

FLORA OF NEW ZEALAND

FERNS AND LYCOPHYTES

INTRODUCTION



P.J. BROWNSEY & L.R. PERRIE

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Introduction

Historical background

All modern Floras build on the botanical groundwork that has preceded them, and the Flora of New Zealand – Ferns and Lycophytes is no different. We have stood on the shoulders of earlier authors and, aided by more extensive field work and modern technological developments, we have been able to see further and more clearly than they were able to do. There have been many Floras and other publications documenting New Zealand ferns and lycophytes since Joseph Banks and Daniel Solander began the process over 250 years ago. It is appropriate, therefore, to begin by acknowledging the work of our predecessors.

Table 1 lists the major Floras that have treated the ferns and lycophytes of New Zealand since Daniel Solander's *Primitiae Florae Novae Zelandiae*, written after the return of James Cook's first visit to New Zealand in 1769. Solander wrote descriptions of 57 ferns and lycophytes collected by him and Joseph Banks in New Zealand, but sadly his work was never published. Table 1 includes the numbers of families, genera, and species accepted by succeeding authors, and demonstrates how our knowledge has developed since those earliest collections.

Table 1: Number of indigenous families, genera, and species recognised in the major New Zealand fern Floras published since James Cook's visit in 1769. Georg Forster's work specifically attributed 20 species to New Zealand, but described several more from other areas that are now known to occur here. The publications by Brownsey & Smith-Dodsworth are not strictly Floras, but are comprehensive accounts included here for completeness.

Date	Author	Publication	Families	Genera	Species
1786	G. Forster	<i>Florulae Insularum Australium Prodrromus</i>	n/a	6	20+
1832	A. Richard	<i>Essai d'une Flore de la Nouvelle Zélande</i>	n/a	17	57
1837	A. Cunningham	<i>Florae Insularum Novae Zelandiae Precursor</i>	5	27	95
1844–1845, 1854–1855	J.D. Hooker	<i>Botany of the Antarctic Voyage, Parts 1 & 2</i>	10	39	121
1867	J.D. Hooker	<i>Handbook of the New Zealand Flora</i>	10	36	135
1906	T.F. Cheeseman	<i>Manual of the New Zealand Flora</i>	12	38	156
1925	T.F. Cheeseman	<i>Manual of the New Zealand Flora, Ed. 2</i>	12	47	159
1961	H.H. Allan	<i>Flora of New Zealand, Vol. 1</i>	26	47	164
1989, 2000	P.J. Brownsey & J. Smith-Dodsworth	<i>New Zealand Ferns and Allied Plants</i>	24	57	189
2021	P.J. Brownsey & L.R. Perrie	<i>Electronic Flora of New Zealand</i>	28	59	204

Substantial taxonomic change among New Zealand's ferns and lycophytes has accompanied the production of the *Flora of New Zealand*. In the last 20 years, since the second edition of *New Zealand Ferns and Allied Plants* (Brownsey & Smith-Dodsworth 2000), 18 species (including one still undescribed) have been added to the indigenous flora and three removed. In addition there have been some 32 changes affecting the genus name (and sometimes also the species epithet), and another 10 changes affecting just the species name. The nomenclature used in the *Flora of New Zealand* is relatively conservative. If all the new generic names suggested by PPG 1 (2016) had been adopted there would have been about 62 changes at this level, almost twice the accepted number.

In addition to the comprehensive accounts of the indigenous New Zealand fern flora listed in Table 1, Brownsey et al. (1985) provided a checklist of all New Zealand ferns and lycophytes, and Brownsey (in Webb et al. 1988) catalogued the adventive fern flora, accepting 23 naturalised species, with nine genera represented only by naturalised species. These figures have since expanded to 64 naturalised species in the current *Flora of New Zealand*, with 19 genera represented only by naturalised species. Further information on many of these exotic taxa can be found in Hoshizaki & Moran (2001), especially those that are classified as casual or garden escapes and are represented by few specimens in New Zealand herbaria.

The classification of ferns and lycophytes worldwide at the family and generic level has been discussed in detail by Kramer & Green (1990). More recently this has been updated and expanded by PPG 1 (2016), providing a phylogenetic basis for classifying ferns and lycophytes, largely based on molecular analyses.

Many other works have contributed to our understanding of New Zealand's fern diversity and its relationship to surrounding areas. Early accounts of the Australian fern flora by Labillardière (1806–1807) and Brown (1810) were hugely influential in the work of later New Zealand botanists, particularly in relation to species with trans-Tasman distributions. Raoul (1846) and Mueller (1864)

provided early regional descriptions of the ferns of Banks Peninsula and the Chatham Islands, respectively. Since the publication of Allan's *Flora of New Zealand* in 1961 there has been a renewed focus on the major offshore islands, with thorough accounts of the ferns and lycophytes of the Kermadec Islands (Sykes 1977; Sykes & West 1996; de Lange 2015a, 2015b), Three Kings Islands (Wright, pers. comm., 6 Mar. 2021), Chatham Islands (de Lange et al. 2011), Stewart Island (Wilson 1982), Solander Island (Johnson 1975), Snares Islands (Fineran 1969; Horning 1983), Antipodes Island (Godley 1989), Auckland Islands (Johnson & Campbell 1975; Meurk 1982), and Campbell Island (Meurk 1975; Given 1978).

Popular-style works written by Thomson (1882), Field (1890), Dobbie (1921, 1931, 1951, 1952), Stevenson (1959), Crookes (1963), Hamlin (1963), Heath & Chinnock (1974), Chinnock & Heath (1981), Firth et al. (1986), Crowe (1994), and Metcalf (2003), albeit sometimes omitting the lycophytes, have helped to bring ferns to the attention of the general public. These have been enhanced by an array of books on the cultivation of New Zealand ferns (Fisher & Ward 1976; Fisher 1984; Goudey 1988; Van der Mast & Hobbs 1998).

The use of New Zealand ferns as food has been described by Crowe (1997), and their medicinal properties documented by Riley (1994). More technical descriptions and photographs of spores have been provided by Large & Braggins (1991), and details of chromosome numbers are given by Dawson et al. (2000) and de Lange et al. (2004). The etymology of botanical names of plants, including ferns, has been comprehensively elucidated by Gledhill (2008), and his work has been closely followed here.

Table 2 lists the major collectors of herbarium specimens of ferns in New Zealand prior to 1940, almost all of whom collected at least one specimen now recognised as a primary type. Before c. 1840 most collectors were participants in voyages of exploration that stopped in New Zealand. From c. 1825 onwards individual collectors started to make visits to New Zealand, initially from Australia and later from continental Europe. Then, from 1835, the first resident collectors became active, mostly amateur botanists who sent specimens to William and Joseph Hooker at Kew. William Colenso was the first of the resident botanists: brought out by the Church Missionary Society as a printer, he went on to become one of New Zealand's most prolific collectors. Initially he, too, collected for the Hookers, but then he began to publish his own descriptions of new species, sometimes based on material given to him by other local collectors. Thomas Kirk and Thomas Cheeseman also developed their own networks of amateur collectors.

Table 2: Significant fern collectors in New Zealand prior to 1940, including the basis and dates of their activity, and the main herbaria for their collections. Herbarium abbreviations follow Thiers (2021).

Collector(s)	Basis of activity	Dates in NZ	Main herbaria
J. Banks & D. Solander	Cook's first voyage 1768–1771	1769–1770	AK, BM, WELT
J.R. & G. Forster	Cook's second voyage 1772–1775	1773–1774	B, BM, GOET, UPS
A. Menzies	Vancouver Expedition 1791–1795	1791	E, K
J.S.C. Dumont d'Urville & R.P. Lesson	Duperrey Expedition 1822–1825	1824	P
C. Fraser	Visit (collector for A. Cunningham)	1825–1826	K
A. Cunningham	Visit	1826	K
J.S.C. Dumont d'Urville	d'Urville's first voyage 1826–1829	1827	P
R. Cunningham	Visit	1833–1834	K
C. von Hügel	Visit	1834	PRC, W
W. Colenso	Resident	1835–1899	AK, K, WELT
J. Edgerley	Resident (collector for Hookers)	1835–1849	K
J.C. Bidwill	Visit (collector for Hookers)	1839–1840	K
E. Dieffenbach	Visit	1839–1841	K
J.B. Hombron & H. Jacquinot	d'Urville's second voyage 1837–1840	1840	P
J.D. Hooker	Ross's Antarctic voyage 1839–1843	1840–1841	K
D. Lyall	Ross's Antarctic voyage 1839–1843	1840–1841	K
W.D. Brackenridge	Wilkes U.S. Exploring Expedition 1838–1842	1840	US
E. Raoul	Visit	1840–1843	K, P
A. Sinclair	Visit/resident (collector for Hookers)	1841, 1843–1856, 1859–1861	K
C. Maling	Resident (collector for Hookers)	1842–1916	K
W. Stephenson	Visit	1843–1844	K
W.T.L. Travers	Resident	1849–1903	K, WELT
H.H. Travers	Resident (collector for Hookers)	1849–1928	WELT
S. Mossman	Visit	1850	K, P
J. Buchanan	Resident	1851–1898	WELT
J. MacGillivray & W.G. Milne	Denham's <i>Herald</i> voyage 1852–1861	1854	K
T.H. Potts	Resident	1854–1888	AK, K
T.F. Cheeseman	Resident	1854–1923	AK, K
G. Drummond Hay	<i>Novara</i> Expedition 1857–1859/ resident	?1852–1881	W
J. Jolliffe	Surgeon on the <i>Pandora</i> survey of New Zealand	1851–1856	K
F. von Hochstetter	<i>Novara</i> Expedition 1857–1859	1857–1859	W
J.D. Enys	Resident (collector for Hookers)	1861–1891	AK, K
T. Kirk	Resident	1863–1898	CHR, K, WELT
H.B. Matthews	Resident	1861–1934	AK
J.F. & J.B. Armstrong	Resident	1862–1926	CHR
R. Helms	Resident	1869–1888	BONN
H. Wawra von Fernsee	P. & A. Saxe-Coburg visit 1872–1873	1872–1873	W
E. Phillips Turner	Resident	1870–1937	AK
S. Berggren	Visit	1873	BONN, LD
D. Petrie	Resident	1873–1925	WELT
H. Hill	Resident (collector for Colenso)	1873–1933	K, WELT
Lt. Rathouis	French Transit of Venus Expedition, 1874–1875	1874–1875	WELT
J.H. McMahon	Resident	1874–1948	WELT
A. Hamilton	Resident	1875–1913	WELT
H.B. Dobbie	Resident	1875–1940	AK
B.C. Aston	Resident	c. 1875–1951	WELT
C.P. Winkelmann	Resident (collector for Colenso)	1877–?	K, WELT
Mrs Mason	Resident (collector for Kirk)	Active c. 1878	WELT
W. Tipler	Resident (collector for Kirk)	Active c. 1879	WELT
R.W. Rowson	Resident (collector for Colenso)	Active 1880–1885	AK, WELT
C.J. Norton	Resident (collector for Colenso)	Active 1881–1889	K, WELT
L. Cockayne	Resident	1881–1934	BONN, WELT
J.E. Holloway	Resident	1881–1945	WELT
J.E. Attwood	Resident	1881–1945	AK
H.H. Allan	Resident	1882–1957	CHR
T. Ranft	Visit	1885	BM
H. Carse	Resident	1885–1930	AK, CHR, WELT
W. Martin	Resident	1886–1975	WELT

Collector(s)	Basis of activity	Dates in NZ	Main herbaria
W.K. Chambers	Resident (collector for Colenso)	Active c. 1888	AK, K, WELT
J. McKerrow Campbell	Resident (collector for Kirk)	Active c. 1890	WELT
W.R.B. Oliver	Resident	1896–1957	WELT
L. Cranwell	Resident	Active 1930s	AK
L.B. Moore	Resident	Active 1930s	AK, CHR

Diversity of the New Zealand fern and lycophyte flora

The *Flora of New Zealand* treats all taxa occurring naturally in the New Zealand political region (Schönberger et al. 2021). The area extends from the Kermadec Islands in the north, through the North, South, Stewart, and Chatham Islands, to the Snares, Antipodes, Auckland, and Campbell Islands in the far south.

As recorded in the *Flora of New Zealand*, a total of 268 species and 10 subspecies of extant ferns and lycophytes occur in this region. Four indigenous species are each represented in New Zealand by two subspecies, and when counted at the lowest taxonomic rank there are 208 indigenous taxa, and a total of 272 indigenous and naturalised taxa.

This total includes 204 native species (one of which remains undescribed – the hexaploid cytotype of *Asplenium trichomanes*) and 64 that are considered to have been introduced since European settlement. There are residual doubts about the biostatus of a couple of taxa: *Deparia petersenii* subsp. *congrua* is treated as native, and was first recorded in the late 19th century, but it could equally well have been introduced through human intervention; and *Pteris vittata* is regarded here as fully naturalised but considered to be native by some others. In most cases, however, the distinction between native and naturalised is clear-cut.

In the *Flora of New Zealand – Ferns and Lycophytes* the species are grouped into 32 families, of which Selaginellaceae, Equisetaceae, Anemiaceae, and Onocleaceae are represented only by naturalised species, and 78 genera, of which 19 are entirely naturalised. There are nine indigenous subspecies and one that is naturalised. The numbers of taxa in the different biostatus categories are summarised in Table 3.

Table 3: New Zealand fern and lycophyte taxa, showing the numbers in total, and indigenous, endemic, and naturalised categories.

Taxon	Total	Indigenous	Endemic	Naturalised
Family	32	28	0	4
Genus	78	57	2	19
Species	268	114	90	64
Subspecies	10	3	6	1

The numbers given in Table 3 for indigenous families and genera may also include some naturalised species and subspecies. The total of naturalised species in Table 3 includes two taxa of hybrid origin (*Asplenium ×lucrosum* and *Salvinia ×molesta*) capable of reproducing vegetatively.

Of the 208 native taxa, 94 are endemic and 114 indigenous; and among the 64 adventive taxa, 27 are fully naturalised and 37 are casual. Biostatus categories are defined by Schönberger et al. (2021).

The six families with the largest numbers of indigenous, endemic, exotic, and total species are shown in Table 4. These six families represent nearly 60% of the fern and lycophyte species in New Zealand. Hymenophyllaceae is the largest family in New Zealand with a total of 31 species, all of which are indigenous. It is also the family with the largest number of endemic species.

Table 4: The six largest families of New Zealand ferns, showing the numbers of species in total, and indigenous, endemic and naturalised categories.

Family	Total	Indigenous	Endemic	Naturalised
Hymenophyllaceae	31	31	17	0
Dryopteridaceae	30	13	8	17
Pteridaceae	27	16	5	11
Blechnaceae	27	25	15	2
Aspleniaceae	24	21	10	3
Polypodiaceae	21	17	7	4

The largest genera of ferns are shown in Table 5. *Blechnum* is the largest genus in New Zealand with a total of 27 species, including the highest number of indigenous species and the most endemic species. It is closely followed by *Hymenophyllum* and *Asplenium*, both of which have a total of 24 species and high numbers of indigenous and endemic species. *Dryopteris* has the most naturalised species (12), followed by *Pteris* with seven.

Table 5: The seven largest genera of New Zealand ferns, showing the numbers of species in total, and indigenous, endemic and naturalised categories.

Genus	Total	Indigenous	Endemic	Naturalised
<i>Blechnum</i>	27	25	15	2
<i>Hymenophyllum</i>	24	24	14	0
<i>Asplenium</i>	24	21	10	3
<i>Pteris</i>	12	5	3	7
<i>Dryopteris</i>	12	0	0	12
<i>Notogrammitis</i>	11	11	4	0
<i>Polystichum</i>	10	6	5	4

Endemism

Of the 208 indigenous taxa of ferns and lycophytes in New Zealand, 94 (45%) are endemic. This compares with figures of 82% for seed plants, 48% for liverworts, and 23% for mosses (Breitwieser et al. 2012; Glenny & Fife 2012).

At higher taxonomic levels endemism is very low in the ferns and lycophytes. There are no endemic families, and probably only one genuinely endemic genus (*Loxsoma*). *Leptolepia* is currently treated as endemic, but will almost certainly prove to nest within *Dennstaedtia*.

Geographically restricted endemic ferns are very rare compared to seed plants. Just seven taxa are endemic to the North Island, four to the Kermadec Islands, two to the South Island, and one each to the Three Kings Islands and Chatham Islands (Table 6). A total of 16 taxa are endemic to the region north of Cook Strait, but only seven south of Cook Strait.

Table 6: Number of indigenous New Zealand fern and lycophyte taxa (species and subspecies) endemic to, or confined to, different island groups and regions.

Area/region	Confined to region	Endemic	Indigenous elsewhere
Kermadec Islands	10	4	6
Three Kings Islands	1	1	0
North Island	17	7	10
South Island	8	3	5
Chatham Islands	1	1	0
Stewart Island	0	0	0
Subantarctic islands	0	0	0
North of Cook Strait	41	16	25
South of Cook Strait	13	7	6

Within New Zealand 17 taxa are confined to the North Island, 10 to the Kermadec Islands, and eight to the South Island. Forty-one taxa (20% of the indigenous taxa) are confined to the region north of Cook Strait and only 13 (6%) to the south. Taxa that are limited within New Zealand in their distribution include the following (endemics asterisked).

Kermadec Islands: *Arachniodes aristata*, *Asplenium shuttleworthianum*, *Blechnum kermadecense**, *Cyathea kermadecensis**, *C. milnei**, *Hymenophyllum polyanthos*, *Nephrolepis brownii*, *Parapolystichum kermadecense**, *Pyrrosia serpens*, *Trichomanes humile*.

Three Kings Islands: *Davallia tasmanii* subsp. *tasmanii**.

North Island: *Adiantum formosum*, *Asplenium trichomanes* (tetraploid cytotype), *Blechnum neohollandicum*, *Cyclosorus interruptus*, *Davallia tasmanii* subsp. *cristata**, *Dicksonia lanata* subsp. *hispida**, *Dicranopteris linearis*, *Isoetes kirkii**, *Lecanopteris novae-zealandiae**, *Loxsoma cunninghamii**, *Lycopodiella serpentina*, *Lygodium articulatum**, *Notogrammitis rawlingsii**, *Phylloglossum drummondii*, *Ptisana salicina*, *Sticherus flabellatus*, *Thelypteris confluens*.

South Island: *Asplenium lepidotum**, *Botrychium lunaria*, *Isoetes alpina**, *Notogrammitis gunnii*, *Pteris epaleata*, *Sticherus tener*, *S. urceolatus*, *Tmesipteris horomaka**.

Chatham Islands: *Asplenium chathamense**.

Hybridism

A total of 63 hybrid combinations for which there are supporting herbarium specimens are recorded in the *Flora of New Zealand – Ferns and Lycophytes*, and there are another 10 for which the evidence is equivocal, either because the identity of the parents is uncertain, or because the specimens cannot be confirmed to be of hybrid origin. The number will almost certainly continue to grow as a result of additional collections and astute field observation.

The overwhelming number of hybrid combinations are found in *Asplenium*, with 37 recorded in the *Flora*. One taxon, *Asplenium flaccidum* subsp. *flaccidum*, hybridises in 11 different combinations, closely followed by *A. bulbiferum* and *A. gracillimum*, with eight combinations each. Seven

combinations are recorded in each of *Polystichum* and *Hypolepis*, five in *Blechnum*, two in *Pteris*, and one each in *Dicksonia* (Shepherd et al. 2019; not yet recorded in the *Flora*), *Hymenophyllum*, *Leptopteris*, and *Notogrammitis*. There is also one combination in *Dryopteris*, unusual in being the only example of a fern hybrid that originated within New Zealand from two naturalised parents (*D. affinis* and *D. filix-mas*).

No hybrids have been recorded among New Zealand lycophytes or eusporangiate ferns, and no inter-generic hybrids are known in any group.

Many fern hybrids are thought to be effectively sterile. All the known combinations in *Asplenium* and *Polystichum*, and most of those in *Hypolepis*, have misshapen spores that are assumed to be inviable, although no detailed germination experiments have been carried out. Spore abnormality is less pronounced in *Blechnum* and *Pteris* hybrids, and apparently normal-looking spores are present in *Leptopteris* hybrids. In general, abnormal spores are more obvious in species with monolete spores than in those with trilete spores.

Two naturalised taxa of hybrid origin have established in New Zealand. One of these, *Salvinia* *×molesta*, is believed to be a hybrid of horticultural origin, which produces only sporocarps with empty sporangia or aborted spores. It is an aggressive floating weed of waterways in tropical and warm temperate regions, which spreads by abundant vegetative growth. The other, *Asplenium* *×lucrosum*, is remarkable for being a hybrid between the New Zealand endemic *A. bulbiferum* and the Norfolk Island endemic *A. dimorphum*. It is believed to have originated in cultivation in England in the 19th century and spread around the world as a popular cultivar, becoming a casual adventive in New Zealand. Despite having aborted spores, it can spread vegetatively by bulbils.

Cytology

Chromosome counts have been obtained for 172 (83%) of the 208 indigenous fern and lycophyte taxa in New Zealand (Dawson et al. 2000; de Lange et al. 2004). However, in several species more than one level of ploidy has been recorded, so that 180 different chromosome numbers are known for the 172 counted species. Based on these 180 counted taxa, 52% are diploid, 31% tetraploid, 13% triploid, pentaploid, hexaploid or octoploid (Table 8), and 4% are of unknown ploidy. In summary, 52% are diploid and 44% polyploid (Table 7).

Among the 32 species for which no chromosome count has been made, some assumptions can be made about ploidy levels in 17 species, based on spore size and other indicators. When these are added to the counted taxa, 54% are assumed to be diploid, 30% tetraploid, 12% triploid and higher ploidies (Table 8), and 3.5% of unknown ploidy. In summary 54% are assumed to be diploid and 42% polyploid (Table 7).

Six (3.3%) of the 180 counted taxa are believed to be apogamous. They occur in Aspleniaceae, Ophioglossaceae, and Pteridaceae.

Table 7: Numbers and percentages of diploid and polyploid indigenous New Zealand fern and lycophyte taxa, from actual chromosome counts, or from counts plus assumptions based on spore size.

Ploidy level	Counted taxa		Counted taxa and assumed ploidy levels	
	Number	%	Number	%
Diploid	93	51.6	107	54.3
Polyploid	80	44.4	83	42.1
Unknown ploidy	7	3.9	7	3.6
Total	180		197	

Table 8: Numbers and percentages of indigenous New Zealand fern and lycophyte taxa at higher ploidy levels, from actual chromosome counts, or from counts plus assumptions based on spore size.

Ploidy level	Counted taxa		Counted taxa and assumed ploidy levels	
	Number	%	Number	%
Triploid	1	0.6	1	0.5
Tetraploid	56	31.1	59	30.0
Pentaploid	1	0.6	1	0.5
Hexaploid	6	3.3	6	3.0
Octoploid	16	8.8	16	8.1
Total	80		83	

Distribution in New Zealand

The numbers of native, naturalised, and total taxa (species and subspecies) occurring on the main islands and island groups of New Zealand are given in Table 9, and those in the different Ecological Provinces (EPs) of the North and South Islands in Table 10.

The distributions of fern and lycophyte taxa in New Zealand have been analysed in detail by Brownsey (2001) and Mountier et al. (2018), based on information available at the time. In general, fern distributions are very extensive: more than half of all native taxa extend across more than half of both islands. Distributions are not significantly correlated with geographical barriers such as Cook Strait, but are strongly correlated with temperature, rainfall, and, in a few cases, with geothermal activity. Diversity is highest in the warmer northern and wetter western regions. Species with a predominantly southern distribution (i.e. widespread in cool lowland to montane forest in the South Island but more restricted in the North Island) have a higher proportion of New Zealand endemics than those with a mainly northern distribution (Brownsey 2001, fig. 5). Species with a northern distribution pattern (i.e. widespread in the North Island but restricted in the South Island) are predominantly tropical and Australasian species that have established themselves in northern New Zealand but are restricted by temperature from spreading south.

The North Island is clearly more diverse than the South Island (Table 9). It is home to 88% of the native taxa, 100% of the naturalised taxa, and 91% of the total taxa, compared to the South Island with 78% of the native taxa, 28% of the naturalised taxa, and 67% of the total taxa. Of the smaller island groups, the Chatham Islands are the most diverse, with 52% of the native taxa, 5% of the naturalised taxa, and 41% of the total taxa, followed by Stewart Island, with figures of 44%, 2%, and 34%, respectively.

The figures for naturalised taxa are particularly striking. All of the known naturalised ferns and lycophytes in New Zealand have been recorded in the North Island, but only 28% in the South Island, 5% on the Chatham Islands, 2% on both the Kermadec Islands and Stewart Island, and none at all on the Three Kings Islands or any of the subantarctic islands.

The most diverse region is the Auckland EP, which has more native, naturalised, and total taxa than any other EP (Table 10): 79% of the native taxa, 67% of the naturalised taxa, and 76% of the total taxa. It is closely followed by Northland EP with 70% of the native taxa, 48% of the naturalised taxa, and 65% of the total taxa. However, this is largely due to the high numbers of naturalised taxa in these two EPs. The proportion of native taxa varies only from 67% to 79% across all the EPs of the North Island, and Western Nelson and Sounds-Nelson in the South Island. The remaining EPs in the South Island vary from 44% to 59% of the total native taxa, with Marlborough EP the least diverse.

Table 9: Numbers and percentages of native, naturalised, and all taxa occurring on the main islands and island groups. Numbers are based on 208 indigenous taxa and 64 naturalised taxa of New Zealand ferns and lycophytes at the species and subspecies level.

Island/island group	All taxa		Native taxa		Naturalised taxa	
	Number	%	Number	%	Number	%
Kermadec Islands	52	19	51	25	1	2
Three Kings Islands	40	15	40	19	0	0
North Island	248	91	184	88	64	100
South Island	181	67	163	78	18	28
Chatham Islands	111	41	108	52	3	5
Stewart Island	93	34	92	44	1	2
Solander Island	18	7	18	9	0	0
Snares Islands	5	2	5	2	0	0
Antipodes Islands	23	9	23	11	0	0
Auckland Islands	43	16	43	21	0	0
Campbell Island	22	8	22	11	0	0
All NZ	272		208		64	

Table 10: Numbers and percentages of native, naturalised, and all taxa occurring in the different Ecological Provinces. Numbers are based on 208 indigenous taxa and 64 naturalised taxa of New Zealand ferns and lycophytes at the species and subspecies level.

Ecological Province	All taxa		Native taxa		Naturalised taxa	
	Number	%	Number	%	Number	%
Northland	177	65	146	70	31	48
Auckland	207	76	164	79	43	67
Volcanic Plateau	174	54	158	76	16	25
Gisborne	146	55	140	67	6	9
Taranaki	149	56	139	67	10	16
Southern North Is.	166	61	148	71	18	28
Western Nelson	155	57	149	72	6	9
Sounds-Nelson	144	53	139	67	5	8
Marlborough	94	35	91	44	3	5
Westland	128	47	123	59	5	8
Canterbury	138	51	123	59	15	23
Otago	114	42	105	50	9	14
Southland	105	39	101	49	4	6
Fiordland	110	40	110	53	0	0
All NZ	272		208		64	

The numbers of native genera (i.e. those that include at least one indigenous species) occurring on the main islands and island groups of New Zealand are given in Table 11, and those in the different EPs of the North and South Islands in Table 12.

As with the species and subspecies, the North Island is clearly more diverse than the South Island (Table 11). It has 98% of the native genera, compared to the South Island with 76%. Of the smaller island groups, the Chatham Islands are the most diverse with 59% of the genera, followed by Stewart Island with 54%, the Three Kings Islands with 48%, and the Kermadec Islands with 47%. The subantarctic islands range from 5% to 27%. One genus, *Arachniodes*, is confined within New Zealand to the Kermadec Islands; all the others occur on the North Island. There is a clear pattern of decreasing numbers from the South Island down to the subantarctic islands, with no genera that occur only south of Cook Strait.

The most diverse region is the Volcanic Plateau EP with 90% of the total genera. It is closely followed by Northland EP with 88% and Auckland with 86%. The remaining North Island EPs are all very similar with 75 to 76% of the total genera. In the South Island, numbers decrease gradually from 73% in Western Nelson and Sounds-Nelson to 63% in Otago, and only 59% in Marlborough, the least diverse EP. These numbers show a similar, but more pronounced, pattern to those for the species and subspecies, reflecting the influence of climate on distribution.

The genera that occur only in the North Island (or sometimes also on the Three Kings or Kermadec Islands) are: *Christella*, *Cyclosorus*, *Davallia*, *Dicranopteris*, *Loxsoma*, *Lygodium*, *Macrothelypteris*, *Nephrolepis*, *Phylloglossum*, *Psilotum*, *Ptisana*, *Thelypteris*, and *Todea*. All are confined to the Northland, Auckland, and Volcanic Plateau EPs, except *Lygodium* and *Ptisana*, which are slightly more widespread. Apart from the endemic *Loxsoma*, all of these genera occur in Australia and/or tropical regions to the north.

Table 11: Numbers and percentages of native genera occurring on the main islands and island groups. Numbers are based on a total of 59 indigenous genera of New Zealand ferns and lycophytes.

Island/island group	Number	%
Kermadec Islands	27	46
Three Kings Islands	28	47
North Island	58	98
South Island	45	76
Chatham Islands	35	59
Solander Island	10	17
Stewart Island	32	54
Snares Islands	3	5
Antipodes Islands	11	19
Auckland Islands	16	27
Campbell Island	10	17
All NZ	59	

Table 12: Numbers and percentages of native genera occurring in the different Ecological Provinces. Numbers are based on a total of 59 indigenous genera of New Zealand ferns and lycophytes.

Ecological Province	Number	%
Northland	52	88
Auckland	51	86
Volcanic Plateau	53	90
Gisborne	45	76
Taranaki	44	75
Southern North Is.	45	76
Western Nelson	43	73
Sounds-Nelson	43	73
Marlborough	35	59
Westland	42	71
Canterbury	42	71
Otago	37	63
Southland	38	64
Fiordland	38	64
All NZ	59	

Overseas distribution

A total of 114 indigenous taxa of ferns and lycophytes (three of them represented by single subspecies) are shared with regions outside New Zealand. This total represents 55% of New Zealand's native fern and lycophyte flora. Of the 114 widespread taxa, 61 (54%) are shared with tropical regions (Table 13) and 103 (90%) with temperate regions (Table 14).

In tropical regions the greatest proportion of the 114 widespread taxa are shared with areas of Australia lying north of the Tropic of Capricorn (33%) and with New Caledonia (30%). Some 13 to 23% are shared with other islands in the Pacific, from the Solomon Islands to the Cook Islands.

In temperate regions, 88% of widespread taxa are shared with temperate Australia and its offshore islands: 77% are shared with mainland Australia, 61% with Tasmania, 22% with Norfolk Island, and 18% with Lord Howe Island. Further afield, 12% are shared with southern Africa, 15% with South America, and 10% with islands in the Southern Ocean.

Overwhelmingly, the affinities of the New Zealand fern and lycophyte flora lie with temperate Australia, although there is also a significant tropical element.

Modern accounts of ferns and lycophytes in nearby regions are available for Australia (McCarthy 1998), Lord Howe and Norfolk Islands (Wilson 1994), Solomon Islands (Chen et al. 2017), Vanuatu (Nakamura 2008), New Caledonia (Brownlie 1969; Nakamura 2008; Munzinger et al. 2021 [continuously updated]; Perrie, unpub.), Fiji (Brownlie 1977; Nakamura 2008; Brownsey & Perrie 2011), Samoa (Christensen 1943; Nakamura 2008), Tonga (Yuncker 1959; Sykes 1978), and Cook Islands (Sykes 2016).

Table 13: Numbers and percentages of New Zealand fern and lycophyte taxa (species and subspecies) shared with neighbouring tropical regions.

Tropical region	Number shared	% of NZ's widespread taxa
Malesia	26	23
Tropical Australia	38	33
Solomon Islands	15	13
Vanuatu	20	18
New Caledonia	34	30
Fiji	26	23
Samoa	19	17
Tonga	16	14
Cook Islands	21	18
Total shared taxa	61	54

Table 14: Numbers and percentages of New Zealand fern and lycophyte taxa (species and subspecies) shared with neighbouring temperate regions.

Temperate region	Number shared	% of NZ's widespread taxa
Australia + offshore islands	100	88
Mainland Australia + Tasmania	92	81
Mainland Australia	88	77
Tasmania	69	61
Norfolk Island	25	22
Lord Howe Island	20	18
Southern Africa	15	12
South America	17	15
Circum-antarctic islands	10	10
Total shared taxa	103	90

Ecological preferences

Most indigenous ferns and lycophytes in New Zealand are relatively widespread, even among those that are limited geographically by temperature constraints. They are also mostly tolerant of different substrates, growing on a range of acidic to calcareous rock types. In this regard they are markedly different from temperate floras elsewhere, notably Europe, where many ferns have clear preferences.

Among New Zealand species, those that have distinctive habitats, or are confined to particular ecological niches, are categorised below.

Alpine habitats

Unlike flowering plants, where there are many genera that have radiated in New Zealand's alpine environment, there are very few ferns and lycophytes that have adapted to these extreme conditions, and none that have radiated to a similar degree. Species that reach the high alpine zone (i.e. above c. 1750 m in the North Island and above c. 1500 m in the South Island; Engel & Glenn 2008) include the following:

North Island (4 taxa): *Asplenium richardii*, *Cystopteris tasmanica*, *Huperzia australiana* and *Polystichum cystostegia*.

South Island (17 taxa): *Asplenium richardii*, *Blechnum penna-marina*, *Cystopteris tasmanica*, *Huperzia australiana*, *Hymenophyllum minimum*, *H. multifidum*, *H. peltatum*, *H. villosum*, *Isoetes alpina*, *Leptopteris superba*, *Lycopodium fastigiatum*, *Notogrammitis crassior*, *N. givenii*, *N. gunnii*, *Ophioglossum coriaceum*, *Polystichum cystostegia*, and *P. vestitum*.

In addition, a number of species extend close to the alpine zone, including *Botrychium lunaria*, *Hypolepis millefolium*, and *Notogrammitis patagonica*. No ferns or lycophytes occur exclusively in the alpine zone, but *Polystichum cystostegia* occurs only above 900 m.

Aquatic habitats

Four indigenous ferns and lycophytes are confined to aquatic habitats: *Azolla rubra*, *Isoetes alpina*, *I. kirkii*, and *Pilularia novae-hollandiae*. In addition, there are three naturalised aquatic species: *Azolla pinnata*, *Marsilea mutica*, and *Salvinia molesta*. A fourth species, *Equisetum arvense*, is most frequently found on the muddy banks of lakes and rivers, or in drains, swamps, and other wet habitats.

Species of *Azolla* and *Salvinia* are found free-floating on the surface of still water. Those of *Isoetes*, *Marsilea*, and *Pilularia* are rooted to the substrate in or around lakes and tarns.

Calcareous substrates

Asplenium cimmeriorum and *A. lepidotum* are the only two New Zealand ferns that could be regarded as obligate basicolous, although even they sometimes occur as low epiphytes, albeit in areas with base-rich substrates. However, about five additional species are more commonly found on limestone or calcareous substrates than on other rock types. These include *Asplenium lyallii*, *A. trichomanes* (tetraploid and hexaploid cytotypes), *Cystopteris tasmanica*, and *Notogrammitis patagonica*.

Coastal habitats

A few species are most strongly associated with the coast, usually growing on exposed rock near the sea or in coastal scrub, and rarely extending far inland. Ten taxa are found in this habitat: *Asplenium appendiculatum* subsp. *maritimum*, *A. chathamense*, *A. decurrens*, *A. flaccidum* subsp. *haurakiense*,

A. obtusatum, *A. pauperequitum*, *A. scleroprium*, *Blechnum banksii*, *B. durum*, and *Notogrammitis rigida*.

Colonising and vagrant species

A few species are thought to have reached New Zealand relatively recently. Some of these have established themselves for varying lengths of time in small populations. A good example is *Adiantum formosum*, a widespread Australian species, which is currently known only from small populations around the Manawatū Gorge. It was formerly known from the Upper Wairoa district of Northland, but is now thought to be extinct there. The two populations differ in the presence or absence of hairs on the abaxial surface of the pinna segments, a natural dimorphism seen in Australian populations that suggests New Zealand populations were the result of two separate dispersal events.

Other Australian species to have reached New Zealand recently include *Blechnum neohollandicum*, which has established in Northland at various times but is currently thought to be extinct. *Pteris epaleata* is established in parts of Fiordland, while *Sticherus tener* and *S. urceolatus* occur in small populations near Westport, and in Fiordland and in north-west Nelson, respectively. A tropical Pacific species, *Macrothelypteris torresiana*, is established on Raoul Island; it has been recorded as a vagrant at Surville Cliffs, Northland, but is no longer extant there.

Epiphytic species

Approximately 20% of indigenous ferns and lycophytes are either predominantly epiphytic or about equally epiphytic and terrestrial. Many more species are occasionally epiphytic, but predominantly terrestrial or rupestral. Included in the total of predominantly epiphytic species are a few climbing epiphytes, but high-climbing ferns are rare in the New Zealand flora.

Twenty of New Zealand's epiphytic species belong to the family Hymenophyllaceae. There are also nine species in Polypodiaceae, five in Psilotaceae, and the rest scattered among other families.

Most epiphytic species occur on tree fern trunks, with many also occurring on other forest trees. A few species almost always occur only on tree fern trunks, and some only on other forest trees. A total of 43 epiphytic species are listed below.

Climbing epiphytes (10 taxa): *Arthropteris tenella*, *Blechnum filiforme*, *Davallia tasmanii* subsp. *cristata*, *Lecanopteris novae-zealandiae*, *L. pustulata*, *L. scandens*, *Lygodium articulatum*, *Pyrrosia elaeagnifolia*, *P. serpens*, and *Rumohra adiantiformis*.

Epiphytes almost always on tree ferns (6 taxa): *Hymenophyllum frankliniae*, *Tmesipteris horomaka*, *T. lanceolata*, *T. sigmatifolia*, *Trichomanes caudatum*, and *T. humile*.

Epiphytes on tree ferns and other forest trees (17 taxa): *Asplenium flaccidum* subsp. *flaccidum*, *A. polyodon*, *Hymenophyllum armstrongii*, *H. demissum*, *H. dilatatum*, *H. flabellatum*, *H. lyallii*, *H. rarum*, *H. sanguinolentum*, *H. scabrum*, *Notogrammitis angustifolia*, *N. billardierei*, *Phlegmariurus varius*, *Tmesipteris elongata*, *T. tannensis*, and *Trichomanes venosum*.

Epiphytes almost always on forest trees (10 taxa): *Hymenophyllum malingii*, *H. multifidum*, *H. peltatum*, *H. pluviale*, *H. polyanthos*, *H. pulcherrimum*, *H. rufescens*, *H. villosum*, *Notogrammitis heterophylla*, *N. pseudociliata*, and *Phlegmariurus billardierei*.

Geothermal habitats

A small group of species in New Zealand of tropical affinity are either confined to, or commonly found in, geothermal areas on heated soil, near steam vents, or beside hot streams and pools.

Species confined to thermal areas in mainland New Zealand (2 taxa): *Dicranopteris linearis* and *Nephrolepis flexuosa*.

Species common in thermal areas (6 taxa): *Christella dentata*, *Cyclosorus interruptus*, *Lycopodiella cernua*, *Nephrolepis brownii*, *Psilotum nudum*, and *Schizaea dichotoma*.

Opportunist species

Most members of the Dennstaedtiaceae are opportunist species, adapted to colonising open or disturbed habitats and invading agricultural land. They germinate rapidly and have long-creeping rhizomes that enable them to spread aggressively. However, they generally cannot tolerate competition and are replaced by regenerating scrub and forest.

The most common of these species are: *Histiopteris incisa*, *Hypolepis ambigua*, *H. rufobarbata*, *Paesia scaberula*, *Pteridium esculentum*, and, in alpine environments, *H. millefolium*.

South Island east/west divide

There is an obvious rainfall gradient in the South Island, with areas west of the Main Divide being much wetter than those on the drier eastern side. There are two groups of species that correlate with this gradient. With a few exceptions, the species in both these two groups are fairly widely distributed in the North Island, but one group is confined to the wetter west and south-eastern coasts of the South Island and Stewart Island, and the other to the drier areas east of the Main Divide (Brownsey 2001). The first group comprises some 36 species, which have distributions that either extend part-way down the west coast, down the whole west coast, or down the west coast and around the southern and eastern coasts, with outlying populations in some, or all of, the Catlins, Dunedin, Banks Peninsula, and occasionally parts of the Marlborough coast. In addition there are five species that are absent from the North Island and confined to the west coast of the South Island. The second group comprises 13 species, which are variously confined to drier parts of Marlborough, Canterbury, and Otago.

Absent from North Island, confined to west coast of South Island (5 taxa): *Asplenium lepidotum*, *Notogrammitis gunnii*, *Pteris epaleata*, *Sticherus tener*, and *S. urceolatus*.

North Island and part-way down west coast of South Island (7 taxa): *Asplenium cimmeriorum*, *Deparia petersenii*, *Diplazium australe*, *Gleichenia inclusisora*, *Lycopodiella cernua*, *L. lateralis*, and *Trichomanes elongatum*.

North Island and entire west coast of South Island (8 taxa): *Blechnum nigrum*, *Gleichenia microphylla*, *Hymenophyllum lyallii*, *H. pluviale*, *Lindsaea trichomanoides*, *Notogrammitis pseudociliata*, *Schizaea australis*, and *Trichomanes strictum*.

North Island, west coast of South Island, and outliers on east coast (21 taxa): *Asplenium bulbiferum*, *A. polyodon*, *Cyathea cunninghamii*, *Gleichenia alpina*, *Hiya distans*, *Hymenophyllum armstrongii*, *H. dilatatum*, *H. frankliniae*, *H. malingii*, *H. nephrophyllum*, *H. rarum*, *H. revolutum*, *H. rufescens*, *Lastreopsis hispida*, *Leptopteris superba*, *Lindsaea linearis*, *Lycopodiella diffusa*, *Phlegmariurus billardierei*, *Tmesipteris elongata*, *Trichomanes colensoi*, and *T. elongatum*.

North Island and eastern regions of South Island (13 taxa): *Adiantum hispidulum*, *Anogramma leptophyllum*, *Azolla rubra*, *Cheilanthes distans*, *C. sieberi*, *Asplenium subglandulosum*, *A. trichomanes* (hexaploid cytotype), *Botrychium australe*, *Lastreopsis velutina*, *Parapolystichum microsorum*, *Pellaea calidurupium*, *Polystichum oculatum*, and *Tmesipteris horomaka* (absent from North Island).

A feature of the group confined to the drier eastern regions of the South Island is an assemblage comprising *Anogramma leptophyllum*, *Asplenium flabellifolium*, *A. subglandulosum*, *Cheilanthes distans*, *C. sieberi*, and *Pellaea calidurupium*. These ferns are frequently found together and characteristically inhabit hot, dry, rocky areas, often in full sun. Several of the group have evolved strategies to adapt to this hostile environment; *Asplenium flabellifolium* and the two *Cheilanthes* species are known to be apomictic in Australia or New Zealand, or both, and *Anogramma leptophyllum* can regenerate from both spores and perennial tubers on the prothalli.

Altitudinal range

The numbers of native New Zealand fern and lycophyte species occurring in different altitudinal zones of the North Island, South Island, and offshore islands are shown in Table 15. Altitudinal zones are those defined by Wardle (1991) and Engel & Glenny (2008, fig. 1), except that we have used the term 'subalpine' rather than 'penalpine'.

The overwhelming majority of native species in both the North and South Islands occur either exclusively in the lowland zone (including the coastal zone) or the lowland-montane zone. A total of 156 taxa grow up to the limit of the montane zone in the North Island (c. 1300 m), and 114 taxa in the South Island (up to c. 1050 m). The difference between the islands is even more obvious in the lowland zone, with only 43 taxa found there in the South Island, whereas 76 are found in this zone in the North Island.

Differences are also apparent at higher altitudes. In the South Island there are 49 taxa that extend into the subalpine and alpine zones, whereas in the North Island only 28 taxa reach those altitudes.

Few ferns and lycophytes are truly alpine in New Zealand. Only about 21 taxa reach the alpine zone, with a smaller number that extend to the upper subalpine. Species with the highest elevation records in the North Island are *Polystichum cystostegia* (2150 m), *Asplenium richardii* (1950 m), and *Cystopteris tasmanica* (1900 m). In the South Island, *Blechnum penna-marina*, *Huperzia australiana*, *Notogrammitis crassior*, and *Polystichum cystostegia* have all been recorded up to 1900 m. Species with the largest altitudinal range in the North Island include *Hymenophyllum minimum* (0–1650 m) and *H. multifidum* (120–1600 m), and, in the South Island, *Polystichum vestitum* (0–1700 m), *Hymenophyllum multifidum* (0–1800 m), and *Blechnum penna-marina* (0–1900 m).

All naturalised species in New Zealand occur below 750 m except for *Dryopteris dilatata*, which extends to 1550 m in the South Island, and *Dryopteris filix-mas*, which reaches 900 m in the North Island and 1580 m in the South Island.

Table 15: Number of native New Zealand fern and lycophyte taxa (species and subspecies) with different altitudinal ranges in the North, South, and offshore islands. In the Table each taxon is assigned to just one range. For example, of the 184 taxa in the North Island, 76 range from sea level to 850 m, another 75 from sea level to 1320 m, and a further 15 from sea level to 1650 m.

Range	North Is.		South Is.		Offshore Islands	
	No. taxa	Altitudinal range	No. taxa	Altitudinal range	No. taxa	Altitudinal range
Coastal only	5	0–250	5	0–200		
Lowland only	76	0–850	43	0–525	12	0–520
Lowland—montane	75	0–1320	66	0–1050		
Lowland—subalpine	15	0–1650	32	0–1550		
Lowland—alpine	0		10	0–1900		
Montane—subalpine	9	500–1700	0			
Montane—alpine	4	500–2150	6	450–1900		
Subalpine—alpine	0		1	900–1900		
Total	184	0–2150	163	0–1900	12	0–520

Conservation threat status

The conservation status of New Zealand's ferns and lycophytes has been assessed most recently by de Lange et al. (2018). For those taxa accepted in *Flora of New Zealand – Ferns and Lycophytes*, the numbers in each conservation status category are summarised in Table 16. Species in the Nationally Critical, Nationally Endangered, and Nationally Vulnerable categories are described and illustrated by de Lange et al. (2010).

Since the threat list was published, *Phlegmariurus billardiarei*, *Pteris epaleata*, and *Pyrrosia serpens* have been added to the Flora but have not yet been formally assessed.

The species in the most critical categories are as follows.

Nationally critical (9 taxa): *Asplenium trichomanes* (tetraploid cytotype), *Botrychium lunaria*, *Davallia tasmanii* subsp. *cristata*, *Hymenophyllum polyanthos*, *Ophioglossum petiolatum*, *Sticherus tener*, *S. urceolatus*, *Trichomanes caudatum*, and *T. humile*.

Nationally endangered (4 taxa): *Asplenium pauperequitum*, *Dicranopteris linearis*, *Phylloglossum drummondii*, and *Tmesipteris horomaka*.

Nationally vulnerable (3 taxa): *Anogramma leptophylla*, *Lycopodiella serpentina*, and *Todea barbara*.

At Risk – Declining (3 taxa): *Cyclosorus interruptus*, *Isoetes kirkii*, and *Ptisana salicina*.

Relict (1 taxon): *Adiantum formosum*.

Some of these species, such as *Asplenium pauperequitum*, *Hymenophyllum polyanthos*, *Trichomanes caudatum*, and *T. humile*, are largely or entirely confined to offshore island habitats and are vulnerable because of their small populations. Others, such as *Adiantum formosum*, *Botrychium lunaria*, *Sticherus tener*, *S. urceolatus*, and *Tmesipteris horomaka*, have probably originated or arrived relatively recently, and have either not had time, or not been able, to expand their distributions. Loss of habitat is responsible for the rarity of *Cyclosorus interruptus*, *Isoetes kirkii*, *Lycopodiella serpentina*, and *Phylloglossum drummondii*, and damage from pigs is the cause of decline in *Ptisana salicina*. The remaining species are threatened due to small populations.

Table 16: Number of species and subspecies of ferns and lycophytes accepted in the eFlora in the different conservation categories.

Category	Number of taxa
Extinct	0
Data Deficient	1
Nationally Critical	9
Nationally Endangered	4
Nationally Vulnerable	3
Declining	3
Recovering	0
Relict	1
Naturally Uncommon	32
Vagrant	1
Coloniser	0
Not Threatened	151
Not assessed	3
Total	208

Naturalised species

Sixty-four fern and lycophyte taxa are listed as naturalised in the *Flora of New Zealand*. Of these, 27 are currently regarded as fully naturalised and 37 as casual (as defined by Schönberger et al. 2021).

We have limited understanding of the status of these taxa in New Zealand, their rate of spread, or their potential to become serious weeds. Such analysis is outside the scope of the *Flora*, but the data compiled in Tables 17 and 18 are a starting point for further investigation.

Table 17 indicates the approximate dates for the first arrival of naturalised ferns and lycophytes in New Zealand, as measured by the earliest known voucher specimen and the date of the first published record. There is close correlation between the two, with the first published record generally lagging slightly behind the first collection, as would be expected. Only six species were collected or recorded before 1950 (*Cystopteris fragilis*, *Equisetum arvense*, *Nephrolepis cordifolia*, *Osmunda regalis*, *Polystichum proliferum*, and *Selaginella kraussiana*). The apparent discrepancy with the first two rows of Table 16 is because not all of these six species were recorded by a voucher or publication before 1950. In the period since then there have been two peaks of new collection records, in the 1970s and again in the early 2000s. Published records peaked in the 1980s with the first listing of adventive ferns by Brownsey (1981), followed by *Flora of New Zealand* Vol. IV (Webb et al. 1988), and then again after 2000 with a series of updated checklists of naturalised species (Heenan et al. 2002, 2004, 2008).

Table 18 shows the regions of natural occurrence from which New Zealand's naturalised ferns and lycophytes have been derived. Of the 64 fully naturalised and casual taxa, 14 occur naturally in the north temperate zone (including North America, Europe and Asia), 13 in eastern Asia (including China, Japan and Taiwan), and 11 in the Palaeotropics, with smaller numbers from other regions. Of the 27 fully naturalised taxa, 15 originate from the north temperate zone or are widespread. This may reflect the fact that fully naturalised taxa have been established in the country for longer and came initially through European contact.

Aside from the 37 casual taxa, which are probably all escapes from cultivation, the exact means by which the fully naturalised species arrived in New Zealand is largely unknown. *Osmunda regalis* was said to have come from Europe with grass seed (Field 1890), *Equisetum arvense* arrived amongst *Iris* roots from Japan (Atkinson 1922), and species such as *Davallia griffithiana*, *Equisetum hyemale*, *Marsilea mutica*, *Polystichum setiferum*, and *Pteris dentata* are probably escapes from cultivation or aquaria.

The current status and threat posed by these species are also poorly known but, on the basis of personal observation the following is a preliminary categorisation of the fully naturalised species. This needs further investigation.

Serious weed over large areas, or capable of aggressive spread (5 taxa): *Dryopteris filix-mas*, *Equisetum arvense*, *Nephrolepis cordifolia*, *Salvinia molesta*, and *Selaginella kraussiana*.

Serious weed in limited areas, or actively spreading (8 taxa): *Adiantum raddianum*, *Azolla pinnata*, *Cyathea cooperi*, *Cyrtomium falcatum*, *Dryopteris affinis*, *Osmunda regalis*, *Polypodium vulgare*, and *Pteris cretica*.

Stable or spreading only slowly (14 taxa): *Adiantum capillus-veneris*, *Asplenium aethiopicum*, *A. scolopendrium*, *Athyrium filix-femina*, *Cystopteris fragilis*, *Davallia griffithiana*, *Dryopteris cycadina*, *D. dilatata*, *Equisetum hyemale*, *Marsilea mutica*, *Polystichum proliferum*, *P. setiferum*, *Pteris dentata*, and *P. vittata*.

Table 17: Number of naturalised and casual fern and lycophyte taxa first recorded in New Zealand either as voucher specimens or as published records.

Date	Vouchered	Published record
Pre-1899	2	3
1900–1949	3	2
1950–1959	4	2
1960–1969	4	2
1970–1979	10	3
1980–1989	8	13
1990–1999	6	8
2000–2009	21	20
2010–2019	6	5
2020–	0	6
Total	64	64

Table 18: Number of all naturalised and casual fern and lycophyte taxa, and naturalised taxa only, from areas where they occur naturally.

Natural occurrence	Naturalised and casual species	Naturalised species
North temperate	8	5
Europe, Asia	6	5
Neotropics	6	1
Palaeotropics	11	3
Indian subcontinent	2	0
East Asia	13	3
Africa, Madagascar	4	2
Malesia, Australia	2	0
Australia, New Caledonia	5	3
Widespread	6	5
Cultivated	1	0
Total	64	27

Basionyms of New Zealand taxa

Some 466 basionyms are listed in *Flora of New Zealand – Ferns and Lycophytes*. This total includes all currently accepted names for New Zealand species and subspecies, and all synonyms based on New Zealand material. Of these, 208 are currently accepted species and subspecies (one still to be described), 224 are synonyms, seven are presumed synonyms based on historical precedent, seven are hybrids, and 20 remain undetermined because type material has not been located (Table 19).

Table 19: Number of accepted taxa, synonyms based on New Zealand types, hybrids, and undetermined names in the native New Zealand fern and lycophyte flora.

Category	Number
Accepted species and subspecies	208
Synonyms based on a NZ type	224
Presumed synonyms (by historical precedent)	7
Hybrids	7
Undetermined (types not located)	20
Total	466

Authors of New Zealand taxa

The main authors of New Zealand fern and lycophyte taxa are listed in Table 20. William Colenso is easily the most prolific, with 112 basionyms attributed to him. However, only 20 of his names are currently accepted today, a success rate of just 18%. Georg Forster, Robert Brown, and the Hookers are the next most important authors. Carl Linnaeus, with just seven species attributed to him, is the only author to have achieved a 100% success rate.

Table 20: Number of basionyms and currently accepted taxa published by authors of native New Zealand fern and lycophyte taxa.

Author	Basionyms	Accepted	% Accepted
W. Colenso	112	20	18
G. Forster	35	28	80
R. Brown	31	22	71
W.J. Hooker	22	14	64
J.D. Hooker	18	10	56
A. Richard	13	8	62
A. Cunningham	13	6	46
T. Kirk	13	3	23
P.J. Brownsey (as 1st author)	10	7	70
J.J. Labillardière	10	6	60
C.L. Willdenow	10	5	50
B.S. Parris	8	6	75
J.B. Hombron	8	2	25
C. Linnaeus	7	7	100
O. Swartz	7	4	57
G. Kunze	6	5	83
L.R. Perrie (as 1st author)	6	5	83
C.B. Presl	6	1	17
J.B. Armstrong	6	0	0
H.B. Dobbie	6	0	0
E. Raoul	5	1	20
H. Nessel	5	0	0
Other authors	57	34	60

Typification

In the initial editions of *Flora of New Zealand – Ferns and Lycophytes*, 466 basionyms relating to native New Zealand ferns and lycophytes were listed. Of these, 151 were typified by holotypes and 281 by lectotypes. However, Brownsey & Perrie (2021) recognised that 37 of the previously identified holotypes required lectotypification to comply with the International Code of Nomenclature for algae, fungi, and plants. The corrected totals are given in Table 21.

Table 21: Different categories of primary types for indigenous New Zealand ferns and lycophytes.

Status	Number
Holotype	114
Lectotype	318
Neotype	4
Conserved type	1
Not determined	4
Not located	25
Total	466

Not surprisingly, the vast majority of primary types originate from New Zealand, with most of the rest coming from mainland Australia, Tasmania, and Norfolk Island (Table 22). A small number come from South Africa, the South Pacific, South America, India, and Java, or originated in cultivation. There are also 15 species from other regions with one each from Africa, China, Cochinchina (Vietnam), Falkland Is., Germany, Japan, Mariana Islands, Martinique, Mauritius, Pitcairn Island, Reunion, Samoa, Spain, West Indies, Yemen. The rest are from cultivation, or are of unknown or uncertain origin.

Table 22: Place of origin of primary types for indigenous New Zealand ferns and lycophytes.

Country/area	Number
New Zealand	308
Tasmania	39
Mainland Australia	36
Norfolk Island	8
South Africa	6
New Caledonia	3
India	3
South America	3
Tahiti	2
Java	2
Jamaica	2
Other regions	15
Cultivation (ex wild)	6
Unknown/uncertain	33

The major repositories of New Zealand fern and lycophyte primary types are WELT, K, and BM (Table 23), reflecting the nationality of early collectors, who were either visiting or resident in New Zealand. AK and CHR in New Zealand, together with P, B, W, FI, and UPS in Europe, house most of the other types. Some 14 types are based on illustrations, and 30 remain unlocated or undetermined.

Table 23: Location of New Zealand fern and lycophyte primary types (holotypes, lectotypes, and neotypes). Herbarium abbreviations follow Thiers (2021).

Herbarium	Number
WELT	99
K	94
BM	71
P	35
CHR	22
AK	17
B	12
W	12
FI	11
UPS	9
BONN	5
LINN	5
S	4
HO	3
L	3
PRC	3
US	3
GOET	2
LY	2
MEL	2
NSW	2
AD	1
BOL	1
BR	1
C	1
G	1
MA	1
Illustrations	14
Unlocated/undetermined	30
Total	466

Conventions

The conventions and guidelines adopted in the *New Zealand Flora – Ferns and Lycophytes* series are outlined in this section.

Abbreviations

Commonly used symbols and abbreviations are listed under 'About' on the *Flora of New Zealand* homepage: <https://www.nzflora.info/about.html>

Nomenclature

Names, authors, and places of publication are cited according to internationally accepted standards.

Author abbreviations follow Brummit & Powell (1992).

Journals are abbreviated according to *Botanico Periodicum Huntianum* (Bridson 2004), and monographs according to *Taxonomic Literature*, Ed. 2 (Stafleu & Cowan 1976–1988). Full bibliographical citations for published names are given in the References.

All synonyms based on New Zealand material are listed, but most of those based on overseas material are beyond the scope of this Flora.

Holotypes have been identified, or lectotypes and neotypes designated where necessary, for almost all basionyms relating to native taxa, although a few types remain unlocated. Holotypes, lectotypes, and neotypes for naturalised taxa are cited where these have been determined by earlier authors, but no attempt has been made to designate lectotypes for naturalised taxa. Lectotypes and neotypes designated in the course of this work have been published by Brownsey & Parris (2012), Brownsey & Perrie (2012; 2013; 2014a, 2014b, 2014c; 2015a, 2015b; 2016a, 2016b, 2016c; 2017a, 2017b; 2019; 2020; 2021), Brownsey et al. (2018, 2019, 2021), and Perrie & Brownsey (2015). Type material in the herbaria listed in Table 19 has been examined either as actual specimens or observed online.

Herbarium abbreviations follow Thiers (2021).

All cited botanical and vernacular names are listed in Manaaki Whenua – Landcare Research's plant names database: *Biota of New Zealand*. <https://biotanz.landcareresearch.co.nz>

The etymology of botanical names relies heavily on the work of Gledhill (2008).

Descriptions

Descriptions are based primarily on specimens in AK, CHR, and WELT, with occasional additions where there are extensive holdings of a particular taxon in another herbarium (notably OTA and WAIK). Specimens seen for the *Flora* have been annotated, either on the sheets themselves or in the relevant institutional database, or both.

Descriptions of families and genera focus on the taxa in New Zealand, but encompass the range of variation seen in other parts of the world. Characters absent in New Zealand material are indicated as 'not NZ' in parentheses.

Species descriptions follow the same format as far as possible throughout the *Flora*. They focus on characters that are diagnostic, and do not attempt to provide a comprehensive description of the species. Measurements are based on fertile fronds, except in the case of dimorphic fronds, when they are given separately for both fertile and sterile fronds. The dimensions given encompass the full range of variation in the character, with occasional outlying figures specifically indicated. Bracketed figures for extreme values are not included. Measurements are given in millimetres (mm) for most frond characters, in metres (m) for habit, and in micrometres (µm) for spores and other micro-characters.

Descriptions of spores are mainly based on the work of Large & Braggins (1991), who illustrated scanning electron microscope and light microscope images for every species then known in New Zealand. Reference is also sometimes made to images in other work where these are particularly illuminating. Spore sizes are only recorded where the information is critical to a particular group. Generally, the measurements given are the mean length and breadth of the exospore for monolete spores, or the diameter of trilete spores, for 30 spores mounted in gum chloral.

Technical terms used in this *Flora* generally follow the international glossary for pteridology (Lellinger 2002).

Taxonomy

Under the family and genus a brief summary is provided of the most recent taxonomic and phylogenetic work. Usually reference is made to the treatment of the groups by PPG 1 (2016), and by New Zealand authors, particularly Allan (1961).

Distributions

A summary of the worldwide distribution of each family and genus is provided, noting the areas of greatest diversity and the number of species accepted in surrounding areas by recent authors, particularly in Australia and the South Pacific.

Distribution maps are provided for every species, based primarily on examination and verification of c. 70,000 collections in the main New Zealand herbaria (AK, CHR, and WELT). Distributions of individual taxa are sometimes supplemented by material in smaller herbaria known to hold specialised collections of particular taxa or material from otherwise under-collected areas. Every dot is based on at least one identified specimen in the above herbaria. Occasionally, distributions known to extend significantly beyond those shown in the maps are documented by reference to iNaturalist observations or other sources.

Distributions are summarised by Ecological Provinces and the main island groups. Ecological Provinces are those defined by Engel & Glenny (2008): Northland, Auckland, Volcanic Plateau, Gisborne, Taranaki, Southern North Island, Western Nelson, Sounds-Nelson, Marlborough, Westland, Canterbury, Otago, Southland, and Fiordland. The main offshore islands or island groups are: Kermadec Islands, Three Kings Islands, Chatham Islands, Stewart Island, Solander Island, Snares Islands, Antipodes Islands, Auckland Islands, and Campbell Island.

Overseas distributions are provided for non-endemic species based on modern Floras.

Altitudinal ranges are given for the whole country, and usually also individually for the North and South Islands. Ranges are based on data taken from herbarium sheets. Altitudinal belts (coastal, lowland, montane, sub-alpine, alpine) are those defined by Engel & Glenny (2008).

Biostatus

The biostatus of every species in the New Zealand political region is summarised in four categories (Schönberger et al. 2021):

- **indigenous (endemic):** the taxon occurs naturally only in the New Zealand region
- **indigenous (non-endemic):** the taxon occurs naturally in the New Zealand and other regions
- **exotic (fully naturalised):** the taxon has been accidentally or deliberately introduced into the New Zealand region and occurs as self-maintaining populations in the wild
- **exotic (casual):** the taxon has been accidentally or deliberately introduced into the New Zealand region, and occurs only occasionally in the wild, or has been collected infrequently, or persists in the wild for only a short period, or occurs only in the vicinity of cultivated parent species

Habitat

Habitat information is summarised based on the authors' field experience and from data on herbarium specimens. The known hosts of epiphytic species are listed, based on data from herbarium specimens.

Recognition

The principal characters for recognising each species are listed, together with more precise measurements and features for distinguishing closely related taxa. The occurrence of occasional aberrant forms is also noted, where appropriate.

Cytology

All published chromosome counts from New Zealand species are recorded, citing the original sources. Occasionally, reference is made to overseas counts if no New Zealand count has been made, or if the overseas number (particularly in Australia) is different to that in New Zealand. Under each genus, reference is made to the range of chromosome numbers that have been reported internationally.

Hybridisation

Known hybrid combinations are recorded under each parent species where there are supporting herbarium specimens. Possible hybrid combinations for which the evidence is equivocal are also mentioned. Named hybrids are listed separately at the end of each genus, together with an indication of parentage.

Incertae sedis

Published names for which type specimens have not been located, and which cannot be identified with certainty, are listed as *incertae sedis*.

Notes

Supplementary information is provided in the Notes. In particular, any misidentifications in earlier Floras are listed, along with any additional information on taxonomy, nomenclature or typification not provided elsewhere. The need for further investigation is also noted, where appropriate.

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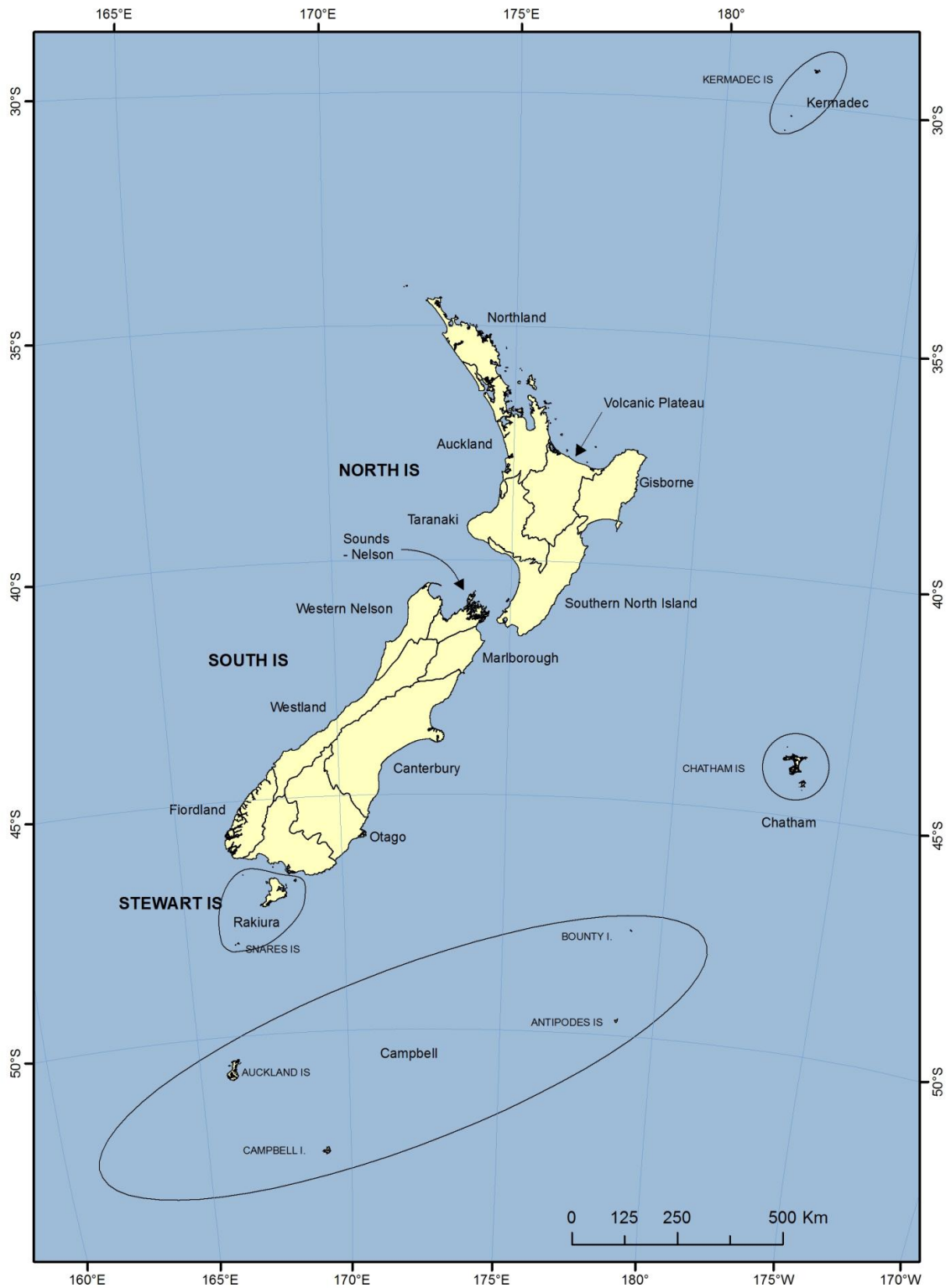
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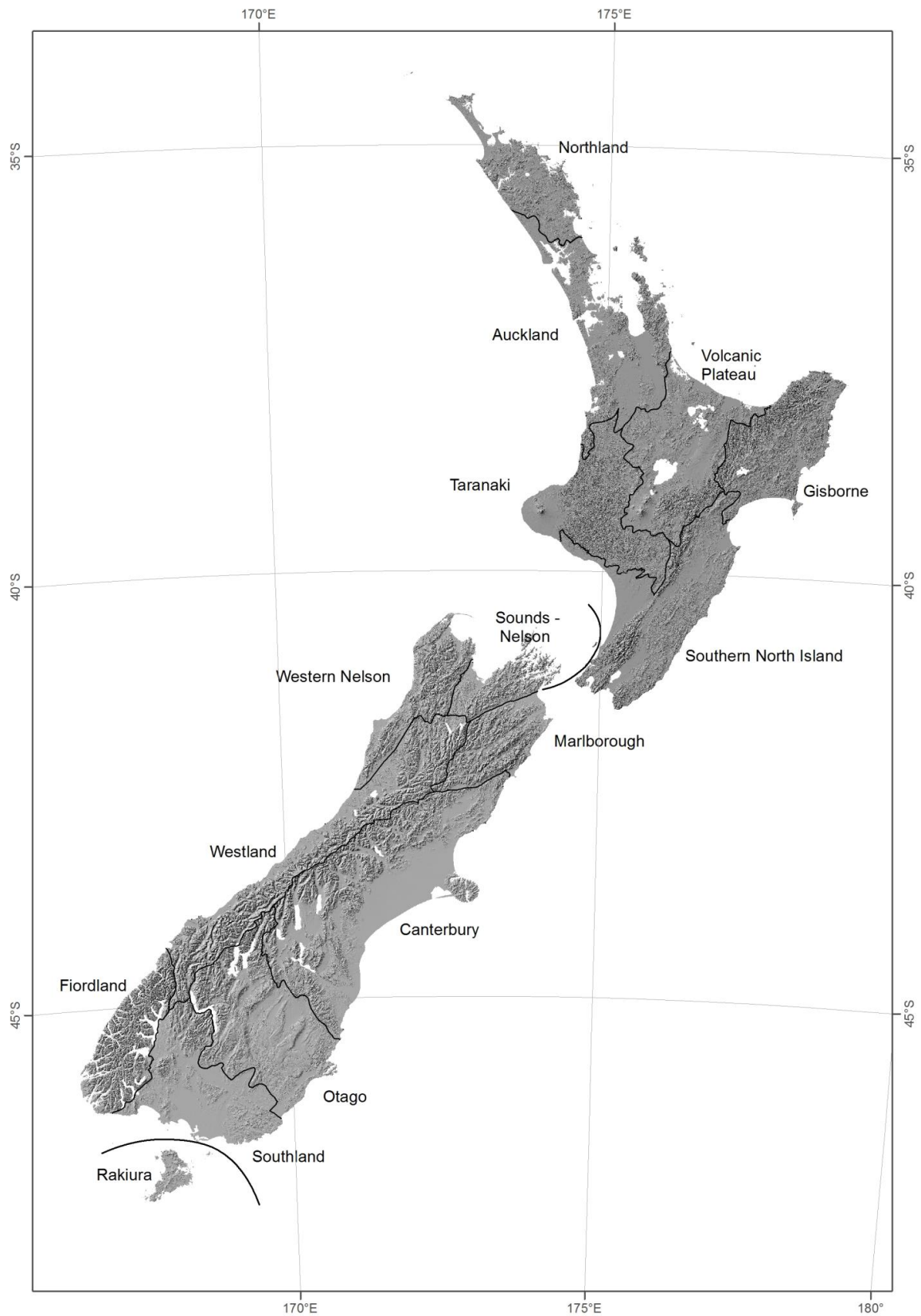
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Map 1: Map of New Zealand and offshore islands showing Ecological Provinces



Map 2: Map of New Zealand showing Ecological Provinces

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