amendments to the original records of "pasture" feet where this was necessary.

Because cases of dominance by individual species were rare, most of the original "pasture" feet were left in that category. Nevertheless, the amended transecting method did detect some cases of dominance by introduced economic species, and also by introduced non-economic species (the latter being mainly of seasonal importance).

The sections of the transect lines chosen for re-checking comprised those lying within the unit areas that were selected for separate sampling, together with adjacent units. It was, therefore, possible that comparisons between the information on introduced species that was obtained by transecting, and that obtained by separate sampling, would be closer than would have been the case if all transects had been re-run).

(vi) Point Analysis and Frequency Measurements in Chosen Unit Areas.

The transects of the vegetation of unit areas indicated cases of definite dominance by phanerophytes or by native non-phanerophytes

(and, in the amended method, by introduced non-phanerophytes as well). In the case of non-phanerophytes, this was measured in terms of more or less exclusive cover of a foot of transect line by one (or two) species. Most of the non-phanerophytic species recorded in this way were perennial vegetatively-spreading indigenous ferns and herbs, the dominance of which was easily recognizable. Most of the remaining feet, for which no individual dominant species could be recorded, appeared to be dominated by introduced pasture species (as might have been expected from Madden's map), and were therefore classified as "pasture".

The main purpose of the analysis of the vegetation of chosen unit areas was to obtain some idea of the frequency and abundance (in terms of cover area) of those species that could not be detected adequately by the transecting method. This referred more particularly to the introduced non-phanerophytes, but it was also likely that the analysis would pick up a few more indigenous non-phanerophytic species, or modify the results for species which had already been detected by the transects.

It was decided to eliminate, or at least reduce, the complications associated with the shading effect of phanerophytes and tall non-phanerophytes, by selecting unit areas in which the vegetation, as sampled by the transects, was predominantly non-phanerophytic and sward-like. (It was thought possible that this restriction would bias the results, which would not necessarily apply to the non-phanerophytic vegetation of unit areas where phanerophytes were predominant. However, in the case of the vegetatively-spreading indigenous herbs, a check was available from the transects, and in fact the results for these species at least have turned out to be much the same for either method). The unit areas were chosen from as wide a range of environmental types as possible. (This range is indicated in Appendix VII).

Point Analysis. Once the unit areas had been selected, it was necessary to choose a suitable method of sampling to determine the abundance

of the various species in the vegetation. The point method of analysis was indicated, since the choice of the sampling unit had to take into consideration the nature of the plants that appear to predominate in the unploughable pastures, namely perennial grasses.

In relation to sampling, one important characteristic of such species is that vegetative spread makes it difficult to distinguish individual plants, so that counts cannot be made. The other is that the intermingling of the leaves of different species makes it difficult to find examples of sole dominance by any one species, even over very small areas. That is, in any horizontal plane within the vegetation (other than through the bases at ground level), the average size of the areas that are occupied by a single species tends towards a point. In view of this circumstance, it is not usually possible to estimate abundance of species in such vegetation by using dimensional sampling units. (This is reflected in the unsuitability of the transecting method for the introduced pasture species). It was, presumably, the recognition of this problem by New Zealand pasture ecologists that led them to develop the point sampling method (Cockayne (1926a: 352); Levy and Madden (1933)).

In the present work, the object of the point method was to estimate abundance in terms of the proportion of points on the ground for which each species provided cover. A species was regarded as providing cover over a point if it was touched by a vertical steel pin thrust down through the vegetation to represent a perpendicular line passing through the point. Some pasture ecologists (e.g. Crocker and Tiver (1948: 5)) have tried to obtain a better indication of the relative importance of each species by recording not only the species touched by the pin in each thrust but also the number of times that each species is touched by the pin in that thrust. However, in a dense tangle of herbage, it is often much easier to determine merely whether or not a pin touches a species than to decide how many times it does so (although Goodall (1952: 24-31) (1953) has shown that, if it is possible to determine the numbers of contacts with a certain species for an adequate proportion of a given

number of points, it will be found that these data can then be fitted by a theoretical distribution, from which an estimate can be made of the mean number of contacts per point for all the points). Further, even where it is practicable, the method of counting all contacts is far slower (Levy and Madden (1933: 269)).

In making point analyses, Levy and Madden (1933) used a frame on legs which carried a single row of 10 steel hatpins in vertical holes spaced two inches apart. However, Blackman (1935: 772) has pointed out that individual point samples should be preferable to random frames of ten points, particularly where there is strong over-dispersion (aggregation) (which is the normal condition in permanent pastures). Goodall (1952: 38) has supported Blackman with statistical findings, but, on the grounds that "the scope for subconscious choice of placement is greater with individual points than with frames", has proposed a random distribution of frames, in each of which only one point is recorded, the position of that point in the frame being chosen randomly. However, after field trials, it was decided to use a dart. This consisted of a sailmaker's needle 10 inches long and with a diameter of about 0.07 inch. It was realized that, although the latter dimension was necessary for rigidity, the results given by a pin of this diameter may tend significantly to overestimate percentage cover as compared with those given by a true point (Goodall (1952: 5-7)). Streamers were threaded through the eye of the needle to ensure a vertical fall and to mark the fall.

This dart was thrown at random within a chosen unit area, and the species touched by the standing needle were recorded. The use of a 10 inch needle meant that a layer was sampled between ground level and approximately 10 inches above the ground (the upper limit of perennating buds of non-phanerophytes). (Normally, only the very point of the needle penetrated the soil, so that little error was expected from variations in penetration. In any case, the height of the non-phanerophytic vegetation was usually well below 10 inches).

The method of recording in the field notebooks was that used by

Gates (1949: 17). The species were listed, and, as each point was taken, the number of the point was placed alongside the names of the species that were touched by the needle. (The number alongside the highest species, that is, the first one hit by the descending needle, was underlined to indicate top cover).

Where the needle did not touch any plants in the 0-10 inches layer, a record of bare ground or dung was made as appropriate. Where any point lay within a microhabitat feature (as defined for the transecting) this was recorded. Where phanerophytes were present, or where leaves<sup>or shoots</sup> of non-phanerophytes rose more than 10 inches above the ground, a record was made of the species that would probably have been touched by an upward projection of the point above 10 inches. (Observations made during transecting had suggested that such estimates could be made by eye). The phanerophyte records were annotated as in the transects. (Where records were made of parts of non-phanerophytes more than 10 inches above the ground, this was indicated by annotating them as though they were phanerophytes).

As far as the number of points per unit area was concerned, it was decided to accept the claim of Levy and Madden (1933: 269) that, for the estimation of percentage cover (number of points in 100 that touch a species), 100 points per paddock are sufficient to give information on the dominants. (Presumably Levy and Madden were working with paddocks that were equivalent to unit areas). (Goodall (1952: 39) has pointed out that the degree of precision attained in an estimate of percentage cover (using random points) may be determined from first principles. "The standard deviation of values obtained by use of  $k$  points will be  $\sqrt{pq/k}$  where  $p$  is the percentage cover and  $q$  its complement (100- $p$ ). If, for instance, a standard error of ten per cent. of the mean were considered satisfactory, this would be attained for a species occupying half the area with the use of 100 randomly distributed points; but for a species occupying only one-tenth of the area, 900 points would be necessary, and for one occupying ~~one~~ one-hundredth, 9900 points"). Field trials indicated that 100 points represent about one

hour's work.

Frequency Measurements. Although the point method was a suitable means of estimating the amount of cover (or of top cover) provided by each species in the pasture vegetation, information was required also on the nature of the distribution of each species. (Goodall (1952: 13) has suggested that an indication of distribution could be obtained with point analysis, but only if "the location of the points in the area and their relation to adjacent points is considered"). Separate frequency measurements were made therefore in each selected unit area. These were made in the usual way by taking a number of randomly distributed small quadrats, and listing the species in each, in order to determine the proportion of such quadrats in which each species occurred. (Both point analysis and the quadrat count are frequency determinations of a kind. The first is used to estimate the percentage of random points in which a species may be expected to occur, and thus to give an estimate of cover. The second is used to estimate the percentage of random small quadrats in which a species may be expected to occur, and thus to give an estimate of distribution. The "frequency" that is estimated from the transects of the systematic survey is different again, being an estimate of the number of transects (one to a unit area) which may be expected to detect a given species. It is important to distinguish between these concepts of transect frequency, or distribution over a number of unit areas, and quadrat frequency, or distribution within a unit area).

It was decided to use a square quadrat, since a rectangular one would probably have reduced the effects of over-dispersion (Clapham (1932: 196-197)). It was then necessary to determine the minimum area for the plots that would "still obtain satisfactory statistics concerning the composition and structure of the community" (Cain (1943: 242-43)). The usual method of plotting number of species against area of quadrat, and taking as the "minimal area" the area co-ordinate of the point at which the curve appears to flatten, can hardly be regarded as objective. The relation between number of species and quadrat area is

usually logarithmic (Williams (1944: 5-11); plotting the untransformed values therefore gives a characteristic curve, which continually lessens in slope; and, as Cain (1943: 242-43) has pointed out, the optical selection of the point on the curve which indicates the minimal area will depend on the ratio between the axes. The method of determining minimal area by plotting the number of "constant species" (that is, species which occur in over 90% of the quadrats examined) against quadrat area, also lacks objectivity (Pearsall (1924: 135-39)).

Pearsall (1924: 139) has concluded that nothing of value will be lost by the arbitrary standardization of minimal areas. For the present work, it was decided to use a quadrat of side 30 cm., that is, with an area of about 900 sq.cm. (approximately one square foot). (Cain (1943: 243), determining frequency in fell-field vegetation, used a plot area of 1000 sq.cm.). It was necessary to realize that the information that could be obtained by the use of these quadrats, namely the probability that a given species would occur in a random plot of this size, would be empirical only.

It would seem that the number of quadrats must also be chosen arbitrarily. (The concept of the "minimal number curve" (Cain (1943: 243)) is analagous with that of the "minimal area curve"). It was decided to use 25 quadrats per unit area to determine percentage frequency. This number may be compared with the 20 used by Cain (1943: 243) at each "station", and the 30 to 50 per "community" of Weaver and Clements (1938: 21). (The degree of precision attained in an estimate of percentage frequency (using random quadrats) may be determined as in the case of point analysis. Thus, for a species having a frequency of 50%, the standard error of the mean for samples of 25 quadrats would be  $\sqrt{50 \times 50 / 25}$ , namely 10%, or 20% of the mean). 25 quadrats were found to represent about one hour's work.

In the present work, a square wooden frame was used which had a side of 30 cm. (internal measurement). To assist examination of the vegetation, the internal area of the frame was divided by lines into nine squares of 100 sq.cm.. This frame was distributed at random. The

frame itself was not thrown about, because it would have tended to slide on steep slopes. The dart that was used in the point analyses was thrown to obtain the random locations of the frame, the frame itself being placed so that the centre coincided with the point on which the dart fell. The frame was oriented randomly when being thus placed in position.

The recording was carried out as for point analysis, in that the species were listed and the number of each sample was placed alongside the names of the species that occurred in that quadrat. Phanerophytes were annotated as in the point analyses. (A non-phanerophytic species was annotated with N for a given quadrat if some or all of the plants of that species within that quadrat had leaves<sup>or shoots</sup> that permanently exceeded 10 inches in height).

If a frame fell in a microhabitat feature (defined as for the transects) this fact was recorded. Dung was not recorded within the frame, but such records might have served as a check of the transect records had they been made.

General. 48 unit areas were sampled by point analysis and frequency quadrat measurements. (This number included three unit areas of ploughable pasture, which were sampled to amplify the results of the extensive examination). Three further areas of swampy ground were sampled by point analysis alone. It was recognized that there was a theoretical need for seasonal checks, but, as in the case of transecting, time and labour were the limiting factors. The sampling was carried out in October-December 1954 (spring and early summer), when the vegetation was most likely to include annuals and die-back perennials.

(vii) Treatment of Sampling Data.

Efficiency of Transect Samples. The original line transects covered a total length of 199,193 feet (about 38 miles), and passed through 1608 unit areas. Table II gives the classification of these 1608 unit areas in terms of land-use, and the total lengths of the sampling transects (that is, sections of the general transect lines) lying

within each class of unit area.

1138 sampling transects, totalling 163,180 feet, were recorded in unploughable pasture. (Of these 1138 transects, 412 were later re-run according to the amended sampling method). These sampling transects range in length from 1 to 1675 feet, with a mean length of about 145 feet and a standard deviation of about 165 feet. The disadvantage in having sampling units of varying lengths has been mentioned in connection with the planning of the field method. An attempt was made to meet this difficulty by dividing the transects into length-groups. Comparisons of estimates of frequency or abundance would be more likely to be valid if based on sets of transects belonging to the same length-group or having similar length-group distributions.

(The opinions of two biometricians, namely Mr. A.C. Glenday and Dr. B.I. Hayman, were obtained on the validity of comparing estimates of frequency based on sets of sampling units of varying size, when such sets of sampling units have similar size-distributions. They considered that there are no apparent objections to making such comparisons, other than the additional work involved in determining the similarity of the size-distributions, and the difficulty of determining the reliability of the results. Neither of these objections would, of course, have arisen with sampling units of uniform size).

It was proposed to delimit the length-groups in such a way that the midmark of each group was roughly twice the preceding midmark. In view of the value of the mean length of the transects, the basic length-group was taken as 101 - 200 feet. (This range contains 241 transects). The lesser groups were therefore taken as 51-100 feet (218 transects), 26-50 feet (171), and 13-25 feet (114). (It was decided arbitrarily to disregard the 107 transects less than 13 feet in length, since many of these represented fragmentary unit areas). The transects greater than 200 feet in length were subdivided in a slightly different way, so that the numbers of transects in the groups would be roughly of the same order as those in the groups of lesser length. One group was taken as 201-350 feet (181 transects), and the other as 351-1675 feet (106). In

TABLE II.                      CLASSIFICATION OF TRANSECTS OF UNIT AREAS

Classification	Number of Unit Areas Transected.	Total Length of Transects (ft.)
Unploughable pasture	1138	163180
Impenetrable vegetation (non-pasture)	145	26700
Cliffs and stream banks	34	1772
Watercourses and stream beds	210	3208 *
Erosion features (active or unhealed)	43	1815
Ploughable land	11	706
Roads and farm tracks	22	972
Plantations, homesteads, stockyards	5	840
<b>Total</b>	<b>1608</b>	<b>199193</b>

\* Includes 3 units totalling 1209 feet.

spite of the greater relative width of the final group, the mean length of the 106 transects is about 435 feet, and 75 of them lie within the range 351-550 feet.

To obtain some assessment of the relative efficiency of sampling transects from different length-groups, the mean and variance were determined for the numbers of species detected by the original transects in each length-group (table III). There is a roughly equal increase in the mean number of species for each (approximate) doubling of the midmark. This indicates a logarithmic relationship, which is confirmed by calculation. The correlation coefficient for the mean number of species and the logarithm of the midmark is a highly significant 0.99 (Moroney (1954: 286-87, 311)).

In view of this clear-cut relationship between length of transect and number of species detected, it was to be expected that there would be significant differences between the means (and variances) for different length-groups. This was confirmed by determining  $t$  (difference of means/standard error of difference) (Moroney (1954: 220-21, 232)) for contiguous length-groups. The results are indicated in table III. This test is not completely reliable in the present case, since the given levels of significance for  $t$  (Mather (1949: 258)) are based on the assumption of random sampling, and also of normal, rather than skewed, distributions.

It was desirable to test the internal consistency of the groups, in view of the marked differences between contiguous groups. This was done for two of the wider-range groups, namely 101-200 feet and 201-350 feet, by dividing them into two and three 50-foot classes respectively, and comparing these classes within groups in the same way as the length-groups were compared. A within-group comparison was also made in the 351-1675 feet group, the classes compared being 351-550 feet and 551-1675 feet. The former class was also compared with the 201-350 feet group. The results of these comparisons are shown in table III. The only inconsistency is a probably significant difference between the first two classes of the 201-350 feet group. However, it was decided

TABLE III.      RELATION OF LENGTH OF TRANSECT TO NUMBER OF SPECIES.

Length-group	n	$\bar{x}$	$s^2$	t (with significance)
13- 25	114	0.77	1.12	$\left. \begin{array}{l} 3.1^{**} \\ 6.0^{***} \\ 4.2^{***} \\ 4.9^{***} \\ 2.9^{**} \end{array} \right\}$
26- 50	171	1.24	1.97	
51- 100	218	2.38	5.22	
101- 200	241	3.44	9.09	
201- 350	181	5.00	12.12	
351-1675	106	6.56	22.30	
101- 150	154	3.34	8.56	$\left. \begin{array}{l} 0.7 \text{ n.s.} \end{array} \right\}$
151- 200	87	3.63	9.98	
201- 250	78	4.42	8.99	$\left. \begin{array}{l} 2.2^* \\ 0.9 \text{ n.s.} \end{array} \right\} 0.9 \text{ n.s.}$
251- 300	63	5.71	14.75	
301- 350	40	5.00	12.65	
201- 350	181	5.00	12.12	$\left. \begin{array}{l} 1.9 \text{ n.s.} \\ 1.5 \text{ n.s.} \end{array} \right\}$
351- 550	75	6.07	18.44	
551 -1675	31	7.74	29.67	

to sustain the 201-350 feet groups since there is no discrepancy between the end classes, and since the tests are only approximate in any case.

The length-groups were symbolized as "I" (13-25 feet), "II" (26-50), "III" (51-100), "IV" (101-200), "V" (201-350), and "VI" (351-1675). The sampling transects of the re-run were classified arbitrarily into the same length-groups. 32 transects were disregarded as being less than 13 feet in length. The rest were classified into: I (40); II (58); III (76); IV (97); V (67); and VI (42).

Estimation of Frequency from Transects. The transects have been used to estimate the distribution ("frequency") of a species or category over a given combination of unit areas, in terms of the number of sampling transects (one in each unit area) in which the species or category occurred. For example, the "total" column of appendix II gives the numbers of transects in which each species or category was detected out of the 1031 original transects or the 380 re-run transects. (In all appendices based on the transecting, the species are separated into the categories "indigenous", "introduced", and "status doubtful", in that order. Within each category, the species are given in the order in which they appear in the "List of Species". The lists of species are followed by the other categories referred to in the accounts of transecting procedure. Species are subdivided according to life form and to microhabitat, as in the same accounts). The apparent relative importance of the larger estimates is not greatly affected by breaking down the results by length-groups (appendix IV). (This is in order, since the apparently logarithmic increase in the efficiency of the transect samples with increase in length may be expected to apply fairly equally to all species). There is, of course, less obvious agreement between length-groups in the case of the smaller estimates.

(Since there is a variation in transect length within each length-group, and since the transect samples were not placed randomly, it is not possible to make a valid determination of the probable accuracy of

these frequency estimates. If these conditions had been fulfilled, then the standard error of the mean could have been calculated as for frequencies determined by point or quadrat sampling units. Thus, if the frequency of a species as determined by transects of a given length were 25% (equivalent to 50 transects out of 200, for example), then the standard error of the results obtained by the use of 200 transects would be  $\sqrt{25 \times 75 / 200}$ , that is, about 3%, or 12% of the mean).

In appendix II, the estimated frequency of each species or category is shown for varying environmental conditions. The environmental factors considered in these tables are orientation, soils, altitude, slope, sheep grazing, and cattle grazing, subdivided as in the account of the transecting method. Each environmental factor is dealt with separately. It would have been more desirable to deal with environmental combinations, but in such case it would have been necessary to reduce the many possible combinations to a workable number by grouping. This was done successfully by Greenall and Hamilton (unpub.: 84-87) (1954: 511-13), in order to obtain a satisfactory interpretation of the varied and complex physical factors influencing land use and erosion. However, it did not appear to be possible to devise such a grouping for the present work.

Soil type might have been expected to provide a basis for grouping. (It would have been necessary to subdivide the soil types in terms of orientation at least). However, when the totals of the original transect samples for each important soil type are subdivided according to altitude, slope, sheep grazing, and cattle grazing respectively (table IV; the figures in parentheses are the equivalent percentages, to the nearest integer), it appears that, while some correlations may exist between soil type and other factors, few of these apparent correlations are at all clear-cut with the exception, to some extent, of that involving altitude.

In dealing with the environmental factors separately, it is necessary to recognize that some of these factors may be correlated. Besides the

apparent correlation between soil type and altitude, the original transects also appear to show some relationships between intensity of grazing and orientation or slope. Thus, there appears to be a correlation between sunny faces and heavy grazing by sheep, the ratios of heavy to light grazing for north, south and east-west orientations respectively being 112/214, 63/207, and 74/199. Cattle grazing does not show such a relationship, the equivalent ratios being 80/246, 69/201, and 78/195. Again, there is an apparent correlation between flat (non-oriented) transects and heavy grazing in the case of both sheep and cattle, the ratios of heavy to light grazing for oriented and non-oriented transects respectively being 249/620 and 76/86 for sheep and 227/642 and 67/95 for cattle. (It is necessary to treat all these data with caution, in view of the varying precision of the dung percentages, together with the possibility that the apparently higher rate of dunging on the flat units is due in part to stock camping at night rather than to differential grazing only).

The estimated frequency of a species or category (appendix II) for each subdivision of an environmental factor (e.g., soil type) is based on the total number of transects lying within that subdivision, regardless of differences in length. (The frequencies of certain important species for the different orientations and soil types are given separately for each length-group in appendix V). In order to obtain some indication of the validity of comparing frequencies of this sort (for a given species or category) from different subdivisions of the same environmental factor, the length-group distributions of the transects lying within these subdivisions have been compared by calculating chi-square (Moroney (1954: ch. 15)). The results are shown in appendix I. The test is not completely reliable in the present case, because the given levels of significance for chi-square (Mather (1949: 259)) are based on the assumption of random sampling. Further, a few of the expected frequencies are less than 5 (Moroney (1954: 258)).

TABLE IV. ENVIRONMENTAL ANALYSIS OF NUMBER OF TRANSECTS IN EACH IMPORTANT SOIL TYPE.

Soil type	Altitude				Slope			Sheep		Cattle		Total.
	0	5	10	15	0	10	30	0	10.1	0	2.6	
11H	68(92)	6(8)	-	-	18(24)	49(66)	7(9)	38(51)	36(49)	46(62)	28(38)	74
13bH	70(73)	26(27)	-	-	20(21)	73(76)	3(3)	78(81)	18(19)	77(80)	19(20)	96
77bH	33(18)	102(55)	52(28)	-	27(14)	136(73)	24(13)	139(74)	48(26)	150(70)	57(30)	187
118a	14(10)	108(76)	21(15)	-	28(20)	111(78)	4(3)	91(64)	52(36)	92(64)	51(36)	143
122	2(1)	118(58)	85(41)	-	36(18)	118(58)	51(25)	145(71)	60(29)	148(72)	57(28)	205
124	-	33(11)	210(73)	44(15)	42(15)	193(67)	52(18)	188(65)	99(34)	217(76)	70(24)	287

The first point that appears from this comparison is that the non-oriented transects are highly significantly shorter on the whole than the oriented transects. It is not surprising, therefore, that the transects in the least steep of the slope groups ( $0-10^{\circ}$ ) are also highly significantly short. The other important point is that, in the original transects only, the transects in the lowest altitude group (0-500 feet) are highly significantly short. In all these cases, the transects may be expected to underestimate frequency as compared with the sets of transects in other subdivisions of the same factor. Less important points are: a possible tendency towards shortness on the part of the transects in soil types 11H and 13bH; and on the part of the transects in the middle slope group (relative to the steepest group); together with the need to pool the re-run transects for soil types 13bH and 11H, and also for altitude groups 1000-1500 feet and 1500-2000 feet, in order to include the latter categories in each case in the comparisons.

In appendix II, the estimated frequencies are accompanied by "expected" frequencies in parentheses. These have been obtained by distributing the total observed frequency for the species or category among the different subdivisions of a given environmental factor, in proportion to the numbers of unit areas in the subdivisions. These are the frequencies that might have been expected if variations in the environment had no effect on the vegetation.

The calculation of the "expected" frequencies assumes that the transects in each subdivision have a similar length-group distribution. This may not apply to the transects in minor soil types, but these are numerically insignificant. It is much more important that the "expected" frequencies, unlike the observed frequencies, do not reflect the tendency to underestimation on the part of the non-oriented transects and those in slope group  $0-10^{\circ}$ , nor (in the original transects only) on the part of altitude group 0-500 feet. To compensate for this, further calculations of "expected" frequency have been made for the environmental factors thus affected. These secondary estimates of "ex-

pected" frequency, which are placed below the primary estimates in appendix II, are obtained in the same way, but with the exclusion of the groups that contain the significantly short transects, and of the portions of the total observed frequency that are contributed by those groups (Since the "expected" frequencies have been rounded off to the nearest integer, and also because the "expected" frequencies for minor soil types are given only in conjunction with positive records, the values for a given environmental factor do not always add up to the same figure as the total frequency on which they are based).

Since some estimates of frequency may be subject to considerable error, no attempt has been made to compare estimated and "expected" frequencies by calculating chi-square. References to environmental associations of species, in the account of the results, are based only on inspection of the data as shown in the appendices.

Only species or categories with an overall frequency of 15 or more (out of 1031 or 380) have been analyzed, since the environmental analysis of lower values produces fragmentary results. Species and categories with overall frequencies of less than 15 are listed separately, and without environmental analysis, in appendix III. (Listing is in the same order as in appendix II).

Estimation of Abundance from Transects. Appendix IV gives the estimated mean abundance for each species or category with an overall frequency of 15 or more. The estimates of abundance on which the means are based are those obtained from each transect in terms of the percentage of the feet within the transect in which that species or category provided cover or occupation (as described in the account of the transecting method). The means have been calculated separately for each length-group, since the accuracy of the percentage from each transect depends partly on the number of feet in the transect. Further, the variance of an estimate of a proportion  $p$  depends on the magnitude of the proportion itself as well as on the size of the sample (in this case, number of feet). Before carrying out simple averaging for

each length-group, it was necessary, therefore, to transform the percentages to angular values ( $\phi = \sin^{-1} \sqrt{p}$ ), subsequently re-converting the mean of the transformed data to the original scale (Bartlett (1947: 40, 45); Mather (1949: 234-35); Fisher and Yates (1953: 44, 66)). The tables of Snedecor (1946: 449-50) were used.

In appendix IV, the mean abundance is given for those transects within a length-group in which the species or category occurs. The number of transects involved (i.e., the frequency) is given in parentheses after each mean.

In the case of the most important species, the mean abundance has been calculated in addition for different orientations and soil types (appendix V). In this appendix, the mean abundance is given for those transects within each length-group subdivision of an orientation or soil type in which the species occurs. The number of transects involved is given in parentheses after each mean. The estimates of abundance in appendix V show little tendency toward clear-cut variations with environment, even in the case of species for which the estimates of frequency (appendix II) do show such tendencies.

Bartlett (1947: 46), dealing with the angular transformation of proper fractions, has advocated "smoothing" the violent jump on the transformed scale between 0 and  $1/n$  and  $(n-1)/n$  and  $n/n$ , by the empirical correction of writing  $0.25/n$  wherever 0 occurs, and  $(n-0.25)/n$  wherever  $n$  occurs. Thus, in the present work, 100% has been treated for the purpose of averaging as  $100(n-0.25)/n$ ,  $n$  being approximated to the midmark of the appropriate length-group).

#### Point Analysis and Frequency Quadrat Measurements.

The results of these measurements are given in appendices VI-VIII. In these appendices, the species are listed as in the appendices based on the transecting, that is, they are separated into "indigenous", "introduced", and "doubtful", and given in the order in which they appear in the "List of Species". The lists of species are followed by the other categories referred to in the accounts of the

field methods. The species are subdivided according to microhabitat, and to life form, as in the same accounts. (The records have also been used to give an estimate of the overall importance of certain microhabitat features).

In appendix VI, the mean percentage cover, mean percentage top cover, and mean percentage frequency are given for each species or category. A mean is given only if positive records were obtained in five or more of the 45 unploughable unit areas that were examined, and such a mean refers only to the units in which the records were made. (The number of unit areas involved is given in parentheses after each mean. In cases where the number is less than five, it is still indicated for the appropriate species or category, but without an accompanying mean). The means have been calculated by simple averaging of angular transformations, followed by re-conversion, as in the estimation of mean abundance from the transects.

In the case of the dominants, and the more important indigenous species, and also Lolium perenne and Trifolium repens, the mean percentage cover and mean percentage frequency have been calculated in addition for varying environmental conditions (appendix VII). The environmental factors (orientation, soils, altitude, slope, sheep grazing, and cattle grazing) are dealt with separately, and are those recorded for the unit areas in question by the transects. As in appendix VI, the means refer only to those unit areas in which positive records were made, and are followed (in parentheses) by the numbers of unit areas involved.

Appendix VIII gives the percentage cover and percentage top cover for three areas of swampy ground. Areas 1 and 2 are in the altitude range 0-500 feet, area 1 being in the 0-10° slope group and area 2 in the 10-30° group (and south-facing). Area 3 is in the altitude range 1000-1500 feet, and in the 0-10° slope group.

(As the estimates are to the nearest 4% in the case of percentage frequency, a "smoothing" correction has been made for the purpose

of averaging by treating frequency estimates of 100% as 99%  
(84.26° on the transformed scale).

## VII. RESULTS OF THE FIELD EXAMINATION

### (1) PLOUGHABLE PASTURE (figs. 6, 7).

Cockayne, Simpson, and Scott-Thomson (1932: 21) have stressed that "as far as we can gather, indigenous weeds are altogether absent (excepting species of Juncus) in artificial pasture of a high class". Madden (1940) has not included any native economic or weed species (other than Juncus species) in his description of high-producing type 3 pasture, such as occupies the Kairanga Plain, although there is a reference to indigenous Danthonia spp. in his account of transitional type 4 pasture. Similarly, rushes (Juncus species) are the only indigenous species mentioned by Levy (1951: 272) in a list of the principal weeds of lowland pastures. The findings of the extensive examination of ploughable pasture within the study area are in agreement with these observations by other workers. The role of indigenous species, other than species of Juncus, appears to be negligible. (Scattered indigenous trees, relics of the former vegetation, are sometimes preserved in ploughable paddocks, but these can hardly be regarded as indigenous weeds).

Three aspects of this state of affairs were studied in a little more detail than was provided by the extensive examination. Firstly, since the most obvious environmental factor associated with ploughable pasture is the actual cultivation, it was thought desirable to pay some attention to the role of indigenous species in the weed flora of land that is under frequent cultivation, namely land that is cropped only. Secondly, the role of indigenous species was examined in pastures on land that, although ploughable and of high or relatively high natural soil fertility, had not in fact been subjected to cultivation. Finally, it was necessary to consider the special case of indigenous species of Juncus in ploughable pasture.

(i) Weeds of Frequently Cultivated Ground

General observations within the study area have indicated that the role of definitely indigenous weeds is more or less negligible under conditions of frequent cultivation. One or two checks have tended to confirm this.

One source of confirmatory information is the data taken from some weed collections that were prepared by horticultural students at Massey College in 1950 and 1951. The majority of these weeds were collected from cultivated ground, but some were from waste ground, hedges, paths, or lawns. 29 collections were presented, each containing single specimens of about 50 species. The elimination of species not taken in the vicinity of Massey College leaves an average number of about 36 species in each collection. As the standard deviation of the numbers of species in the amended collections is about 7 (the extremes being 20 and 47), the collections may be regarded as samples of very roughly equivalent size, which may be expected to give some indication of the relative importance of the various weeds of cultivated ground in the vicinity of Massey College. Table V gives the results of this sampling, the species being grouped according to the number of collections in which each was found. (Indigenous species and those of doubtful status are underlined).

21 species occur in more than half of the collections. None of these is definitely indigenous, but one (Solanum nigrum) is in the "doubtful" category. A further 38 species occur in more than a quarter but less than a half of the collections. Of these, one (Pteridium esculentum) is indigenous, and three (Calystegia sepium, Cotula australis, Oxalis corniculata) are of doubtful status. 29 species occur in more than a tenth but less than a quarter of the collections. These include two indigenous species (Acaena sanguisorbae, Haloragis erecta), and one "doubtful" species (Juncus bufonius). 51 species occur in less than a tenth of the collections, that is, in one or two collections only. (These are not listed in table V). This group includes five indigenous

**TABLE V. FREQUENCY OF OCCURRENCE OF SPECIES IN HORTICULTURAL  
WEED COLLECTIONS**

No. of collections (out of 29)	Species Present in Given Number of Collections
29	-
28	-
27	-
26	<i>Achillea millefolium</i>
25	<i>Capsella bursapastoris</i>
24	<i>Gallega officinalis</i>
23	-
22	<i>Solanum nigrum</i> , <i>Euphorbia peplus</i> , <i>Spergula arvensis</i> ,
21	<i>Chenopodium album</i> , <i>Plantago lanceolata</i>
20	<i>Anagallis arvensis</i> , <i>Erigeron canadensis</i> , <i>Polygonum</i> <i>aviculare</i> , <i>Polygonum persicaria</i> , <i>Prunella vulgaris</i>
19	<i>Fumaria muralis</i> , <i>Matricaria discoidea</i>
18	<i>Bellis perennis</i> , <i>Plantago major</i>
17	<i>Crepis capillaris</i>
16	<i>Mentha pulegium</i>
15	<i>Ranunculus repens</i> , <i>Senecio vulgaris</i>
<hr/>	
14	<i>Agropyron repens</i> , <i>Amaranthus</i> spp., <i>Lepidium ruderales</i> , <i>Linum marginale</i>
13	<i>Polygonum hydropiper</i> , <i>Rumex obtusifolius</i>
12	<i>Calystegia sepium</i> , <i>Anthemis cotula</i> , <i>Cerastium</i> <i>glomeratum</i> , <i>Cirsium arvense</i> , <i>Conium maculatum</i> , <i>Coronopus didymus</i> , <i>Lapsana communis</i> , <i>Rumex</i> <i>acetosella</i> , <i>Silene gallica</i> , <i>Sisymbrium officinale</i> , <i>Taraxacum officinale</i> , <i>Vinca major</i>
11	<i>Galium aparine</i> , <i>Polycarpon tetraphyllum</i> , <i>Trifolium</i> <i>dubium</i>
10	<i>Cirsium lanceolatum</i> , <i>Foeniculum vulgare</i> , <i>Lathyrus</i> <i>latifolius</i> , <i>Sherardia arvensis</i> , <i>Sonchus oleraceus</i>
9	<i>Cotula australis</i> , <i>Oxalis corniculata</i> , <i>Pteridium</i> <i>esculentum</i> , <i>Cytisus scoparius</i> , <i>Lythrum</i> <i>hyssopifolia</i> , <i>Poa annua</i> , <i>Trifolium pratense</i> , <i>Trifolium repens</i> , <i>Veronica persica</i>
8	<i>Geranium dissectum</i> , <i>Lamium purpureum</i> , <i>Vicia sativa</i>
<hr/>	
7	<i>Juncus bufonius</i> , <i>Cardamine hirsuta</i> , <i>Hypochoeris</i> <i>radicata</i> , <i>Lupinus arboreus</i> , <i>Senecio jacobaea</i> , <i>Stachys arvensis</i>
6	<i>Cytisus proliferus</i> , <i>Geranium molle</i> , <i>Stellaria</i> <i>media</i> , <i>Ulex europaeus</i>
5	<i>Galinsoga parviflora</i> , <i>Hedera helix</i> , <i>Rubus fruticosus</i> , <i>Sagina procumbens</i>
4	<i>Acaena sanguisorbae</i> , <i>Haloragis erecta</i> , <i>Allium</i> <i>triquetrum</i> , <i>Helminthia echinoides</i> , <i>Lecntodon</i> <i>hispidus</i> , <i>Odontites viscosa</i> , <i>Ranunculus sardous</i> , <i>Rumex conglomeratus</i> , <i>Sonchus asper</i>
3	<i>Brassica campestris</i> , <i>Erodium cicutarium</i> , <i>Ranunculus</i> <i>sceleratus</i> , <i>Sisymbrium orientale</i> , <i>Veronica</i> <i>serpyllifolia</i> , <i>Vicia hirsuta</i>
<hr/>	
2	16 species
1	35 species

species (Coprosma robusta, Cotula coronopifolia, Mariscus ustulatus, Muehlenbeckia australis, Paesia scaberula), but no "doubtful" species.

Of the five species of doubtful status on the list, four (Juncus bufonius, Calystegia sepium, Oxalis corniculata, Solanum nigrum) are cosmopolitan species of cultivated ground. To the knowledge of the present writer, none of the definitely indigenous species in the collections occurs on regularly cultivated ground in the vicinity of Massey College. All are rather species of uncultivated ground (as around hedges and trees) or of waste ground.

A further small check was made of this apparently negligible role of indigenous species in cultivated ground. A vegetable-growing area at Massey College, on soil type 13, had been ploughed in the autumn of 1955, and left untouched through the winter. By spring there was a dense growth of weeds. In September, 16 square quadrats, each of 900 sq. cm., were taken at random in the area and the numbers of individuals of each species were determined for each quadrat. The results of the analysis are given in Table VI. (The species are listed as in the appendices that deal with point analysis).

Of the species listed, only Hydrocotyle spp. is definitely indigenous, and this taxon is of little numerical significance. Of the two species of doubtful status, Juncus bufonius is both of high abundance and of high frequency, while Cotula australis is of relatively low frequency and of low abundance.

(ii) Analyses of Pasture on Unploughed Land

Point analyses and frequency quadrat measurements were made for three areas of ploughable, but unploughed, pasture in the course of the present work (table VII). These analyses may be compared with three point analyses of similar pastures recorded by Merry (unpub.: 40-41, 43-45) (table VIII). In tables VII and VIII, the species are listed as in the appendices that deal with point analysis.

TABLE VI. FREQUENCY AND ABUNDANCE OF WEED SPECIES ON CULTIVATED  
GROUND. BASED ON 16 QUADRATS.

Species	Frequency	Total No. of Indivs.	Mean No. of Indivs.
<u>Hydrocotyle spp.</u>	2	3	0.2
Ranunculus parviflorus	3	3	0.2
Coronopus didymus	14	57	3.6
Capsella bursapastoris	10	20	1.3
Cardamine hirsuta	1	1	0.1
Spergula arvensis	15	181	11.3
Sagina procumbens	1	1	0.1
Cerastium glomeratum	16	166	10.4
Cerastium caespitosum	1	1	0.1
Stellaria media	14	188	11.8
Rumex acetosella	1	2	0.1
Polygonum aviculare	2	4	0.3
Trifolium dubium	11	59	3.7
Trifolium repens	13	38	2.4
Trifolium subterraneum	2	4	0.3
Erigeron canadensis	1	1	0.1
Soliva sp.	1	1	0.1
Senecio vulgaris	2	2	0.1
Cirsium lanceolatum	4	4	0.3
Helminthia echioides	1	2	0.1
Sonchus oleraceus	2	2	0.1
Crepis capillaris	5	6	0.4
Plantago lanceolata	1	1	0.1
Veronica persica	16	310	19.4
Veronica arvensis	3	9	0.6
Dactylis glomerata	4	5	0.3
Poa annua	16	560	35.0
Agrostis tenuis	2	6	0.4
<hr/>			
Juncus bufonius	15	1145	71.6
Cotula australis	5	15	0.9

Table VII shows the following values for each of three unit areas: (1) percentage cover of each species, that is, number of points in 100 at which the species occurred; (2) percentage top cover of each species, that is, number of points in 100 for which the species provided top cover; (3) percentage frequency, that is, four times the number of 900 sq.cm. quadrats (out of 25) in which the species occurred.

Unlike the figures given for the present work, Merry's figures for "percentage cover" are not based on direct determinations. They are derived from 300-point analyses of the "total sward", by means of a formula of Levy and Madden (1933: 269-70), and thus refer rather to the relative importance of each species in the "total sward". However, if the different handling of the data is borne in mind (and also the possibility that Merry used needles with a diameter significantly different from 0.07 in.), there seems to be no reason why a general comparison should not be made between Merry's figures and those for the present work. To assist the comparison, Merry's analyses for the month of December are shown, since two of the three analyses given in table VII were made in that month. (The analysis of unit area 1 was made at the end of October). Where a species was detected by Merry's monthly analyses at some time, but not in December, the maximum value for that species is given in parentheses, together with the month nearest December in which that maximum was recorded.

None of the unit areas in table VII had been cultivated prior to the analysis. Each is bounded by unploughable pasture, and in no case does the unit area appear to be large enough to justify the provision of access. Several soil types are involved. In unit area 1, a stream floodplain, the soil type is 1 (Manawatu loam, etc.). In unit area 2, a damp flat, the soil appears to be a peaty loam, possibly type 107. Unit area 3, which seems to be a remnant of the original surface of the Fitzherbert Plain, is in the area mapped as carrying soil type 13 (Tokomaru silt loam).

The dominant species in the analyses shown in table VII are Lolium perenne and Trifolium repens. The other important species are Holcus lanatus, Agrostis tenuis, and Anthoxanthum odoratum, while Cynosurus cristatus is of variable frequency but low abundance. The dominants are those expected in high-producing pasture (Madden's type 3). The presence of Agrostis and Anthoxanthum indicates that the pastures are not of particularly high quality, being somewhat allied to Madden's type 4, and this is not surprising in view of their status as uncultivated fragments. Nevertheless, species other than grasses and clovers are of low abundance, although a few, such as Ranunculus repens, Cerastium glomeratum, and Hypochoeris radicata, tend to be of fairly high frequency. (Madden has cited Ranunculus species and Juncus species as typical weeds of the wetter parts of pasture type 3, and Plantago lanceolata, Hypochoeris radicata, Leontodon hispidus, and Frunella vulgaris as typical of type 4). The only indigenous species recorded are small amounts of Juncus polyanthemus in two unit areas and Triguetella papillata in one unit area.

Merry's analyses were made on unploughed land of soil type 13, under varying conditions of drainage. Pasture 1 had been mole drained, pasture 2 was on a knoll, and pasture 3 was undrained and seasonally wet. Although the varying environment may be reflected in the composition of these pastures, and although bare ground tends to be prominent, there is a general resemblance to the pasture sampled during the present work. Lolium perenne and Trifolium repens are less important, each being a clear-cut dominant in one pasture only. The other important grasses and clovers are Cynosurus cristatus, Holcus lanatus, Agrostis tenuis, Anthoxanthum odoratum, and Trifolium dubium. The only important species other than grasses and clovers are Hypochoeris radicata and Leontodon hispidus. It is noteworthy that these species are unimportant in the pasture in which Lolium perenne is a clear-cut dominant. Records of indigenous species are limited to traces of Musci (almost certainly indigenous), and of Danthonia spp., Juncus vaginatus,

TABLE VII.      PERCENTAGE COVER, PERCENTAGE TOP COVER, AND PERCENTAGE  
FREQUENCY OF SPECIES IN UNPLOUGHED PASTURE UNITS.

Unit area no.	% cover			% top cover			% frequency		
	1	2	3	1	2	3	1	2	3
<i>Triquetella papillata</i>	-	-	-	-	-	-	4	-	-
<i>Juncus polyanthemos</i>	3	-	-	3	-	-	-	-	4
<u><i>Juncus polyanthemos</i> N</u>	-	-	-	-	-	-	16	-	-
<i>Ranunculus repens</i>	4	2	1	-	1	-	60	20	8
<i>Sagina procumbens</i>	-	-	-	-	-	-	4	-	-
<i>Cerastium glomeratum</i>	-	1	-	-	-	-	8	20	32
<i>Rumex acetosella</i>	-	-	-	-	-	-	4	-	-
<i>Rumex obtusifolius</i>	-	-	-	-	-	-	-	12	-
<i>Medicago lupulina</i>	-	-	-	-	-	-	4	-	-
<i>Trifolium repens</i>	45	59	43	5	29	14	100	100	100
<i>Bellis perennis</i>	-	-	-	-	-	-	-	4	-
<i>Cirsium lanceolatum</i>	1	-	3	-	-	3	8	-	8
<i>Cirsium arvense</i>	-	-	-	-	-	-	-	4	-
<i>Hypochoeris radicata</i>	1	-	4	1	-	3	44	24	60
<i>Leontodon hispidus</i>	-	-	-	-	-	-	4	4	-
<i>Taraxacum officinale</i>	-	-	-	-	-	-	-	-	4
<i>Crepis capillaris</i>	-	-	1	-	-	-	-	-	4
<i>Plantago lanceolata</i>	-	-	-	-	-	-	4	12	4
<i>Plantago major</i>	-	-	-	-	-	-	-	52	-
<i>Prunella vulgaris</i>	-	-	-	-	-	-	-	12	-
<i>Mentha pulegium</i>	-	-	2	-	-	1	4	-	8
<i>Juncus tenuis</i>	-	-	-	-	-	-	-	-	4
<i>Lolium perenne</i>	79	47	70	62	36	61	100	100	100
<i>Cynosurus cristatus</i>	4	-	2	1	-	1	4	12	56
<i>Dactylis glomerata</i>	2	-	-	1	-	-	8	-	-
<i>Bromus mollis</i>	-	-	-	-	-	-	-	4	-
<i>Poa</i> spp.	-	-	-	-	-	-	-	-	52
<i>Festuca arundinacea</i>	2	-	-	2	-	-	8	-	-
<i>Holcus lanatus</i>	27	30	21	8	15	9	80	96	40
<i>Agrostis tenuis</i>	28	17	10	11	13	3	56	72	36
<u><i>Anthoxanthum odoratum</i></u>	22	7	9	3	6	5	60	44	48
<u><i>Juncus articulatus</i></u>	1	-	-	1	-	-	-	-	-
cow dung	1	-	-	1	-	-	-	-	-
sheep dung	1	-	-	1	-	-	-	-	-

TABLE VIII.    "PERCENTAGE COVER" IN THREE PASTURES IN DECEMBER  
(MERRY).

Pasture no.	1	2	3
Musci	{ Aug 0.4 }	-	{ Aug 2.0 }
Danthonia spp.	{ Jan 0.3 }	0.4	-
Juncus vaginatus	-	-	{ Sep 0.2 }
<u>Acaena spp.</u>	{ Nov 0.2 }	-	-
Ranunculus repens	{ Nov 0.4 }	{ Aug 1.4 }	-
Cerastium glomeratum	{ Aug 0.4 }	0.4	{ Feb 0.4 }
Trifolium dubium	8.9	4.4	11.7
Trifolium repens	4.6	0.4	22.8
Bellis perennis	0.2	{ Aug 0.6 }	1.2
Cirsium lanceolatum	{ Jan 0.5 }	{ Sep 0.4 }	-
Hypochoeris radicata } Leontodon hispidus }	17.1	1.7	17.3
Taraxacum officinale	{ Oct 0.7 }	-	0.8
Plantago lanceolata } Plantago major }	1.0	-	1.5
Veronica sp.	{ Nov 0.2 }	0.4	-
Prunella vulgaris	-	-	0.9
Mentha pulegium	1.7	{ Jun 1.7 }	1.9
Lolium perenne	9.2	47.3	6.6
Cynosurus cristatus	11.9	0.8	11.5
Dactylis glomerata	0.2	5.0	-
Bromus hordeaceus	-	0.2	0.2
Poa annua	0.2	0.2	-
Festuca capillata	{ Sep 0.2 }	-	-
Holcus lanatus	5.6	9.6	1.7
Phleum pratense	0.2	{ Nov 0.2 } { Jan " }	0.4
Agrostis tenuis	22.1	6.7	8.8
<u>Anthoxanthum odoratum</u>	12.5	1.3	5.3
<u>Juncus articulatus</u>	{ Sep 0.4 }	-	-
Bare ground	4.5	21.2	7.7

and Acaena spp. (Determinations of frequency might, of course, have detected more indigenous species). Although there is hardly any record of indigenous Juncus species in the analyses, Merry has referred to rushes as being present in pasture 1, and important in pasture 3.

Although these two sets of analyses are too fragmentary to permit definite conclusions to be drawn, they do suggest that, even on uncultivated ground, a pasture that in its general composition tends to resemble Madden's type 3 pasture (which is, presumably, equivalent to the "artificial pasture of high class" of Cockayne, Simpson, and Scott-Thomson), will also resemble that pasture type in the virtual absence of indigenous species other than Juncus species.

#### (iii) Indigenous Species of Juncus in Ploughable Pasture

Healy (1953b: 2), in discussing Juncus species as a farming problem, has pointed out that "Group I, leafless species, is the group of greatest significance to farmers, comprising six perennial species which occur as major pasture weeds throughout New Zealand". Five of these species (Juncus polyanthemus, J. luxurians, J. pallidus, J. vaginatus, J. pauciflorus) are indigenous. The sixth (J. effusus) is of doubtful status.

All six of these species occur in the ploughable pastures of the Manawatu district. These are high-producing pastures, which are usually of the long-rotation type on the Kairanga Plain, but are liable to more frequent cultivation on the lower floodplain of the Manawatu River, where there is often an alternation of pasture and cash crops. The pastures consist predominantly of Lolium perenne and other ryegrasses, Trifolium repens, and Cynosurus cristatus.

To obtain an indication of the relative importance of the above-mentioned Juncus species in these pastures, an examination was made of paddocks adjacent to some of the roads of the Kairanga Plain and of the lower floodplain. About 16 miles of road were traversed in the former area, and about 10 miles in the latter, and the numbers of paddocks

examined were 262 and 100 respectively. Of the paddocks examined on the Kairanga Plain, 37 (14%) were occupied by newly-ploughed land, crops, homesteads, or orchards; 168 (64%) by rush-free pasture; 53 (20%) by pasture with light rush infestation (rushes appearing to dominate less than 10% of the paddock); and 4 (2%) by pasture with moderate rush infestation (10-25% of the paddock). The corresponding figures for the lower floodplain were 28 paddocks (out of 100) not in pasture; 64 in rush-free pasture; and 5 lightly, and 3 moderately, infested with rushes. (The visual impression of the species involved was that the principal species was Juncus polyanthemus, while the other important species were J. luxurians and J. vaginatus. All of these species are indigenous).

These figures suggest that there is a higher degree of rush infestation in the long-rotation pastures of the Kairanga Plain than under the more frequent cultivation of the lower floodplain, the chi-square of the ratios of infested to non-infested grassed paddocks being about 6.5 (probability about 1%) (Moroney (1954: 254-55). (There was, of course, some variation in the size of the paddocks, but for the purposes of this very rough estimate they were regarded as equal in size). This conclusion (if correct) tends to confirm the conclusion of Merry (unpub.: 62) that adequate cultivation (combined with the sowing of high-grade strains of pasture species) eliminates Juncus species.

## (2) UNPLOUGHABLE PASTURE.

This section is based largely on the results of the sampling survey (appendices II-VIII), together with some additional general information obtained from the extensive examination. In many respects, the results of the sampling survey are in accordance with the observations made during the extensive examination, and with relevant observations of other workers (which are referred to at the appropriate points). To this extent, the sampling survey might seem to give some point to "that old jibe which defines ecology as 'the painful elaboration of the obvious'". (Ellison (1957: 64)). On the other hand, Galton

has pointed out that "general impressions are never to be trusted". (Mather (1949:2)). The use of more objective methods to check the general observations is surely desirable even where the results turn out to be purely confirmatory, and much more so where they do not.

(i) Introduced Species as an Environmental Factor

The stated object of the systematic examination of unploughable pasture has been to determine what indigenous species are present in such pasture (and the relative importance of such species), and under what environmental conditions. One factor of that environment, namely the assemblage of introduced economic and non-economic species, is relatively uniform. They are mostly species of the sward, and that sward does not vary greatly in composition as far as the introduced components are concerned.

With the exception of the indigenous economic taxon Danthonia spp. and the introduced weed Hypochoeris radicata (which are discussed later), the dominant species and also the chief subordinate species of the sward are introduced economic species (appendices VI, VII). Agrostis tenuis and Anthoxanthum odoratum (the former being the more important) are the chief sward-forming species, being of high frequency and high abundance in nearly every unit area sampled. Festuca rubra var. commutata has a more limited distribution, but also tends to be a dominant where it does occur. The principal expression of this species would appear to be on soil type 118a, and under relatively heavy sheep grazing. (The analyses made by Suckling (1954: 252, 254-55) appear to confirm that Festuca rubra var. commutata is an important species of some unploughable pastures, although it is not shown as such in Madden's pasture types 4, 8, or 9).

The economic species of lesser importance are Holcus lanatus, Trifolium repens, T. dubium, Lolium perenne, Cynosurus cristatus, and Dactylis glomerata. All are widely distributed, and of relatively high frequency and abundance, although not in the same class as the

dominants. In terms of environment, Lolium perenne and Trifolium repens tend to be more prominent on easier slopes and under relatively heavy sheep and cattle grazing. Lolium perenne does not appear to have any special significance on stock tracks, but the relative importance of Trifolium repens may be increased in this microhabitat.

All of these economic species are perennials, with the exception of Trifolium dubium (annual).

As far as the introduced non-economic species are concerned, most are subordinate species of the sward. There are a few exceptions (appendices II, IV). The only important introduced phanerophyte is Ulex europaeus, which tends to form thickets at lower altitudes, particularly on steeper slopes and under relatively light grazing. (Gibson (unpub.) has noted the relative importance of Ulex europaeus on the lower foothills of the Fitzherbert district). The less important Cytisus scoparius forms a few localized thickets, more particularly on north-facing slopes and at lower altitudes. (Cockayne (1928: 359) has pointed out that both Ulex europaeus and Cytisus scoparius lose their aggressive powers with increasing altitude). Further, three non-phanerophytic species with a somewhat different life-form from that of the species of the sward, namely Cirsium lanceolatum, C. arvense, and C. palustre, occur over a wide range of habitat. Such importance as they have is largely seasonal, since the first is an annual and the others are die-back perennials.

The most important introduced weed in the sward is Hypochoeris radicata (appendices VI, VII). (This is supported by the analyses made by Suckling (1954: 255)). In terms of abundance and frequency, it ranks next to the dominant economic species. The principal expression of Hypochoeris radicata tends to be on soil types 122 and 124, and at higher altitudes. Several other introduced non-phanerophytes, namely Sagina procumbens, Cerastium glomeratum, Linum catharticum, Bellis perennis, Leontodon hispidus, Taraxacum officinale, Plantago lanceolata, and Prunella vulgaris, are widely distributed, and often of relatively high frequency within the unit areas in which they occur.

In terms of abundance, however, none is as important as the lesser economic species, let alone Hypochoeris radicata.

Most of these non-economic sward-forming species are perennials, the exceptions being Cerastium glomeratum and Linum catharticum.

(ii) Indigenous Species

The indigenous species of unploughable pasture are treated in this section in terms of general life-form, being classified into phanerophytes, ferns, large monocotyledons, and sward-forming species. The first three classes are covered essentially by the results of the transecting survey (appendices IIA, IIIA, IVA, V). They tend to be minimized in the results of the point analysis and frequency quadrat measurements (appendices VI, VII), since these latter are based on unit areas in which the vegetation is predominantly swardlike. Conversely, the fourth class is covered essentially by appendices VI and VII. However, the results of the transecting survey are relevant also in the case of those indigenous sward-forming species that tend to occur in aggregations. Many of the important indigenous sward-formers do tend to occur in this way; and thus are subject to a double check.

Phanerophytes (figs. 8-13).

The most important phanerophytic species, both as nanophanerophyte and as a macrophanerophyte, is Leptospermum scoparium. Within the area of the systematic survey, it tends to be associated more particularly with soil types 11H, 13bH, and 118a, and with the lower altitudes. (As with Ulex europaeus, Gibson (unpub.) has noted the relative importance of this species on the lower foothills of the Fitzherbert district). However, it occurs on the Pohangina Plain at all altitudes up to 2000 feet and higher. Although Leptospermum scoparium is at present of little relative importance on the soils derived from greywacke (types 122, 124), it appears to be colonizing

these soils at several places. It is certainly an important species in pastures on greywacke soils in some other parts of New Zealand, for example at the southern end of the Tararua Range (Crocker (1953: 12-14)).

Crocker (1956: 55-56) has described Leptospermum scoparium in pasture as a species of sunny slopes, but the analyses made in the present work do not show this distinction. Again, while the entry of Leptospermum scoparium into pasture may be encouraged by close and continuous grazing (as stated by Levy (1923: 154)), the presence of established plants of the species (more particularly the macrophanerophytic examples) may tend to be associated with relatively light sheep and cattle grazing.

(Cockayne, Simpson, and Scott-Thomson (1932: 18) have claimed that no weeds in the exotic flora can compete in aggressiveness with Pteridium esculentum or Leptospermum scoparium, and this is supported by the classical account by Guthrie-Smith (1926: ch. XIX) of his forty-year struggle to replace these species by pasture. Since then, the importance of Leptospermum scoparium as a pasture weed has been reduced in some parts of New Zealand by the "manuka blight" disease (Mulcock (1954); Hoy (1954)), but it should be pointed out that this disease appears to be rare in the study area, in spite of attempts to establish it. This is borne out by a distribution map for the causative insect that was prepared by Hoy (1954: 473)).

Next in importance to Leptospermum scoparium is Coprosma rhamnoides, essentially a nanophanerophytic species. Like Leptospermum scoparium, it is a species of lower altitudes, and tends to be associated with soil types 13bH and 118a and with relatively light sheep and cattle grazing, but, unlike Leptospermum, it shows a slight tendency to favour steeper slopes and shady faces. Probably associated with this latter tendency is the relative importance of Coprosma rhamnoides in the shade microhabitat provided by macrophanerophytes (notably Leptospermum scoparium). Another largely nanophanerophytic species, Leucopogon fasciculatus, occurs in similar environments to

Coprosma rhamnoides, but is less important numerically. (Another less important species, Geniostoma ligustrifolium, also tends to occur at lower altitudes on steeper slopes and shady faces, and under relatively light sheep grazing, but has not the same tendency to be associated with soil types 13bH and 118a).

(Allan (1924: 404) has referred to the occurrence of three of these shrubby species in pasture at the western edge of the study area. Leptospermum scoparium is classed as a "serious weed", while Coprosma rhamnoides and Leucopogon fasciculatus are classed as "plentiful").

Although there are only a few scattered specimens within the area of the systematic survey, Cassinia leptophylla is of some importance, along with Leptospermum scoparium, at lower altitudes at the southern extremity of the study area. (This species is an aggressive weed in the pastures of the coastal regions of Wellington Province (Cockayne, Simpson, and Scott-Thomson (1932: 18)), and according to Croker (1953: 12, 14), it tends to occur in similar situations to Leptospermum scoparium).

Shrubby species tend to be less important on soil types 77bH, 122, and 124, until an altitude of about 1500 feet is reached. (Gibson (unpub.) has observed that the shrub vegetation of the Fitzherbert foothills (on soil types 11H, 13bH, and 118a, and characterized by Leptospermum scoparium and Ulex europaeus) appears to be more important than that on the higher parts of the Range (soil types 122 and 124)). However, several characteristic species are of some importance below this altitude.

Brachyglottis repanda and Melicytus ramiflorus are fairly important, both as nanophanerophytes and as macrophanerophytes. They occur more particularly on soil types 122 and 124, on steeper slopes, and under relatively light sheep and cattle grazing, and show a possible slight tendency to favour shady slopes. (Croker (1956: 55-56) has described these species as more characteristic of shady slopes).

The tree-ferns Dicksonia squarrosa and Cyathea medullaris are also of some importance. (Their aggressiveness in pasture is mentioned by Allan (1936: 191)). They occur more particularly on soil type 124, at higher altitudes, under relatively light grazing, and on shady faces and steeper slopes. (Crocker (1953: 12, 14) has referred to these species as occupying gullies and damper slopes in pasture).

Two other shrubby species of note are not always technically phanerophytes. These are Muehlenbeckia complexa and Metrosideros diffusa, which are characteristic cushion-formers in open pasture (although they are climbers when other phanerophytes are present). Both species tend to favour soil type 124 and higher altitudes, and to occur under relatively light sheep grazing. The microhabitats provided by the uprights of stock tracks and by logs and stumps appear to encourage the establishment of Muehlenbeckia complexa and Metrosideros diffusa.

The shrubs Olearia virgata and Olearia solandri, the former being found more particularly at higher altitudes and the latter at lower altitudes, are less important numerically, although Olearia solandri is quite aggressive in at least one valley. Both species tend to be associated with relatively light grazing.

It is evident that, as far as the soil types derived from grey-wackie (122 and 124) are concerned, phanerophytes become more important at higher altitudes, and the same thing is found to apply to soil type 77bH at the northern end of the study area. Besides the species mentioned already, several other species become prominent towards the upper limit of unploughable pasture. (Because they occur near the boundaries, these species do not figure largely in the results of the transecting).

Pseudowintera colorata appears as a pasture shrub at about 1500 feet, and is often the most common phanerophytic species above about 1750 feet, particularly on ridge tops. Fuchsia exorticata, which is recorded in appendix IIA as a species of higher altitudes and shady

faces, tends to be prominent in similar situations to Pseudowintera colorata, and to occur instead of that species in the vicinity of watercourses. (Jones (1947: 3) has referred to the establishment of Fuchsia excorticata along watercourses in grassland in the absence of grazing). Finally, there is copious regeneration of Nothofagus fusca in pasture at about 2000 feet at the northern extremity of the study area. (Cockayne, Simpson, and Scott-Thomson (1932: 33) have pointed out that, whereas many successions lead to the climax in the regeneration of podocarp-broadleaf forest, Nothofagus forest usually produces its like either from the start of the new growth, or from an early stage in succession).

#### Ferns (figs. 10, 14-17).

An important feature of the indigenous fern species that occur in unploughable pasture is that they are not merely of seasonal significance. While they may suffer some damage from heavy frosts, their occupation of any area is essentially continuous.

Paesia scaberula and Pteridium esculentum are the most important ferns, and indeed rank among the most important indigenous species, in the unploughable pastures of the study area. (The aggressiveness of Paesia scaberula has been mentioned by Allan (1936: 191), while the views of some other workers on the great aggressiveness of Pteridium esculentum have already been mentioned in connection with Leptospermum scoparium). Although both species occur over a wide range of environment, they tend to be associated more particularly with steeper slopes, with the soil types derived from greywacke (124 in the case of Paesia, and 122 and 124 in the case of Pteridium), and with relatively light sheep and cattle grazing. (Levy (1923: 148, 151, 282-86) has pointed out that both these species tend to become established under light stocking, and are damaged by heavy stocking. However, Levy has also observed that, once established, Paesia scaberula is encouraged by close grazing of the sward by sheep alone (a practice that is not normal in the study area), and that a

good growth of grass is required if this species is to be controlled by heavy stocking). Pteridium tends to be slightly more important at lower altitudes, and Paesia at higher altitudes (although both have wide altitudinal ranges), while another distinction is the apparent tendency of Paesia to be associated with shady faces. (Greenall and Hamilton (unpub.: 33) have referred to Paesia scaberula ("hard fern") as a species of shady slopes, while Moore (1942: 122-23) has pointed out that steep cold hillsides in high rainfall areas are particularly favourable for this species, although its range of habitat is wide).

Next to these species in importance is Blechnum fluviatile, which occurs in similar environments to Paesia scaberula, but with a stronger tendency towards high altitudes. (This species does not seem to have been recognized elsewhere as an important fern species in pasture). All three species are prominent on the microhabitat provided by the uprights of stock tracks and by other vertical places.

Several other species of ferns, namely Histiopteris incisa, Polystichum vestitum, Cyclosorus pennigerus, Blechnum procerum, and B. discolor, while of less importance than the three foregoing species, are also of some significance in pasture. (Allan (1936: 191) has referred to the aggressiveness of Histiopteris incisa and Blechnum procerum, while Cockayne, Simpson, and Scott-Thomson (1932: 36) and Dobbie (1951: 232) have mentioned the aggressiveness of Polystichum vestitum). All these species tend to be associated with soil type 124, and with relatively light grazing. Histiopteris incisa tends to be a species of higher altitudes. (Levy (1923: 148, 286) has referred to this species as one that becomes established under light stocking, and spreads at higher altitudes). Blechnum procerum and B. discolor tend to be associated with shady faces, while the latter tends also to be a species of higher altitudes and steeper slopes. (Levy (1923: 146) has described Blechnum procerum as a species of steep shady places).

Polystichum vestitum tends to be associated with shady faces,

steeper slopes, and higher altitudes. As in the case of certain phanerophytes mentioned above, Polystichum vestitum becomes important towards the upper limits of unploughable pasture. It is common in the northern part of the study area at altitudes above 1500 feet, particularly on shady faces where the frost lasts through the day in winter. Cyclosorus pennigerus also tends to be a species of steeper slopes, higher altitudes, and shady faces. It is largely associated with the shade microhabitat provided by phanerophytes.

#### Large Monocotyledons (figs. 8, 9).

The main species considered under this heading are three indigenous species of Juncus, namely J. polyanthemos, J. vaginatus, and J. luxurians. The first of these is among the most important indigenous species in the unploughable pastures of the study area, the other two being of less importance but still noteworthy. All three are more particularly species of lower altitudes, and all have a slight tendency to be associated with sunny slopes. Further, all three species appear to occur under "normal" grazing (that is, with no special tendency towards either heavy or light grazing), except for possible tendencies towards relatively heavy sheep grazing in the case of Juncus vaginatus, and relatively light cattle grazing in the case of J. polyanthemos and J. luxurians. J. polyanthemos and J. vaginatus tend to be more important on soil types 77bH and 118a, and J. luxurians on soil type 11H.

(No species besides Juncus polyanthemos and J. vaginatus appears to have particular associations with soil type 77bH. However, the principal species of lower altitudes, namely Leptospermum scoparium, occurs on this soil type at its "expected" frequency, as does Pteridium esculentum, while several other species of high overall frequency, notably Paesia scaberula, Acaena spp., and Nertera setulosa, are well represented).

Although the swampy microhabitat is of some importance within the

area of the systematic survey, these species of Juncus are not associated with it to any great degree. (Merry (unpub.: 7) has pointed out that Juncus polyanthemos is a species both of wet swamps and of dry uplands, although it has a preference for the former).

The other large monocotyledons that require mention are Carex lucida and Arundo kakaho. Like the species of Juncus mentioned above, Carex lucida tends to be associated with low altitudes, sunny slopes, and "normal" grazing. This species appears to favour soil types 13bH and 113a. Arundo kakaho also tends to be a species of sunny slopes, but appears to be associated with higher altitudes and with relatively light grazing.

#### Sward-forming Species (figs. 18-20).

Undoubtedly the most important indigenous sward-former is Danthonia spp., the one indigenous economic taxon of sown pastures. It ranks next in numerical importance in the sward after Agrostis tenuis, Anthoxanthum odoratum, and Festuca rubra var. commutata (and is present in more unit areas than the last-named). Danthonia tends to be more important numerically on steeper slopes. There appears to be general agreement among other workers that Danthonia spp. tends to replace Agrostis tenuis on sunny faces (Levy (1928: 301, 309); Madden (1940: 30); Greenall and Hamilton (unpub.: 52); Gibson (unpub.); Suckling (1954: 255)). However, the analyses made in the present work (appendix VIIA) show very little difference in the relative importance of these two species as between north- and south-facing slopes.

Most of the important indigenous sward-forming species are of similar life-form to the introduced economic species, in that they are low vegetatively-spreading perennials. Nertera setulosa is the most important of these species, both in the results of the transecting survey (in which it ranks among the chief indigenous species of the unploughable pastures of the study area) and in the results of the point analysis and frequency quadrat measurements (in which it ranks numerically with the lesser economic species). Nertera setu-

losa tends to be of more importance on soil types 122 and 124, and at higher altitudes. There is some association with relatively heavy grazing by sheep, and possibly by cattle as well.

Three other perennial herb taxa are also of importance, according to the results of both sampling methods. These are Acaena spp., Hydrocotyle spp., and Helichrysum filicaule. All three (especially the latter two) tend to be associated more particularly with soil type 124 and with higher altitudes, while Hydrocotyle spp. and Helichrysum filicaule show some tendency to be more important on shady faces. (Cockayne (1921b: 140) has referred to the increasing importance of these three taxa in sown pasture with increasing altitude). In the matter of grazing, the results of the point analysis and frequency quadrat measurements (appendix VIIB) are not very conclusive in relation to these species (but some of the sub-totals are based on very few unit areas). On the basis of the results of the transecting survey, it would appear that all three species tend to be associated with "normal" sheep and cattle grazing. (Levy (1923: 148, 290) has stated that Acaena spp. is normally found in closely grazed turf, and tends to spread if grazed by sheep only. As has been pointed out in connection with Paesia scaberula, the latter stocking practice is not normal in the study area).

Mention should be made of four other species of small perennial herbs which have a more scattered distribution but are sometimes of local importance. These are Centella uniflora, Oreomyrrhis andicola, Dichondra repens, and Nertera depressa. The first tends to occur at lower altitudes and under "normal" sheep and cattle grazing. Dichondra repens also appears to occur under "normal" sheep and cattle grazing, whereas Oreomyrrhis andicola may be associated with relatively light sheep grazing. Nertera depressa appears to favour shady faces and to have some association with vertical microhabitats.

The results of the point analysis and frequency quadrat measurements shows that certain indigenous species are of importance in the sward although not detected, or rarely detected, by the transecting.

(The most notable example is Danthonia spp.). Thus, Luzula campestris and Wahlenbergia marginata var. australis are found to be of minor local importance. Much more important are the mosses. (The analyses made by Suckling (1954: 254-55) also show "moss" to be important on some sites). Thuidium furfurosum and Acrocladium auriculatum appear to be among the most important indigenous species of the sward. Thuidium furfurosum tends to be associated with soil types 122 and 124, and with higher altitudes, while Acrocladium auriculatum has a wider range. Both tend to be more important on shady faces, and to be associated with "normal" or with relatively heavy sheep and cattle grazing. (Sainsbury (1955: 415) has referred to Thuidium furfurosum as occurring especially in open pasture). Triquetella papillata and Campylopus clavatus are also fairly widespread, although much less important numerically.

It is also necessary to consider the role of the indigenous sward-forming species in pasture on the specialized environment of swampy ground (in terms of the results of the point analyses shown in appendix VIII). The dominant species in this microhabitat would appear to be Juncus articulatus, a species of doubtful status. Of the introduced species that are dominant in the normal pasture, Agrostis tenuis and Festuca rubra var. commutata are of no significance, while Anthoxanthum odoratum is reduced to subordinate status, which it shares with Holcus lanatus, followed by Trifolium dubium and T. repens. The principal indigenous species, which are of varying importance, are Scirpus prolifer, Schoenus apogon var. laxiflorus, and Juncus planifolius.

### (3) NON-PASTURE (fig. 21).

Non-pasture has been defined (VI(1)) as any area on which man's activities are not directed towards maintaining sown pasture. Examples of vegetation other than pasture that are under human control (such as plantations and gardens) are not included. It is recogniz-

ed that these excluded categories may provide examples of interaction, such as: the entry of indigenous shrubs and small trees into exotic plantations (Cockayne, Simpson, and Scott-Thomson (1932: 24); Hannken (1954); the occurrence of Muehlenbeckia complexa in hedges; and the appearance of indigenous shrubs (e.g., Coprosma species) in gardens (Cockayne, Simpson, and Scott-Thomson (1932: 24-25)). However, the present work is concerned with the predominant types of vegetation, namely sown pasture on one hand and the vegetation of idle and unused land on the other.

The principal categories of non-pasture vegetation are remnant forest (more or less modified), and vegetation that appears to be in succession back towards forest following complete clearing and sowing to pasture. (The shrubby species of unploughable pasture tend, if not controlled, to form a continuous cover, which gives rise to a dense vegetation of shrubs and small trees. This type of vegetation (on normal slopes) accounts for most of the non-pasture unit areas detected by the original transecting). The other categories are: cliffs and stream banks; active or unhealed erosion features; watercourses and stream beds.

(i) Remnant Forests

There has been little penetration of introduced species into remnant forests, even where there has been considerable modification of these forests. (Zotov (1938a: 261) has pointed out that almost the only places subject to invasion within these remnants are the riverbeds. These are discussed below). The few introduced species that are found in the forests themselves within the study area are nearly all non-phanerophytic. One shrubby invader, Solanum pseudocapsicum, may be found at Awahuri, on the Kairanga Plain, as an undergrowth species in a forest remnant to which stock have access. (Allan (1940: 197) has recorded similar occurrences of this species). The herbaceous species Arctium minus and Tradescantia fluminensis occur in damaged forest adjacent to pasture at several places in the

study area, the former being a species of hill country and the latter of easier country. (Allan (1940: 165, 216) has referred to the occurrence of these species in damaged forest).

A few herbaceous species, such as Carduus tenuiflorus, Cirsium lanceolatum, Crepis capillaris, Digitalis purpurea, Hypochoeris radicata, and Senecio jacobaea, may be found on the Range in open places within the forests (particularly on ridges), where the original vegetation has been destroyed by fire or hurricane. The characteristic vegetation of these open places is dominated by the indigenous Microlaena avenacea, the introduced species always being in very limited numbers. Some of these open places are grazed by deer, and in one such "deer pasture" were found also Holcus lanatus, Stellaria media, and Veronica serpyllifolia. (Moore and Cranwell (1934) have described the replacement of forest by Microlaena avenacea grassland through the agency of wild animals alone. This grassland contained scattered introduced species, such as Anthoxanthum odoratum and Prunella vulgaris).

Few of these examples of introduced species of open places appear to occur more than a mile or so from the nearest pasture vegetation, or at altitudes much above 2500 feet, with the exception of Cirsium lanceolatum, which penetrates somewhat further, and Hypochoeris radicata, which extends into the mountain vegetation at altitudes above 4000 feet. (Zotov (1938a: 261) has also referred to Hypochoeris radicata as the only species to be found in the Tararua Range above the upper limit of forest).

(ii) Successional Vegetation

The records of the unit areas of impenetrable vegetation that were made during the original transecting are tabulated in table IX. This table lists, for each soil type, the numbers of such unit areas for which each species is dominant. As might be expected, many of these dominant species are among the principal

shrubby species of the adjacent unploughable pasture. Thus, Leptospermum scoparium is the principal species in successional vegetation on soil types 13bH and 118a, and also (with the introduced Ulex europaeus) on soil type 11H, while Brachyglottis repanda and Melicytus ramiflorus are the principal species on the other soil types (in association with Pteridium esculentum on soil type 77bH, with Ulex europaeus on 122, and with Cyathea medullaris on 124).

As in unploughable pasture, the only introduced phanerophytes of any importance are Ulex europaeus and Cytisus scoparius. It would appear that both of these species are characteristic only of the earlier stages of succession, and that they tend to be overshadowed and eventually replaced by those indigenous species that are capable of taller growth. Even in the denser thickets of Ulex europaeus and Cytisus scoparius, indigenous species may be found entering the communities where breaks or folds in the ground provide an opening. Most of the important indigenous successional species, such as Leptospermum scoparium, Brachyglottis repanda, Melicytus ramiflorus, Cyathea medullaris, and Coprosma robusta, appear to be capable of replacing the introduced species. Even Pteridium esculentum will overtop Ulex europaeus and Cytisus scoparius by adopting a scrambling life-form. (Similar examples of the replacement of Ulex europaeus by such indigenous phanerophytes as those listed above have been recorded by Cockayne, Simpson, and Scott-Thomson (1932: 41), "Northlander" (1943: 5), and Croker (1953: 16), while the first-named have also recorded the replacement of Cytisus scoparius, and the lianoid behaviour of Pteridium esculentum).

Two other introduced shrubby species, namely Rubus fruticosus and Cytisus proliferus, were detected by the systematic survey. The extensive examination shows that these two species, together with such other introduced species as Berberis vulgaris, Foeniculum vulgare (which has also been recorded by Zotov (1938a: 278) as a species of roadside scrub in the Manawatu Gorge), Leycesteria for-

TABLE IX. . DOMINANT SPECIES OF UNIT AREAS OF IMPENETRABLE VEGETATION, BY SOIL TYPES

soil type	11H	13bH	77bH	118a	122	124	1	Total
no. of unit areas	18	35	12	27	14	38	1	145
<i>Cyathea medullaris</i>	-	-	-	3	3	16	-	
<i>Dicksonia squarrosa</i>	-	-	-	-	-	12	-	
<i>Pteridium esculentum</i>	2	-	5	3	-	6	1	
<i>Pseudowintera colorata</i>	-	-	-	-	-	9	-	
<i>Beilschmiedia tawa</i>	-	-	3	-	-	-	-	
<i>Carpodetus serratus</i>	-	-	-	-	-	7	-	
<i>Coriaria arborea</i>	3	-	-	4	-	-	-	
<i>Melicytus ramiflorus</i>	-	-	5	7	6	15	-	
<i>Leptospermum scoparium</i>	12	32	3	16	-	-	1	
<i>Leptospermum ericoides</i>	2	-	-	-	-	-	-	
<i>Schefflera digitata</i>	-	-	-	-	4	-	-	
<i>Leucopogon fasciculatus</i>	-	-	3	-	-	-	-	
<i>Geniostoma ligustrifolium</i>	-	-	3	-	-	10	-	
<i>Hebe salicifolia</i>	-	-	-	4	-	-	-	
<i>Coprosma australis</i>	-	-	-	-	3	4	-	
<i>Coprosma robusta</i>	-	-	3	9	-	7	-	
<i>Olearia rani</i>	-	-	-	-	-	5	-	
<i>Brachyglottis repanda</i>	-	-	8	8	7	29	-	
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<i>Rubus fruticosus</i>	-	-	-	1	-	-	-	
<i>Ulex europaeus</i>	14	3	-	-	5	-	-	
<i>Cytisus scoparius</i>	-	-	-	6	2	-	-	
<i>Cytisus proliferus</i>	-	-	-	1	-	-	-	

mosa, Lupinus arboreus, and Sambucus nigra, have a scattered distribution in successional vegetation under similar circumstances to Ulex europaeus and Cytisus scoparius. (Crocker (1953: 14) has recorded the occurrence of Leycesteria formosa in the early stages of succession, while Cockayne, Simpson, and Scott-Thomson (1932: 41) have recorded the replacement of this species by indigenous species in the same way as Ulex and Cytisus). Although all these species form localized thickets, and some are prominent in vacant town sections, none appears to be of any overall importance. Cytisus proliferus, which tends to grow taller than the other introduced species, appears to be more persistent.

The extensive examination also detected Pinus radiata in areas of indigenous successional scrub or small trees at scattered points throughout the study area. Although not numerically important at present, this species is of special interest as being the only introduced species of the non-pasture vegetation that has a mature life-form similar to that of the indigenous forest dominants. (Certain other tree species used on farms, such as Cupressus macrocarpa, Acacia decurrens, and A. dealbata, may spread into open non-pasture areas if planted adjacent to such areas, but they appear to be of much less overall importance in non-pasture than Pinus radiata).

### (iii) Cliffs and Stream Banks

The cliffs and stream banks recorded in the original transecting are predominantly bare (21 out of 34 unit areas). Table X lists the dominant species in the vegetated unit areas in which each species was a dominant. Most of the species in table X are shrubby species of unploughable pasture (and of non-pasture on normal slopes), notably the three principal species (Brachyglottis repanda, Cyathea medullaris, and Melicytus ramiflorus).

No introduced species was recorded by the systematic survey. However, Cytisus scoparius is a member of a limestone cliff community at the eastern end of the Manawatu Gorge (actually beyond the

eastern boundary of the study area), the principal indigenous members of which are Hebe salicifolia and Phormium colensoi. Cytisus scoparius is also found on some road-cuttings within the study area, with Hebe salicifolia and other indigenous species. (Cockayne, Simpson, and Scott-Thomson (1932: 39) have recorded a similar community). Further, occasional examples of Pinus radiata may be found in the fairly open forest vegetation, dominated by Nothofagus solandri and Edwardsia microphylla, that occurs on the mudstone cliffs of some gorges in the Pohangina Plain.

(iv) Active or Unhealed Erosion Features

As recorded by the transects, the active or unhealed erosion features are also predominantly bare. The principal colonizer is plainly Leptospermum scoparium, which was recorded as an important species in 8 of the 43 unit areas. (34 of these unit areas are situated in the soil types on which Leptospermum scoparium is important, the distribution being: 11H (4); 13bH (3); 77bH (14); 118a (13) 122 (5); 124(4)). (Greenall and Hamilton (unpub.: 50, 53) have spoken of Leptospermum scoparium as a ready and rapid colonizer of the raw subsoil of slips on the Pohangina Plain). Paesia scaberula was recorded as an important species on 3 erosion features, and Pteridium esculentum and Leucopogon fasciculatus each on one.

Various introduced and indigenous sward-forming species of neighbouring pastures were seen establishing themselves on some erosion features. Cytisus scoparius was noted on one erosion feature, where it was of no importance.

(v) Watercourses and Stream Beds

Of the various types of non-pasture vegetation within the study area, perhaps the most favourable, as far as the entry of introduced species is concerned, is the vegetation of watercourses and stream beds. The soil of such areas tends to be unstable, and the vegetation open. (Where the soil is more stable, successional shrub

TABLE X. DOMINANT SPECIES OF VEGETATED CLIFFS AND STREAM BANKS

	<u>no. of unit areas</u>
<i>Cyathea medullaris</i>	5
<i>Pteridium esculentum</i>	2
<i>Blechnum procerum</i>	2
<i>Carpodetus serratus</i>	1
<i>Pittosporum eugenioides</i>	1
<i>Weinmannia racemosa</i>	3
<i>Edwardsia microphylla</i>	1
<i>Hoheria sexstylosa</i>	1
<i>Melicytus ramiflorus</i>	4
<i>Leptospermum scoparium</i>	2
<i>Fuchsia excorticata</i>	1
<i>Nothopanax arboreum</i>	1
<i>Leucopogon fasciculatus</i>	3
<i>Geniostoma ligustrifolium</i>	2
<i>Hebe salicifolia</i>	1
<i>Coprosma australis</i>	1
<i>Coprosma robusta</i>	2
<i>Olearia virgata</i>	1
<i>Olearia solandri</i>	1
<i>Helichrysum glomeratum</i>	3
<i>Brachyglottis repanda</i>	9

vegetation is liable to develop, as in ordinary non-pasture. Thus, a vegetation dominated by Arundo kakaho and Leptospermum scoparium may be found in places in the beds of the Manawatu, Pohangina, and Oroua Rivers. The introduced Lupinus arboreus is frequently a component of this vegetation, and is predominant (often along with the introduced Galega officinalis) in the lower reaches).

Where watercourses or streams run through pasture, the introduced species of the pasture have free access to them. (Croker (1955) has described the vegetation of a shingle stream bed adjoining pasture. It consisted largely of introduced species commonly associated with pastures). Of the 210 watercourses and stream beds crossed by the original transects, many were found to carry little or no vegetation, but 131 were observed to contain various introduced sward-forming species. Because of the difficulty of determining the principal species among these by inspection only, a detailed record was not made, but most of the important pasture species appeared to be involved, with Holcus lanatus possibly among the most prominent.

Where it was possible to determine the principal species in a watercourse or stream bed unit area, these were recorded. Table XI shows the percentage of the watercourses and stream beds, crossed by the transects, in which each listed species was found to be important. The only species of any general importance is Juncus articulatus (a species of doubtful status), which is also a very important species of swampy pasture (appendix VIII). The open nature of the vegetation, as compared with non-pasture vegetation in general, is reflected in the virtual absence of phanerophytes from table XI.

The introduced sward-forming species (and also, of course, those introduced species that tend to be confined to watercourses and stream beds) are liable to work up the stream beds from pasture

TABLE XI. IMPORTANT SPECIES OF WATERCOURSES AND STREAM BEDS

	<u>Page of total unit areas</u>
<i>Blechnum procerum</i>	1
<i>Blechnum fluviatile</i>	1
<i>Arundo kakaho</i>	1
<i>Mariscus ustulatus</i>	1
<i>Eleocharis cunninghamii</i>	2
<i>Scirpus prolifer</i>	3
<i>Carex secta</i>	4
<i>Juncus polyanthemus</i>	8
<i>Juncus luxurians</i>	1
<i>Leptospermum scoparium</i>	1
<i>Fuchsia excorticata</i>	1
<i>Gunnera strigosa</i>	1
<i>Nertera depressa</i>	1
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<i>Ranunculus repens</i>	1
<i>Nasturtium officinale</i>	4
<i>Trifolium repens</i>	1
<i>Lotus uliginosus</i>	1
<i>Cirsium palustre</i>	4
<i>Hypochoeris radicata</i>	1
<i>Mimulus moschatus</i>	1
<i>Carex leporina</i>	1
<i>Glyceria fluitans</i>	5
<i>Holcus lanatus</i>	4
-----	
<i>Juncus articulatus</i>	21

areas into areas of non-pasture. (Zotov (1938a: 261, 284) has classed Agrostis tenuis, Anthoxanthum odoratum, Hypochoeris radicata, Holcus lanatus, and Trifolium repens as aggressive in riverbeds within the forests of the Tararua Range, and has pointed out that Dactylis glomerata and Nasturtium officinale are of common occurrence in the same habitat, and that most of the other species of nearby [pasture] areas also occur there). In covering this habitat, the extensive examination detected most of the species referred to by Zotov. The vegetation produced by this type of penetration is roughly continuous, and is more prominent near the pastures from which it originated. However, certain introduced species, such as Cirsium arvense, C. lanceolatum, C. palustre, Digitalis purpurea, Hypochoeris radicata, and Senecio jacobaea, most of which are found scattered through the forests in open places, have a similarly scattered distribution in the riverbeds of the forests, beyond the limits of the sward-forming invaders.

## VIII. DISCUSSION OF RESULTS

### (1) PLOUGHABLE PASTURE

The question of sociological relations between introduced and indigenous plant species hardly arises in the case of ploughable pasture. Both the economic and the non-economic species are almost exclusively introduced. The only indigenous species of any importance are certain species of Juncus.

#### (i) Cultivation

In cropping areas, and in areas where there is a regular alternation of crop and pasture, cultivation may act directly in discouraging indigenous weeds. Annual cultivation is strongly selective for the annual habit (Wulff (1943:106)), and annuals of any sort are notably lacking in the indigenous flora. (According to Cockayne (1928: 70, 132, 244) and Allan (1940:10), annual species comprise about 3% of the indigenous vascular flora, as compared with about 37% of the introduced flora). (The relationship between cultivation and perennial weeds is referred to below in connection with Juncus).

#### (ii) Intensive Pasture Management

However, in the case of long-rotation and permanent pastures, which are essentially communities of perennial species, it would appear that the virtual absence of indigenous species is associated rather with the dominance in these pastures of Lolium perenne and Trifolium repens. It would seem that indigenous species may be virtually absent from pasture even on uncultivated land if these two species are dominant, while the introduced weeds (although still appreciably present) tend to be of lower abundance in uncultivated pastures dominated by Lolium perenne than in typical unploughable pastures.

Thus the relationship between ploughability and the absence of indigenous species would seem to be indirect in the case of permanent and long-rotation pastures. Reference has been made previously to

the higher degree of control over the vegetation that is possible on ploughable land. Under present conditions, it is generally only on such land that it is economically practicable to maintain pastures dominated by Lolium perenne and Trifolium repens. (The examples given in the present work, of the dominance of these two species on land that had not been cultivated, refer to land that was, however, ploughable, and thus was suitable for other measures of intensive management).

Cockayne, Simpson, and Scott-Thomson (1932:21) have stated that the absence of indigenous species (other than species of Juncus) from "artificial pasture of high class" is largely due to the dense sward, the practice of top-dressing with artificial fertilizers, good drainage, and constant heavy grazing. This largely summarizes the significance of the Lolium perenne-Trifolium repens pasture. These species are high-producing and high-fertility-demanding (Levy (1951: 68-69, 115)). (Even before the development of modern high-producing strains of Lolium perenne and Trifolium repens, a report on British grasslands (Armstrong (1907:304)) stated that no plants appear to be more capable of producing a dense growth of herbage than these two species, providing the soil is suitable for them). Where intensive management is practicable, a dense sward dominated by these species can be established and maintained (Levy (1951: ch. VIII)). Some aspects of this intensive management are the clearing of the ground (in most cases) before sowing, the maintenance of the necessary high level of soil fertility, the possible use of herbicides, and the adequate fencing that permits controlled stocking and thus ensures that the sward is neither opened up nor allowed to become rank.

If a volunteer species is present at the time of sowing, it is only likely to survive in the sward if it is a perennial, with a growth-rate approaching the growth-rate (under optimum conditions) of the sown species, and with the ability to tolerate heavy stocking. (The last point is largely associated with the vulnerability of the growing-point. As Levy (1951:104) has pointed out, growth-form is

one of the factors that governs persistency in the sward). Further, it will obviously be very difficult for any volunteer to enter the closed community of the established sward while it is properly maintained. In view of the fact that even the introduced pasture weeds, with a long history as species of grazing land, are deterred to a large extent by intensive pastoral farming (Levy (1951: ch.XIV)), it is not surprising that the indigenous species are in general not found under such conditions.

Cockayne, Simpson, and Scott-Thomson (1932:21) have also given as a reason for the absence of indigenous species from high-class pastures, the usually considerable distance between such pastures and any indigenous plant-community. Certainly this may reduce the availability of the disseminules of indigenous species. Nevertheless, even in intensively-farmed regions there are usually some refuges for the indigenous flora. Further, indigenous species appear to be of no importance in areas of Lolium perenne-Trifolium repens pasture (such as those analyzed in table VII) that are bounded by areas of unploughable pasture.

(iii) Species of Juncus

It is evident from the conclusions of Merry (unpub.:59-69) that the control of certain indigenous species of Juncus in pasture is essentially a matter of the fullest application of the principles of intensive pasture management that have been referred to in (ii) above. The ability of these species (notably J. polyanthemos, J. vaginatus, and J. luxurians) to tolerate management that will hardly permit the existence of any other indigenous species appears to be mainly a matter of degree. It is necessary, however, to consider why these species of Juncus should be so tolerant of moderately intensive management as to be the only significant indigenous weeds of ploughable pasture.

A possible factor is the rhizomatous nature of these species. While cultivation gives a set-back to perennial weeds in general, it is liable to encourage the perennial weeds that have underground

stems, and those that can bud from the roots (Levy (1951:274-75): Brenchley (1920:46-47)). As far as some species, including Juncus species, are concerned, this appears to be more particularly the case when the cultivation is only occasional, as on land that is used for permanent or long-rotation pasture. The conclusions of Merry (unpub.:59-62), supported by the few observations made during the present work, indicate that occasional cultivation has little or no effect on Juncus species, whereas repeated cultivation controls them.

Besides the species of Juncus, very few of the important indigenous weeds of unploughable pasture have the rhizomatous or radicigenous habit, the only other example of note being Pteridium esculentum. However, it has already been noted that the weeds of ploughable pasture must be able to tolerate heavy stocking. This excludes Pteridium esculentum. While the tough leafless erect stems of the Juncus species do not appear to be affected by trampling, and are hardly ever browsed by stock, the tender young leaves of Pteridium esculentum are vulnerable both to trampling and to grazing. In fact, management control of the latter species is based on this weakness (Levy (1923:284-86)).

The example of the indigenous species of Juncus raises the possibility that other tough unpalatable indigenous species with the rhizomatous habit may also become weeds in ploughable pastures of the permanent or long-rotation type. In fact, one member of the Cyperaceae that has the required characteristics, namely Scirpus nodosus, has been described by Merry (unpub.:27-29) as being far more important than the species of Juncus in the pastures of the Manawatu coast. (In surviving areas of the original coastal vegetation, it is most prominent in damp sand-hollows).

Pastures on wetter ground are the most likely places for the appearance of rhizomatous monocotyledons as weeds, since many such species occur naturally under swampy conditions. Further, the establishment of such species may be expected to be associated with inadequate drainage, since Merry (unpub.: 59, 68) has stressed the

need for good drainage as an essential prerequisite for the intensive pasture management that will control the Juncus species.

(2) UNPLOUGHABLE PASTURE

(i) Relationship of Weeds to Altitude

In the interpretation of the general pattern of vegetation for the study area (see "The Present Vegetation"), it was concluded that the possible degree of control over the vegetation decreases with altitude, as the environment becomes less favourable in various ways. It might be expected that one manifestation of this lessening of control would be an increase in the importance of weeds with increasing altitude. This is largely confirmed by the results of the field work that was carried out in the area of unploughable pasture. With the notable exceptions of Leptospermum scoparium and certain associated species, and of several large monocotyledons, the indigenous weeds show a general tendency to be of greater importance at the higher altitudes and on the soil types derived from greywacke, especially type 124. (As indicated in table IV, there is some degree of correlation between these environmental factors).

The position is fairly clear in the case of the indigenous species, which comprise a considerable proportion of the herbaceous weeds of the sward, and are predominant among the weeds of higher life-form. It is less clear among the introduced weeds. The same general tendencies as for the indigenous weeds may be observed with some introduced weeds, notably Hypochoeris radicata and (to some extent) Cirsium arvense and C. palustre. However, Ulex europaeus and Cytisus scoparius are more particularly species of lower altitudes. (The behaviour of these two species is discussed below in connection with that of the indigenous shrubs of lower altitudes). Further, even though the introduced sward-forming species may be of increased importance under less intensive management, the difference would appear to be less marked than in the case of the indigenous species. As indicated in the account of ploughable pasture, this distinction might be

expected, in view of the far shorter history of the latter as weeds of pasture.

(ii) Indigenous Ferns and Phanerophytes

Many of the ferns, shrubs, and small trees described as important in the unploughable pastures of the study area have been discussed by Levy (1923) and Croker (1953) as characteristic components of successional stages in the regeneration of indigenous forest. (These "secondary growth" species of unploughable pasture are referred to by Allan (1936: 192) as the greatest enemies of the pastoralist).

Relationship to Grazing. There appears to be a general tendency for species of these life-forms to be associated with relatively light grazing. In some cases, this relationship may be a straightforward one. Light grazing may encourage the invasion of the pasture by indigenous ferns and phanerophytes, through permitting the rank growth that leads eventually to the weakening of the sward. Further, light grazing may also mean that there is inadequate trampling and browsing of the invaders. It is probable that the apparent tendency of many indigenous ferns and phanerophytes to favour steep and/or shady slopes is at least partially due to the lighter grazing pressure on such slopes.

It is noteworthy that the tendency to favour steep and/or shady slopes is less marked with some of the phanerophytic species, both indigenous and introduced, that are important at lower altitudes. Leptospermum scoparium shows no special preference for steep or shady slopes. Ulex europaeus, although tending to favour the steeper slopes, shows no preference for shady slopes, while Cytisus scoparius is definitely more important on sunny faces. The association of these species, at least, with light grazing may be the effect rather than the cause of the invasion, in that the increase of the invaders has reduced the carrying capacity of the land. In the first place, the germination and establishment of Leptospermum scoparium is favoured by close and continuous grazing (Levy (1923: 154, 288)), and Ulex

europaeus also appears to be strongly light-demanding in establishment. Such species are likely to be more aggressive in a sward that has been opened up directly by over-grazing or fire than in one that has merely weakened as the result of under-grazing. It is true that heavy stocking can control these species in the seedling stage (Levy (1951: 279)), but only in conjunction with the establishment and maintenance of a dense sward, and this combination is very difficult to achieve except on ploughable land. Once past the seedling stage, species such as Leptospermum scoparium, Cytisus scoparius, and Ulex europaeus might be expected to be tolerant even of fairly heavy stocking, since they are tough, twiggy bushes, which have respectively, small coriaceous leaves, few leaves, and none.

Among the species of higher altitudes, Pseudowintera colorata appears to have no special preference for steep or shady slopes, being often of most importance on ridges. Although probably enhanced by the higher rainfall and lower temperature, the aggressiveness of this species in pastures above about 1750 feet appears to be due in part to its unpalatability, the leaves having a fiery taste.

Relationship to the Original Vegetation. It has been suggested above that the apparent preference of many ferns and phanerophytes for steep and/or shady slopes is due in part to the lighter grazing pressure on such slopes, and this may certainly be a contributing factor. However, it is evident, from descriptions of the surviving forests of the study area (see "The Original Vegetation") and from personal observations, that many of the species that show such a preference are common, or even important, subordinate species in these forests within the warm temperate belt (0-2000 feet). (Species in this category would appear to include Geniostoma ligustrifolium, Brachyglottis repanda, Melicytus ramiflorus, Dicksonia squarrosa, Cyathea medullaris, Muehlenbeckia complexa, Metrosideros diffusa, Fuchsia excorticata, Blechnum fluviatile, B. procerum, B. discolor, Histiopteris incisa, Cyclosorus pennigerus, and (at higher altitudes) Polystichum vestitum). Since the natural habitat of these species is characterized by reduced light and wind, and high humidity, it is

only to be expected that when growing in the open they will tend to occur on the shady slopes and on the (usually steep) sides of the sheltered gullies. (Croker (1956) has stressed the great climatic differences between north-facing and south-facing slopes).

Similarly, it is to be expected that they will tend to favour the higher altitudes, since these are associated with increased cloud and increased rain. The shade-tolerant nature of these species may also explain their apparent ability to germinate and establish themselves in the still relatively shaded habitat provided by pastures that have weakened through rank growth.

In the case of the species that are more particularly associated with the lower altitudes, it is noteworthy that Leptospermum scoparium is not found in forest at all, while Leucopogon fasciculatus and Coprosma rhamnoides are usually only of importance in Nothofagus solandri forest. (There is considerably more light under Nothofagus solandri than inside the multi-storeyed podocarp-broadleaf forest. The same applies to the shady places that the transects suggest are favoured by Coprosma rhamnoides and Leucopogon fasciculatus). It would appear from this that Leptospermum scoparium is strongly light-demanding and that Leucopogon fasciculatus and Coprosma rhamnoides are moderately so. Further, it has been noted already that Leptospermum scoparium has small coriaceous leaves, and the same applies to the other two species. (In forest), the leaves of Coprosma rhamnoides may be larger and almost membranous). In effect, these would appear to be species of well-lit, dry places. (Croker (1956: 55-56) has indicated that this is definitely the case with Leptospermum scoparium). It might be expected, therefore, that such species would tend to favour the lower altitudes, which are associated with relatively little cloud and relatively low rainfall. (It might be expected that similar factors would control the distribution of Ulex europaeus and Cytisus scoparius, which are definitely light-demanding (as shown by their behaviour in non-pasture vegetation), and also have reduced leaves).

To some extent this may be the case. However, Leptospermum scoparium occurs on the Pohangina Plain, on soil types 77bH and 118a, at altitudes up to and above 2000 feet (while the reference by Cockayne (1928:359) to the loss of aggressiveness by Ulex europaeus and Cytisus scoparius with increasing altitude applies more to altitudes above 2000 feet). Therefore, the reduction of the indigenous species, at least, with increasing altitude, would appear to be related in some way to the soil types of higher altitudes, namely 122 and 124, rather than to altitude as such. Nevertheless, soil types 122 and 124 appear to be quite capable of supporting these species of lower altitudes, which are advancing actively on to them at some points. It would seem likely, therefore, that the lesser importance of these species on soil types 122 and 124 is due to their absence from the original vegetation of these soils, and not to any antagonistic factor in the soils. This is obviously the case with the introduced species Ulex europaeus and Cytisus scoparius, which presumably are simply still moving uphill. Similarly, Leptospermum scoparium, Leucopogon fasciculatus, and Coprosma rhamnoides may still be moving in. It is evident that Leptospermum scoparium could only occur in the original vegetation in well-lit open places, such as wide riverbeds (which are only found at the lower altitudes) and erosion features (which, within the area transected, appear to be much less numerous on the soils derived from greywacke than on those derived from relatively unconsolidated rocks). Leucopogon fasciculatus and Coprosma rhamnoides may have been largely limited to similar places and to areas of Nothofagus solandri forest (which appear to have been more or less absent from soil types 122 and 124).

Another species, with similar growth-form and similar environmental requirements to Leptospermum scoparium, may also still be in the process of advancing into suitable habitats that have been provided by the removal of the original vegetation. This is Cassinia leptophylla. Formerly more or less confined to coastal vegetation, and only found in quantity at the southern (seaward) extremity of the study area at present, it is known to be aggressive elsewhere.

Its means of dissemination appear to be efficient. Only half-a-dozen bushes have been located within the area of the transecting survey, but they range over twenty miles in a north-easterly direction from the south-west corner of that area. Olearia solandri, a not very important shrubby species of the lower altitudes, appears to be another species, formerly more or less confined to the coast, that is now extending into the hills.

Besides the abovementioned species of lower altitudes, the only notable absentees from the surviving forests are Paesia scaberula and Pteridium esculentum (also Olearia virgata, a not very important shrubby species found more particularly at higher altitudes). It would appear that, although the first two species can occur over a fairly wide range of environment (and although Paesia scaberula tends to be more important on shady faces) they are not sufficiently shade-tolerant to occur in undamaged forest. Like the species of lower altitudes, they must have been confined to breaks and openings in the original forest, but, unlike these species, they appear to have been present on all soil types. This may have been due to the ability to colonize small breaks, not sufficiently open to encourage Leptospermum scoparium and its associates. (Olearia virgata must also have been present in breaks in the forest, particularly at higher altitudes.

(iii) Large Indigenous Monocotyledons

Although Juncus polyanthemos, J. vaginatus, and J. luxurians are not confined to wet ground in pasture, they may have been so confined in the original vegetation (Cheeseman (1925:294-95)). Further, the slight tendency of these species to be associated with sunny slopes suggests that they are moderately light-demanding species, that would be more likely to occur in the original vegetation in places where the soil was too wet to support forest. (Zotov (1938a:297) has described Juncus polyanthemos as a species of wet open places in the surviving forests of the Tararua Range). Therefore, the tendency for these species to be of greater importance at lower altitudes may be due to the greater prominence of swampy ground in the lower-lying areas. A further possibility is that the apparent tendency for these

species to be less important at higher altitudes may be associated to some extent with soil type. Soil types 122 and 124, being stony loams, might conceivably be less suited to rhizomatous species than such soils as 11H, 77bH, and 118a, which are derived from relatively unconsolidated sediments. However, another rhizomatous species, namely Pteridium esculentum, appears to flourish on the greywacke soils.

The three species of Juncus appear from the results of the transection to be associated with "normal" grazing, that is, to be of equal importance under relatively heavy grazing or under relatively light grazing. This may simply reflect the ability of these species to tolerate relatively heavy stocking, a point to which reference has been made in connection with ploughable pasture. However, Merry (unpub.: 57-58) has stressed the importance of maintaining a close sward as a measure of control of these species of Juncus. As already indicated, this is very difficult to achieve in the unploughable pastures, which tend to become weakened indirectly and eventually by relatively light grazing, or directly and rapidly by relatively heavy grazing. If these species of Juncus are really of equal aggressiveness in under-grazed and over-grazed pastures, it is, presumably, because they are not so strongly light-demanding as to tend to favour the latter.

The other large monocotyledons that are of some importance in unploughable pastures, namely Carex lucida and Arundo kakaho, also seem to favour sunny slopes. Both would appear to have been species of open places in the original vegetation. According to Cheeseman (1925:181), Arundo kakaho, was a species of swamps, riverbanks, sand-hills, etc., while Cockayne (1928:212) has described Carex lucida as a characteristic species of native lowland grasslands. In the case of Carex lucida, the apparent tendency to be of greater importance at lower altitudes might have a similar explanation to that already advanced for other light-demanding species. In view of its status in the original vegetation, Arundo kakaho might also have been

expected to be of greater prominence at lower altitudes, but this is not confirmed by the transects. (However, some of these higher-altitude records were made on the limited areas above 1000 feet that are occupied by soil types 77bH and 118a, and breaks caused by erosion may have been a feature of the original vegetation on these soils).

The apparent tendency of Carex lucida to be associated with "normal" grazing is probably due to similar factors to those governing the distribution of the Juncus species. The possible tendency of Arundo ~~Kakaho~~ to occur under conditions of light grazing may be related to the certain degree of palatability that has been noted in this species (Buchanan (1880)).

(iv) Indigenous Sward-forming Species

Little attention seems to have been paid in the past to the indigenous herbs of sown pasture (with the notable exception of Acaena spp., which can be a serious nuisance to wool-growers, thanks to its spiny fruits). This is understandable, since these species are obviously much less likely to attract notice than the species of higher lifeform (some of which, furthermore, are generally recognized as serious weeds). The probability that the role of the sward-forming species has not been appreciated in the past is reflected in a brief note by Druce (1957:7). This is to the effect that a pasture (similar to the unploughable pastures of the study area), on the eastern side of the Tararua Range, is "remarkable for the large number of small indigenous species present". (A list of such species in support of this statement contains many of the species referred to in the present work). Cockayne, Simpson, and Scott-Thomson (1932:21) have recognized that other small vegetatively-spreading indigenous herbs, besides Acaena spp., do occur as weeds in sown pasture, but have given few details.

Relationship to Grazing. There appears to be a general tendency for the indigenous sward-forming weeds to be of equal importance under relatively heavy grazing and under relatively light grazing. As in

the case of the species of Juncus, this distribution may be due to the apparent ability of these species to tolerate relatively heavy stocking. A probable factor in this tolerance is unpalatability. Acaena spp., Hydrocotyle spp., and Helichrysum filicaule have been referred to specifically as unpalatable species by Cockayne (1921b:140) (although Levy (1923: 290, 293) has indicated that cattle will eat Acaena spp.). Another probable factor is lifeform. Madden (1952:39-41) has pointed out that the successful weeds of lawns are those that grow close to the ground, thus escaping pruning by the mower. The ability of the low creeping indigenous herbs of unploughable pasture to occur under relatively heavy grazing may be analagous with the success of similar species in lawns. (In fact, at least two indigenous taxa, namely Hydrocotyle spp. and Dichondra repens, occur in both habitats). Some species that are variable in life-form appear to be able to adopt the low creeping habit under relatively heavy grazing. One example is Acaena spp. (which can form dense clumps in more favourable environments). The same may apply to Muehlenbeckia complexa and Metrosideros diffusa, which are sometimes found creeping in the sward, although they are more characteristically cushion-forming shrubby species of pasture.

Relationship to Pasture Management. Reference has been made already to the lesser importance of weeds as a whole, and in particular to the virtual absence of indigenous weeds, in the intensively managed pastures that are dominated by Lolium perenne and Trifolium repens. It has also been indicated that the establishment of various ferns, phanerophytes, and large monocotyledons in unploughable pasture may be due to the weakening of these pastures through the indirect effects of under-grazing or the direct effects of over-grazing. This would also appear to be particularly the case with the indigenous sward-forming species.

Because of their life-form, these species are subject to competition from the pasture species at all stages, and not just in the seedling stage. Therefore, their importance as pasture weeds

depends on a weak sward, and in general the unploughable pastures are necessarily relatively weak. The degree of management that is possible at present on most of these pastures will not permit the maintenance of anything better than a pasture dominated by such low-fertility tolerating species (Levy (1951:115-16)) as Agrostis tenuis, Anthoxanthum odoratum, Festuca rubra var. commutata, and Danthonia spp. These species are low-producing (Levy (1951:69-70)), especially in this environment, and in general it is simply not possible to establish or maintain a sward dense enough to exclude even the indigenous weeds.

Even on the easier unploughable country, and with the use of aircraft, the degree of human control is still much less than on ploughable land. The better unploughable land may be more or less free of "secondary growth", and Lolium perenne may figure as an important subordinate species in the sward, but even in these pastures the sward-forming weed species tend to play a relatively important role. However, as might be expected, the indigenous element in the weed flora of these better pastures is often of reduced importance. As a rule, the indigenous sward-forming species share in the general tendency of the indigenous weeds to be of greater importance at higher altitudes, that is, under a lesser degree of control.

Relationship to the Original Vegetation. It is desirable first to consider the way in which Danthonia spp. came to occupy its present position in sown pasture, since the history of the indigenous sward-forming weeds appears to be related to that of the economic taxon. Since Danthonia spp. appears to be generally recognized as a species of sunny faces, it may well have been a pioneer species in the same situations that permitted Leptospermum scoparium and similar species to exist in the original vegetation, that is, well-lit open riverbeds and erosion features. (Levy (1928: 297, 299)) has described Danthonia spp. essentially as a pioneer of bare soil). However, Danthonia spp. has also been spread deliberately from "danthonia country", either by harvesting the fruits and including them in "seed-mixtures", or by

bringing in stock that have been feeding on "danthonia country" (Cockayne, Simpson, and Scott-Thomson (1932:27)).

It is probable that most of the important indigenous sward-forming species occurred in the original vegetation of the study area in a similar environment to that of Danthonia spp. That their ecological requirements are at least to some extent similar to those of Danthonia spp. is shown by the fact that most of the important indigenous species of the sward (Acaena spp., Hydrocotyle spp., Oreomyrrhis andicola, Dichondra repens, Nertera setulosa, Helichrysum filicaule, Centella uniflora, and Thuidium furfurosum), together with such lesser species as Luzula campestris and Wahlenbergia marginata var. australis are found, along with Danthonia spp., as subordinates in natural low tussock-grassland dominated by Festuca novaezelandiae and Poa caespitosa (Cockayne (1928:211-12); Barker (1953)). Further, most of these species have also been recorded by Cockayne, Simpson, and Scott-Thomson (1932: 27-30, 42) as present in the vegetation that results from the burning and grazing of these natural grasslands. Such vegetation is often dominated by Danthonia spp., the former subordinate (Cockayne (1928: 362)). (Although inducing the occurrence of this (often) Danthonia-dominated grassland may be roughly equivalent to inducing the pioneering succession of pre-European times (Levy (1928: 297, 299)), there is, of course, one marked environmental difference, namely the grazing factor).

It would appear, therefore, that Danthonia spp. and the indigenous sward-forming weeds of the study area may have been among the pioneering species of well-lit breaks in the original vegetation, and that they were enabled to spread when a suitable habitat was provided through the conversion of forest to pasture. Further, if the amount of Danthonia spp. in the unploughable pastures has been increased by the deliberate introduction of this taxon to the area, it is probable that some of the indigenous weeds of the sward have been inadvertently reinforced at the same time.

(v) Aggressiveness of Indigenous Weeds

For the study area as a whole, the most important indigenous weeds would appear to be Leptospermum scoparium, Coprosma rhamnoides, Paesia scaberula, Pteridium esculentum, Blechnum fluviatile, Juncus polyanthemos, J. vaginatus, Nertera setulosa, Acaena spp., Helichrysum filicaule, and Hydrocotyle spp. (Some reference has been made already to the recognition of Leptospermum scoparium and Pteridium esculentum as the worst weeds in New Zealand, and of Paesia scaberula as an aggressive species).

One factor in the aggressiveness of these species would appear to be the ability to flourish over a relatively wide range of environment. (In several cases, this would appear to include tolerance of relatively heavy stocking). Another is the possession of efficient means of spreading. In the case of Leptospermum scoparium, the significant factor is the production of vast numbers of seeds from each plant (Levy (1923:287)). (According to Cheeseman (1925: 588), most of the seeds in any fruit are sterile. If this is so, there must still be a large viable residue, in view of the great numbers involved. Even allowing for this sterility, Coprosma rhamnoides does not appear to be nearly as well equipped, producing as it does only two seeds per fruit).

As far as the ferns are concerned, Moore (1942) has pointed out that reproduction by spores is not particularly significant in the case of Paesia scaberula (and probably Pteridium esculentum), except in areas of high rainfall. In fact, nearly all of the ferns that are of some importance in pasture possess the means of vegetative spread. Pteridium esculentum and Histiopteris incisa are rhizomatous (Levy (1923:285-86)), while Paesia scaberula is stoloniferous (Levy 1923:282), as are Blechnum fluviatile, B. discolor, and B. procerum, and also the tree-fern Dicksonia squarrosa (Cockayne, Simpson and Scott-Thomson (1932:23)). Only Polystichum vestitum appears to rely on rapid propagation by spores (Cockayne, Simpson, and Scott-Thomson

(1932:23)), and this species is prominent more particularly above about 1500 feet, and is therefore subject to a relatively high rainfall. (With regard to the relative aggressiveness of the ferns, Moore (1942:120) has pointed out that Pteridium esculentum spreads vegetatively much faster than such other important ferns of pasture as Paesia scaberula, Histiopteris incisa, Blechnum procerum, and B. discolor).

It has already been noted that vegetative spread appears to be a significant characteristic of the indigenous species of Juncus, and of most of the indigenous sward-forming species.

A further reason for the apparent aggressiveness of these species would appear to be the widespread deforestation that amounts to the creation on a large scale of a habitat suitable for them. (This has been referred to by Cockayne (1928:188)). The pioneer species in the regenerative process must be light-demanding, or at least light-tolerant, and able to tolerate the drier conditions of the open. Unless they are extremely adaptable, such species will not tend to be of much importance as subordinates within the climax forest. (Blechnum fluviatile occurs as a forest subordinate, but this species appears to have a more limited distribution in pasture than most of the other species discussed in this section). Conversely, the subordinate species of the forest will not tend to be of much importance as pioneers in the open, except in shady and/or sheltered places, or in the relatively wet and cloudy climates of higher altitudes. Elsewhere, they will be more likely to enter the succession only in the shelter of the hardier pioneers.

The lesser importance of phanerophytic (but not fern) weeds on soil types 122 and 124 would appear to be due to the fact that species of this life-form that are suited to life in the open are still only in the process of moving on to these soils.

### (3) NON-PASTURE

Both in the areas that approximate roughly to their original

condition, and in the areas that are definitely under human control, the watercourses and stream beds of the study area appear to be characterized by a fairly open non-phanerophytic vegetation. In view of the instability of the soil, it is probable that the vegetation of this habitat has always been of this type. It is the only type of non-pasture vegetation in which introduced non-phanerophytic species may establish themselves freely and persist.

With the exception of watercourses and stream beds (and the possible exception of areas that are subject to heavy grazing by wild animals), the general vegetative tendency on the non-pasture land within the study area that is not at present occupied by indigenous forest, is towards the regeneration of that forest. Even where idle or unused land is far from the nearest indigenous community, the tendency may be observed. On the roadsides of the intensively-farmed Kairanga Plain may be seen scattered specimens or clumps of such species as Pteridium esculentum, Muehlenbeckia complexa, Arundo kakaho, Cordyline australis, and Leptospermum scoparium.

In general, the introduced species do not persist in the non-pasture vegetation, once succession towards forest gets under way. This would appear to be largely a matter of life-form, together with a tendency for most of the introduced species involved to be light-demanding rather than shade-tolerant. If land adjacent to pasture or crop land is cleared and abandoned, introduced non-phanerophytes may be common enough in the early stages of succession. As has been shown, a scattering of introduced non-phanerophytic species (particularly those with wind-borne fruits) may even be found in damaged forest at some distance from occupied land. When the succession proceeds to the phanerophytic stages, the role of the introduced species changes. The introduced non-phanerophytes do not appear to survive the earliest phanerophytic stage. (This is confirmed by the observations of Croker (1953:14-15)).

As far as the introduced phanerophytes are concerned, it is true

that Ulex europaeus and Cytisus scoparius may be important at the first phanerophytic stage, and may be very persistent in places where few disseminules of indigenous species are available. (The same applies to the introduced Lupinus arboreus and Galega officinalis along the lower reaches of the rivers). However, the total number of introduced phanerophytic species involved is very small. Further, the species that are available are essentially nanophanerophytic rather than macrophanerophytic (with the notable exception of Pinus radiata, which is referred to later). Even a pioneer indigenous shrub like Leptospermum scoparium is sufficiently tall-growing to be able, to a large extent, to overtop the introduced species and shade them out, and they are certainly hardly able to survive the development of the small-tree layers (characterized by the mature forms of such species as Melicytus ramiflorus and Brachyglottis repanda), let alone that of the layer characterized by Beilschmiedia tawa.

It is possible, of course, that shade-tolerant introduced species might be able to persist as subordinates in regenerating forest. However, they have yet to enter the study area. (Even the few introduced species that have been referred to as entering damaged undergrowth in standing indigenous forest, namely the shrubby Solanum pseudocapsicum, and the herbaceous Arctium minus and Tradescantia fluminensis, rarely occur far from the forest margin).

Thus, in general, the introduced species would appear at present to be important only in the earliest stages of succession in non-pasture vegetation. However, the role of Pinus radiata is of interest. This species is of widespread occurrence, even if not numerically important, in the successional non-pasture vegetation of the study area, and may be expected to be very persistent. Although it resembles most of the other introduced phanerophytes that occur in the non-pasture vegetation, in being more or less light-demanding, it differs from them in being capable of much taller growth. Fairly open successional vegetation appears to be necessary for the germination and establishment of Pinus radiata, but, unlike the introduced shrubs, it is able to

survive the increasing competition for light as succession proceeds. By the time that the shrubs are being affected by competition from the indigenous species, the fast-growing plants of Pinus radiata have overtopped the successional vegetation. (Thus, "Northlander" (1943:5) has spoken of Ulex europaeus being overgrown and killed by indigenous species in 10 to 15 years. This could hardly happen to Pinus radiata, which, according to Yeates (1948:89), may increase in height by three or four feet a year after the first year or two).

Where only scattered seeds reach a non-pasture area while it is at a suitable stage for the entry of Pinus radiata, isolated trees may be expected, and this is usually the case in the non-pasture vegetation of the study area, except where such vegetation is close to a Pinus radiata plantation. (In the latter case, because larger numbers of seeds are available, the indigenous successional vegetation may be replaced by a Pinus forest. Such a replacement has been recorded by "Northlander" (1943:4). Further, as predicted by Cockayne (1928:358), it has been happening on a large scale on the Volcanic Plateau of the North Island, where large Pinus plantations adjoin large areas of successional vegetation). The fate of isolated trees of Pinus radiata when the regenerating indigenous vegetation around them at last achieves the forest climax remains to be seen. (According to Croker (1953:20), it takes about 80 years to develop a climax forest dominated by Beilschmiedia tawa).

#### (4) CONCLUSION

##### (i) General Relationships

The paper by Cockayne, Simpson, and Scott-Thomson (1932) which may be regarded as the principal contribution to the knowledge of the relationships between the introduced and the indigenous plant species of New Zealand, tends to place the emphasis on the incompatibility of the two floras. The same approach is used in the subsequent paper by Allan (1936), and indeed this is made clear in the title of Allan's paper. This treatment might be thought to be

due to the fact that both papers are concerned with refuting earlier allegations of the innate "superiority" of the introduced species. However, Cockayne, Simpson, and Scott-Thomson (1932: 15-18, 43) have claimed that there are "certain fundamental differences" between the two floras in the matters of life-form and habitat-preference. Essentially, the position as described in their paper is that the exotics are mostly annual species, and the indigenous plants largely woody or semiwoody evergreen perennials; with the expectable result that the exotics tend to be restricted to the ground laid bare in the process of settlement, and can only hold their ground there if the regeneration of the indigenous woody vegetation is prevented. (In connection with this last point, they have observed that the exotics are aided by the grazing and browsing animals that were absent from the original indigenous vegetation).

As far as life-form is concerned, the "fundamental difference" is to some extent based on over-generalization. Actually, according to Allan (1940:10) and Cockayne (1928:128-38), trees and shrubs comprise about 10% of the introduced flora, semi-shrubs about 5%, perennial terrestrial herbs about 45%, annuals about 37%, and others 3%, whereas the corresponding figures for the indigenous vascular species of the lowlands and lower hills are approximately 30%, 4%, 46%, 3%, and 16%. (In the latter case, ferns account for more than a fifth of the combined value for semi-shrubs and perennial terrestrial herbs). It is true that the introduced flora may at any rate be regarded as predominantly herbaceous, even if not "for the most part annuals". Further, the results of the present study suggest that only a few of the introduced woody species are of any numerical importance. However, except in the case of the annuals, the differences in life-form classification are hardly sufficiently clear-cut to be described as "fundamental". Further, although the indigenous flora may have evolved in the absence of grazing and browsing mammals, it is evident, both from previous work that has been cited and from the findings of the present study, that some indigenous species are fairly tolerant

of this environmental factor.

To some extent the idea of a definite distinction between the two floras is valid, in that most of the introduced species are economic species or weeds of long standing, that is, are species of crop or pasture land, while a large proportion of the indigenous flora comprises forest species. This distinction is perhaps most applicable to the vegetative extremes, namely frequently-tilled land and non-pasture. However, it is evident from the results of the present work that there is a considerable overlap between the indigenous and introduced floras in the matters of life-form and habitat, and that this is most noticeable in the areas of unploughable pasture. (In fact, this overlap may be inferred from observations made by previous workers. Even Cockayne, Simpson, and Scott-Thomson (1932), while stressing "fundamental differences", have recognized that "mixed" communities may occur, in which the introduced and indigenous species occupy equal positions, and indeed have given some examples). For this reason, the neutral term "interaction" is preferable to "competition" in a discussion of the relationships between the two floras.

(ii) Need for Further Work

The present work can only be regarded as a preliminary study of the subject of interaction. It would be very much enhanced by further investigations along at least two lines.

The first of these would be a practical determination of changes in the vegetation of the study area, through the repetition of the field work, and in particular of the sampling surveys, after a lapse of time. It has been noted earlier that the sampling surveys were carried out in 1954, that is, at about the time when the aerial topdressing of unploughable pastures with artificial fertilizers became a normal practice in the Manawatu district.

In view of the known effects of the topdressing of unploughable pastures (Levy (1951:70-71)), it may be predicted that this practice

(in conjunction, where necessary, with aerial oversowing, and possibly (Matthews and Maclean (1957:257)) the aerial distribution of herbicides), will tend to bring about an increase in the proportion of higher-producing pasture species in the sward, and a consequent decrease in the proportion of lower-producing and weed species, including indigenous species. However, this development implies heavier stocking, and more intensive stock control, which in turn involves adequate subdivision. The more difficult the country, the more difficult will this be, even allowing for the distribution of fencing material by air. In effect, aerial farming may be expected to increase the degree of human control over the vegetation in areas of unploughable pasture, but limiting factors will still apply.

Another possible change of some interest concerns the distribution of certain important shrubby weeds, notably Leptospermum scoparium, that are at present more important at lower altitudes. Since these species appear to be spreading into the higher-altitude areas, and since there does not appear to be any environmental barrier, they may eventually be of equal importance at higher altitudes. On the other hand, the more intensive pasture management just referred to, possibly in combination with biological control, may result in a considerable reduction in the significance as weeds of these species.

The other desirable line of investigation is the development of autecological studies of the more important species among these involved in interaction. (This applies most particularly to the indigenous weeds. The economic species are the subject of studies by the Grasslands Division of the D.S.I.R. (Levy (1951)), while some information on the introduced weeds is available from other countries). As in the case of the studies of vegetative changes, the autecological studies would amount to an experimental, more detailed, investigation of relationships that have only been inferred in the present study. Such work would also necessitate studies of the systematics of the species involved. "Aggregate species" are perhaps not quite as meaningless for ecology as suggested by Cockayne (1926b: 274), but if

work of a "biological flora" standard is to be carried out in New Zealand, then a great deal of unspectacular but essential taxonomic work will have to be done.

From the economic point of view, the need is plain for more detailed studies of the pasture weeds of New Zealand. Forty years ago, Cockayne (1918:73) was stressing the importance of the intensive study of the ecology of weed species as a pre-requisite for their control. Since then, some investigations have been made by such workers as Levy (1923), Merry (unpub.), and Moore (1942), but in general the need for information is as great as it was in Cockayne's time. If anything, the need has been intensified, since improved management techniques now permit much more effective action to be taken on the basis of ecological information.

### IX. SUMMARY

(1) The object of the present work has been to contribute to the knowledge concerning the sociological relations between the indigenous plant species of New Zealand and those introduced to the country by man. (Taxonomic literature provides an almost complete separation of the two floras).

(2) The investigation has been limited to the Manawatu district, which contains a fairly wide range of habitat. Brief accounts are given of the physiography, climate, and soils of this district.

(3) Prior to the coming of European settlers, the vegetation of the district was predominantly forest. Since then, large areas have been cleared of forest, and sown to pasture with introduced grasses and clovers. The present vegetation may be divided into three major categories, namely ploughable pasture, unploughable (sown) pasture, and "non-pasture" vegetation (that is, vegetation of idle or unused land).

(4) It was expected that few examples of interaction between the two floras would be found in ploughable pasture or in non-pasture vegetation. Therefore, extensive methods have been used in studying these types of vegetation. Since the intensity of interaction was expected to be much greater in unploughable pasture, this type of vegetation has been examined by means of line transecting, point analysis, and frequency quadrat measurements.

(5) The transecting method is described in some detail. It is derived from the "unit area" method, but involves sampling instead of a 100% survey. A grid of line transects, spaced at intervals of 5000 yards (about 4600 m.), is employed for sampling, each transect being used to make a continuous record of vegetation and environment.

(6) Indigenous weeds appear to be virtually absent from land that is frequently cultivated, probably because there are hardly any

annuals in the indigenous flora.

(7) In the case of the perennial vegetation of long-rotation or permanent ploughable pastures, the relative unimportance of indigenous species appears to be due to the factors that make this habitat unfavourable for weeds from either flora, namely strong competition from the high-producing economic species Lolium perenne and Trifolium repens, and heavy stocking. The only indigenous species of any importance are several species of Juncus, which appear to be tolerant of heavy stocking, and in addition belong to a life-form class that tends to be encouraged by occasional cultivation.

(8) The unploughable pastures contain a copious weed flora. Indigenous species comprise a considerable proportion of the herbaceous weeds, and are predominant among the weeds of higher life-form. (In addition, the pasture contains one indigenous economic taxon, in the partly volunteer, partly sown Danthonia complex (Danthonia penicillata (D. pilosa) and D. semiannularis)). The principal factor that permits these elements to flourish would appear to be the fact that, under present conditions, unploughable land in general will not support a better pasture than one dominated by the low-producing species Agrostis tenuis and Anthoxanthum odoratum.

(9) Some of the indigenous species of unploughable pasture appear to have been subordinate species in the forests that formerly covered the study area, while others appear to have been confined to breaks and open places, such as erosion features, riverbeds, and swampy areas. The species in the former category are mainly phanerophytes and ferns. They tend to occur on shady and/or steeper slopes, at higher altitudes, and under relatively light grazing. The species in the latter category include some phanerophytes and ferns, but also large monocotyledons, and creeping perennial herbs. (Little attention seems to have been paid in the past to the role of the fourth group in sown pasture). Since, for various reasons, they appear to be more suited to the pasture habitat, the species in this category include most of the important indigenous weeds of unploughable pasture.

(10) In non-pasture areas, there is a general tendency towards the regeneration of indigenous forest. Since the few important introduced phanerophytes tend to be light-demanding and relatively low-growing, they are confined to the earlier stages of succession. (Pinus radiata may prove to be much more persistent).

(11) The need is stressed for studies of changes in the "new vegetation", and of the autecology of the more important species.



FIG. 6. Ploughable pasture. Dense sward of Lolium perenne and Trifolium repens.



FIG. 7. Infestation of ploughable pasture by indigenous species of Juncus.



FIG. 8. Leptospermum scoparium spreading in unploughable pasture. Indigenous species of Juncus in foreground.



FIG. 9. Brachyglottis repanda and Arundo kakaho replacing pasture on steep slope.



FIG. 10. Brachyglottis repanda and Pteridium esculentum invading rank pasture.



FIG. 11. Late stage in replacement of unploughable pasture by Dicksonia squarrosa. The shrub is Pseudowintera colorata.

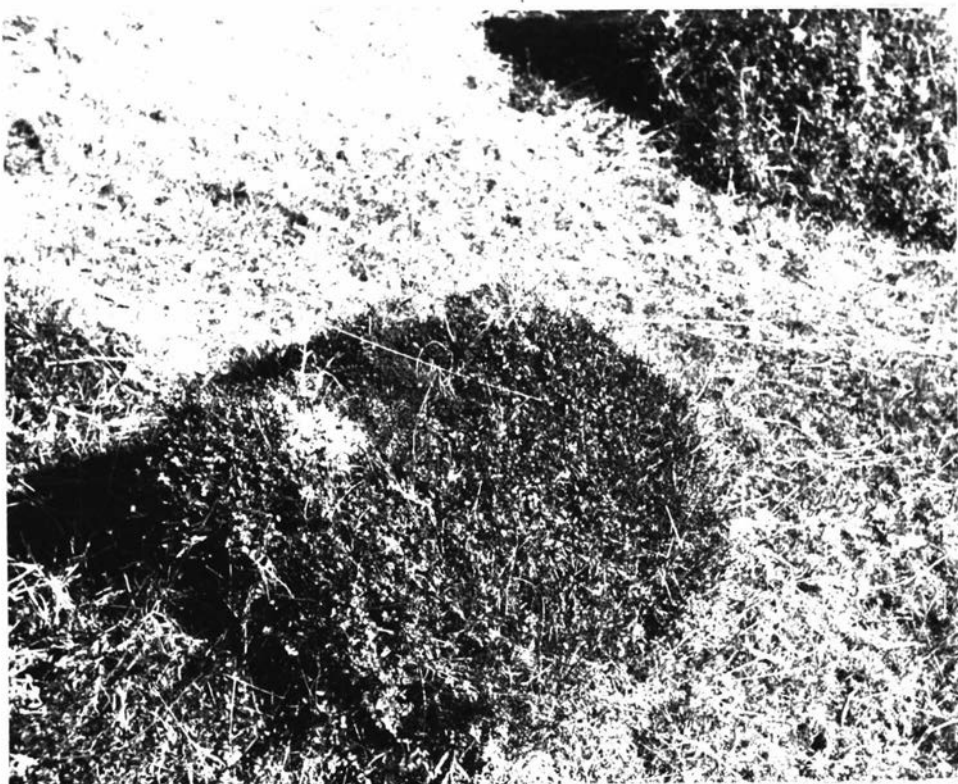


FIG. 12. Cushion form of Metrosideros diffusa.



FIG. 13. Pseudowintera colorata forming thickets at about 1800 ft.



FIG. 14. Paesia scaberula under relatively light grazing.



FIG. 15. Blechnum fluviatile adopting low-growing form in pasture.



FIG. 16. Replacement of unploughable pasture by ferns, notably Paesia scaberula (foreground), young Dicksonia squarrosa (in gully), and Pteridium esculentum (background). Species of Blechnum also present.



FIG. 17. Polystichum vestitum at about 2000 ft.



FIG. 20. Hydrocotyle spp. in unploughable pasture.



FIG. 21. Non-pasture vegetation. Leptospermum scoparium replacing Ulex europaeus. Young Pinus radiata (left of centre) is overtopping the indigenous vegetation.

X. LIST OF SPECIES

(1) ANIMALS

The species are listed in alphabetical order. The nomenclature is that used by Jodzicki (1950), unless otherwise stated.

Bos taurus L.

Canis familiaris L. (Bailey (1936: 279); no authority given by Jodzicki)

Capra hircus L.

Cervus elaphus L.

Equus caballus L.

Lepus europaeus Pallas

Oryctolagus cuniculus L.

Ovis aries L.

Rattus exulans Peale

Sus scrofa L.

Trichosurus vulpecula Kerr

(2) PLANTS

The classification into divisions and classes is essentially that of Smith (1955: 6-10, 516). The reference after the name of a division or class is to the source of the classification and nomenclature that have been used within that division or class.

Throughout the text, a generic name followed by "spp." implies a particular superspecific taxon, which is described in this species list. A generic name followed by "species" represents the normal use of "spp.", that is, "several species of this genus". The meaning of "sp." after a generic name is normal, that is, "an unidentified species".

The species in this list are represented in the herbarium of Massey Agricultural College.

(i) Indigenous Species

The thanks of the present writer are due to Mr. R.G. Robbins for the identification of most of the Lichenes and Bryophyta, namely those prefixed by "L".

LICIDINES (Hooker (1867); Watson (1929))

## CLADONIACEAE

R. genus Cladonia Hoffmann

## PARMELIACEAE

R. genus Parmelia Ach.BRYOPHYTAHepaticae (Evans (1939))

## PORELLACEAE

R. genus Porella L.

## MARCHANTIACEAE

genus Marchantia (March.f.)L.Musci (Sainsbury (1955))

## SPHAGNACEAE

genus Sphagnum L.

## POLYTRICHACEAE

R. Polytrichum juniperinum Hedw.

## DICRANACEAE

R. Campylopus clavatus (R.Br.) H.f.& W.R. Campylopus introflexus (Hedw.) Mitt.

## POTTIACEAE

Triquetella papillata (H.f.& W.) Broth.

## BARTRAMIACEAE

R. Breutelia pendula (Hook.) Mitt.

## THUIDIACEAE

R. Thuidium furfurosum (H.f.& W.) Jaeg.

## AMBLYSTEGIACEAE

R. Acrocladium auriculatum (Mont.) Mitt.

## BRACHYTHECIACEAE

R. Rhynchostegium tenuifolium (Hedw.) Jaeg.LEPIDOPHYTALycopodinae (Cheeseman (1925))

## LYCOPODIACEAE

Lycopodium volubile Forst.

PTEROPHYTA

References to hybridism in the indigenous Pterophyta and Spermato-  
phyta are from Cockayne and Allan (1934) unless otherwise stated.

(These references have been restricted to the more important species  
in the present study). Many of the species referred to below should  
be regarded as including those hybrids that could not be readily dis-  
tinguished from them in the field. Again, because of intraspecific  
hybridism in the many compound species, varieties have not normally  
been distinguished.

Filicinae (Dobbie (1951); also Cheeseman (1925), unless otherwise  
stated)

## OPHIOGLOSSACEAE

Ophioglossum pedunculatum Desv.

## CYATHEACEAE

Cyathea medullaris Swartz

Cyathea smithii (Hook.) Domin (Hemitelia smithii Hook. of  
Cheeseman)

## PTERIDACEAE

Dicksonia squarrosa Swartz.

Hypolepis rugulosa (Labill.) J. Smith (Dryopteris punctata  
C. Christen. of Cheeseman)

This species hybridizes with other species of Hypolepis.

Paesia scaberula Kuhn

Pteridium esculentum (Forst.) Diels (P. aquilinum Kuhn var.  
esculentum Hook.f. of Cheeseman)

Histiopteris incisa J. Smith

Adiantum affine Willd.

## ASPIDIACEAE

Polystichum vestitum Presl

Polystichum richardi J. Smith

These two species probably hybridize.

Cyclosorus pennigerus (Forst.) Ching (Dryopteris pennigera  
C. Christen. of Cheeseman)

## BLECHNACEAE

Blechnum filiforme Ettiingsh.

Blechnum pennamarina Kuhn

Blechnum procerum (Forst.f.) Labill. (B. capense Schlecht. of  
Cheeseman)

Blechnum fluviatile Salom.

Blechnum discolor Keys

## ASPLENIACEAE

Asplenium lucidum Forst.

Asplenium bulbiferum Forst.

## POLYPODIACEAE

Microsorium diversifolium (Willd.) Copeland (Polypodium diversifolium Willd. of Cheeseman)

SPERMATOPHYTA

Gymnospermae (Cheeseman (1925); revised by Cassie (1954))

CUPIRESACEAE (Pinaceae of Cheeseman)

Libocedrus bidwillii Hook.f.

PODOCARPACEAE (Taxaceae of Cheeseman)

Podocarpus spicatus R.Br.

Podocarpus ferrugineus D.Don.

Podocarpus dacrydioides A. Rich.

Podocarpus totara D.Don.

Podocarpus hallii T. Kirk

The last two species hybridize.

Dacrydium cupressinum Soland.

Phyllocladus alpinus Hook.f.

Angiospermae (Cheeseman (1925))

There have been many taxonomic alterations and additions to Cheeseman's manual. A revised edition is being prepared at present (Gudex (1955: 311)). Meanwhile, the revisions are spread over many publications, so that the amendments shown are not necessarily exhaustive. References to revisions are given after the taxa to which they apply.

Monocotyledons

## TYPHACEAE

Typha angustifolia L.

## PANDANACEAE

Freycinetia banksii A. Cunn.

## GRAMINEAE

Microlaena avenacea Hook.f.

Agrostis dyeri Petrie

Deyeuxia crinita (L.) Zotov (Zotov (1943: 234))

(Dichelachne crinita Hook.f. of Cheeseman)

Danthonia penicillata (Labill.) Palisot (Zotov (1943: 234))

(D. pilosa R.Br. of Cheeseman)

Danthonia semiannularis R.Br.

Both of these species are exceedingly compound, and hybrid swarms are plentiful. For practical purposes, it has been necessary to pool them. A reference to "Danthonia spp." in the text means some part of this complex.

Arundo kakaho Steudel (Zotov (1943: 233)) (A. conspicua Forst.f. of Cheeseman)

Poa anceps Forst. f.

Poa caespitosa Sprengel (Zotov (1943: 236)) (P. caespitosa  
Forst.f. of Cheeseman)

Festuca novaezelandiae Cock.

#### CYPERACEAE

Mariscus ustulatus C.B. Clarke

Eleocharis acuta R.Br.

Eleocharis cunninghamii Boeck.

Scirpus cernuus Vahl.

Scirpus prolifer Rottb.

Scirpus nodosus Rottb.

(According to Hamlin (1956: 34), the section Isolepis of Scirpus  
(to which the above three species belong) should be isolated as a  
separate genus).

Schoenus axillaris Poir.

Schoenus apogon Roem. & Schult.

var. laxiflorus C.B. Clarke

Vincentia sinclairii (Hook.f.) Hamlin (Hamlin (1956: 36)) (Cladium  
sinclairii Hook. f. of Cheeseman)

genus Gahnia Forst.

Uncinia uncinata Kükenth. (Zotov (1938a: 296)) (U. australis  
Pers. of Cheeseman)

Carex secta Boott

Carex geminata Schkuhr (Hamlin (1954: 56)) (C. temaria Forst.  
f. of Cheeseman)

Carex lucida Boott

Carex dissita Sol.ex Hook.f.

Carex solandri Boott

#### PALMAE

Rhopalostylis sapida Wendl. & Drude

#### JUNCACEAE

Juncus pallidus R.Br.

Juncus pauciflorus R.Br.

Juncus vaginatus R.Br.

Juncus polyanthemus Buchen.

Juncus luxurians Col. (J. luxurians was given by Cheeseman as a  
synonym of J. polyanthemus Buchen., but it is a very distinct species,  
and has been justifiably restored by Cockayne and Allan (1934: 15)).

There is much hybridism among the above five species. This topic  
is dealt with further by Merry (Unpub.).

Juncus planifolius R.Br.

Luzula campestris DC.

#### LILIACEAE

Rhipogonum scandens Forst.

Cordyline australis Hook.f.

Astelia nervosa Banks & Sol.ex Hook.f. (confirmed by Skottsberg  
(1937: 219))

Phormium tenax Forst.  
Phormium colensoi Hook.f.

LYRACEAE

Libertia ixioides Spreng.

ORCHIDACEAE

Thelymitra longifolia Forst.

Microtis unifolia Reichenbach f.

Dicotyledons

(Archichlamydeae)

PIPERACEAE

Macropiper excelsum Miq.

FAGACEAE

Nothofagus fusca Oerst.  
Nothofagus solandri Oerst.

MORACEAE

Paratrophis microphylla Cock.

URTICACEAE

Urtica ferox Forst.f.

PROTEACEAE

Knightia excelsa R.Br.

POLYGONACEAE

Muehlenbeckia australis Meissn.  
Muehlenbeckia complexa Meissn.  
 These two species hybridize.

PORTULACACEAE

Montia fontana L.

RANUNCULACEAE

Clematis paniculata J.F. Gmelin (Allan (1947: 594)) (C. indivisa Willd. of Cheeseman)

Ranunculus hirtus Banks & Sol. ex Forst.f.

WINTERACEAE (Dandy (1933)) (Magnoliaceae of Cheeseman)

Pseudowintera axillaris (Forst.) Dandy (Drimys axillaris Forst. of Cheeseman)

Pseudowintera colorata (Raoul) Dandy (Drimys colorata Raoul of Cheeseman)

MONIMIACEAE

Hedycarya arborea Forst.

Laurelia novaezelandiae A. Cunn.

## LAURACEAE

Beilschmiedia tawa Hook.f. & Benth.ex T.Kirk

## SAXIFRAGACEAE

Carpodetus serratus Forst.

## PITTOSPORACEAE

Pittosporum euzenioides A. Cunn.

## JUNONIACEAE

Weinmannia racemosa Linn.f.

## ROSACEAE

Rubus cissoides A. Cunn. (Allan (1935: 229)) (R. australis Forst.f. of Cheeseman)

Acaena novaezelandiae T. Kirk

Acaena sanguisorbae Vahl.

These highly compound species hybridize freely, and in any case are difficult to distinguish in the field when in the vegetative condition. A reference to "Acaena spp." in the text means some part of this complex. The introduced A. ovina A. Cunn. hybridizes with both these species, so that references to "Acaena spp." may include a few indigenous-introduced hybrids that could not be distinguished readily from the indigenous complex.

## LEGUMINOSAE

Edwardisia microphylla Salisb. (Zotov (1938a: 301)) (Sophora microphylla Ait. of Cheeseman)

## RUTACEAE

Melicope simplex A. Cunn.

## CORIARIACEAE

Coriaria arborea Lindsay (Oliver (1942: 33)) (part of C. ruscifolia L. of Cheeseman)

## ICACINACEAE

Pennantia corymbosa Forst.

## SAPINDACEAE

Alectryon excelsum Gaertn.

## ELAEOCARPACEAE

Elaeocarpus dentatus Vahl.

Aristotelia serrata W.R.B. Oliver (Zotov (1938a: 302)) (A. racemosa Hook.f. of Cheeseman)

## MELVACEAE

Hoheria sexstylosa Col.

## VIOLACEAE

Melicytus ramiflorus Forst.

## MYRTACEAE

Leptospermum scoparium Forst.

Leptospermum ericoides A. Rich.

These two species are highly compound but distinct. There may be some hybridism.

(genus Metrosideros Banks. Revised by Oliver (1928))

Metrosideros scandens (Forst.) Druce (M. florida Smith of Cheeseman)

Metrosideros diffusa (Forst.) W.R.B. Oliver (M. hypericifolia A. Cunn. of Cheeseman)

Metrosideros robusta A. Cunn.

Metrosideros perforata (Forst.) Rich. (M. scandens Sol. ex Gaertn. of Cheeseman)

Myrtus bullata Sol. ex A. Cunn.

## ONAGRACEAE

Epilobium nummularifolium R. Cunn. ex A. Cunn.

Epilobium pedunculare A. Cunn.

Fuchsia excorticata Linn. f.

## HALORAGIDACEAE

Haloragis erecta Schindler

Haloragis micrantha R.Br. ex Sieb. & Zucc.

Gunnera strigosa Col.

## ARALIACEAE

Nothopanax arboreum Seem.

Schefflera digitata Forst.

Pseudopanax crassifolium C. Koch

## UMBELLIFERAE

Hydrocotyle novaezelandiae DC.

Hydrocotyle moschata Forst. f.

Cheeseman regarded these two species as closely allied but distinct, and Cockayne and Allan (1934) have made no reference to hybridization between them. However, what appeared to be intermediate forms were found during the field work, for which reason it was decided to pool these species as "Hydrocotyle spp."

Centella uniflora (Col.) Nannfeldt (Cockayne and Allan (1926a: 62)) (C. asiatica Urban of Cheeseman)

Oreomyrrhis andicola Endl.

## CORNACEAE

Griselinia littoralis Raoul

(Sympetalae)

## ERICACEAE

Gaultheria antipoda Forst. f.

## EPACRIDACEAE

Leucopogon fasciculatus A. Rich.

## MYRSINACEAE

Rapanea salicina Mez (Oliver (1951: 111-12)) (Suttonia salicina Hook.f. of Cheeseman)

## LOGANIACEAE

Geniostoma ligustrifolium A. Cunn.

## APOCYNACEAE

Parsonsia heterophylla A. Cunn.

## DROSERACEAE

Dichondra repens Forst.

## SOLANACEAE

Solanum aviculare Forst.f.

## SCROPHULARIACEAE

Hebe salicifolia (Forst.f.) Pennell (Veronica salicifolia Forst.f. of Cheeseman)

This species hybridizes with many other species of Hebe.

## GESNERIACEAE

Rhabdothamnus solandri A. Cunn.

## MYOPORACEAE

Myoporum laetum Forst.f.

## UBIACEAE

Coprosma australis (A.Rich.) Robinson (Oliver (1935: 107)) (C. grandifolia Hook.f. of Cheeseman)

Coprosma robusta Raoul

Coprosma rhamnoides A.Cunn.

Coprosma parviflora Hook.f.

Coprosma foetidissima Forst.

Coprosma colensoi Hook.f.

There is much hybridism in the genus Coprosma.

Nertera depressa Banks & Sol. ex Gaertn.

Nertera setulosa Hook.f.

## CAMPANULACEAE

Wahlenbergia marginata (Thunb.) A.D.C. var. australis Hatch (Hatch (1952: 369)). (W. gracilis Schrad. of Cheeseman)

## COMPOSITAE

Lagenophora pumila Cheesem.

Olearia colensoi Hook.f.

Olearia rani Druce (Zotov (1938a: 303)) (O. cunninghami Hook. f. of Cheeseman)

Olearia virgata Hook.f.

Olearia solandri Hook.f.

Raoulia glabra Hook.f.

Raoulia tenuicaulis Hook.f.

Helichrysum filicaule Hook.f.

Helichrysum glomeratum Berth. & Hook. f.

These two species hybridize. In addition, a possible hybrid between Raoulia glabra and Helichrysum filicaule was found in the course of the field work.

Cassinia leptophylla R.Br.Craspedia uniflora Forst. f.Cotula coronopifolia L.Brechtites prenanthoides DC.Brachyglottis repanda Forst.(ii) Introduced Species (Allan (1940))

References to taxonomic alterations, or additions to Allan's manual, are given after the taxa to which they apply.

Dicotyledonae(Archichlamydeae)

## RANUNCULACEAE

Ranunculus repens L.Ranunculus sardous Crantz.Ranunculus sceleratus L.Ranunculus parviflorus L.

## BERBERIDACEAE

Berberis vulgaris L.

## FUMARIACEAE

Fumaria muralis L.

## CRUCIFERAE

Brassica campestris L.Lepidium rulerale L.Coronopus didymus (L.) Sm.Capsella bursapastoris (L.) Medik.Sisymbrium officinale (L.) Scop.Sisymbrium orientale L.Cardamine hirsuta L.Nasturtium officinale R.Br.

Healy (1954: 265-66) has pointed out that two species are involved, namely N. officinale (sensu stricto) and N. microphyllum Boenn. ex Rohb.

## ARYOPHYLLACEAE

Spergula arvensis L.Polycarpon tetraphyllum L.

Sagina procumbens L.

Cerastium glomeratum Thuill.

Cerastium caespitosum Gilib.

Stellaria media (L.) Vill.

Silene gallica L.

#### POLYGONACEAE

Rumex acetosella L.

Rumex conglomeratus Murray

Rumex obtusifolius L.

Polygonum aviculare L.

Polygonum hydropiper L.

Polygonum persicaria L.

#### CHENOPODIACEAE

Chenopodium album L.

#### AMARANTHACEAE

Amaranthus hybridus L.

Amaranthus retroflexus L.

These two species are often confused. They are pooled in the text as "Amaranthus spp."

#### LINACEAE

Linum catharticum L.

Linum marginale A. Cunn. ex Hook. (Cheeseman (1925: 1071); no authority given by Allan)

#### GERANIACEAE

Geranium molle L.

Geranium dissectum L.

Erodium cicutarium (L.) L. Her.

#### LYTHRACEAE

Lythrum hyssopifolia L.

#### HYPERICACEAE

Hypericum humifusum L.

#### EUPHORBIACEAE

Euphorbia peplus L.

#### ROSACEAE

Rubus fruticosus L. (Cheeseman (1925: 1156); no authority given by Allan)

Acaena ovina A. Cunn.

#### MIMOSACEAE

Acacia decurrens Willd.

Acacia dealbata Link.

## PAPILIONACEAE

Ulex europaeus L.Lupinus arboreus L.Cytisus scoparius Link.Cytisus proliferus L.Lathyrus latifolius L.Vicia sativa L.Vicia angustifolia L.Vicia hirsuta (L.) GrayMedicago lupulina L.Trifolium dubium Sibth.Trifolium repens L.Trifolium subterraneum L.Trifolium pratense L.Trifolium arvense L.Galega officinalis L. (Cheeseman (1925: 1070); no authority given by Allan)Lotus uliginosus Schkuhr.

## SALICACEAE

Salix fragilis L.

## ARALIACEAE

Hedera helix L.

## UMBELLIFERAE

Conium maculatum L.Foeniculum vulgare Mill.

## (Metachlamydeae)

## APOCYNACEAE

Vinca major L.

## RUBIACEAE

Sherardia arvensis L.Galium parisiense L.Galium aparine L.

## CAPRIFOLIACEAE

Sambucus nigra L.Leycesteria formosa Wall.

## COMPOSITAE

Erigeron canadensis L.Bellis perennis L.

Gnaphalium purpureum L.

This species hybridizes with G. luteoalbum L. (a species of doubtful status)

Galinsoga parviflora Cav.

genus Soliva Ruiz & Pavon (Healy (1953a: 23))

Matricaria discoidea DC.Achillea millefolium L.Anthemis cotula L.Senecio vulgaris L.Senecio jacobaea L.Arctium minus Bernh.Carduus tenuiflorus Curt.Cirsium lanceolatum (L.) HillCirsium arvense (L.) Scop.Cirsium palustre (L.) Scop.Lapsana communis L.Hypochoeris radicata L.Leontodon hispidus L.

It is sometimes difficult to separate the last two species in the vegetative condition and there may have been some wrong allocations for this reason.

Helminthia echioides Gaertn.Taraxacum officinale WeberBonchus asper (L.) HillBonchus oleraceus L.Crepis capillaris (L.) Wallr.

## PRINULACEAE

Anagallis arvensis L.

## PLANTAGINACEAE

Plantago lanceolata L.Plantago major L.

## BORAGINACEAE

Mysotis scorpioides L.em.Hill

## SOLANACEAE

Solanum pseudocapsicum L.

## CONVOLVULACEAE

Ipomoea batatas Poir. (Cheeseman (1925: 1074))

## SCROPHULARIACEAE

Veronica persica Poir. (Healy (1954: 266-68); Bentham (1924: 349))  
(V. tournefortii Gmel., and most of V. agrestis L., of Allan)

Veronica serpyllifolia L.

Veronica arvensis L.

Odontites viscosa (L.) Rehb.

Mimulus moschatus Dougl.

Digitalis purpurea L.

#### LABIATAE

Prunella vulgaris L.

Lunium purpureum L.

Stachys arvensis L.

Mentha pulegium L.

#### Monocotyledones

#### COMMELINACEAE

Tradescantia fluminensis Vell.

#### AMARYLLIDACEAE

Allium triquetrum L.

#### JUNCACEAE

Juncus tenuis Willd. (Healy (1953b: 9)) (J. macer S.F. Gray (J. tenuis auth. non Willd.; J. involucratus T. Kirk) of Allan) (Cheeseman (1925: 296) regarded this species as "a very doubtful native". Cockayne and Allan (1926a: 66) have stated that it should be removed from the indigenous flora).

#### CYPERACEAE

Carex glauca Murray

Carex leporina L. em. Good.

(This species has been treated by Cheeseman (1925: 263) as "probably introduced", and by Cockayne and Allan (1926a: 62) as definitely introduced).

#### GRAMINEAE

Lolium perenne L.

Cynosurus cristatus L.

It is sometimes difficult to distinguish between the above two species in the vegetative condition, unless a close examination is made. There may have been some wrong allocations for this reason.

Dactylis glomerata L.

Bromus mollis L.

Bromus hordeaceus L.

Poa pratensis L.

Poa annua L.

It is sometimes difficult to distinguish between these two species in pasture. A reference to "Poa spp." in the text means one or both of these species.

Glyceria fluitans (L.) R.Br.

Vulpia dertonensis (All.) Volk.

Festuca rubra L. var. commutata Gaud.

The introduced varieties of F. rubra L. may hybridize with the indigenous varieties (if any) (Cockayne and Allan (1926a: 64-65)).

Festuca arundinacea Schreb.

Festuca capillata Lam.

Agropyron repans (L.) Beauv.

genus Eragrostis Host. (Willis (1948: 247): no authority given by Allan)

Holcus lanatus L.

Aira caryophyllea L.

Phleum pratense L.

Agrostis tenuis Sibth.

The complex of forms linking this species with other introduced species of Agrostis appears in part to be due to hybridism (Allan (1940: 264)). A. tenuis may also hybridize with the indigenous A. dyeri in modified indigenous grasslands (Cockayne and Allan (1934: 11)).

Anthoxanthum odoratum L.

Gymnospermae

#### PINACEAE

Pinus radiata D. Don.

Pinus muricata D. Don. (Dallimore and Jackson (1923: 424))

Cupressus lawsoniana (L.) Parl.

Cupressus macrocarpa Hartw.

#### (iii) Species of Doubtful Status

Classification and nomenclature are as in Cheeseman (1925) unless otherwise stated. All species in this section were listed by Cheeseman as indigenous. (He included Juncus articulatus with some doubt, and indicated that Festuca rubra and Juncus bufonius are introduced as well as indigenous).

#### Monocotyledons

##### GRAMINEAE

Festuca rubra L. vars.

See F. rubra var. commutata (introduced).

##### JUNCACEAE

Juncus effusus L. (Allan (1940: 309); given by Cheeseman (1925: 295) as a synonym for J. polyanthemus Buchen.)

Allan has treated this species as in part introduced, and has stated that it is now impossible to say how far it is indigenous.

Juncus bufonius L.

Cockayne and Allan (1926a: 65) have claimed that their field observations strongly support the view that this species is introduced only. Allan (1940: 308) has described the species as "usually treated as indigenous, and possibly so in some forms".

Juncus articulatus L. (Healy (1953b: 10)) (J. lampocarpus Ehr. of Allan (1940) and Cheeseman (1925)).

Cockayne and Allan (1926a: 66) have said of this species that possibly there are both indigenous and introduced varieties.

## Dicotyledons

### OXALIDACEAE

#### Oxalis corniculata L.

According to Allan (1940: 95, 285) this species is in part introduced, and it is now possible to determine how far it is indigenous.

### CONVOLVULACEAE

#### Calystegia sepium R.Br.

Allan (1940: 198) has suggested that this species is in part introduced.

### SOLANACEAE

#### Solanum nigrum L.

Allan (1940: 197) has claimed that the forms found in waste places and cultivated land are, at least in most part, introduced. It is possible that the "indigenous" parts of the above three species may have been introduced by the Maoris (Healy (1949: 160)).

(Recent (unpublished) cytological work by Prof. G.T.S. Baylis, of Otago University, has indicated that Solanum nigrum (hexaploid) is wholly introduced, and that the forms present in New Zealand from pre-European times belong to the very similar diploid S. nodiflorum Jacq.).

### COMPOSITAE

#### Gnaphalium luteoalbum L.

According to Allan (1940: 295), some of the forms of this species are almost certainly introduced.

#### Cotula australis Hook.f.

Cockayne and Allan (1926a: 63) left this species in the indigenous flora with considerable doubt, and Allan (1940: 152) has treated it as introduced.

#### genus Sonchus Tourn.

According to Cockayne and Allan (1926a: 67-68) and Allan (1940: 176), it is probable that the only species of Sonchus in pre-European New Zealand was S. littoralis (T. Kirk) Cock., and that the earliest records of other species of Sonchus actually referred to this species. Healy (1949: 160) has suggested that "Sonchus sp." may have been introduced by the Maoris.

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APPENDIX I. ENVIRONMENTAL ANALYSIS OF LENGTH-GROUP DISTRIBUTION  
OF TRANSECTS

A. ORIGINAL TRANSECTS

<u>Orientation</u>	Length-group						Total
	I	II	III	IV	V	VI	
N	30	43	61	84	65	43	326
S	18	43	55	69	57	28	270
EW	27	43	59	71	45	28	273
-	39	42	43	17	14	7	162
	114	171	218	241	181	106	1031

chi-square 77.2\*\*\*  
(without non-oriented transects 6.2 (n.s.))

<u>Soil Type</u>	I	II	III	IV	V	VI	Total
11H	13	17	15	12	14	3	74
13bH	14	23	23	20	13	3	96
77bH	19	37	35	44	32	20	187
118a	15	22	38	32	24	12	143
122	22	21	45	58	34	25	205
124	24	41	54	68	57	43	287
-----							
1	5	8	4	4	1	-	22
1c	1	-	1	-	2	-	4
12	1	-	2	-	2	-	5
13	-	-	-	2	2	-	4
77b	-	2	1	1	-	-	4
	114	171	218	241	181	106	1031

chi-square (of data above dotted line) 42.4\*;  
without 13bH 29.8 (n.s.); without 11H 32.0\*;  
without 11H and 13bH 16.7 (n.s.)

APPENDIX IA (cont.)Altitude

0	34	54	44	37	33	13	215
5	45	61	82	103	73	36	400
10	33	45	86	93	65	50	372
15	2	11	6	8	10	7	44
	114	171	218	241	181	106	1031

chi-square 41.0 \*\*\*  
 (without 0-500 feet group 15.6 (n.s); if comparison  
 is between 0-1000 and 1000-2000, chi-square is  
 16.8 \*\*)

Slope

0	50	52	52	25	21	10	210
10	58	106	138	179	126	73	680
30	6	13	28	37	34	23	141
	114	171	218	241	181	106	1031

chi-square 86.7 \*\*\*  
 (without 0-10° group 11.7 \*)

Sheep grazing

0	80	119	143	158	138	68	706
10.1	34	52	75	83	43	38	325
	114	171	218	241	181	106	1031

chi-square 8.0 (n.s.)

Cattle grazing

0	77	114	149	178	141	78	737
2.6	37	57	69	63	40	28	294
	114	171	218	241	181	106	1031

chi-square 8.4 (n.s.)

B. RE-RUN TRANSECTS

	Length-group						Total
	I	II	III	IV	V	VI	
<u>Orientation</u>							
N	10	12	18	29	20	16	105
S	6	17	15	26	22	13	99
EW	9	12	29	35	19	13	117
-	15	17	14	7	6	-	59
	40	58	76	97	67	42	380

chi-square 47.3 \*\*\*  
(without non-oriented transects 7.2 (n.s.))

Soil Type

11H	-	1	-	2	3	-	6
13bH	5	9	8	3	3	-	28
77bH	3	11	6	17	11	5	53
118a	5	3	10	11	7	4	40
122	18	13	28	36	20	12	127
124	9	20	23	24	20	21	117
-----							
1	-	1	1	3	1	-	6
1c	-	-	-	-	1	-	1
13	-	-	-	1	1	-	2
	40	58	76	97	67	42	380

chi-square (of data above dotted line): with 11H and 13bH pooled 32.5 \*; without 11H and 13bH 21.3 (n.s.)

Altitude

0	6	13	11	13	10	5	58
5	22	21	30	48	30	10	161
10	11	17	31	30	23	22	134
15	1	7	4	6	4	5	27
	40	58	76	97	67	42	380

chi-square (with 1000-1500 and 1500-2000 pooled) 16.4 (n.s.);  
(with 0-500 and 500-1000 also pooled) 12.1 \*

APPENDIX 1B (contd.)Slope

0	22	21	18	12	9	1	83
10	17	35	50	74	44	32	252
30	1	2	8	11	14	9	45
	40	58	76	97	67	42	380

chi-square 59.9 ~~\*\*\*~~  
 (without 0-10<sup>6</sup> group 10.4 ~~\*~~)

Sheep grazing

0	27	40	50	65	52	30	264
10.1	13	18	26	32	15	12	116
	40	58	76	97	67	42	380

chi-square 2.8 (n.s.)

Cattle grazing

0	28	42	57	66	52	33	278
2.6	12	16	19	31	15	9	102
	40	58	76	97	67	42	380

chi-square 2.8 (n.s.)

APPENDIX II. ENVIRONMENTAL ANALYSIS OF FREQUENCY OF SPECIES AND CATEGORIES. A. ORIGINAL TRANSECTS

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0.	2.6	
<u>Cyathea medullaris</u> M	-	-	4	3	6	10	6	10	6	1	1	6	15	1	1	12	10	22	1	21	2	23
	(2)	(2)	(4)	(3)	(5)	(6)	(7)	(6)	(6)	(4)	(5)	(9)	(8)	(1)	(5)	(15)	(3)	(16)	7	(16)	(7)	
							(8)	(7)	(7)			(11)	(10)	(1)		(18)	(4)					
<u>Dicksonia squarrosa</u> N	-	-	1	1	5	29	11	20	5	-	-	3	26	7	-	26	10	35	1	28	8	36
	(3)	(3)	(7)	(5)	(7)	(10)	(11)	(9)	(10)	(6)	(8)	(14)	(13)	(2)	(7)	(24)	(5)	(25)	(11)	(26)	(10)	
							(14)	(11)	(11)			(18)	(16)	(2)		(30)	(6)					
<u>Paesia scaberula</u>	2	4	17	25	31	80	49	63	46	1	5	59	79	16	3	102	54	135	24	130	29	159
	(11)	(15)	(29)	(22)	(32)	(44)	(50)	(42)	(42)	(25)	(33)	(62)	(57)	(7)	(32)	(105)	(22)	(109)	(50)	(114)	(45)	
							(59)	(49)	(50)			(75)	(70)	(8)		(129)	(27)					
<u>Paesia scaberula</u> - shade	-	3	1	12	8	14	7	19	12	-	2	19	16	1	-	25	13	34	4	32	6	38
	(3)	(4)	(7)	(5)	(8)	(11)	(12)	(10)	(10)	(6)	(8)	(15)	(14)	(2)	(8)	(25)	(5)	(26)	(12)	(27)	(11)	
							(14)	(12)	(12)			(18)	(16)	(2)		(31)	(7)					
<u>Paesia scaberula</u> - vertical	-	1	7	9	11	19	11	20	16	-	-	25	19	3	-	30	17	41	6	36	11	47
	(3)	(4)	(9)	(7)	(9)	(13)	(15)	(12)	(12)	(7)	(10)	(18)	(17)	(2)	(10)	(31)	(6)	(32)	(15)	(34)	(13)	
							(18)	(15)	(15)			(23)	(21)	(3)		(39)	(8)					
<u>Pteridium esculentum</u>	3	10	32	24	55	57	69	54	53	7	17	91	71	4	9	103	71	169	14	149	34	183
	(13)	(17)	(33)	(25)	(36)	(51)	(58)	(48)	(48)	(29)	(38)	(71)	(66)	(8)	(37)	(121)	(25)	(125)	(58)	(131)	(52)	
							(66)	(55)	(55)			(81)	(76)	(9)		(144)	(30)					
	also soil 1:			2	4																	

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Pteridium esculentum</u> - shade	-	3	7	4	18	6	11	14	12	1	2	27	9	-	1	16	21	37	1	32	6	38
	(3)	(4)	(7)	(5)	(8)	(11)	(12)	(10)	(10)	(6)	(8)	(15)	(14)	(2)	(8)	(25)	(5)	(26)	(12)	(27)	(11)	
							(14)	(12)	(12)			(18)	(16)	(2)		(31)	(6)					
<u>Pteridium esculentum</u> - vertical	-	-	2	2	8	8	6	4	10	-	1	14	5	-	-	8	12	18	2	13	7	20
	(1)	(2)	(4)	(3)	(4)	(6)	(6)	(5)	(5)	(3)	(4)	(8)	(7)	(1)	(4)	(13)	(3)	(14)	(6)	(14)	(6)	
							(8)	(6)	(6)			(9)	(9)	(1)		(17)	(3)					
<u>Histiopteris incisa</u>	-	-	2	1	4	20	11	10	5	1	1	1	22	3	2	19	6	26	1	21	6	27
	(2)	(3)	(5)	(4)	(5)	(8)	(9)	(7)	(7)	(4)	(6)	(10)	(10)	(1)	(6)	(18)	(4)	(18)	(9)	(19)	(8)	
							(10)	(8)	(8)			(13)	(12)	(1)		(21)	(4)					
<u>Polystichum vestitum</u>	-	-	-	-	7	20	8	12	6	1	-	-	16	11	1	17	9	25	2	23	4	27
	(2)	(3)	(5)	(4)	(5)	(8)	(9)	(7)	(7)	(4)	(6)	(10)	(10)	(1)	(6)	(18)	(4)	(18)	(9)	(19)	(8)	
							(10)	(8)	(8)			(13)	(12)	(1)		(22)	(4)					
<u>Cyclosorus pennigerus</u>	-	-	2	5	6	10	6	11	5	1	-	7	16	-	1	12	10	22	1	23	-	23
	(2)	(2)	(4)	(3)	(5)	(6)	(7)	(6)	(6)	(4)	(5)	(9)	(8)	(1)	(5)	(15)	(3)	(16)	(7)	(16)	(7)	
							(8)	(7)	(7)			(11)	(10)	(1)		(18)	(4)					
<u>Cyclosorus pennigerus</u> - shade	-	-	3	1	3	13	5	8	7	-	-	6	14	-	-	8	12	19	1	19	1	20
	(1)	(2)	(4)	(3)	(4)	(6)	(6)	(5)	(5)	(3)	(4)	(8)	(7)	(1)	(4)	(13)	(3)	(14)	(6)	(14)	(6)	
							(8)	(6)	(6)			(10)	(9)	(1)		(17)	(3)					

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.4	0	2.6	
<u>Blechnum procerum</u>	2	1	5	1	8	13	6	12	12	-	1	13	12	4	1	23	6	27	3	28	2	30
	(2)	(3)	(5)	(4)	(6)	(8)	(9)	(8)	(8)	(5)	(6)	(12)	(11)	(1)	(6)	(20)	(4)	(21)	(9)	(21)	(9)	
							(11)	(9)	(9)			(14)	(13)	(2)		(24)	(5)					
<u>Blechnum procerum - shade</u>	1	1	1	3	8	3	5	5	7	-	1	12	3	1	-	9	8	15	2	15	2	17
	(1)	(2)	(3)	(2)	(3)	(5)	(5)	(4)	(5)	(3)	(4)	(7)	(6)	(1)	(3)	(11)	(2)	(12)	(5)	(12)	(5)	
							(6)	(5)	(5)			(8)	(7)	(1)		(14)	(3)					
<u>Blechnum fluviatile</u>	-	1	9	-	22	84	30	53	31	2	-	12	89	15	2	76	38	98	18	97	19	116
	(8)	(11)	(21)	(16)	(23)	(32)	(37)	(30)	(31)	(18)	(24)	(45)	(42)	(5)	(24)	(77)	(16)	(79)	(37)	(83)	(33)	
							(43)	(35)	(36)			(57)	(53)	(6)		(94)	(20)					
<u>Blechnum fluviatile - shade</u>	-	-	-	-	7	23	9	13	8	-	-	5	20	5	3	16	11	29	1	22	8	30
	(2)	(3)	(5)	(4)	(6)	(8)	(9)	(8)	(8)	(5)	(6)	(12)	(11)	(1)	(6)	(20)	(4)	(21)	(9)	(21)	(9)	
							(11)	(9)	(9)			(15)	(14)	(2)		(22)	(5)					
<u>Blechnum fluviatile - vertical</u>	-	-	7	-	10	34	12	29	10	-	-	9	36	6	-	37	14	42	9	40	11	51
	(4)	(5)	(9)	(7)	(10)	(14)	(16)	(13)	(14)	(8)	(11)	(20)	(18)	(2)	(10)	(34)	(7)	(35)	(16)	(36)	(15)	
							(19)	(16)	(16)			(25)	(23)	(3)		(42)	(9)					
<u>Blechnum discolor</u>	-	-	-	-	5	23	6	19	3	-	-	2	17	9	-	19	9	28	-	24	4	28
	(2)	(3)	(5)	(4)	(6)	(8)	(9)	(7)	(7)	(4)	(6)	(11)	(10)	(1)	(6)	(18)	(4)	(19)	(9)	(20)	(8)	
							(10)	(9)	(9)			(14)	(13)	(2)		(23)	(5)					



APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Muehlenbeckia complexa</u> NC	-	-	1	2	6	7	6	5	4	1	1	5	9	1	2	11	3	15	1	11	5	16
	(1)	(1)	(3)	(2)	(3)	(4)	(5)	(4)	(4)	(3)	(3)	(6)	(6)	(1)	(3)	(11)	(2)	(11)	(5)	(11)	(5)	
							(6)	(5)	(5)			(7)	(7)	(1)		(12)	(2)					
<u>Muehlenbeckia complexa</u>	+	-	2	2	11	29	18	10	16	1	3	9	27	6	3	27	15	40	5	37	8	45
	(3)	(4)	(8)	(6)	(9)	(13)	(14)	(12)	(12)	(7)	(9)	(18)	(16)	(2)	(9)	(30)	(6)	(31)	(14)	(32)	(13)	
			also soil 1: 1	(1)			(16)	(14)	(14)			(21)	(19)	(2)		(35)	(7)					
<u>Rubus cissoides</u> NC	-	-	3	-	5	9	3	7	7	-	1	6	8	2	-	9	8	17	-	15	2	17
	(1)	(2)	(3)	(2)	(3)	(5)	(5)	(4)	(5)	(3)	(4)	(7)	(6)	(1)	(3)	(11)	(2)	(12)	(5)	(12)	(5)	
							(6)	(5)	(5)			(8)	(7)	(1)		(14)	(3)					
<u>Acaena spp.</u>	20	15	18	15	40	83	64	50	61	17	30	63	85	14	22	132	38	131	61	148	44	192
	(14)	(18)	(35)	(27)	(38)	(53)	(61)	(50)	(51)	(30)	(40)	(74)	(69)	(9)	(39)	(127)	(26)	(132)	(60)	(137)	(55)	
			also soil 1: 1	(4)			(66)	(54)	(55)			(79)	(74)	(9)		(141)	(29)					
<u>Melicytus ramiflorus</u> M	-	-	7	8	13	13	15	15	10	1	2	15	22	2	2	26	13	39	2	34	7	41
	(3)	(4)	(7)	(6)	(8)	(11)	(13)	(11)	(11)	(6)	(9)	(16)	(15)	(2)	(8)	(27)	(6)	(28)	(13)	(29)	(12)	
							(15)	(12)	(13)			(19)	(18)	(2)		(32)	(7)					
<u>Melicytus ramiflorus</u> N	-	-	2	2	6	9	8	8	3	-	-	4	13	2	-	12	7	16	3	17	2	19
	(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(7)	(1)	(4)	(13)	(3)	(13)	(6)	(14)	(5)	
							(7)	(6)	(6)			(9)	(9)	(1)		(16)	(3)					

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total	
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6		
<u>Leptospermum scoparium</u> M																							
	8	45	4	32	2	1	27	34	28	4	43	49	1	-	5	83	5	79	14	79	14	93	
	(7)	(9)	(17)	(13)	(19)	(26)	(29)	(24)	(25)	(15)	(19)	(36)	(34)	(4)	(19)	(61)	(13)	(64)	(29)	(66)	(27)		
	<u>also soil 1c: 1(-)</u>						(33)	(28)	(28)			(24)	(23)	(3)		(73)	(15)						
<u>Leptospermum scoparium</u> N																							
	28	53	30	34	7	5	59	55	54	10	73	98	7	-	16	143	19	146	32	135	43	178	
	(13)	(17)	(32)	(25)	(35)	(49)	(56)	(47)	(47)	(28)	(37)	(69)	(64)	(8)	(36)	(117)	(24)	(122)	(56)	(127)	(51)		
	<u>also soil 1: 1(4)</u>						(63)	(52)	(53)			(51)	(48)	(6)		(134)	(28)						
<u>Leptospermum scoparium</u> N - shade																							
	-	14	2	2	1	-	5	8	6	-	13	6	-	-	-	18	1	18	1	17	2	19	
	(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(7)	(1)	(4)	(13)	(3)	(13)	(6)	(14)	(5)		
							(7)	(6)	(6)			(3)	(3)	-		(16)	(3)						
<u>Metrosideros diffusa</u>																							
	-	-	2	-	4	17	8	7	8	-	-	4	11	8	2	16	5	22	1	13	10	23	
	(2)	(2)	(4)	(3)	(5)	(6)	(7)	(6)	(6)	(4)	(5)	(9)	(8)	(1)	(5)	(15)	(3)	(16)	(7)	(16)	(7)		
							(9)	(7)	(7)			(11)	(10)	(1)		(17)	(4)						
<u>Metrosideros diffusa</u> - log																							
	-	-	2	-	6	18	13	8	5	-	-	-	19	7	2	21	3	25	1	19	7	26	
	(2)	(2)	(5)	(4)	(5)	(7)	(8)	(7)	(7)	(4)	(5)	(10)	(9)	(1)	(5)	(17)	(4)	(18)	(8)	(19)	(7)		
							(10)	(8)	(8)			(13)	(12)	(1)		(20)	(4)						
<u>Fuchsia excorticata</u> M																							
	-	-	1	-	2	13	4	8	4	-	-	3	13	-	-	10	6	15	1	10	6	16	
	(1)	(1)	(3)	(2)	(3)	(4)	(5)	(4)	(4)	(3)	(3)	(6)	(6)	(1)	(3)	(11)	(2)	(11)	(5)	(11)	(5)		
							(6)	(5)	(5)			(8)	(7)	(1)		(13)	(3)						

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Hydrocotyle spp.</u>	-	-	3	4	6	47	19	20	20	3	-	7	44	11	5	46	11	44	18	46	16	62
	(4)	(6)	(11)	(9)	(12)	(17)	(20)	(16)	(16)	(10)	(13)	(24)	(22)	(3)	(13)	(41)	(8)	(42)	(20)	(44)	(18)	
	also soil 1:		1(1)				(22)	(18)	(19)			(30)	(28)	(3)		(47)	(10)					
			77b: 1(-)																			
<u>Centella uniflora</u>	7	4	5	5	10	9	14	8	14	4	9	22	9	-	4	28	8	27	13	28	12	40
	(3)	(4)	(7)	(6)	(8)	(11)	(13)	(10)	(11)	(6)	(8)	(16)	(14)	(2)	(8)	(26)	(5)	(27)	(13)	(29)	(11)	
							(13)	(11)	(11)			(15)	(14)	(2)		(30)	(6)					
<u>Oreomyrrhis andicola</u>	-	-	-	-	3	12	5	5	5	-	-	-	13	2	-	14	1	14	1	15	2	15
	(1)	(1)	(3)	(2)	(3)	(4)	(5)	(4)	(4)	(2)	(3)	(6)	(5)	(1)	(3)	(10)	(2)	(10)	(5)	(11)	(4)	
							(6)	(5)	(5)			(7)	(7)	(1)		(12)	(3)					
<u>Leucopogon fasciculatus</u> N	-	10	6	7	1	-	9	11	3	1	11	13	-	-	1	19	4	24	-	21	3	24
	(2)	(2)	(4)	(3)	(5)	(7)	(8)	(6)	(6)	(4)	(5)	(9)	(9)	(1)	(5)	(16)	(3)	(16)	(8)	(17)	(7)	
							(9)	(7)	(7)			(6)	(6)	(1)		(19)	(4)					
<u>Geniostoma ligustrifolium</u> N	-	1	3	2	6	6	3	6	9	-	1	12	5	-	-	7	11	16	2	13	5	18
	(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(6)	(1)	(4)	(12)	(2)	(12)	(6)	(13)	(5)	
							(7)	(6)	(6)			(8)	(8)	(1)		(15)	(3)					
<u>Dichondra repens</u>	1	-	-	-	6	8	3	5	7	1	2	5	9	-	1	13	2	12	4	11	5	16
	(1)	(1)	(3)	(2)	(3)	(4)	(5)	(4)	(4)	(3)	(3)	(6)	(6)	(1)	(3)	(11)	(2)	(11)	(5)	(11)	(5)	
	also soil 1:		1(-)				(6)	(5)	(5)			(7)	(6)	(1)		(12)	(3)					

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Coprosma rhamnoides</u> N																						
1	35	4	26	13	3	24	34	17	8	31	46	6	-	9	56	18	80	3	69	14	83	
(6)	(8)	(15)	(12)	(17)	(23)	(26)	(22)	(22)	(13)	(17)	(32)	(30)	(4)	(17)	(55)	(11)	(57)	(26)	(59)	(24)		
<u>also soil 13: 1(-)</u>						(28)	(23)	(24)			(25)	(24)	(3)		(61)	(13)						
<u>Comprosmia rhamnoides</u> N - shade																						
1	15	-	2	-	-	5	13	-	-	14	4	-	-	-	18	-	18	-	18	-	18	
(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(6)	(1)	(4)	(12)	(2)	(12)	(6)	(13)	(5)		
						(7)	(6)	(6)			(2)	(2)	(-)		(15)	(3)						
<u>Nertera depressa</u>																						
2	2	7	5	6	7	7	14	8	-	1	15	13	-	-	22	7	24	5	24	5	29	
(2)	(3)	(5)	(4)	(6)	(8)	(9)	(8)	(8)	(5)	(6)	(11)	(10)	(1)	(6)	(19)	(4)	(20)	(9)	(21)	(8)		
						(11)	(9)	(9)			(14)	(13)	(2)		(24)	(5)						
<u>Nertera depressa</u> - vertical																						
-	-	5	1	4	9	7	9	3	-	-	7	12	-	-	12	7	12	7	17	2	19	
(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(7)	(1)	(4)	(13)	(3)	(13)	(6)	(14)	(5)		
						(7)	(6)	(6)			(9)	(9)	(1)		(16)	(3)						
<u>Nertera setulosa</u>																						
11	11	21	17	52	118	80	77	65	9	20	67	128	16	24	174	33	148	83	166	65	231	
(17)	(21)	(42)	(32)	(46)	(64)	(73)	(61)	(61)	(36)	(48)	(90)	(83)	(10)	(47)	(152)	(32)	(158)	(73)	(165)	(66)		
<u>also soil 1: 1(5)</u>						(83)	(69)	(70)			(103)	(96)	(11)		(171)	(36)						
<u>Nertera setulosa</u> - vertical																						
2	-	5	3	7	7	7	7	10	-	1	11	11	1	-	19	5	18	6	18	6	24	
(2)	(2)	(4)	(3)	(5)	(7)	(8)	(6)	(6)	(4)	(5)	(9)	(9)	(1)	(5)	(16)	(3)	(16)	(8)	(17)	(7)		
						(9)	(7)	(7)			(11)	(10)	(1)		(20)	(4)						



APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Cytisus scoparius</u> N	-	2	-	8	7	1	11	5	1	1	7	11	-	-	1	14	3	17	1	13	5	18
	(1)	(2)	(3)	(3)	(4)	(5)	(6)	(5)	(5)	(3)	(4)	(7)	(6)	(1)	(4)	(12)	(2)	(12)	(6)	(13)	(5)	
							(6)	(5)	(5)			(5)	(5)	(1)		(14)	(3)					
-----																						
<u>Pasture</u>	74	95	183	142	204	283	323	266	270	160	213	393	369	44	207	677	135	694	325	725	294	1019
	(73)	(95)	(184)	(142)	(203)	(283)	(322)	(267)	(270)	(160)	(213)	(395)	(368)	(44)	(208)	(673)	(140)	(698)	(321)	(729)	(290)	
<u>also soil</u>	1	1c	12	13	77b																	
	21	4	5	4	4																	
	(21)	(4)	(5)	(4)	(4)																	
<u>Pasture - shade</u>	34	71	56	77	58	90	127	131	111	24	111	172	95	15	33	278	82	342	51	303	90	393
	(28)	(37)	(71)	(55)	(78)	(109)	(124)	(103)	(104)	(62)	(82)	(152)	(142)	(17)	(80)	(259)	(54)	(269)	(124)	(281)	(112)	
<u>also soil</u>	1	1c	12	13																		
	3	1	2	1																		
	(8)	(2)	(2)	(2)																		
<u>Pasture - swampy</u>	1	1	5	3	18	41	29	23	17	1	4	13	44	9	2	54	14	56	14	55	15	70
	(5)	(7)	(13)	(10)	(14)	(19)	(22)	(18)	(19)	(11)	(15)	(27)	(25)	(3)	(14)	(46)	(10)	(48)	(22)	(50)	(20)	
<u>also soil</u>	12	1(-)																				
							(26)	(21)	(22)			(32)	(30)	(4)		(56)	(12)					
<u>Dense phanerophytes</u>	4	10	2	4	5	10	10	9	15	1	10	14	9	2	2	25	8	30	5	32	3	35
	(3)	(3)	(6)	(5)	(7)	(10)	(11)	(9)	(9)	(5)	(7)	(14)	(13)	(2)	(7)	(23)	(5)	(24)	(11)	(25)	(10)	
							(13)	(11)	(11)			(12)	(11)	(1)		(27)	(6)					

APPENDIX II A. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Bare - track</u>	12 (13)	21 (17)	36 (34)	30 (26)	28 (37)	55 (52)	70 (59)	63 (49)	44 (49)	9 (29)	46 (39)	68 (72)	66 (67)	6 (8)	11 (38)	135 (123)	40 (25)	138 (127)	48 (59)	151 (133)	35 (53)	186
	<u>also soil 1: 4(4)</u>						66	55	56			69	64	8		145	30					
<u>Bare - stock trampling</u>	7 (11)	1 (14)	18 (27)	27 (21)	33 (30)	61 (42)	49 (48)	44 (40)	48 (40)	10 (24)	12 (32)	64 (59)	66 (55)	9 (6)	12 (31)	105 (100)	34 (21)	113 (103)	38 (48)	115 (108)	36 (43)	151
	<u>also soil 1: 1(3)</u> 77b: 3(1)						53	44	44			68	63	8		115	24					
<u>Bare - slip</u>	5 (3)	4 (4)	12 (8)	14 (6)	3 (9)	8 (13)	23 (15)	10 (12)	13 (12)	- (7)	12 (10)	23 (18)	9 (17)	2 (2)	- (9)	32 (30)	14 (6)	36 (32)	10 (14)	41 (33)	5 (13)	46
							17	14	15			17	16	2		38	8					
<u>Bare - Log</u>	12 (28)	22 (36)	65 (71)	60 (54)	81 (73)	148 (108)	135 (123)	121 (102)	106 (103)	28 (61)	32 (82)	140 (151)	191 (141)	27 (17)	36 (80)	303 (257)	51 (53)	270 (267)	120 (123)	269 (279)	121 (111)	390
	<u>also soil 1: 1(8)</u> 1c: 1(2)						136	113	114			175	163	19		293	61					
<u>Bare - shade</u>	12 (2)	3 (2)	3 (5)	1 (3)	4 (5)	4 (7)	8 (8)	8 (7)	7 (7)	2 (4)	14 (5)	7 (10)	4 (9)	- (1)	2 (5)	18 (17)	5 (3)	24 (17)	1 (8)	22 (18)	3 (7)	25
	<u>also soil 1: 1(1)</u>						9	7	7			5	5	1		19	4					
<u>Bare - greywacke</u>	3 (8)	1 (11)	8 (21)	7 (16)	38 (23)	59 (33)	45 (37)	34 (31)	33 (31)	6 (19)	4 (25)	38 (46)	63 (43)	13 (5)	7 (24)	69 (78)	42 (16)	95 (81)	23 (37)	89 (84)	29 (34)	118
	<u>also soil 1: 2(2)</u>						42	35	35			56	52	6		92	19					

APPENDIX II. B. RE-RUN TRANSECTS

	soil type						orientation				altitude				slope			sheep		cattle		Total	
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6		
<u>Trifolium dubium</u>	3	-	2	3	1	6	3	4	7	3	4	6	2	5	3	13	1	10	7	14	3	17	
	(1)	(2)	(2)	(6)	(5)	(5)	(4)	(5)	(3)	(3)	(7)	(6)	(1)	(4)	(11)	(2)	(12)	(5)	(12)	(5)			
	<u>also soil 1: 2(-)</u>						(5)	(4)	(5)						(4)	(12)	(2)						
<u>Trifolium repens</u>	2	1	5	3	8	9	12	7	8	5	9	9	10	4	6	23	3	18	14	22	10	32	
	(1)	(2)	(4)	(3)	(11)	(10)	(9)	(8)	(10)	(5)	(5)	(14)	(11)	(2)	(7)	(21)	(4)	(22)	(10)	(23)	(9)		
	<u>also soil 1: 2(1)</u>						(9)	(8)	(10)						(7)	(22)	(4)						
	1c: 1(-)																						
	13: 1(-)																						
<u>Cirsium lanceolatum</u>	1	-	18	11	9	7	12	12	14	11	7	33	6	3	12	30	7	26	23	35	14	49	
	(1)	(4)	(7)	(5)	(16)	(15)	(14)	(13)	(15)	(8)	(7)	(21)	(17)	(3)	(11)	(32)	(6)	(34)	(15)	(36)	(13)		
	<u>also soil 1: 1(1)</u>						(12)	(12)	(14)						(11)	(31)	(6)						
	1c: 1(-)																						
	13: 1(-)																						
<u>Cirsium arvense</u>	-	-	2	6	3	19	7	8	13	4	3	7	18	4	4	17	11	18	14	27	5	32	
	(1)	(2)	(4)	(3)	(11)	(10)	(9)	(8)	(10)	(5)	(5)	(14)	(11)	(2)	(7)	(21)	(4)	(22)	(10)	(23)	(9)		
	<u>also soil 1: 1(1)</u>						(9)	(9)	(10)						(7)	(24)	(4)						
	13: 1(-)																						
<u>Cirsium palustre</u>	-	-	5	7	9	16	4	14	18	2	-	17	16	5	4	26	8	22	16	33	5	38	
	(1)	(3)	(5)	(4)	(13)	(12)	(10)	(10)	(12)	(6)	(6)	(16)	(13)	(3)	(8)	(25)	(4)	(26)	(12)	(28)	(10)		
	<u>also soil 13: 1(-)</u>						(12)	(11)	(13)						(8)	(29)	(5)						

APPENDIX II B. (cont.)

	soil type						orientation				altitude				slope			sheep		cattle		Total
	11H	13bH	77bH	118a	122	124	N	S	EW	-	0	5	10	15	0	10	30	0	10.1	0	2.6	
<u>Hypochoeris radicata</u>	1	2	3	3	33	36	28	24	21	5	8	15	50	5	10	53	15	55	23	62	16	78
	(1)	(6)	(11)	(8)	(26)	(24)	(22)	(20)	(24)	(12)	(12)	(33)	(28)	(6)	(17)	(52)	(9)	(54)	(24)	(57)	(21)	
							(24)	(22)	(27)						(58)	(10)						
<u>Holcus lanatus</u>	-	6	2	-	9	6	14	3	3	3	9	4	9	1	5	14	4	19	4	18	5	23
	(-)	(2)	(3)	(2)	(8)	(7)	(6)	(6)	(7)	(4)	(4)	(10)	(8)	(2)	(5)	(15)	(3)	(16)	(7)	(17)	(6)	
							(7)	(6)	(7)						(15)	(3)						
<u>Agrostis tenuis</u>	-	13	5	2	29	32	28	25	23	5	15	20	40	6	7	61	13	68	13	65	16	81
	(1)	(6)	(11)	(9)	(27)	(25)	(22)	(21)	(25)	(13)	(12)	(34)	(29)	(6)	(18)	(54)	(10)	(56)	(25)	(59)	(22)	
							(25)	(23)	(28)						(63)	(11)						
-----																						
<u>F</u>	1	4	1	-	24	25	18	17	19	1	6	14	30	5	4	39	12	41	14	39	16	55
	(1)	(4)	(8)	(6)	(18)	(17)	(15)	(14)	(17)	(9)	(8)	(23)	(19)	(4)	(12)	(36)	(6)	(38)	(17)	(40)	(15)	
							(18)	(17)	(20)						(43)	(8)						
<u>Pasture - shelf</u>	2	-	-	3	9	3	2	11	4	-	2	11	4	-	-	14	3	12	5	11	6	17
	(-)	(1)	(2)	(2)	(6)	(5)	(5)	(4)	(5)	(3)	(3)	(7)	(6)	(1)	(4)	(11)	(2)	(12)	(5)	(12)	(5)	
							(6)	(5)	(6)						(14)	(3)						
<u>Pasture - track</u>	3	4	22	18	55	54	41	50	65	-	15	68	64	9	-	116	40	128	28	123	33	156
	(2)	(12)	(22)	(16)	(52)	(48)	(43)	(41)	(48)	(24)	(24)	(66)	(55)	(11)	(34)	(103)	(18)	(108)	(48)	(114)	(42)	
							(51)	(48)	(57)						(132)	(24)						

APPENDIX III. FREQUENCY OF MINOR SPECIES AND CATEGORIESA. ORIGINAL TRANSECTS

<u>Cladonia</u> sp.	2
<u>Porella</u> sp. - greywacke	1
<u>Marchantia</u> sp.	1
<u>Sphagnum</u> sp.	2
<u>Campylopus introflexus</u> .....	1
<u>Thuidium furfursum</u> - shade	2
<u>Rhynchostegium tenuifolium</u> - shade	2
<u>Lycopodium volubile</u>	4
" " - shade	1
<u>Cyathea medullaris</u> N .....	5
" " - log	1
" " - shade	1
" " - vertical	1
<u>Cyathea medullaris</u> - vertical	1
<u>Dicksonia squarrosa</u> M .....	11
<u>Dicksonia squarrosa</u> N - shade	4
- swampy	2
- vertical	1
<u>Dicksonia squarrosa</u> - vertical	1
<u>Hypolepis rugulosa</u> .....	14
" " - log	1
" " - shade	5
" " - vertical	1
<u>Paesia scaberula</u> - log	5
<u>Pteridium esculentum</u> - log .....	3
<u>Histiopteris incisa</u> - log	1
" " - shade	8
<u>Adiantum affine</u> - shade	1
" " - vertical	2
<u>Polystichum vestitum</u> - shade .....	7
" " - vertical	1
<u>Polystichum richardi</u>	8
" " - shade	3
" " - vertical	4
<u>Cyclosorus pennigerus</u> - swampy .....	1
- vertical	3
<u>Blechnum filiforme</u> MC	1
<u>Blechnum pennamarina</u>	10
<u>Blechnum procerum</u> - swampy	8
" " - vertical .....	11
<u>Blechnum fluviatile</u> - log	2
" " - swampy	1
<u>Blechnum discolor</u> - shade	7
" " - swampy	2
" " - vertical .....	4
<u>Asplenium lucidum</u> - vertical	1
<u>Asplenium bulbiferum</u>	2
" " - shade	1
" " - vertical	1
<u>Microsorium diversifolium</u> .....	1
" " - shade	1
<u>Podocarpus dacrydioides</u> M	1
<u>Podocarpus totara</u> M	4
<u>Freycinetia banksii</u>	1
<u>Microlaena avenacea</u> .....	3
<u>Danthonia</u> spp.	4
" - vertical	1
<u>Arundo kakaho</u> - shade	3
<u>Poa anceps</u>	1
<u>Poa caespitosa</u> .....	2

## APPENDIX III A. (cont.)

<u>Mariscus ustulatus</u>	1
<u>Eleocharis acuta</u>	4
<u>Eleocharis cunninghamii</u>	7
" " - swampy	1
" " - vertical .....	1
<u>Scirpus prolifer</u>	1
" " - shade	1
" " - swampy	6
<u>Scirpus nodosus</u>	2
<u>Schoenus axillaris</u> - shade .....	1
<u>Schoenus apogon</u>	5
" " - shade	1
<u>Schoenus apogon var. laxiflorus</u>	4
<u>Vincentia sinclairii</u>	1
<u>Gahnia sp.</u> .....	1
<u>Uncinia unciniata</u>	1
<u>Carex secta</u>	6
" " - swampy	2
<u>Carex geminata</u>	1
<u>Carex lucida</u> - shade .....	3
<u>Carex dissita</u>	7
" " - shade	2
" " - vertical	1
<u>Carex solandri</u>	4
<u>Rhopalostylis sapida</u> M .....	1
<u>Juncus pallidus</u>	8
" " - swampy	1
<u>Juncus pauciflorus</u>	1
<u>Juncus vaginatus</u> - shade	1
<u>Juncus polyanthemus</u> - shade .....	10
" " - swampy	10
<u>Juncus luxurians</u> - swampy	1
<u>Juncus planifolius</u>	3
" " - swampy	3
<u>Rhipogonum scandens</u> MC .....	12
<u>Rhipogonum scandens</u> N	2
<u>Rhipogonum scandens</u>	1
<u>Cordyline australis</u> M	1
<u>Astelia nervosa</u>	1
" " - shade .....	1
<u>Libertia irioides</u>	1
<u>Macropiper excelsum</u> M	4
<u>Macropiper excelsum</u> N	4
" " - vertical	1
<u>Nothofagus solandri</u> M .....	5
<u>Nothofagus solandri</u> N	4
" " - shade	2
<u>Paratrophis microphylla</u> M	1
<u>Urtica ferox</u> N	1
<u>Urtica ferox</u> .....	1
<u>Knightia excelsa</u> M	1
<u>Muehlenbeckia australis</u> MC	1
<u>Muehlenbeckia australis</u> - shade	1
<u>Muehlenbeckia complexa</u> MC	1
<u>Muehlenbeckia complexa</u> NC - log .....	2
" " - shade	2
" " - swampy	1
" " - vertical	1
<u>Muehlenbeckia complexa</u> N	1
" " - log .....	2
<u>Muehlenbeckia complexa</u> - greywacke	1
" " - log	14
" " - shade	3
" " - vertical	7
<u>Clematis paniculata</u> NC .....	1
<u>Ranunculus hirtus</u> - vertical	1
<u>Pseudowintera axillaris</u> M	1

## APPENDIX III A. (cont.)

<u>Pseudowintera axillaris</u> N	1
<u>Pseudowintera colorata</u> M	7
<u>Pseudowintera colorata</u> N .....	14
"          "          - log	1
"          "          - shade	2
<u>Pseudowintera colorata</u>	2
<u>Hedycarya arborea</u> M	8
<u>Beilschmiedia tawa</u> M .....	8
<u>Carpodetus serratus</u> M	5
<u>Carpodetus serratus</u> N	10
"          "          - swampy	1
<u>Carpodetus serratus</u>	1
<u>Weinmannia racemosa</u> M .....	4
<u>Weinmannia racemosa</u> N	5
"          "          - swampy	1
"          "          - vertical	1
<u>Weinmannia racemosa</u>	1
"          "          - log .....	1
<u>Rubus cissoides</u> MC	11
<u>Rubus cissoides</u> NC - log	1
"          "          -- shade	6
<u>Rubus cissoides</u> N	9
"          "          - shade .....	2
<u>Rubus cissoides</u>	1
<u>Acaena</u> spp. - log	4
"          - shade	4
"          - vertical	7
<u>Melicope simplex</u> N .....	1
<u>Coriaria arborea</u> M	1
<u>Pennantia corymbosa</u> M	4
<u>Pennantia corymbosa</u> N	4
<u>Alectryon excelsum</u> M	1
<u>Alectryon excelsum</u> N .....	1
<u>Elaeocarpus dentatus</u> M	1
<u>Aristotelia serrata</u> M	4
<u>Aristotelia serrata</u> N	2
<u>Aristotelia serrata</u>	1
<u>Hoheria sexstylosa</u> M .....	4
<u>Hoheria sexstylosa</u> N	5
"          "          - vertical	1
<u>Leptospermum scoparium</u> N - swampy	1
"          "          - vertical	5
<u>Leptospermum scoparium</u> .....	1
<u>Leptospermum ericoides</u> M	2
<u>Leptospermum ericoides</u> N	1
"          "          - shade	1
<u>Metrosideros scandens</u> MC	3
<u>Metrosideros scandens</u> NC .....	2
"          "          - log	1
<u>Metrosideros scandens</u> N	2
<u>Metrosideros scandens</u> - log	2
"          "          - shade	1
<u>Metrosideros diffusa</u> MC .....	4
<u>Metrosideros diffusa</u> NC	2
"          "          - shade	1
<u>Metrosideros diffusa</u> N	8
"          "          - log	2
"          "          - shade .....	1
<u>Metrosideros diffusa</u> - shade	9
"          "          - vertical	14
<u>Metrosideros robusta</u> M	1
<u>Metrosideros perforata</u> MC	4
<u>Metrosideros perforata</u> NC - log .....	1
<u>Metrosideros perforata</u> N	3

## APPENDIX III A. (cont.)

<u>Metrosideros perforata</u>	1
" " - log	1
" " - vertical	1
<u>Myrtus bullata</u> M .....	2
<u>Myrtus bullata</u> N	1
<u>Fuchsia excorticata</u> N	1
" " - shade	1
<u>Haloragis erecta</u> N	1
<u>Haloragis micrantha</u> .....	4
" " - vertical	1
<u>Gunnera strigosa</u>	10
" " - log	1
" " - shade	2
" " - swampy .....	3
" " - vertical	5
<u>Nothopanax arboreum</u> M	1
<u>Nothopanax arboreum</u> N	3
<u>Schefflera digitata</u> M	8
<u>Pseudopanax crassifolium</u> N .....	1
" " - shade	1
<u>Hydrocotyle</u> spp. - greywacke	1
" - log	8
" - shade	2
" - swampy .....	2
" - vertical	4
<u>Centella uniflora</u> - shade	4
<u>Griselinia littoralis</u> N	1
<u>Gaultheria antipoda</u> N	1
<u>Gaultheria antipoda</u> .....	2
<u>Leucopogon fasoiculatus</u> M	9
<u>Leucopogon fasciculatus</u> N - log	1
" " - shade	6
<u>Leucopogon fasoiculatus</u>	3
<u>Rapanea salicina</u> M .....	1
<u>Geniostoma ligustrifolium</u> M	1
<u>Geniostoma ligustrifolium</u> N - shade	5
" " - vertical	1
<u>Geniostoma ligustrifolium</u>	2
<u>Parsonsia heterophylla</u> MC .....	4
<u>Parsonsia heterophylla</u> N	1
<u>Parsonsia heterophylla</u>	1
<u>Solanum aviculare</u> N	2
<u>Hebe salicifolia</u> M	1
<u>Hebe salicifolia</u> N .....	3
<u>Hebe salicifolia</u> - vertical	1
<u>Rhabdothamnus solandri</u>	1
<u>Myoporum laetum</u> M	2
<u>Coprosma australis</u> M	5
<u>Coprosma australis</u> N .....	2
<u>Coprosma robusta</u> M	3
<u>Coprosma robusta</u> N	11
<u>Coprosma rhamnoides</u> M	1
<u>Coprosma rhamnoides</u> N - greywacke	1
" " - log .....	2
" " - vertical	2
<u>Coprosma rhamnoides</u> - vertical	1
<u>Coprosma parviflora</u>	1
<u>Coprosma foetidissima</u> N	1
<u>Coprosma colensoi</u> M .....	1
<u>Nertera depressa</u> - greywacke	1
" " - log	4
" " - shade	3
" " - swampy	3
<u>Nertera setulosa</u> - log	8

## APPENDIX III A. (cont.)

<u>Nertera setulosa</u> - shade	10
" " - swampy	1
<u>Wahlenbergia marginata</u> var. <u>australis</u>	1
<u>Olearia rani</u> M	3
<u>Olearia rani</u> N .....	4
<u>Olearia virgata</u> M	5
<u>Olearia virgata</u> N - swampy	1
" " - vertical	1
<u>Olearia virgata</u>	1
<u>Olearia solandri</u> N - vertical .....	1
<u>Olearia solandri</u>	2
" " - vertical	1
<u>Raoulia glabra</u>	5
" " - vertical	1
<u>Raoulia tenuicaulis</u> .....	1
<u>Helichrysum filicaule</u> - log	1
" " - shade	1
" " - vertical	7
X <u>Helichrysum filicaule</u> - <u>Raoulia glabra</u> ?	1
<u>Helichrysum glomeratum</u> N .....	6
" " - vertical	1
<u>Cassinia leptophylla</u> N	1
<u>Erechtites prenanthoides</u>	3
" " - shade	1
<u>Brachyglottis repanda</u> N - shade .....	5
-----	
<u>Berberis vulgaris</u> N	1
<u>Rubus fruticosus</u> N	4
" " - shade	2
<u>Ulex europaeus</u> M	13
<u>Ulex europaeus</u> N - shade .....	5
<u>Cytisus scoparius</u> M	7
<u>Salix fragilis</u> M	1
<u>Carex leporina</u>	1
<u>Pinus radiata</u> M	2
<u>Pinus muricata</u> M .....	1
<u>Cupressus lawsoniana</u> N	1
<u>Cupressus macrocarpa</u> M	6
-----	
<u>Juncus effusus</u>	10
" " - swampy	1
-----	
<u>Phanerophyte bases</u>	14
<u>Bare</u> - burrow entrance	5
" - vertical	9
" - gully	1
" - slump .....	3
" - wind erosion	2
" - greywacke gravel	3
" - mudstone	3
" - sand	2
" - sandstone .....	2
" - silt	1

B. RE-RUN TRANSECTS

<u>Nasturtium officinale</u>	1
<u>Geranium molle</u>	1
<u>Trifolium dubium</u> - swampy	2
" " - track	1
<u>Trifolium repens</u> - swampy .....	1
" " - track	5
<u>Lotus uliginosus</u>	3
<u>Achillea millefolium</u>	5
<u>Carduus tenuiflorus</u>	4
<u>Hypochaeris radicata</u> - track .....	4
<u>Leontodon hispidus</u>	1
<u>Digitalis purpurea</u>	10
" " - vertical	4
<u>Mentha pulegium</u>	1
<u>Carex glauca</u> .....	3
<u>Carex leporina</u>	1
<u>Lolium perenne</u>	1
<u>Dactylis glomerata</u>	9
" " - shade	1
" " - track .....	1
<u>Poa spp.</u>	1
<u>Festuca rubra</u> var. <u>commutata</u>	12
<u>Festuca arundinacea</u>	8
<u>Holcus lanatus</u> - swampy	3
" " - track .....	4
<u>Agrostis tenuis</u> - shade	1
" " - vertical	1
<u>Anthoxanthum odoratum</u>	4
" " - track	2
-----	
<u>Juncus bufonius</u> - swampy	1
<u>Juncus articulatus</u> - swampy	4
-----	
<u>F</u> - track	2

APPENDIX IV. MEAN ABUNDANCE OF SPECIES AND CATEGORIES, BY LENGTH-GROUPS. A. ORIGINAL TRANSECTS

Length - group Total no. of transects	I (114)	II (171)	III (218)	IV (241)	V (181)	VI (106)	(Total freq.) (1031)
<u>Cyathea medullaris</u> M	-	13.2 (2)	6.6 (2)	17.7 (8)	6.6 (5)	1.5 (6)	23
<u>Dicksonia squarrosa</u> N	-	5.6 (4)	2.5 (4)	2.6(15)	2.0 (6)	0.7 (7)	36
<u>Paesia scaberula</u>	5.0 (2)	20.3 (9)	17.1(23)	7.8(49)	4.8(42)	3.3(34)	159
<u>Paesia scaberula</u> - shade	-	5.0 (4)	3.1 (3)	4.1(12)	0.7(11)	0.6 (8)	38
<u>Paesia scaberula</u> - vertical	-	-	4.0 (5)	3.1(13)	1.4(12)	0.9(17)	47
<u>Pteridium esculentum</u>	11.5 (7)	17.2(15)	17.5(33)	9.7(61)	5.9(37)	5.0(30)	183
<u>Pteridium esculentum</u> - shade	4.3 (1)	3.6 (1)	3.2 (7)	7.5(13)	1.8 (9)	0.4 (7)	38
<u>Pteridium esculentum</u> - vertical	-	-	-	1.5 (6)	1.1 (6)	0.4 (8)	20
<u>Histiopteris incisa</u>	36.4 (1)	2.1 (1)	4.8 (5)	3.4 (3)	1.0 (7)	0.8(10)	27
<u>Polystichum vestitum</u>	-	12.6 (2)	4.3 (2)	1.6 (6)	0.9 (9)	0.6 (8)	27
<u>Cyclosorus pennigerus</u>	-	2.2 (1)	4.2 (4)	1.2 (7)	0.6 (7)	0.3 (4)	23
<u>Cyclosorus pennigerus</u> - shade	-	-	2.1 (2)	8.4 (9)	4.0 (5)	1.9 (4)	20
<u>Blechnum procerum</u>	6.4 (2)	2.5 (2)	32.4 (3)	1.1 (5)	1.0(11)	0.6 (7)	30
<u>Blechnum procerum</u> - shade	100.0 (1)	2.8 (1)	1.5 (2)	2.6 (5)	0.4 (4)	0.4 (4)	17

APPENDIX IV A. (cont.)

Length-group Total no. of transects	I (114)	II (171)	III (218)	IV (241)	V (181)	VI (106)	(Total freq.) (1031)
<u>Blechnum fluviatile</u>	5.0 (3)	3.3 (4)	4.1(12)	2.5(30)	1.9(35)	1.0(32)	116
<u>Blechnum fluviatile</u> - shade	-	-	4.8 (4)	1.1 (6)	0.6(11)	0.4 (9)	30
<u>Blechnum fluviatile</u> - vertical	-	4.0 (2)	3.2 (7)	1.8 (14)	1.3 (15)	0.5 (13)	51
<u>Blechnum discolor</u>	5.6 (1)	2.8 (2)	9.3 (4)	2.1 (6)	3.0 (9)	1.6 (6)	28
<u>Arundo kakaho</u>	-	11.9 (5)	11.3 (2)	15.7 (4)	4.7 (7)	2.3 (2)	20
<u>Carex lucida</u>	-	2.2 (1)	2.9 (5)	1.0 (8)	0.7(11)	0.3 (7)	32
<u>Juncus vaginatus</u>	4.3 (2)	3.1 (9)	1.7(11)	1.5(22)	0.6(32)	0.6(22)	98
<u>Juncus polyanthemos</u>	9.6(12)	5.5(25)	3.7(42)	2.0(75)	1.6(98)	0.9(68)	320
<u>Juncus luxurians</u>	-	4.2 (2)	2.4(10)	1.8(14)	0.5(19)	0.7 (4)	49
<u>Muehlenbeckia complexa</u> NC	-	-	6.6 (3)	1.4 (3)	1.1 (4)	0.5 (6)	16
<u>Muehlenbeckia complexa</u>	-	2.1 (1)	2.0 (3)	1.3 (9)	1.0(18)	0.4(14)	45
<u>Rubus cissoides</u> NC	-	-	3.1 (2)	5.0 (7)	3.2 (3)	0.7 (5)	17
<u>Acaena</u> spp.	8.6 (6)	4.1(13)	2.3(30)	1.4(37)	0.8(66)	0.5(40)	192
<u>Melicytus ramiflorus</u> M	100.0 (1)	24.1 (1)	7.1 (8)	5.6(13)	3.8 (8)	1.4(10)	41
<u>Melicytus ramiflorus</u> N	-	-	2.2 (2)	1.0 (5)	0.6 (6)	0.4 (6)	19

APPENDIX IV A (cont.)

Length-group Total no. of transects	I (114)	II (171)	III (218)	IV (241)	V (181)	VI (106)	(Total freq.) (1031)
<u>Leptospermum scoparium</u> M	14.3 (6)	22.7(11)	15.7(23)	14.4(25)	7.6(20)	3.2 (8)	93
<u>Leptospermum scoparium</u> N	16.8 (9)	9.8(25)	7.2(37)	4.8(43)	2.5(45)	1.4(19)	178
<u>Leptospermum scoparium</u> N - shade	-	5.0 (4)	1.2 (4)	1.1 (5)	4.3 (4)	3.1 (2)	19
<u>Metrosideros diffusa</u>	-	-	2.4 (3)	1.8 (7)	0.7(10)	0.6 (3)	23
<u>Metrosideros diffusa</u> - log	-	-	2.5 (4)	1.7 (5)	1.1 (9)	1.0 (8)	26
<u>Fuchsia excorticata</u> M	3.7 (1)	14.5 (1)	1.2 (1)	3.0 (4)	1.9 (5)	2.6 (4)	16
<u>Hydrocotyle</u> spp.	-	4.7 (4)	1.8 (9)	1.0(12)	0.5(17)	0.4(20)	62
<u>Centella uniflora</u>	4.9 (1)	2.8 (1)	2.6 (4)	1.1(12)	0.5(17)	0.2 (5)	40
<u>Oreomyrrhis andicola</u>	-	-	-	0.8 (3)	0.6 (7)	0.5 (5)	15
<u>Leucopogon fasciculatus</u> N	8.9 (2)	6.5 (4)	1.9.(4)	2.2 (4)	0.7 (6)	0.9 (4)	24
<u>Geniostoma ligustrifolium</u> N	-	3.8 (2)	3.1 (3)	1.8 (5)	0.9 (2)	0.2 (6)	18
<u>Dichondra repens</u>	-	-	0.8 (3)	0.6 (3)	0.5 (5)	0.4 (5)	16
<u>Coprosma rhamnoides</u> N	20.8 (4)	5.8 (7)	7.5(17)	3.1(25)	2.1(19)	1.0(11)	83
<u>Coprosma rhamnoides</u> N - shade	4.3 (1)	6.2 (3)	4.4 (6)	3.8 (5)	6.0 (2)	7.8 (1)	18
<u>Netera depressa</u>	-	2.5 (1)	1.7 (5)	0.9 (5)	0.9(11)	2.7 (7)	29

APPENDIX IV A. (cont.)

length-group Total no. of transects	I (114)	II (171)	III (218)	IV (241)	V (181)	VI (106)	(Total freq.) (1031)
<u>Nertera depressa</u> - vertical	-	-	2.2 (3)	1.1 (6)	0.5 (4)	0.4 (6)	19
<u>Nertera setulosa</u>	6.3 (2)	4.8(13)	2.6 (25)	1.3(67)	1.1(78)	0.8 (46)	231
<u>Nertera setulosa</u> - vertical	-	3.6 (1)	1.6 (3)	1.2 (4)	0.5(12)	0.3 (4)	24
<u>Olearia virgata</u> N	-	5.2 (2)	-	0.6 (4)	4.5 (2)	0.4 (7)	15
<u>Olearia solandri</u> N	-	-	2.0 (2)	1.2 (4)	1.3 (6)	0.3 (6)	18
<u>Helichrysum filicaule</u>	21.2 (1)	5.2 (5)	1.3 (6)	2.0(15)	1.9(25)	1.0(22)	74
<u>Brachyglottis repanda</u> M	5.6 (1)	2.9 (2)	5.9 (4)	12.1 (9)	6.1 (8)	2.0 (6)	30
<u>Brachyglottis repanda</u> N	-	-	2.2 (5)	1.6(10)	1.2 (7)	0.8 (7)	29
<u>Ulex europaeus</u> N	13.6 (3)	13.8 (6)	8.3(12)	3.0(10)	4.8(11)	1.2 (9)	51
<u>Cytisus scoparius</u> N	-	2.5 (2)	2.5 (4)	3.3 (5)	3.1 (4)	0.4 (3)	18
<u>Pasture</u>	91.0(111)	88.8(169)	87.0(215)	87.1(237)	87.3(181)	89.4(106)	1019
<u>Pasture - shade</u>	29.1(22)	17.8(45)	12.1(82)	7.5(104)	4.8(85)	2.6(55)	393
<u>Pasture - swampy</u>	-	10.6 (2)	11.4 (5)	8.0(10)	3.7(25)	1.9(28)	70
<u>Dense phanerophytes</u>	24.9 (1)	23.5 (1)	28.8 (5)	11.7(11)	7.4(10)	1.0 (7)	35
<u>Bare - track</u>	6.0 (1)	7.2(17)	5.0(28)	1.9(41)	1.0(56)	0.5(43)	186

APPENDIX IV A. (cont.)

Length-group Total no. of transects	I (114)	II (171)	III (218)	IV (241)	V (181)	VI (106)	(Total freq.) (1031)
<u>Bare</u> - stock trampling	9.4 (2)	6.2(10)	2.9(19)	1.5(36)	0.9(47)	0.7(37)	151
<u>Bare</u> - slip	-	13.7 (1)	3.3 (5)	2.0(11)	0.7(14)	0.4(15)	46
<u>Bare</u> - log	8.6 (6)	6.1 (28)	3.5 (68)	1.6(98)	1.6(113)	1.1(77)	390
<u>Bare</u> - shade	7.0 (2)	8.6 (3)	33.4 (5)	5.9 (6)	3.7 (5)	8.7 (4)	25
<u>Bare</u> - greywacke	18.7 (5)	6.5 (6)	2.1(12)	1.5(25)	1.2(36)	0.9(34)	118

B. RE-RUN TRANSECTS

Length-group Total no. of transects	I (40)	II (58)	III (76)	IV (97)	V (67)	VI (42)	(Total freq.) (380)
<u>Trifolium dubium</u>	-	2.1 (2)	1.7 (1)	0.9 (1)	0.8 (9)	0.8 (4)	17
<u>Trifolium repens</u>	6.3 (1)	2.9 (2)	2.8 (4)	1.0(10)	0.5 (9)	0.4 (6)	32
<u>Cirsium lanceolatum</u>	5.9 (1)	7.1 (4)	3.8 (5)	1.2(17)	0.6(10)	0.5(12)	49
<u>Cirsium arvense</u>	-	3.9 (3)	4.3 (4)	1.6 (9)	1.0 (7)	0.6 (9)	32
<u>Cirsium palustre</u>	-	2.2 (1)	1.6 (5)	0.7 (7)	0.5(17)	0.4 (8)	38
<u>Hypochoeris radicata</u>	6.6 (2)	3.8 (5)	1.6(11)	1.7(16)	0.9(21)	0.6(23)	78
<u>Holcus lanatus</u>	9.1 (1)	2.4 (3)	1.9 (3)	0.7 (6)	0.5 (7)	0.5 (3)	23
<u>Agrostis tenuis</u>	39.3 (3)	5.8(11)	3.4(11)	1.7(13)	1.8(22)	1.4(21)	81
<u>F</u>	6.0 (1)	2.3 (2)	2.0(11)	1.3 (8)	0.8(18)	0.4(15)	55
<u>Pasture - shelf</u>	-	-	7.2 (2)	3.9 (5)	2.0 (7)	1.4 (3)	17
<u>Pasture - track</u>	7.3 (2)	6.5 (8)	4.4(28)	3.0(46)	2.3(39)	3.5(33)	156

APPENDIX V. MEAN ABUNDANCE OF CERTAIN SPECIES AND CATEGORIES, FOR DIFFERENT ORIENTATIONS AND SOIL TYPES, BY LENGTH-GROUPS

Length-Group		I	II	III	IV	V	VI	
<u><i>Paesia scaberula</i></u>								
	orien.	N	-	23.6 (3)	14.8 (9)	8.5(14)	5.3 (9)	2.9(14)
		S	4.5 (1)	15.0 (4)	14.5 (8)	7.1(22)	5.4(18)	2.3(10)
		EW	-	37.3 (2)	23.5 (6)	8.4(13)	3.8(15)	5.1(10)
		-	5.5 (1)	-	-	-	-	-
	soil	11H	5.5 (1)	-	-	-	0.9 (1)	-
		13bH	-	-	-	1.0 (2)	2.2 (1)	1.3 (1)
		77bH	-	-	33.5 (3)	3.9 (5)	4.2 (6)	0.5 (3)
		118a	-	30.7 (2)	8.1 (5)	6.4 (9)	5.1 (7)	12.2 (2)
		122	-	32.3 (2)	14.1 (3)	10.2(14)	4.5 (5)	3.5 (7)
		124	4.5 (1)	12.8 (5)	18.7(12)	9.8(19)	5.3(22)	3.3(21)
-----								
<u><i>Pteridium esculentum</i></u>								
	orien.	N	12.5 (2)	3.6 (4)	11.6(12)	11.7(19)	6.1(16)	4.7(16)
		S	6.3 (2)	6.9 (4)	18.4 (6)	9.7(23)	5.1(13)	2.1 (6)
		EW	16.6 (1)	22.6 (7)	17.5(13)	8.9(16)	7.0 (8)	8.5 (8)
		-	14.0 (2)	-	61.4 (2)	3.7 (3)	-	-
	soil	11H	21.8 (1)	2.8 (1)	-	1.0 (1)	-	-
		13bH	6.3 (2)	2.9 (1)	6.7 (2)	2.6 (4)	1.7 (1)	-
		77bH	14.2 (1)	11.9 (2)	6.5 (6)	16.5(13)	6.2 (7)	1.5 (3)
		118a	-	2.5 (4)	14.9 (4)	2.5 (8)	2.2 (7)	0.6 (1)
		122	13.7 (2)	49.8 (2)	19.2(11)	9.4(17)	2.9(10)	6.9(13)
		124	7.7 (1)	35.1 (5)	28.3(10)	14.4(16)	13.0(12)	4.7(13)
		1	-	-	-	3.9 (2)	-	-
-----								

APPENDIX V (cont.)

Length-group		I	II	III	IV	V	VI
<u>Blechnum fluviatile</u>							
orien.	N	-	-	2.1 (3)	2.8(10)	2.9 (5)	1.0(12)
	S	4.3 (2)	3.4 (2)	6.3 (7)	2.8(15)	1.8(18)	1.4 (9)
	EW	6.7 (1)	3.2 (2)	1.3 (1)	1.3 (5)	2.0(11)	0.6(11)
	-	-	-	1.3 (1)	-	0.3 (1)	-
soil	13bH	-	-	-	0.8 (1)	-	-
	77bH	6.7 (1)	2.5 (1)	1.3 (1)	-	0.6 (3)	0.2 (3)
	122	-	-	2.8 (1)	1.4 (8)	2.2 (7)	1.2 (6)
	124	4.3 (2)	3.6 (3)	4.6(10)	3.1(21)	2.1(25)	1.1(23)
-----							
<u>Juncus vaginatus</u>							
orien.	N	-	4.6 (2)	1.7 (1)	1.7(10)	0.5(14)	0.6(12)
	S	4.6 (1)	3.1 (2)	1.3 (2)	0.9 (1)	0.7 (7)	0.2 (1)
	EW	-	3.2 (2)	1.9 (4)	1.3(10)	0.6 (8)	0.6 (6)
	-	4.0 (1)	2.1 (3)	1.6 (4)	4.2 (1)	0.5 (3)	0.5 (3)
soil	11H	4.0 (1)	-	-	7.4 (2)	0.5 (4)	0.7 (1)
	13bH	-	2.6 (1)	-	-	0.6 (1)	0.2 (1)
	77bH	4.6 (1)	3.6 (5)	2.3 (3)	0.9 (9)	0.5 (7)	0.6 (8)
	118a	-	2.5 (1)	1.3 (4)	1.7 (2)	0.7(10)	0.9 (6)
	122	-	2.6 (1)	2.1 (1)	1.0 (6)	0.4 (4)	0.4 (4)
	124	-	2.0 (1)	1.6 (2)	1.4 (2)	0.7 (4)	0.2 (2)
	12	-	-	1.3 (1)	-	0.4 (1)	-
	13	-	-	-	4.2 (1)	0.5 (1)	-
-----							

APPENDIX V (cont.)

Length-group		I	II	III	IV	V	VI
<u>Juncus polyanthemos</u>							
orien.	N	-	4.6 (7)	4.2 (13)	1.8 (26)	1.8 (40)	1.1 (28)
	S	8.8 (2)	2.8 (4)	2.8 (11)	1.5 (16)	1.4 (25)	0.7 (16)
	EW	6.6 (4)	3.5 (7)	3.1 (10)	2.6 (27)	1.2 (26)	0.7 (20)
	-	12.1 (6)	11.7 (7)	6.2 (8)	1.9 (6)	4.2 (7)	1.1 (4)
soil	11H	9.2 (1)	2.3 (3)	4.1 (1)	2.5 (6)	2.3 (11)	0.4 (3)
	13bH	-	3.9 (5)	3.0 (6)	2.0 (8)	2.1 (13)	1.6 (3)
	77bH	9.3 (1)	4.2 (7)	3.4 (4)	2.2 (26)	1.9 (20)	1.3 (17)
	118a	7.2 (2)	2.5 (1)	3.7 (13)	3.6 (12)	1.8 (17)	1.7 (11)
	122	6.6 (3)	2.9 (1)	6.4 (8)	1.0 (11)	0.7 (11)	0.5 (9)
	124	14.3 (1)	6.7 (4)	1.5 (4)	1.1 (9)	0.9 (22)	0.6 (25)
	1	17.6 (3)	16.6 (4)	5.5 (3)	1.8 (1)	-	-
	1c	5.6 (1)	-	1.3 (1)	-	1.4 (1)	-
	12	-	-	1.3 (2)	-	6.8 (2)	-
	13	-	-	-	1.7 (2)	10.4 (1)	-
-----							
<u>Acaena spp.</u>							
orien.	N	5.1 (2)	2.4 (4)	1.7 (7)	1.4 (12)	1.0 (22)	0.5 (17)
	S	-	4.6 (2)	2.9 (4)	1.6 (9)	0.8 (22)	0.5 (13)
	EW	5.0 (1)	4.8 (5)	2.3 (12)	1.0 (13)	0.7 (20)	0.4 (10)
	-	11.8 (3)	5.8 (2)	2.4 (7)	2.8 (3)	0.4 (2)	-
soil	11H	11.6 (2)	2.8 (1)	2.2 (3)	1.3 (3)	0.7 (9)	0.3 (2)
	13bH	-	2.1 (1)	3.1 (2)	1.4 (4)	1.2 (7)	1.2 (1)
	77bH	8.7 (1)	2.5 (1)	3.1 (3)	1.2 (2)	0.7 (9)	0.2 (2)
	118a	10.9 (1)	-	1.7 (2)	2.2 (3)	0.4 (7)	0.3 (2)
	122	5.0 (1)	6.3 (2)	2.0 (7)	1.0 (12)	0.8 (9)	0.5 (10)
	124	4.9 (1)	4.6 (7)	2.2 (13)	1.7 (13)	0.9 (26)	0.5 (23)
	1	-	2.6 (1)	-	-	-	-
-----							

APPENDIX V (cont.)

Length-group		I	II	III	IV	V	VI
<u>Leptospermum scoparium</u> N							
orient.	N	31.9 (2)	7.2 (8)	14.7 (8)	4.8(11)	2.2(22)	0.5 (8)
	S	10.9 (2)	17.4 (6)	4.4(13)	4.8(16)	4.0(13)	2.0 (5)
	EW	14.7 (4)	8.6 (8)	7.8(13)	5.0(15)	1.8 (9)	2.3 (5)
	-	5.7 (1)	7.0 (3)	2.8 (3)	3.0 (1)	0.3 (1)	3.8 (1)
soil	11H	-	6.3 (3)	7.6 (7)	11.8 (7)	4.8 (9)	3.5 (2)
	13bH	25.5 (4)	7.4(11)	7.7(12)	4.2(12)	3.0(11)	1.6 (3)
	77bH	17.0 (2)	14.0 (3)	2.9 (5)	2.2 (8)	1.1 (8)	0.7 (4)
	118a	9.6 (2)	13.5 (8)	10.6(11)	4.5(12)	2.4(15)	2.0 (6)
	122	-	-	4.2 (1)	5.6 (3)	0.5 (1)	1.2 (2)
	124	4.0 (1)	-	-	0.9 (1)	0.4 (1)	0.4 (2)
	1	-	-	1.6 (1)	-	-	-
	-	-	-	-	-	-	-
<u>Nertera setulosa</u>							
orient.	N	-	3.6 (4)	3.0 (8)	1.2(30)	1.1(25)	0.7(13)
	S	-	4.2 (5)	2.3 (9)	1.7(18)	1.0(27)	0.9(18)
	EW	6.3 (2)	6.2 (3)	2.4 (7)	1.0(17)	1.4(22)	1.0(14)
	-	-	10.4 (1)	3.7 (1)	2.1 (2)	0.8 (4)	0.2 (1)
soil	11H	-	-	2.7 (3)	1.2 (3)	0.9 (5)	-
	13bH	-	4.5 (2)	1.8 (2)	1.2 (3)	0.9 (2)	0.6 (2)
	77bH	6.7 (1)	2.4 (1)	3.8 (2)	1.6 (5)	0.6 (7)	0.5 (5)
	118a	-	-	1.0 (1)	1.6 (5)	0.8 (8)	0.2 (3)
	122	5.9 (1)	6.5 (3)	2.2 (4)	1.2(14)	0.8(18)	0.6(12)
	124	-	3.9 (6)	2.8(13)	1.3(37)	1.5(38)	1.2(24)
	1	-	10.4 (1)	-	-	-	-

APPENDIX VI. MEAN PERCENTAGE COVER, MEAN PERCENTAGE TOP COVER,  
AND MEAN PERCENTAGE FREQUENCY OF SPECIES AND  
CATEGORIES.

Species or category	% cover	% top cover	% freqcy.
<u>Cladonia</u> sp.	-	-	- (1)
<u>Parmelia</u> sp.	-	-	- (1)
<u>Porella</u> sp.	- (1)	-	- (2)
<u>Polytrichum juniperinum</u>	- (1)	-	6.2 (8)
<u>Campylopus clavatus</u>	- (3)	- (1)	6.4 (15)
" " - track	-	-	- (1)
" " - vertical	- (1)	-	-
<u>Triquetella papillata</u>	1.1 (8)	- (1)	8.7 (14)
<u>Breutelia pendula</u>	- (4)	-	8.4 (6)
" " - track	-	-	- (1)
<u>Thuidium furfursum</u>	2.7 (25)	1.5 (5)	32.6 (36)
" " - track	- (2)	-	6.2 (5)
<u>Acrocladium auriculatum</u>	3.1 (24)	1.1 (6)	19.6 (28)
" " - track	- (2)	-	- (4)
<u>Ophioglossum pedunculatum</u>	-	-	- (1)
<u>Paesia scaberula</u>	4.3 (5)	2.4 (5)	12.3 (6)
" " - track	-	-	- (1)
<u>Pteridium esculentum</u>	2.0 (7)	2.4 (5)	11.6 (15)
" " - track	-	-	- (1)
" " - vertical	- (1)	- (1)	- (1)
<u>Polystichum richardi</u>	- (1)	-	-
<u>Blechnum pennsylvanicum</u>	- (1)	-	-
<u>Blechnum fluviatile</u>	- (3)	- (1)	- (4)
<u>Deyeuxia crinita</u>	- (1)	- (1)	-
<u>Danthonia</u> spp.	13.2 (40)	7.9 (39)	64.0 (41)
" - shade	- (2)	- (1)	- (1)
" - track	1.7 (9)	1.3 (7)	9.5 (14)
" - vertical	- (1)	- (1)	- (4)
<u>Scirpus cernuus</u>	-	-	- (3)
<u>Schoenus apogon</u>	- (1)	- (1)	-
<u>Schoenus apogon</u> var. <u>laxiflorus</u>	- (2)	- (1)	12.1 (6)
" " - track	-	-	- (1)
<u>Carex lucida</u>	1.8 (5)	1.2 (5)	- (4)
" " - track	- (2)	- (1)	- (1)
" " - vertical	- (1)	- (1)	-
<u>Carex dissita</u>	-	-	- (1)

## APPENDIX VI. (cont.)

Species or category	% cover	% top cover	% freqcy.
<u>Juncus vaginatus</u> N	-		- (1)
<u>Juncus vaginatus</u>	-	-	- (4)
" " - track	-	-	- (2)
<u>Juncus polyanthemus</u> N	1.2(10)		7.3(12)
<u>Juncus polyanthemus</u>	1.5 (7)	1.5 (7)	8.5 (5)
" " - shade	- (3)	- (3)	-
<u>Luzula campestris</u>	1.0 (6)	- (3)	11.9(13)
" " - track	- (1)	-	- (2)
<u>Thelymitra longifolia</u>	- (2)	- (1)	- (4)
<u>Microtis unifolia</u>	- (1)	-	6.4(14)
<u>Muehlenbeckia complexa</u>	- (3)	- (2)	11.3 (5)
" " - track	-	-	- (1)
<u>Montia fontana</u>	- (1)	-	- (1)
<u>Ranunculus hirtus</u>	-	-	- (1)
<u>Carpodetus serratus</u>	-	-	- (1)
<u>Acaena</u> spp.	1.6(13)	- (4)	10.1(29)
" " - track	-	-	- (2)
<u>Leptospermum scoparium</u> N	- (1)		4.0 (5)
<u>Leptospermum scoparium</u>	- (1)	- (1)	- (3)
<u>Metrosideros diffusa</u>	- (2)	- (2)	- (1)
<u>Epilobium nummularifolium</u>	-	-	- (4)
<u>Epilobium pedunculare</u>	- (1)	- (1)	6.8 (8)
" " - vertical	-	-	- (1)
<u>Epilobium</u> sp.	-	-	- (1)
<u>Haloragis micrantha</u>	- (2)	-	23.6 (5)
<u>Gunnera strigosa</u>	-	-	- (1)
<u>Hydrocotyle</u> spp.	3.1(12)	1.0 (5)	38.8(25)
" " - shelf	-	-	- (1)
" " - track	- (2)	-	- (4)
<u>Centella uniflora</u>	3.0 (8)	- (3)	23.9(11)
" " - shelf	-	-	- (1)
" " - track	-	-	- (2)
<u>Oreomyrrhis andicola</u>	- (2)	- (2)	21.8 (8)
" " - shelf	-	-	- (1)
<u>Leucopogon fasciculatus</u> N	- (1)		- (1)
" " - shade	- (1)		-
<u>Leucopogon fasciculatus</u>	- (1)	- (1)	-

## APPENDIX VI (cont.)

Species or category	% cover	% top cover	% freqcy.
<u>Dichondra repens</u>	- (4)	-	16.1 (9)
" " - shelf	-	-	- (1)
<u>Coprosma rhamnoides</u> N	- (1)		- (2)
<u>Coprosma rhamnoides</u>	- (2)	- (1)	- (4)
" " - shade	- (1)	- (1)	-
<u>Nertera depressa</u>	- (1)	- (1)	- (4)
" " - track	-	-	- (1)
<u>Nertera setulosa</u>	5.2(26)	2.2(12)	37.7(31)
" " - shelf	-	-	- (1)
" " - track	- (2)	-	6.5(10)
<u>Wahlenbergia marginata</u> var.			
<u>australis</u>	- (1)	-	10.3 (9)
" " - track	- (1)	- (1)	- (2)
" " - vertical	-	-	- (1)
<u>Lagenophora pumila</u>	- (3)	- (1)	8.7 (6)
<u>Olearia virgata</u>	- (1)	-	-
<u>Olearia solandri</u> N	-		- (1)
<u>Olearia solandri</u>	-	-	- (2)
<u>Raoulia glabra</u>	-	-	- (1)
<u>Helichrysum filicaule</u>	3.2(15)	1.8 (9)	32.0(18)
" " - track	-	-	- (2)
<u>Graspedia uniflora</u>	-	-	- (1)
<u>Erechtites prenanthoides</u>	-	-	- (1)
-----			
<u>Ranunculus repens</u>	- (4)	- (2)	16.1 (5)
" " - track	- (2)	- (1)	- (2)
<u>Sagina procumbens</u>	- (1)	-	9.0(24)
" " - track	-	-	- (4)
<u>Cerastium glomeratum</u>	1.8(16)	1.3 (5)	19.9(36)
" " - shelf	-	-	- (1)
" " - track	-	-	4.8 (9)
<u>Cerastium caespitosum</u>	- (3)	- (2)	- (3)
<u>Silene gallica</u>	-	-	- (1)
<u>Rumex acetosella</u>	- (4)	- (2)	14.0(12)
" " - track	- (2)	- (2)	-
" " - vertical	-	-	- (1)
<u>Linum catharticum</u>	1.4 (7)	- (3)	19.6(27)
" " - track	- (1)	- (1)	7.1 (6)
" " - vertical	- (1)	- (1)	- (1)
<u>Linum marginale</u>	- (4)	- (3)	13.7(11)
" " - track	- (1)	- (1)	- (3)

## APPENDIX VI (cont.)

Species of category	% cover	% top cover	% freqcy.
<u>Geranium molle</u>	- (2)	- (2)	- (3)
<u>Erodium cicutarium</u>	-	-	- (1)
<u>Hypericum humifusum</u>	-	-	- (1)
<u>Hypericum</u> sp.	-	-	- (1)
<u>Lupinus arboreus</u> N	-	-	- (1)
<u>Cytisus scoparius</u>	-	-	- (1)
<u>Vicia angustifolia</u>	- (1)	- (1)	- (1)
" " - track	-	-	- (1)
<u>Trifolium dubium</u>	6.7(35)	3.1(27)	64.3(39)
" " - shelf	-	-	- (1)
" " - track	1.8(12)	1.1 (6)	7.1(16)
" " - vertical	-	-	- (2)
<u>Trifolium repens</u>	7.1(39)	3.6(33)	61.4(44)
" " - shade	- (1)	- (1)	-
" " - shelf	-	-	- (1)
" " - track	1.8(13)	1.3 (7)	5.8(18)
" " - vertical	-	-	- (2)
<u>Trifolium subterraneum</u>	- (1)	- (1)	- (4)
<u>Trifolium arvense</u>	- (1)	- (1)	- (1)
<u>Lotus</u> sp.	-	-	- (1)
<u>Sherardia arvensis</u>	- (1)	- (1)	- (1)
<u>Galium parisiense</u>	-	-	- (1)
<u>Bellis perennis</u>	2.5(15)	1.6 (9)	27.4(25)
" " - track	-	-	- (3)
<u>Gnaphalium purpureum</u>	- (4)	- (1)	6.0(14)
" " - shelf	-	-	- (1)
" " - track	-	-	- (1)
<u>Soliva</u> sp.	-	-	- (1)
<u>Achillea millefolium</u>	2.2 (5)	- (3)	17.8(10)
" " - track	- (1)	-	- (3)
<u>Senecio jacobaea</u>	-	-	- (1)
<u>Carduus tenuiflorus</u>	- (1)	- (1)	4.0 (5)
<u>Cirsium lanceolatum</u>	1.2(14)	1.3 (8)	6.2(22)
" " - track	-	-	- (1)
<u>Cirsium arvense</u>	- (4)	- (3)	12.5 (9)
" " - track	- (1)	- (1)	- (2)
<u>Cirsium palustre</u>	- (3)	- (3)	11.8 (9)
" " - shelf	-	-	- (1)
" " - track	-	-	- (1)

## APPENDIX VI (cont.)

Species or category	% cover	% top cover	% freqcy.
<u>Hypochoeris radicata</u>	13.3(45)	4.1(41)	80.3(45)
" " - shelf	-	-	- (1)
" " - track	1.5(13)	1.1 (6)	9.5(18)
" " - vertical	-	-	- (3)
<u>Leontodon hispidus</u>	1.8(10)	- (4)	16.8(20)
" " - track	-	-	- (3)
" " - vertical	-	-	- (1)
<u>Taraxacum officinale</u>	1.6(12)	1.1(11)	15.7(42)
" " - track	-	-	5.2 (9)
" " - vertical	-	-	- (1)
<u>Sonchus asper</u>	-	-	- (1)
<u>Crepis capillaris</u>	-	-	- (3)
<u>Anagallis arvensis</u>	-	-	- (1)
<u>Plantago lanceolata</u>	1.8(13)	1.2 (8)	21.1(25)
" " - track	-	-	4.9 (7)
<u>Plantago major</u>	- (1)	-	- (1)
<u>Myosotis scorpioides</u>	-	-	- (1)
<u>Myosotis sp.</u>	-	-	- (1)
<u>Veronica arvensis</u>	-	-	- (3)
<u>Digitalis purpurea</u>	-	-	- (1)
<u>Prunella vulgaris</u>	1.3(23)	1.0 (9)	20.4(38)
" " - track	- (2)	-	5.6(13)
<u>Mentha pulegium</u>	- (2)	-	- (2)
<u>Juncus tenuis</u>	- (1)	- (1)	- (3)
<u>Carex glauca</u>	3.2 (5)	- (3)	17.6 (5)
" " - track	- (1)	-	- (1)
<u>Carex leporina</u>	- (3)	- (2)	- (1)
<u>Lolium perenne</u>	6.4(25)	4.7(23)	26.6(29)
" " - shade	- (1)	- (1)	-
" " - shelf	- (2)	- (1)	- (1)
" " - track	1.3 (5)	- (4)	6.0 (7)
<u>Cynosurus cristatus</u>	2.9(32)	2.6(26)	31.2(40)
" " - shelf	-	-	- (1)
" " - track	1.7(13)	1.5 (9)	7.5(12)
" " - vertical	-	-	- (1)
<u>Dactylis glomerata</u>	3.5(29)	2.7(26)	35.0(34)
" " - track	- (3)	- (3)	6.2 (9)
" " - vertical	-	-	- (2)
<u>Bromus mollis</u>	-	-	- (1)
<u>Poa spp.</u>	3.6 (6)	2.7 (5)	15.9(16)
" - shelf	-	-	- (1)
" - track	- (1)	- (1)	- (3)

## APPENDIX VI (cont.)

Species or category	% cover	% top cover	% freqcy.
<u>Glyceria fluitans</u>	- (2)	- (1)	- (1)
" " - track	-	-	- (1)
<u>Vulpia dettonensis</u>	- (2)	- (1)	- (3)
" " - track	-	-	- (1)
<u>Festuca rubra</u> var. <u>commutata</u>	28.6(31)	22.2(29)	67.8(31)
" " - shade	- (3)	- (2)	-
" " - shelf	-	-	- (1)
" " - track	2.5(10)	1.8(10)	9.3(13)
<u>Festuca arundinacea</u>	4.6 (6)	4.5 (5)	19.9(11)
" " - shade	- (1)	- (1)	-
" " - track	- (3)	- (3)	- (1)
<u>Eragrostis</u> sp.	-	-	- (1)
<u>Holcus lanatus</u>	8.2(41)	5.2(35)	56.2(44)
" " - shade	- (1)	-	-
" " - shelf	-	-	- (1)
" " - track	1.1(13)	1.0 (8)	6.4(17)
" " - vertical	-	-	- (1)
<u>Aira caryophyllea</u>	-	-	- (1)
<u>Agrostis tenuis</u>	38.5(45)	25.5(45)	86.8(45)
" " - shade	- (4)	- (4)	-
" " - shelf	- (1)	- (1)	- (1)
" " - track	3.3(20)	2.9(19)	8.8(21)
" " - vertical	-	-	- (4)
<u>Anthoxanthum odoratum</u>	21.1(45)	12.0(45)	89.6(45)
" " - shade	- (2)	- (1)	-
" " - shelf	-	-	- (1)
" " - track	1.8(17)	1.5(13)	8.8(23)
" " - vertical	- (1)	- (1)	- (4)
-----			
<u>Juncus bufonius</u>	-	-	- (3)
" " - track	-	-	- (3)
<u>Juncus articulatus</u>	- (4)	- (2)	10.2 (7)
" " - track	- (1)	-	- (1)
<u>Oxalis corniculata</u>	- (1)	-	- (2)
<u>Gnaphalium luteoalbum</u>	-	-	- (3)
" " - track	-	-	- (1)
<u>Gnaphalium</u> sp.	-	-	- (2)
-----			
<u>Dung</u> - cow	1.2 (9)		
" - track	- (1)		
<u>Dung</u> - horse	- (1)		
<u>Dung</u> - sheep	- (1)		
<u>Bare</u> - unqualified	2.3(27)		-
<u>Bare</u> - track	1.3 (6)		- (1)

APPENDIX VI (cont.)

<u>Species or category</u>	<u>% cover</u>	<u>% top cover</u>	<u>% freqcy.</u>
<u>Bare</u> - stock trampling	- (2)		-
<u>Bare</u> - slip	- (2)		-
<u>Bare</u> - log	1.1 (7)		-
<u>Bare</u> - greywacke	1.4 (5)		-
<u>Microhabitat</u> - shelf	- (1)		- (1)
<u>Microhabitat</u> - track	7.3(23)		8.7(22)
<u>Microhabitat</u> - vertical	- (3)		- (4)

APPENDIX VII. ENVIRONMENTAL ANALYSIS OF MEAN PERCENTAGE COVER (UPPER LINE) AND MEAN PERCENTAGE FREQUENCY (LOWER LINE) OF CERTAIN SPECIES. A. SOIL TYPE AND ORIENTATION.

11H	13bH	77bH	soil type					orientation			
			118a	122	124	1c	13	N	S	EW	-
<u>Thuidium furfurosus</u>											
2.0 (1)	-	1.0 (3)	2.2 (5)	2.8 (9)	4.6 (6)	1.0 (1)	-	2.6 (10)	3.5 (10)	1.6 (4)	1.0 (1)
16.0 (1)	-	27.0 (4)	25.9 (10)	31.7 (11)	47.6 (9)	-	24.0 (1)	32.1 (15)	37.4 (13)	34.0 (5)	14.6 (3)
<u>Acrocladium auriculatum</u>											
1.0 (1)	-	1.0 (1)	3.1 (9)	3.6 (7)	3.7 (6)	-	-	3.2 (11)	3.6 (10)	1.6 (3)	-
5.8 (2)	-	19.4 (2)	27.7 (8)	21.9 (6)	17.6 (9)	4.0 (1)	-	19.9 (13)	23.7 (10)	14.3 (4)	4.0 (1)
<u>Danthonia spp.</u>											
11.5 (2)	13.0 (1)	15.4 (4)	14.6 (10)	11.8 (11)	16.9 (9)	1.5 (2)	11.0 (1)	14.2 (16)	13.8 (14)	21.6 (5)	3.4 (5)
80.6 (2)	44.0 (1)	67.6 (4)	60.0 (10)	68.4 (11)	67.2 (10)	16.8 (2)	84.0 (1)	65.0 (17)	64.3 (14)	87.0 (5)	32.2 (5)
<u>Acaena spp.</u>											
2.0 (1)	-	-	1.5 (3)	1.5 (3)	1.7 (5)	-	1.0 (1)	1.5 (5)	1.9 (4)	1.0 (2)	1.9 (2)
9.9 (2)	-	4.0 (2)	8.2 (8)	10.4 (6)	13.3 (10)	-	8.0 (1)	12.6 (9)	8.0 (12)	9.0 (5)	13.6 (3)
<u>Hydrocotyle spp.</u>											
-	-	3.0 (1)	-	2.5 (4)	3.6 (7)	-	-	2.3 (4)	3.9 (7)	-	2.0 (1)
-	-	40.8 (4)	15.7 (3)	27.4 (7)	52.9 (11)	-	-	37.4 (11)	47.4 (9)	23.9 (4)	40.0 (1)
<u>Nertera setulosa</u>											
6.5 (2)	-	1.0 (2)	3.9 (6)	4.8 (7)	8.7 (8)	-	1.0 (1)	4.7 (10)	4.5 (11)	9.4 (3)	5.4 (2)
30.0 (2)	-	25.0 (2)	34.1 (8)	41.1 (8)	41.0 (10)	-	48.0 (1)	34.6 (13)	32.8 (12)	42.8 (4)	76.7 (2)

APPENDIX VII A. (cont.)

		soil type							orientation			
11H	13bH	77bH	118a	122	124	1c	13	N	S	EW	-	
<u>Helichrysum filicaule</u>												
-	-	1.0 (1)	2.0 (1)	2.6 (5)	4.2 (8)	-	-	2.5 (8)	3.7 (5)	5.7 (2)	-	
4.0 (1)	-	16.8 (2)	5.8 (2)	46.5 (6)	39.9 (7)	-	-	38.6 (6)	19.9 (9)	59.1 (3)	-	
-----												
<u>Trifolium repens</u>												
3.0 (1)	4.0 (1)	11.0 (7)	4.7 (9)	7.9 (8)	6.7(10)	9.8 (2)	6.0 (1)	7.5(14)	4.5(15)	8.1 (4)	13.3 (6)	
9.9 (2)	56.0 (1)	84.4 (7)	51.6 (9)	58.1(11)	67.6(11)	50.0 (2)	76.0 (1)	59.3(17)	57.2(16)	62.4 (5)	76.6 (6)	
<u>Hypochoeris radicata</u>												
7.9 (2)	2.0 (1)	5.5 (7)	11.1(10)	18.3(11)	20.5(11)	4.8 (2)	26.0 (1)	14.8(18)	11.7(16)	16.7 (5)	10.4 (6)	
68.3 (2)	44.0 (1)	52.3 (7)	79.0(10)	88.7(11)	91.5(11)	78.3 (2)	96.0 (1)	83.0(18)	73.7(16)	89.0 (5)	85.3 (6)	
<u>Lolium perenne</u>												
-	4.0 (1)	15.5 (7)	1.0 (5)	6.9 (6)	1.8 (4)	7.0 (1)	20.0 (1)	5.1(12)	3.8 (7)	1.0 (2)	24.4 (4)	
-	64.0 (1)	48.9 (7)	7.0 (4)	26.5 (7)	13.6 (7)	23.5 (2)	56.0 (1)	25.4(11)	22.4(10)	10.7 (2)	43.1 (6)	
<u>Festuca rubra var. commutata</u>												
53.0 (2)	-	6.9 (3)	46.5 (8)	28.5 (7)	16.7 (9)	46.0 (1)	31.0 (1)	22.4(15)	30.2(10)	48.9 (3)	36.9 (3)	
86.1 (2)	-	37.7 (3)	89.6 (8)	57.0 (8)	47.8 (8)	96.0 (1)	96.0 (1)	67.7(13)	49.8(12)	91.3 (3)	97.2 (3)	
<u>Agrostis tenuis</u>												
33.5 (2)	42.0 (1)	36.2 (7)	46.9(10)	43.6(11)	28.4(11)	43.2 (2)	29.0 (1)	40.6(18)	38.3(16)	39.9 (5)	31.8 (6)	
84.3 (2)	88.0 (1)	89.2 (7)	92.6(10)	92.7(11)	67.4(11)	97.7 (2)	80.0 (1)	88.1(18)	85.6(16)	78.3 (5)	91.7 (6)	
<u>Anthoxanthum odoratum</u>												
22.9 (2)	32.0 (1)	15.1 (7)	18.6(10)	23.2(11)	27.4(11)	7.0 (2)	22.0(1)	21.3(18)	24.5(16)	25.2 (5)	10.0 (6)	
86.1 (2)	84.0 (1)	77.2 (7)	91.6(10)	91.3(11)	95.9(11)	52.1 (2)	100.0(1)	91.6(18)	88.8 (16)	93.5 (5)	81.1 (6)	

APPENDIX VII. B. ALTITUDE, SLOPE, SHEEP GRAZING, AND CATTLE GRAZING.

altitude				slope			sheep		cattle	
0	5	10	15	0	10	30	0	10.1	0	2.6
<u>Thuidium furfurosus</u>										
1.3 (3)	2.2(13)	4.1 (9)	-	1.0 (1)	2.6(19)	3.2 (5)	2.3(17)	3.5 (8)	2.5(18)	3.2 (7)
15.0 (4)	32.4(19)	39.7(12)	32.0 (1)	11.4 (4)	37.3(25)	30.3 (7)	29.1(25)	40.8(11)	31.7(28)	35.7 (8)
<u>Acrocladium auriculatum</u>										
1.0 (1)	3.3(15)	3.2 (8)	-	-	3.6(18)	2.0 (6)	2.7(16)	4.0 (8)	3.1(19)	3.1 (5)
4.9 (4)	27.0(14)	18.7 (9)	8.0 (1)	4.0 (2)	23.5(20)	14.4 (6)	18.4(18)	20.4(10)	20.8(23)	14.7 (5)
<u>Danthonia spp.</u>										
7.1 (8)	14.2(19)	15.8(12)	17.0 (1)	2.9 (6)	12.6(24)	23.9(10)	14.7(29)	9.4(11)	12.5(32)	16.1 (8)
50.3 (8)	66.7(19)	64.0(13)	100.0 (1)	18.4 (6)	67.2(25)	75.2(10)	65.0(29)	61.4(12)	62.6(32)	68.5 (9)
<u>Acaena spp.</u>										
1.5 (2)	1.4 (4)	1.8 (7)	-	1.9 (2)	1.4 (7)	1.9 (4)	1.8(10)	1.0 (3)	1.6 (9)	1.8 (4)
7.8 (4)	7.3(12)	13.8(13)	-	13.6 (3)	9.5(20)	10.4 (6)	11.5(21)	6.7 (8)	10.9(22)	7.7 (7)
<u>Hydrocotyle spp.</u>										
-	1.5 (3)	3.8 (9)	-	2.0 (1)	3.0 (8)	4.1 (3)	4.6 (7)	1.5 (5)	3.4(10)	2.0 (2)
-	24.7(10)	49.4(14)	40.0 (1)	40.0 (1)	35.2(19)	52.3 (5)	37.8 (15)	40.3(10)	34.9(21)	59.5 (4)
<u>Nertera setulosa</u>										
4.1 (3)	3.8 (12)	5.8(10)	27.0 (1)	5.4 (2)	5.5(20)	3.3 (4)	4.6(15)	6.0(11)	5.0(19)	5.6 (7)
27.6 (4)	38.6(14)	35.6(12)	88.0 (1)	52.2 (3)	38.3(24)	24.0 (4)	30.3(19)	49.9(12)	34.3(24)	49.6 (7)

APPENDIX VVI B. (cont.)

altitude				slope			sheep		cattle	
0	5	10	15	0	10	30	0	10.1	0	2.6
<u>Helichrysum filicaule</u>										
-	2.5 (6)	3.1 (8)	11.0 (1)	-	3.7(13)	1.0 (2)	3.1 (6)	3.3 (9)	3.6(11)	2.3 (4)
4.0 (1)	30.2 (9)	29.4 (7)	96.0 (1)	-	37.3(14)	15.6 (4)	24.1(10)	42.5 (8)	34.7(14)	23.1 (4)
<u>Trifolium repens</u>										
10.7 (8)	5.2(17)	6.8(13)	22.0 (1)	12.6 (7)	6.4(23)	5.1 (9)	6.9(28)	7.5(11)	6.5(30)	9.3 (9)
59.2 (9)	53.4(20)	71.6(14)	88.0 (1)	77.7 (7)	64.9(27)	39.4(10)	59.1(30)	66.3(14)	61.5(34)	61.2(10)
<u>Hypochoeris radicata</u>										
9.0 (9)	10.9(21)	20.5(14)	14.0 (1)	11.2 (7)	13.2(28)	15.1(10)	13.3(31)	13.1(14)	12.0(35)	17.9(10)
72.0 (9)	77.0(21)	90.0(14)	92.0 (1)	85.7 (7)	80.3(28)	79.2(10)	81.1(31)	80.6(14)	80.4(35)	82.8(10)
<u>Lolium perenne</u>										
17.1 (6)	4.7(11)	3.2 (8)	-	24.9 (5)	3.9 (16)	1.8 (4)	4.7(19)	13.1 (6)	4.8(19)	12.6 (6)
48.2 (7)	20.9(11)	20.1(11)	-	43.8 (7)	26.0(16)	11.6 (6)	22.7(20)	35.8 (9)	23.4(21)	35.4 (8)
<u>Festuca rubra var. commutata</u>										
29.3 (6)	38.9(15)	13.3 (9)	32.0 (1)	29.1 (4)	29.2(21)	26.3 (6)	25.2(19)	34.3(12)	31.1(23)	22.0 (8)
72.7 (6)	82.3(15)	33.1 (9)	92.0 (1)	87.0 (4)	62.0 (22)	74.9 (5)	55.9(20)	86.3(11)	69.9(24)	60.3 (7)
<u>Agrostis tenuis</u>										
33.1 (9)	45.5(21)	34.5(14)	7.0 (1)	33.5 (7)	42.2(28)	29.5(10)	38.3(31)	39.0(14)	40.9(35)	30.5(10)
85.9 (9)	93.0(21)	80.7(14)	8.0 (1)	91.8 (7)	92.0 (28)	61.9(10)	84.4(31)	90.9(14)	89.0(35)	78.1(10)
<u>Anthoxanthum odoratum</u>										
18.5 (9)	19.5(21)	25.3(14)	22.0 (1)	13.2 (7)	21.1(28)	27.4(10)	22.5(31)	18.1(14)	21.8(35)	18.7(10)
80.2 (9)	89.0(21)	94.3(14)	106.0 (1)	83.8 (7)	91.5(28)	87.7(10)	88.8(31)	91.3(14)	89.9(35)	88.7(10)

APPENDIX VIII. PERCENTAGE COVER AND PERCENTAGE TOP COVER FOR THREE AREAS OF SWAMPY GROUND.

Area no.	% cover			% top cover		
	1	2	3	1	2	3
<i>Breutelia pendula</i>	3	1	-	-	-	-
<i>Acrocladium auriculatum</i>	-	1	-	-	1	-
<i>Scirpus cernuus</i>	-	1	-	-	1	-
<i>Scirpus prolifer</i>	15	19	-	10	12	-
<i>Schoenus axillaris</i>	3	-	-	3	-	-
<i>Schoenus apogon</i> var. <i>laxiflorus</i>	12	1	-	4	-	-
<i>Carex lucida</i>	-	6	-	-	4	-
<i>Juncus polyanthemos</i>	1	5	-	-	5	-
<i>Juncus planifolius</i>	1	-	10	-	-	8
<i>Luzula campestris</i>	-	2	-	-	1	-
<i>Epilobium pedunculare</i>	-	8	4	-	2	-
-----						
<i>Ranunculus repens</i>	6	-	-	2	-	-
<i>Sagina procumbens</i>	1	7	-	-	2	-
<i>Cerastium glomeratum</i>	-	1	-	-	-	-
<i>Stellaria media</i>	-	-	10	-	-	6
<i>Trifolium dubium</i>	12	6	2	2	3	2
<i>Trifolium repens</i>	9	12	5	1	6	4
<i>Gnaphalium purpureum</i>	-	-	7	-	-	4
<i>Hypochoeris radicata</i>	5	-	-	2	-	-
<i>Taraxacum officinale</i>	-	1	-	-	-	-
<i>Myosotis scorpioides</i>	1	-	-	1	-	-
<i>Mimulus moschatus</i>	-	-	5	-	-	4
<i>Prunella vulgaris</i>	1	1	-	-	1	-
<i>Juncus tenuis</i>	1	-	-	1	-	-
<i>Lolium perenne</i>	4	-	-	3	-	-
<i>Cynosurus cristatus</i>	2	-	-	-	-	-
<i>Dactylis glomerata</i>	-	-	3	-	-	3
<i>Glyceria fluitans</i>	1	5	3	1	3	3
<i>Festuca rubra</i> var. <i>commutata</i>	1	1	-	-	-	-
<i>Festuca arundinacea</i>	1	3	-	1	2	-
<i>Holcus lanatus</i>	12	13	21	6	4	14
<i>Agrostis tenuis</i>	1	2	2	-	-	2
<i>Anthoxanthum odoratum</i>	26	15	12	16	5	7
-----						
<i>Juncus bufonius</i>	-	13	2	-	12	2
<i>Juncus articulatus</i>	67	56	45	46	35	33
-----						
Bare	1	1	8			