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Pollen analysis of New Zealand honey

N. T. MOAR
Botany Division, DSIR
Private Bag, Christchurch, New Zealand

Abstract A pollen analytical study of New Zealand honey provides a basis for identifying the origins of a honey in terms of locality and floral source. The information may be used to develop analytical standards for pollen, contributing to quality control of a product offered for export or for the home market. General principles outlined by the International Commission for Bee Botany have been used as a guide, although in practice these are considerably modified. Samples were processed by acetolysis, and absolute pollen counts were obtained by spiking with a known number of *Lycopodium* spores. Most New Zealand honey falls within the "normal" category (20 000–100 000 pollen grains in a standard 10 g sample). Clover honey is in this category. Thyme honey with a pollen content less than 20 000 grains per 10 g sample, and manuka honey where the pollen content exceeds 100 000 grains, are examples of "under-represented" and "over represented" categories respectively. The analyses confirm the importance of white clover to apiarists, they provide details of characteristic pollen spectra for New Zealand honey, and draw attention to difficulties associated with assessing honey type by organoleptic criteria. Standards developed for New Zealand honey by pollen analysis should be flexible enough to accommodate changes as more data become available.

Keywords melissopalynology; pollen analysis; honey

INTRODUCTION

There has never been a systematic pollen analytical study of New Zealand honey, although nearly 70 years ago Waters (1915a, b, 1916) began a series of short papers describing pollen grains commonly found in local honey. The series was begun to "satisfy the increasing demand" for such information. Nevertheless, it was 30 years before the next serious study was attempted. Harris & Filmer (1947) used pollen analysis during the search for the toxic principle in honey from Pongakawa, Bay of Plenty. It is now known that the toxin, a derivative of tutin, is incorporated into honey by bees which have worked the honeydew excreted by the naturalised passion-vine hopper, *Scolypopa australis*, as it feeds on the sap of tutu plants (*Coriaria arborea*) (Sutherland & Palmer-Jones 1947; Connor 1977).

Harris & Filmer (1948) extended their observations to include bee loads (pollen pellets) taken from hives in the same area, and their work showed that pollen analysis could contribute to a knowledge of New Zealand honey despite the difficulty of correlating pollen with nectar sources. They concluded that "if there were no relationship between the proportion of pollen and parent nectars, a more fortuitous occurrence of pollen maxima might be expected".

Nevertheless this optimism did not generate much response from apiarists, possibly because of a negligible export market, and home consumption favouring the production of clover honey. Pollen analysis therefore was not used as in Europe to determine geographical origins, or floral sources of honey (e.g., Crane 1975). As interest in creating export markets for characteristic New Zealand honeys increased, it became clear that customer requirements, including those of product quality, had to be met. These requirements were emphasised at the Christchurch Honeydew Seminar (1978) where matters relating to the production, utilisation, and recognition of honeydew honey were discussed.

However, occasional pollen analyses have shown that hyphae of a sooty mould are characteristic of honeydew honey and that the pollen spectrum of a floral source honey is sometimes characteristic of the district in which it has been produced. The work reported in this paper expands these general observations into a more coherent pollen analytical statement of New Zealand honey. Identification of honey-type is based upon the results of pollen analysis and not upon the more traditional organoleptic characteristics of taste, colour, and odour. Beginning late in 1979, the study extended over 3 years. Besides establishing analytical criteria for pollen, it was hoped to provide apiarists with guidelines for monitoring the quality of their product as well as meeting the requirement of a microscopical examination sometimes demanded by importing countries.

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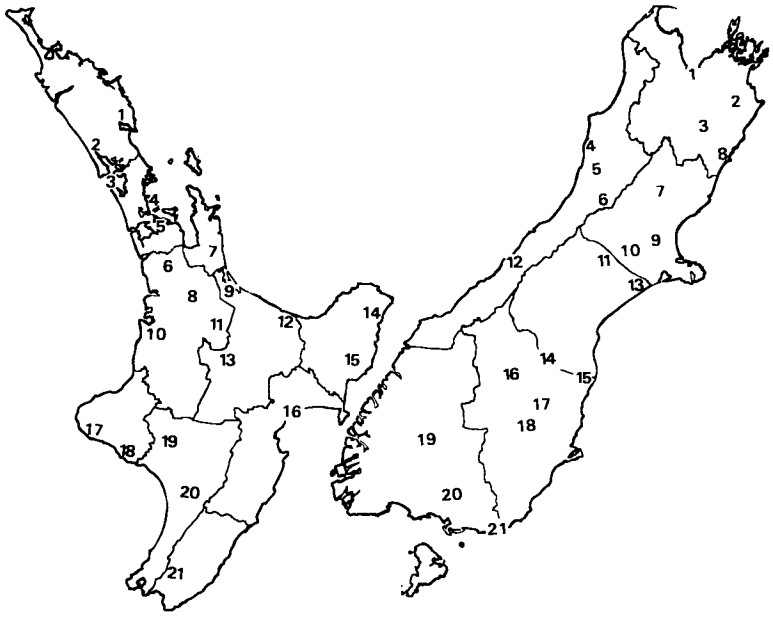

Fig. 1 Localities from which honey samples were obtained. In many instances the location is a generalised one involving several neighbouring districts which are indicated below. Details of site locations are available from the author on request.
North Island: 1 Whangarei; 2 Dargaville; 3 South Head Kaipara Harbour; 4 Rangitoto Island; 5 Auckland; 6 Waerenga; Te Kauwhata, Rotongaro; 7 Whangamata, Paeroa; 8 Gordonton, Morrinsville, Hamilton, Eureka, Matamata, Taetoaroa, Ohaupo; 9 Broadlands, Manawaru, Kaimai Range, Paeroa, Papamoa-Tauranga; 10 Otorohanga, Waitomo, Te Kuiti; 11 Tokoroa; 12 Taneatua; 13 Mangakino, Whakamaru, Taupo, Broadlands; 14 Ruatoria, Hiruharama; 15 Rakauroa, Otoko, Tolaga Bay, Gisborne, Poverty Bay; 16 Taupo Road, Raupanga, Wairoa; 17 Opunake; 18 Waverley; 19 Raetihi; 20 Kimbolton, Aokautere, Linton; 21 Greytown.
South Island: 1 Nelson; 2 Blenheim; 3 Molesworth; 4 Greymouth/Westport area; 5 Blackball, Lady Lake, Haupiri; 6 Taramakau River; 7 Hanmer; 8 Kaikoura; 9 Fox Creek, Horsford Downs, Okuku Pass, Mt. Thomas, Ashley, Oxford, Swannanoa, Kimberley; 10 Hororata, Darfield; 11 Rakaia Gorge, Pudding Hill, Staveley; 12 Franz Josef; 13 Chertsey, Seafield, Laghmor; 14 Benmore, Otematata, Aviemore; 15 Glenavy, Pukeuri, Ngapara, 16 Tarras; 17 Poolburn, Ranfurly; 18 Alexandra, Fruitlands, Roxburgh, Dumbarton; 19 Milford Sound/Te Anau highway; 20 Mandeville; 21 Tahakopa Valley.

The International Commission for Bee Botany, a commission of the International Union of Biological Sciences, has published recommendations relating to the palynology of honey based on many years of experience in Europe (Louveaux et al. 1978). The objectives are to assist in the development of quality control by pollen analysis, to discover geographical origins, and to determine the nectar source of any particular honey. The principal methods involve qualitative and quantitative pollen analysis. The first permits calculation of relative pollen frequencies on the basis of a total count of pollen and other microscopical particles, and the recognition of a pollen spectrum characteristic of a honey from a particular area. The second (quantitative analysis) involves calculation of the absolute number of pollen grains in a honey sample, which can be used as a basis for determining the floral source of any honey, as well as assessing claims made by an apiarist as to the purity of the product.

This report discusses the results of pollen analysis of 119 samples from many parts of New Zealand, although not every region is represented (Fig. 1). The number of specialist honeys received, in contrast to mixed source and clover honey, was not great, and some of them were rejected as such after pollen analysis. Despite these limitations the results should provide a basis for a better understanding of New Zealand honey, and a technique which can

be modified or improved in the future to extend and to test the observations reported here.

METHODS

Because of the need to deal with many samples quickly, involving the counting of thousands of pollen grains, simple and rapid laboratory procedures were required. The procedure adopted is based upon a 10 g honey sample, standard acetolysis (Erdtman 1943), and "spiking" — adding tablets containing a known number of *Lycopodium* spores to the sample (Stockmarr 1971). Two batches of tablets were used containing 12 500 $\pm$500 and the second 10 850 $\pm$200 spores per tablet respectively. Two tablets from the same batch were added to each sample.

The number of pollen grains counted for qualitative analysis varies according to the information required, and the principles outlined by Louveaux et al. (1978) are adopted in this paper. The simplest, intended to establish the general character of the honey, involves the identification of only the most numerous, or characteristic pollen grains, and is defined as an orienting analysis. More detailed counts, referred to as complete analyses, are used to determine the geographical origins of a honey, and involve identification of every pollen-type noted and calculation of their relative frequencies in counts of up to 300 pollen grains. The pollen-types are distributed among frequency classes, each representing a defined range as follows: predominant pollen, 45% or more; secondary pollen, 16–44%; important minor pollen, 3–15%; minor pollen, < 3%. Louveaux et al. (1978) state that counts of 1200 or more pollen grains per sample are necessary to apply reliable percentage frequencies to individual pollen-types, expressed with an accuracy of $\pm$1%.

For the present study complete analyses were always made and, for many samples, involved counts of 1000 or more pollen grains. However, consistent results were obtained with lower counts (Table 1) and as a general rule a total of 500 pollen grains was considered adequate, although the standard error at $\pm$2% was greater. The pollen sum excludes pollen of anemophilous (wind-pollinated) plants, nectarless plants, and any other microscopic particles which may be present. Quantitative data are based on results of complete analyses, and the absolute pollen content of the 10 g sample is derived from the ratio of the total pollen counted to the number of *Lycopodium* spores counted during the pollen analysis. Details of processing and counting are presented in Appendix 1.

The value of absolute pollen counts as a means of determining the floral source and quality of a honey depends upon the purity of the sample. Most samples received for pollen analysis were named in the field on the basis of their organoleptic characteristics and were as pure as the collector could obtain. Some however were known to be blends, or to have been taken from commercial packs. These were processed and examined, but their results were not used when assessing the characteristics of a unifloral honey.

A unifloral honey is derived mainly from one species, but not exclusively so (Louveaux et al. 1978) and is extracted by standard methods of centrifugation. Most unifloral honey, including white clover, contains 20 000–100 000 pollen grains in a standard 10 g sample, and in this respect is regarded as "normal" (Crane 1975) — the principal pollen type is predominant and therefore present in frequencies of 45% or more. The term "single species honey" is reserved for honey produced by bees working one species under controlled conditions. In this context a "normal" honey derived from various floral sources without any one predominating is a "mixed source honey". Since pollen production varies greatly between species, some unifloral honey may contain less than 20 000 pollen grains, and some more than 100 000 pollen grains. Honey in the lower range is "under-represented" in terms of "normal" absolute pollen content, and that in the higher range is "over-represented".

Because the quality of New Zealand thyme honey is sometimes questioned by an importing country it was necessary to collect the purest honey possible for pollen analysis. Ministry of Agriculture and Fisheries officers attempted to do this by placing hives in 2 areas dominated by thyme at the beginning of its flowering period and removing them when flowering had passed its peak. The honey produced during this time was extracted by hand centrifuge.

Having established that the pollen content of a sample is under- or over-represented in relation to normal honey, the next step is to calculate the minimum percentage frequency that defines it as a unifloral honey. For this only the purest samples are used, and as noted already, samples received as blends, commercial packs, or without collecting details are discarded.

Average values for absolute pollen content and relative frequencies for particular pollen types are calculated and corrected for the minimum "normal" value of 45%. This value is then expressed as a percentage of the sum of the average absolute pollen content of the pollen-type under review and the average absolute pollen content of clover-type pollen in "normal" clover honey.

The following calculations, using thyme honey as an example, illustrate this.

Table 1 Percentage frequency of 4 main pollen types in each of 7 slides, based on pollen sums ranging from 100 to 1000.

Honey sample	Pollen type	Pollen sum (100–1000) 100 %	200 %	300 %	400 %	500 %	600 %	700 %	800 %	900 %	1000 %
H30	*Thymus*	16	21	27	24	23	22	22	23	23	23
	Trifolium repens-type	22	19	20	19	19	19	19	19	19	19
	Rosaceae	12	16	16	16	16	17	18	18	18	19
	Salix	19	16	13	14	15	15	15	15	14	14
H118	*Leptospermum*	89	91	91	92	93	93	93	93	93	93
	Trifolium repens-type	3	3	3	3	3	3	3	3	3	3
	Lotus	1	1	3	3	3	3	2	2	2	2
	Taraxacum-type	1	1	1	1	1	< 1	< 1	< 1	< 1	< 1
H125	*Lotus*	75	70	71	71	70	70	71	71	71	71
	Trifolium repens-type	14	14	13	13	13	13	13	12	12	13
	Mentha	8	12	13	13	13	13	13	12	12	12
	Taraxacum-type	3	1	2	2	2	3	2	2	2	2
H146	*Weinmannia*	69	73	71	71	69	71	70	70	70	70
	Metrosideros	22	16	16	16	17	16	16	16	16	16
	Elaeocarpus	2	3	3	2	2	3	3	3	3	4
	Lotus	2	1	4	3	4	3	2	3	3	3
H148	*Metrosideros*	70	71	69	68	69	67	67	67	67	67
	Weinmannia	18	19	20	21	21	21	22	21	22	22
	Lotus	7	5	5	6	5	5	4	4	4	4
	Elaeocarpus	3	1	2	1	1	1	1	2	1	1
H204	*Echium*	90	87	87	88	88	89	88	88	88	88
	Trifolium repens-type	7	8	9	8	8	8	8	9	9	9
	Ulex-type	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
	Rosaceae	1	1	1	1	1	1	1	1	1	1
H207	*Trifolium repens*-type	42	37	38	38	37	39	41	42	42	42
	Weinmannia	15	19	19	18	18	17	16	16	17	16
	Knightia	13	12	12	10	11	11	10	10	10	10
	Ulex-type	12	9	8	9	9	8	8	8	8	9

(1) Average values of thyme pollen in thyme honey.

Sample	APC of Thyme pollen	% Thyme pollen
H18	9157	50
H61	3712	40
H62	3580	39
H162	5251	40
Average value	5415	42

(2) Correction to "normal" value

$$= \frac{5415 \times 45}{42}$$

$$= 5801$$

(white clover-type = 23 116)

(3) Minimum frequency thyme pollen in unifloral thyme honey

$$= \frac{5801}{5801 + 23\,116} \times \frac{100}{1} = 20\%$$

Because present data are limited, calculated values are accepted as guides which may be modified as more samples are analysed.

Correction factors can be determined experimentally (Maurizio 1975), but these demand long-term studies and guaranteed sample purity, which were beyond the scope of the present investigation.

Pollen grains were identified by comparison with prepared reference slides, and the level of identification depended upon the characteristics of each pollen type. Thus, although white clover (*Trifolium repens*) is an important nectar source and its pollen is found in most New Zealand honeys, it is sometimes difficult to separate from the pollen of other

clovers present as minor components in a sample. It is therefore recorded as white clover-type pollen. However, the characteristic pear-shaped pollen of vipers bugloss (*Echium vulgare*) allows identification to the species level.

RESULTS

The results of all pollen analyses are tabulated according to floral source. Most samples are listed as a named unifloral honey although some are treated as being derived from mixed sources (see Table 12).

The samples forwarded for pollen analysis were named in the field on the basis of organoleptic characteristics, i.e., flavour, odour, and colour. It was realised early in the survey that characterisation by pollen analysis may be at variance with this traditional method of identification as illustrated by the following examples.

Barberry (*Berberis vulgaris*), buttercup (*Ranunculus*), ling (*Calluna vulgaris*), nodding thistle (*Carduus nutans*), and tawari (*Ixerba brexioides*) honey samples were received and examined during the survey. In most instances the pollen frequency of the named source was so low as to suggest misidentification, especially as another pollen, often white clover-type, was predominant. A sample received as barberry honey (H24) contained < 1% barberry pollen, 82% white clover-type pollen, and 2% buttercup pollen. Although barberry pollen tends to fragment under acetolysis, there were very few broken grains noted during the counts, so the predominance of white clover-type pollen was not fortuitous. The samples received as nodding thistle honey (H46, H116, H122, H123, H124) and tawari honey (H40, H47, H186) are classed as clover honey, as pollen of the named plant is either absent or present in low frequencies.

Two samples, H45 and H192, were received as penny royal (*Mentha pulegium*) honey. The first contained 59% white clover-type pollen and 6% penny royal pollen, and is regarded as a clover honey (see Table 3). The second was dominated by lotus pollen (65%), with penny royal (14%) being the next most common pollen — it is listed as lotus honey (see Table 10). Penny royal pollen was recorded as a minor element in another 18 samples, but the flavour of penny royal nectar was detected in only 2 of these (H68 and H125). Both contained 2% penny royal pollen; the first is classed as clover honey, and the second as a mixed source honey (see Tables 3 and 12). Unifloral penny royal honey is rare in Europe where the pollen is mostly recorded as a minor component in honey (Maurizio & Louveaux 1962).

Heather honey, whether derived from ling or Spanish heath (*Erica lusitanica*) has a characteristic flavour (Walsh 1967). Ling pollen is poorly represented (2%) in the only ling honey sample (H26) received during the survey, whereas white clover-type pollen and lotus (*Lotus* spp.) pollen together accounted for 94% of the pollen sum. However, a honey from Glenledi, near Milton, (H63) of uncertain source, but "probably Spanish heath", contained secondary pollen including *Erica* (21%), gorse (25%), and manuka (31%). Maurizio & Louveaux (1964) note that ling produces an almost pure honey in parts of Europe and that the pollen is predominant or secondary in importance (see also Maurizio 1949, 1979). It is interesting that a New Zealand ling honey containing only 1% ling pollen was acceptable in Germany as a ling-type honey, but not as ling honey, on the basis of its organoleptic properties (Rope pers. comm.). There are insufficient data to characterise New Zealand heather honey on pollen analytical criteria with any confidence, and until better documentation is available the Glenledi sample is treated as a mixed source honey, and the ling sample as a clover honey.

Ability to identify honey on the basis of traditional methods varies between individuals who may recognise different sources for the same, or similar, product. Four samples (H27, H126, H130, H191) identified by flavour as manuka (*Leptospermum scoparium*), buttercup, manuka blend, and manuka respectively, illustrate this point. The "manuka" (H27) and the "buttercup" honey (H126) each contained < 1% buttercup pollen and a similar frequency of manuka pollen (22 and 20% respectively). In the "manuka" blend (H130), 59% manuka pollen, and < 1% buttercup pollen was recorded in contrast to the 55% manuka pollen and 5% buttercup pollen in the "manuka" honey (H191). These 4 are classed as mixed source honeys (see Table 12) on pollen analytical criteria, and emphasise the difficulties involved in identifying nectar sources consistently and accurately by flavour.

One hundred and twenty pollen types, and a few fern spores, were identified during the pollen analyses. Thirteen of the pollen types are derived from wind-pollinated plants of which dock (*Rumex*), grass (Gramineae), and plantain (*Plantago*) are the most regularly recorded, albeit in low numbers. Beech pollen (*Nothofagus fusca*-type) is regularly present in honeydew honey and the rest are sporadic in their occurrence. All other pollen types come from nectar producing plants, except Californian poppy (*Eschscholtzia californica*), kawakawa (*Macropiper excelsum*), *Muehlenbeckia*, pigeon wood (*Hedycarya arborea*), and pukatea (*Laurelia novae-zelandiae*) the flowers of which produce little or no nectar. Their presence in honey is probably

Table 2a Pollen analysis of clover honey, North Island.

	Locality													
	N3	N7	N8	N8	N8	N8	N8	N9	N9	N9	N9	N10	N11	N12
	Honey sample													
Pollen source	H3	H68	H40	H70	H122	H187	H189	H4	H47	H50	H124	H28	H46	H25
Trifolium repens-type	74	59	47	82	67	53	63	66	67	77	77	66	74	72
Lotus	22	20	22	5	28	2	26	17	10	14	10	6	14	14
Taraxacum-type	< 1	< 1	1	+	< 1	< 1	1	< 1	1	1	1	1	1	< 1
Cirsium-type	< 1	+	< 1			< 1	< 1	< 1	< 1	1	3	< 1	1	< 1
Rosaceae			1	3	1	10	1		< 1	5	1	6	< 1	1
Salix		2	2		1	1	< 1	5	2		< 1	1		< 1
Leptospermum	3	13	1				1	3			< 1	10	3	
Trifolium pratense		< 1	2	+	< 1	< 1	+	< 1	3		1	2	< 1	2
Ranunculus		< 1	1	3			< 1	3	< 1	< 1	< 1	< 1	3	
Eucalyptus		1		1	1		2	< 1	1		2		2	
Weinmannia			5			30		< 1	1			2	< 1	
Metrosideros		< 1	2						2		< 1	< 1	1	9
Mentha		2				< 1	3		< 1		1		< 1	
Ulex-type			2			< 1			< 1	+	< 1		< 1	
Cruciferae			+				+				< 1	< 1	< 1	
Cordyline			+	1		< 1		< 1	< 1		1	< 1		
Medicago		< 1		3				1			< 1		< 1	1
Ixerba			4			< 1			10					
Muehlenbeckia						< 1		< 1	1	< 1		< 1		
Pseudopanax											< 1		< 1	
Knightia			5						1			3		
Compositae						< 1		< 1			< 1			
Elaeocarpus					< 1	< 1			< 1					
Caryophyllaceae		< 1						< 1						
Echium									< 1				1	
Ericaceae						3		< 1						
Quintinia						< 1								
Vicia											< 1			
Acacia		< 1	1											< 1
Aristotelia			1											
Fuchsia													< 1	
Lonicera			< 1											< 1
Umbelliferae									< 1	+				

Table 2a (continued).

	Locality													
	N3	N7	N8	N8	N8	N8	N8	N9	N9	N9	N9	N10	N11	N12
	Honey sample													
Pollen source	H3	H68	H40	H70	H122	H187	H189	H4	H47	H50	H124	H28	H46	H25
Citrus						< 1								
Corynocarpus	< 1													
Lupinus											< 1			
Freycinetia			< 1											
Geniostoma										< 1				
Geranium										< 1				
Laurelia												< 1		
Ligustrum		1												
Papilionaceae														
Pittosporaceae											< 1			
Polygonum					+					+				
Pomaderris			1											
Gramineae (W)	< 1	1	1	6	< 1	1	< 1		1	1	1	< 1	1	< 1
Rumex (W)		+	< 1	+			< 1	< 1	< 1	2		< 1	1	
Plantago (W)		< 1	1	1			< 1	< 1	< 1			< 1	< 1	< 1
Coprosma (W)													< 1	
Cupressaceae (W)						1								
Pinus (W)		< 1												
Monolete fern (W)		+												
Cyathea (W)			< 1											
Pollen sum	766	650	555	502	523	1146	801	1124	682	511	1101	1201	1018	791
APF	20 512	29 247	89 211	21 268	10 433	96 031	25 000	98 630	24 165	29 162	90 309	96 031	47 877	988 750

Table 2b Pollen analysis of clover honey, North Island (continued).

	Locality													
	N13	N13	N13	N13	N14	N15	N16	N16	N17	N18	N20	N20	N20	N21
	Honey sample													
Pollen source	H26	H66	H116	H186	H123	H114	H24	H55	H43	H51	H45	H128	H133	H127
Trifolium repens-type	47	51	73	51	69	52	82	86	74	99	59	69	55	79
Lotus	32	19	6	8	28	34	2	2	33	< 1	5	10	27	11
Taraxacum-type	< 1	< 1	1	1	1	6	1	< 1	1	< 1	2	1	2	1
Cirsium-type	1	1	< 1	1	+	1		2	< 1	< 1		< 1	1	< 1
Rosaceae	< 1	8	1	2	< 1		< 1	< 1	2			< 1		1
Salix	1	1	< 1	4		< 1	2	< 1			2	1	< 1	2
Leptospermum	1	14	< 1	1		< 1	< 1		< 1	< 1	< 1	12	2	4
Trifolium pratense	1	1		8	< 1		< 1		< 1		< 1	1		1
Ranunculus			< 1	3	< 1	1	2	< 1	< 1			1		
Eucalyptus				1	< 1	< 1		1			1			1
Weinmannia	2	2	5			< 1			< 1		< 1	1		
Metrosideros	< 1			< 1		< 1	< 1		< 1		5			
Mentha				1		< 1					6	1	4	< 1
Ulex-type	2	1	3	1			1							< 1
Cruciferae						< 1		1			< 1	< 1		< 1
Cordyline						< 1		< 1						
Medicago	< 1	< 1					2							
Ixerba	< 1	< 1		14		2	< 1							
Muehlenbeckia				< 1		< 1	< 1							
Pseudopanax	7	< 1	2			< 1	< 1				4			
Knightia	1	< 1	< 1				2							
Compositae							< 1						< 1	< 1
Elaeocarpus			< 1				< 1					< 1		
Caryophyllaceae							< 1			< 1	< 1			
Echium		< 1	< 1											
Ericaceae			4	+			< 1							
Quintinia		< 1	< 1											
Vicia			< 1			< 1			< 1					
Aristotelia		< 1												
Fuchsia	< 1		< 1											
Lonicera				+										
Umbelliferae														2

Table 2b (continued).

	Locality													
	N13	N13	N13	N13	N14	N15	N16	N16	N17	N18	N20	N20	N20	N21
	Honey sample													
Pollen source	H26	H66	H116	H186	H123	H114	H24	H55	H43	H51	H45	H128	H133	H127
Citrus						< 1								
Corynocarpus												< 1		
Galega											9		5	
Lupinus													< 1	
Malvaceae							< 1				6			
Phormium								< 1	< 1					
Alectryon			< 1											
Berberis							< 1							
Calluna	< 1													
Cotula-type											2			
Papilionaceae	3													
Scrophulariaceae											2			
Gramineae (W)	< 1	1	< 1	2	1	1	< 1	1	< 1		< 1	3	1	< 1
Rumex (W)	1	1	< 1	< 1		1		2	< 1			< 1	< 1	< 1
Plantago (W)				1		< 1	< 1		< 1		+	< 1	< 1	
Coprosma (W)	< 1	< 1				< 1								
Coriaria (W)	< 1					< 1								
Chenopodiaceae								< 1						
Dacrycarpus (W)							< 1							
Monolete fern (W)								< 1						
Pollum sum	1423	1073	945	675	1005	1304	869	514	817	500	500	517	507	576
APF	1 373 076	184 863	473 837	38 415	107 172	85 128	139 226	20 930	30 261	17 006	23 784	15 104	17 118	131 590

In this, and subsequent tables, + indicates pollen type noted during a scan after counting had finished; APF = calculated total of all pollen on a particular slide; and (W) indicates pollen dispersed by wind.

Table 3a Pollen analysis of clover honey, South Island.

	Locality													
	S[1]	S[1]	S[1]	S[1]	S[1]	S9	S9	S10	S10	S10	S11	S11	S13	S13
	Honey sample													
Pollen source	H22	H98	H103	H169	H170	H180	H182	H72	H179	H181	H71	H73	H53	H171
Trifolium repens-type	94	64	64	68	94	96	94	94	96	93	85	84	92	93
Ulex-type	1	3		6	< 1	< 1	< 1	< 1	< 1	2	6	8	2	1
Rosaceae	< 1	1	1	6	< 1		< 1		< 1	< 1	1	< 1	< 1	
Salix	1	9	8	10	1		1	< 1		< 1	1	< 1	< 1	1
Trifolium pratense	< 1			1		< 1	< 1	3	< 1	< 1	2	1	2	< 1
Taraxacum-type	< 1	< 1	1	1	< 1		1			< 1		1		
Vicia	< 1	< 1	1		< 1	1	1	< 1	< 1	1	3		1	1
Cruciferae	1			< 1	< 1				1		< 1			< 1
Eucalyptus			2	4	1	< 1			< 1	< 1				4
Cirsium-type		1			< 1	1	< 1					< 1	< 1	
Echium	< 1	1		1		< 1		2	< 1	1		< 1		
Discaria		< 1				< 1						1		
Leptospermum		5	6	< 1				< 1	< 1		< 1			
Lotus					< 1									
Muehlenbeckia	1	3	2						< 1					
Papilionaceae													< 1	
Ranunculus		1												
Scrophulariaceae												1	< 1	
Weinmannia		< 1							< 1				1	
Bulbinella												+		
Cotula-type	< 1			< 1										< 1
Aristotelia			3	2										
Caryophyllaceae	< 1													
Ericaceae		< 1												
Griselinia											1		< 1	
Pennantia		4	2											
Alectryon			1											
Clematis			1											
Fuchsia		< 1												
Lophamyrtus			1											
Macropiper			1											
Metrosideros		2												
Myoporum			< 1											
Parsonsia		< 1												
Phormium			1											

Table 3a (continued).

	Locality													
	S[1]	S[1]	S[1]	S[1]	S[1]	S9	S9	S10	S10	S10	S11	S11	S13	S13
	Honey sample													
Pollen source	H22	H98	H103	H169	H170	H180	H182	H72	H179	H181	H71	H73	H53	H171
Stellaria												< 1		
Gramineae (W)	< 1	2		1	1	1	< 1	1	1	< 1	1		2	1
Rumex (W)	< 1				< 1				< 1	< 1				1
Plantago (W)		< 1		< 1	< 1		< 1	< 1					< 1	< 1
Nothofagus fusca-type (W)	< 1													
Chenopodiaceae (W)				< 1										
Unidentified			5											
Pollen sum	790	1009		540	513	573	564	512	570	509	633	518	504	536
APC	41 709	69 391		63 310	41 088	62 283	31 543	14 550	48 311	56 223	13 333	74 143	21 827	49 729

Table 3b Pollen analysis of clover honey, South Island (continued).

	Locality												
	S13	S13	S13	S14	S15	S15	S15	S16	S17	S17	S18	S19	S20
	Honey sample												
Pollen source	H172	H173	H174	H184	H20	H21	H177	H163	H32	H33	H157	H17	H23
Trifolium repens-type	95	88	81	54	72	83	87	89	75	96	92	67	95
Ulex-type	1	< 1	1	< 1	< 1	< 1	4	< 1	1	< 1	2		1
Rosaceae	< 1	1	3	4	< 1		1	< 1	1	< 1	< 1	< 1	
Salix		< 1		< 1	5	1	3	2	8	1	< 1		< 1
Trifolium pratense			< 1	2	4	< 1	1			< 1	< 1		< 1
Taraxacum-type		< 1			1	1	1	1	< 1		< 1		< 1
Vicia	1	2	1	1	1		< 1			< 1			
Cruciferae		1	1	< 1	9		< 1		< 1	< 1		< 1	
Eucalyptus	1	5	13	< 1	< 1	< 1	2				< 1		< 1
Cirsium-type					2	3			< 1	< 1			
Echium				35		< 1		6	3				
Discaria							< 1	1	1			< 1	
Leptospermum												32	
Lotus										< 1	1	< 1	

Table 3b (continued).

	Locality												
	S13	S13	S13	S14	S15	S15	S15	S16	S17	S17	S18	S19	S20
	Honey sample												
Pollen source	H172	H173	H174	H184	H20	H21	H177	H163	H32	H33	H157	H17	H23
Papilionaceae					1	1			2				
Ranunculus				+					< 1				< 1
Scrophulariaceae						7			1				
Weinmannia													< 1
Bulbinella								< 1					< 1
Caryophyllaceae					< 1								
Ericaceae													< 1
Thymus									5	< 1			
Viola		< 1	< 1										
Acacia					< 1								
Aciphylla											2		
Cordyline							< 1						
Lupinus		1											
Gramineae (W)	< 1	1	1	1	< 1	< 1	1	< 1	1	< 1	1	1	2
Rumex (W)	< 1			< 1	< 1	< 1		< 1	< 1	1	< 1	< 1	
Plantago (W)					< 1					< 1			
Nothofagus fusca-type (W)												1	
Chenopodiaceae (W)										< 1			
Unidentified								< 1	< 1				
Pollen sum	553	545	586	685	475	711	571	500	804	844	563	1290	1185
APC	91 447	44 094	112 121	136 811	22 749	19 988	92 581	68 716	96 642	55 318	146 649	169 736	73 240

[1] Localities are not precisely known, but the samples come from within the general area represented by Localities 9, 10, 11, and 13.

accidental, although pukatea and Californian poppy are known to be worked by bees for pollen (Walsh 1967; Maurizio & Grafl 1982).

Grass, white clover-type, and Rosaceae pollen occurred in almost every sample, and dandelion (*Taraxacum*-type), lotus, thistle, and willow (*Salix*) in more than half the samples received.

Most pollen recorded occur as minor or secondary components in honey, and only a few — kamahi (*Weinmannia racemosa*), manuka, matagouri (*Discaria toumatou*), rata (*Metrosideros* spp.), vipers bugloss, and white clover-type — are consistently predominant. Thyme pollen (*Thymus vulgaris*) is usually recorded as a secondary pollen (16–44%) in thyme honeys, although it is occasionally predominant (> 45%). Rewarewa pollen (*Knightia excelsa*) is either an important minor (3–15%) or secondary pollen in rewarewa honeys.

The number of pollen types in any one sample is not great (generally 9–22). The lowest number (4) was recorded in the only Chatham Island sample received (H29), and the highest (33) occurred in a rewarewa honey (H206).

Geographical origins

A New Zealand honey can usually be recognised by its pollen spectrum. However, to identify the district from which a honey is derived, pollen analytical characteristics need to be closely defined. The present survey has gone some way in achieving this objective, and the results demonstrate that a locality may sometimes be identified as much by the presence of a particular pollen, as by the pollen spectrum.

Thus, goats rue pollen (*Galega officinalis*) occurs only in honey from the Manawatu district in the southern North Island, and relatively high frequencies of thyme pollen, sometimes associated with pollen of Californian poppy, are characteristic of honey from the Central Otago valleys of the Clutha, Kawarau, and Manuherikia Rivers (Wilson et al. 1979). Similarly, honey with relatively high frequencies of vipers bugloss pollen probably comes from the drier inland areas of eastern South Island. Tawari pollen restricts the source area to forested sites in central and northern North Island, and rewarewa pollen identifies any North Island district where there are forests or forest remnants with rewarewa. Rewarewa extends south into the extreme north-east of the South Island, but so far honey from this area has not been available for examination. Whereas rewarewa and tawari pollen identify a North Island honey, the combination of kamahi, *Elaeocarpus*, quintinia (*Quintinia*), and rata pollen generally is representative of South Island Westland honeys. Although clover honey is produced throughout New Zealand, careful scrutiny of pollen spectra separates a North Island from a South Island honey (see especially Tables 2 and 3).

Pollen analytical characterisation of honey

The pollen content of the unifloral, mixed source, and honeydew honeys identified are reported, and complement the tables which record the details of each pollen analysis.

Unifloral honey

(1) Clover honey (Tables 2 and 3)

Fifty-five samples are listed as clover honey — 27 from the South Island and 28 from the North Island.

Honey from the North Island contains more pollen types than that from the South Island and each reflects the different combination of species available to bees. White clover-type pollen was the dominant pollen type in North Island samples. Lotus pollen, the next most important pollen type in North Island samples, along with low frequencies of dandelion and grass pollen. The combination of these with a mixed representation of other herbs (buttercup, thistle) and some pollen derived from native shrubland (manuka) or forest (rewarewa, tawari) identifies a North Island origin.

South Island honey is clearly dominated by white clover-type pollen and there are low frequencies of gorse, Rosaceae, and other herbs in most samples. This combination of pollen types is especially characteristic of pastoral areas in Canterbury and North Otago; inland areas are often identified by the presence of bulbinella, matagouri, and vipers bugloss pollen.

Absolute pollen counts for white clover-type pollen varied from 16 000 to 120 000, and most were in the 20 000–100 000 range so that a minimum frequency of 45% satisfies the requirement of a unifloral honey.

White clover is so widely grown that clover honey is produced throughout New Zealand and white clover-type pollen can be expected in varying proportions in most honey.

(2) Thyme honey (Table 4)

Eight samples are listed as thyme honey.

Thyme, matagouri, and white clover-type pollen occur in every sample, and other frequently recorded pollen-types are dock, grass, gorse-type, vipers bugloss, and willow.

Absolute counts for thyme pollen varied from 3700 to 9100 in the purest samples examined (H18, H61, H62, H162). On this basis thyme pollen is under-represented in honey and it is calculated that a minimum of 20% thyme pollen is required to characterise a unifloral honey; this is in accord with

Table 4 Pollen analysis of thyme (*Thymus vulgaris*) honey, Central Otago, South Island.

	Locality							
	S18	S18	S18	S18	S18	S18	S18	S18
	Honey sample							
Pollen source	H18	H30	H31	H61	H62	H75	H155	H162
Thymus	50	25	26	40	40	21	23	38
Discaria	4	3	42	57	42	10	30	5
Trifolium repens-type	8	23	13	2	< 1	16	4	20
Salix	2	14	2	< 1	1	13		2
Ulex-type	4	6		< 1	14	2	2	2
Rosaceae	3	17		< 1	1	13		4
Echium	14	< 1	9			15		26
Cruciferae	5	1	1			< 1		1
Papilionaceae	1	6	< 1		1	5		
Taraxacum-type	< 1	< 1				1		1
Aciphylla	< 1						41	< 1
Scrophulariaceae		1	< 1			< 1		
Acaena		< 1				< 1		
Cirsium-type	< 1	< 1						
Cordyline			1			1		
Escholtzia		1				< 1		
Eucalyptus						< 1		2
Lotus	1					< 1		
Medicago	1	< 1						
Myrtaceae	< 1	< 1						
Trifolium pratense		< 1				1		
Aesculus		< 1						
Bulbinella						2		
Caryophyllaceae		< 1						
Geraniaceae			< 1					
Helianthemum		< 1						
Juglans		< 1						
Leptospermum	3							
Ligustrum		< 1						
Nothofagus fusca-type	1							
Ranunculus				< 1				
Umbelliferae						< 1		
Gramineae (W)	< 1	< 1	< 1	2	1	< 1	< 1	< 1
Cupressus (W)	< 1			< 1	< 1		< 1	
Plantago (W)	< 1	< 1				< 1		< 1
Rumex (W)	2	< 1				1		< 1
Coriaria (W)	< 1							
Cyperaceae (W)	< 1							
Unidentified	1	10						
Pollen sum	775	1198	654	527	505	1057	1136	503
APF	18 691	195 626	41 745	9529	9339	95 267	55 409	12 751

European experience (Maurizio 1946, 1975). Thyme honey is a product of Central Otago (South Island Location 16, Fig. 1) which is the only district in New Zealand where thyme occurs as a dominant in the naturalised vegetation.

An attempt to produce an especially pure thyme honey failed. The unexpectedly high frequencies of Umbelliferae pollen (*Aciphylla*-type) in samples H155 and H156 reflected the presence of *Aciphylla* plants which were subsequently discovered in large numbers near the thyme communities in which the hives were located. Sample H155 is accepted as a thyme honey, but H156 is treated separately as Umbelliferae honey (see Table 10).

Table 5 Pollen analysis of manuka (*Leptospermum*) honey, North Island.

	Locality					
	N5	N6	N14	N14	N18	N19
			Honey sample			
Pollen source	H2	H69	H64	H65	H118	H42
Leptospermum	91	77	72	95	91	77
Lotus	1	5	13	2	1	5
Salix	1	< 1	1	2	< 1	< 1
Trifolium repens-type	3	17	12	< 1	6	2
Cirsium-type		+	< 1	< 1	< 1	1
Rosaceae	< 1	+	< 1	< 1		3
Metrosideros	< 1			< 1	< 1	2
Taraxacum-type	< 1		< 1		1	1
Lonicera	< 1			< 1		+
Ranunculus	< 1	+		< 1		
Eucalyptus		< 1	< 1			
Acacia	< 1					
Caryophyllaceae		< 1				
Elaeocarpus	< 1					
Hedycarya	< 1					
Knightia	1					
Labiatae						< 1
Ligustrum			< 1			
Mentha						+
Mida						< 1
Onagraceae		< 1				
Phormium	< 1					
Pseudopanax	< 1					
Quintinia				< 1		
Thymus				+		
Tilia						+
Ulex-type		+				
Weinmannia						6
Gramineae (W)	< 1	< 1	< 1	< 1	1	< 1
Coriaria	< 1		< 1	< 1		
Coprosma (W)	< 1			< 1		
Cyperaceae (W)			< 1	+		
Plantago (W)	< 1					< 1
Rumex (W)		+		+		
Cyathea (W)						< 1
Pollen sum	1225	585	1078	1109	1291	821
APF	1 701 388	130 803	124 885	844 696	196 818	148 469

(3) Manuka honey (Table 5)

Six samples are listed as manuka honey.

Manuka, grass, lotus, white clover-type, and willow pollen occur in every sample, and Rosaceae and thistle pollen are present in 5 of them. Manuka pollen is clearly predominant, and other pollen is almost always present in the "minor" category.

Absolute pollen content is in excess of 100 000, and in this respect manuka pollen is over-represented in comparison with "normal" honey, and minimum frequencies of 70% manuka pollen are necessary to classify a sample as unifloral manuka honey. Sample H2 has an absolute pollen count of over 1 000 000; it cannot be compared with other samples because the honey was extracted by "crushing and straining" (Simpson pers.comm.) and not by centrifugation.

Manuka honey has a strong flavour and is produced wherever there are suitable shrublands, often in areas of regenerating forest. Two taxa — manuka (*Leptospermum scoparium*) and kanuka (*Leptospermum ericoides*) — produce identical pollen

Table 6 Pollen analysis of rata (*Metrosideros*) honey. Sample H1 was received as pohutukawa honey (*M. excelsa*) from North Island Locality 4. The locality for H145 is not precisely known, but it originated in Westland.

	Locality						
	N4	S4	S4	S6	S7	S12	S12
	Honey sample						
Pollen source	H1	H147	H148	H97	H95	H120	H145
Metrosideros	58	56	66	94	76	47	81
Lotus	9	10	2	+	2	24	2
Taraxacum-type	1	+	1	+	+	2	1
Trifolium repens-type	26	1	1	+	2	3	1
Elaeocarpus		2	2	+	1	+	1
Quintinia		1	1	+	4	1	+
Weinmannia		29	23	4	12	17	12
Leptospermum	3		1		+	+	1
Pennantia			+	+	2	2	+
Rosaceae		+	+		+	+	+
Aristotelia			+	+	+	+	
Cirsium-type	+	+		+	+		
Ranunculus	+		+			+	1
Cordyline	+		+	+			
Ulex-type			+		+	+	
Ericaceae	+		+				
cf. Ligustrum			+				
Nothofagus fusca-type			+	+			
Ripogonum			+		+		
Rubus			+		+		
Acaena				+			
Cistaceae					+		
Compositae				+			
Hoheria					+		
Knightia	+						
Labiatae	+						
Lonicera	+						
Medicago	+						
Phormium	+						
Pseudopanax	+						
Griselinia			+				
Salix					+		
Schefflera				+			
Gramineae (W)	1		+	+		+	+
Coprosma (W)			+				
Dacrydium cupressinum (W)				+			
Plantago (W)	1						
Pollen sum	735	666	552	584	1078	556	523
APF	18 025	276 000	97 661	841 95	106 944	31 808	74 431

grains. Both produce honey of similar flavour, but Walsh (1967) comments that kanuka is an unreliable source of nectar although a honey surplus is sometimes produced. In view of this comment the samples examined are accepted as manuka honey.

(4) Rata honey (Table 6)

Six samples are listed as unifloral rata honey, but only 3 (H95, H97, H145) were used to determine absolute pollen content. The others were received as commercial packs and not used for that reason.

Table 7 Pollen analysis of kamahi (*Weinmannia*) honey. The precise locality of Sample H146 is not known.

	Locality				
	N18	N19	S1	S12	S21
	Honey sample				
Pollen source	H52	H44	H193	H146	H178
Weinmannia	89	65	60	69	90
Elaeocarpus	< 1	21	5	4	1
Rosaceae	< 1	1	2	1	1
Trifolium repens-type	5	5	4	1	6
Leptospermum		1	9	< 1	< 1
Lotus	4	3	9	3	
Metrosideros		1	2	16	< 1
Taraxacum-type		< 1	< 1	< 1	< 1
Ulex-type	< 1	< 1	+	< 1	
Aristotelia	< 1	1			
Hedycarya		< 1	+		
Ligustrum			+	< 1	
Quintinia			8	2	
Cirsium-type		< 1			
Knightia		2			
Laurelia		+			
Muehlenbeckia					1
Pennantia				1	
Phormium			+		
Pittosporum			< 1		
Ranunculus			+		
Ripogonum			+		
Rubus				2	
Salix		< 1			
Tetrapathaea		< 1			
Trifolium pratense	< 1				
Gramineae (W)	< 1	< 1	< 1		< 1
Plantago (W)	< 1	< 1	+		
Coprosma (W)			+		
Cyperaceae (W)					< 1
Nothofagus fusca-type (W)			+		
Unidentified	< 1	1	< 1	< 1	< 1
Pollen sum	1028	958	703	741	988
APF	65 672	94 663	164 486	247 000	125 634

Besides rata, characteristic pollen types are: dandelion; kamahi; lotus; *Elaeocarpus*; quintinia; and white clover-type. Kaikamako (*Pennantia corymbosa*) and Rosaceae are each represented in 5 samples, and only 11 out of the 37 recorded are common.

Absolute pollen content varies within the "normal" range although it tends towards the upper limit of 100 000 pollen grains. The honey is treated as "normal" so that a minimum frequency of 45% rata pollen identifies a rata honey.

A sample (H1) received from North Island Locality 5 as pohutukawa (*Metrosideros excelsa*) honey contains few forest pollen and reflects the pastoral character of the locality. Its North Island origins are confirmed by the presence of rewarewa pollen.

Pohutukawa and rata pollen are similar in appearance, and size differences are so slight that separation is not easy. The term rata may involve northern rata (*M. robusta*) or southern rata (*M. umbellata*), and since their ranges overlap the nec-

tar source may be difficult to determine. However, most samples have originated in areas of western South Island outside the limits of *M. robusta* where *M. umbellata* is often a distinctive member of lowland or montane forests.

(5) Kamahi pollen (Table 7)

Five samples, 2 from the North Island (H44, H52) and 3 from the South Island (H146, H178, H193) are listed as kamahi honey.

Characteristic pollen types are kamahi, pokaka, Rosaceae, and white clover-type — dandelion, gorse, lotus, manuka and rata each occur in 4 out of the 5 samples.

The pollen spectra in North and South Island samples are similar, although the records of pukatea and rewarewa pollen in Sample H44 are evidence of its North Island origin. Kohia (*Tetrapathaea tetrandra*) extends to about latitude 44S in the South Island, so its presence in the sample does not positively identify a North Island honey.

Absolute pollen content is less than 100 000 grains in the North Island samples and greater than 100 000 in the South Island samples. The average value is about 140 000 grains per sample. On this basis, pollen in kamahi honey is "over-represented", although an accurate assessment of the required frequency for a pure honey is not possible from available data, but probably lies between 60 and 70%.

Kamahi honey is most frequently produced in the western South Island although some comes from Southland (South Island Locality 21) and from the North Island.

(6) Matagouri honey (Table 8)

Three samples are treated as matagouri although none were received under that name. One (H59) came from a commercial pack of vipers bugloss honey, a second (H78) was from an unknown source, and the third (H16) was labelled as thyme honey.

The pollen spectra are variable and reflect the characteristics of the districts in which the honey was produced. Thus the relatively high frequency of thyme pollen identifies Central Otago (South Island Locality 18) as the source of H16, and the frequency of vipers bugloss pollen confirms an inland area of eastern South Island as the source for H59. Absolute pollen content is high, suggesting that pollen is over-represented, but since the collection details of one sample are not known, and another is from a commercial pack, quantitative data are treated with reserve, and until more information is available no attempt will be made to determine minimum pollen frequencies.

Table 8 Pollen analysis of matagouri (*Discaria*) honey, South Island.

	Locality		
	S3	S8	S18
	Honey sample		
	H59	H48	H16
Discaria	69	96	65
Rosaceae	2	< 1	1
Echium	24	3	
Medicago		+	< 1
Salix	2		5
Taraxacum-type	< 1		< 1
Trifolium repens-type	3		6
Unidentified		< 1	1
Bulbinella			< 1
Campanulaceae		+	
Cordyline			< 1
Cruciferae			< 1
Cyathodes fraseri	< 1		
Eucalyptus			1
Leptospermum	< 1		
Lotus			1
Metrosideros			1
Papilionaceae		+	
Parsonsia		+	
Phormium			< 1
Ranunculus			< 1
Thymelaceaceae	+		
Thymus			15
Ulex-type			1
Gramineae (W)	< 1		< 1
Plantago (W)	< 1		< 1
Nothofagus fusca-type (W)			< 1
Rumex (W)	< 1		< 1
Pollen sum	1108	878	976
APF	1 416 852	226 816	43 528

(7) Vipers bugloss honey (Table 9)

Five samples are listed as vipers bugloss honey. Characteristic pollen types are vipers bugloss, gorse-type, matagouri, white clover-type, and Rosaceae.

Absolute pollen counts, based on only a few samples, fall into the "normal" category, and on this basis a minimum of 45% vipers bugloss pollen is required to identify a unifloral honey.

Vipers bugloss occurs in the North Island, but it is abundant only in eastern districts of central and northern South Island where it occurs along roadsides and in poor, gravelly soils.

(8) Citrus honey (Table 10)

Only one sample (H129) was studied. According to Vorwohl (1973) and Maurizio (1975) citrus (*Citrus*) pollen is grossly under-represented and a frequency of between 10 and 20% citrus pollen

Table 9 Pollen analysis of vipers bugloss (*Echium vulgare*) honey, South Island.

	Locality				
	S2	S8	S14	S14	S14
	Honey sample				
Pollen source	H58	H49	H194	H190	H204
Echium	51	84	90	94	87
Discaria	44	5	1	+	< 1
Rosaceae	1	1	< 1	+	1
Trifolium repens-type	1	4	5	3	9
Ulex-type	< 1	< 1	+	1	< 1
Cirsium-type	< 1		+	+	< 1
Salix	1	< 1	1	1	
Eucalyptus			1	< 1	< 1
Escholtzia				< 1	< 1
Leptospermum	< 1	1			
Taraxacum-type			+		< 1
Trifolium pratense	< 1				< 1
Papilionaceae			< 1		< 1
Caryophyllaceae	< 1				
Cruciferae					< 1
Ericaceae	< 1				
Ligustrum			+		
Lotus				+	
Medicago		+			
Mentha			+		
Muehlenbeckia	< 1				
Phormium		4			
Ranunculus					< 1
Gramineae (W)		< 1	< 1	+	< 1
Plantago (W)					< 1
Pollen sum	1141	477	905	520	763
APF	707 420	19 753	66 770	94 890	75 603

identifies a unifloral honey. The single sample meets this criterion — the absolute pollen content is 11 545 of which citrus pollen accounts for only 1288, and the relative frequency of citrus pollen is 11%.

The pollen spectrum is characterised by relatively high frequencies of citrus, kiwifruit (*Actinidia chinensis*, 18%), willow (13%), and buttercup (13%) pollen, all of which are usually poorly represented in honey.

According to Walsh (1967) there is not much citrus honey produced although it provides a good pollen source in northern North Island.

(9) Lotus honey (Table 10)

Three samples are listed as lotus honey. The first (H29) was received as clover honey from the Chatham Islands, the second (H149) was labelled "pure bush honey", and the third (H192) was received as penny royal honey. Their diverse origins are not clearly reflected by the pollen spectra, and there is no pollen which characterises the Chatham Islands as the source for sample H29. Since no samples were received as "pure" lotus honey no attempt has been made to determine absolute pollen values for a unifloral honey — the 3 samples are treated as lying within the "normal" range of honeys.

(10) Rewarewa honey (Table 11)

Four samples (H41, H134, H207a, H207b) are listed as unifloral rewarewa honey.

In these samples rewarewa, dandelion, *Geniostoma*, kamahi, lotus, white clover-type, and willow pollen are always present, and several forest pollen types, including manuka, pigeon wood, rata, tawari, and wineberry occur in most of them.

Absolute pollen counts vary considerably and offer no firm basis for determining the characteristics of a unifloral honey, although on present evidence a minimum frequency of 10% rewarewa pollen is probable.

Table 10 Pollen analysis of *Lotus* (N2, N14, Chatham Island), *Citrus* (N15) and *Aciphylla* (S18) honey.

	Locality				
	Chatham Is.	N2	N14	N15	S18
		Honey sample			
Pollen source	H29	H192	H149	H129	H156
Trifolium repens-type	35	9	20	27	3
Lotus	48	65	66	1	
Actinidia				18	
Citrus				11	
Discaria					23
Mentha		14			
Ranunculus			2	13	
Rosaceae	15			2	
Salix			1	13	
Thymus					18
Aciphylla					53
Acacia		< 1			
Aesculus				< 1	
Amaranthus		1			
Aristotelia			1	1	
Cirsium	< 1		1		
Compositae				< 1	
Cordyline				1	
Cotula				< 1	
Cruciferae				4	< 1
Elaeocarpus				1	
Eucalyptus				1	
Hedycarya			< 1		
Ixerba			2	1	
Leptospermum		9	1		
Metrosideros			1		
Papilionaceae				2	
Pseudopanax			< 1		
Taraxacum-type	< 1	< 1	3	1	
Ulex	< 1				< 1
Vicia				1	
Weinmannia		< 1			
Coprosma (W)				< 1	
Coriaria (W)				1	
Gramineae (W)	2	< 1	< 1		< 1
Nothofagus fusca-type (W)					< 1
Plantago (W)	< 1	< 1		1	
Pollen sum	694	1109	316	510	1171
APF	48 360	160 227	492 187	11 545	88 746

Seven samples were received as rewarewa honey. Rewarewa pollen frequencies varied from 12 to 31% in the 4 listed unifloral honey samples and from 2 to 4% in the other 3 (H44, H188, H206). Because of these differences, 3 samples received as buttercup honey (H28, H117, H126), 2 samples received as tawari honey (H40, H47), and 1 sample received as ling honey (H26), all containing low frequencies of rewarewa pollen (1–8%), are included in Table 11 for comparison. The pollen analyses show that all those samples with low frequencies of rewarewa pollen have similar spectra, and on this basis they are classed as clover honey (H26, H28, H40, H47), kamahi honey (H44), or mixed source honey (H117, H126, H188, H206). The only unifloral rewarewa honey samples recognised are the 4 cited at the beginning.

Rewarewa honey is produced in lowland areas of the North Island where areas of secondary forest occur. The tree grows in the Marlborough Sounds (north-east South Island), but honey from this locality has not been investigated.

Mixed source honey (Table 12)

Seventeen samples are listed in this category in which the main pollen types recorded are secondary or minor elements. Of these, 10 were received as named honey, 4 (H54, H126, H131, H132) as mixed source honey, and 1 (H117) was of unknown origin. Those named were kamahi (H67), manuka (H27, H113, H115, H130, H191), rata (H119), rewarewa (H188, H206), and vipers bugloss (H158). Some were received in commercial packs, and none met the criteria for unifloral honeys. Twelve samples came from various North Island localities, and the records of rewarewa, tawari, and other forest pollen types in some of them, usually as minor components, reflect their origins. Similarly, the relatively high frequencies for rata pollen in (H119) and vipers bugloss pollen in (H158) are evidence of the South Island origin of these 2 samples. As usual, the North Island honey samples contain more pollen types, including buttercup, grass, lotus, manuka, Rosaceae, willow, and white clover-type. One North Island sample (H54) contained a few fungal spores. Absolute pollen content varies from about 20 000 to 150 000 pollen grains, and most lie within the "normal" range of 20 000–100 000/10 g sample, a result similar to that obtained by Maurizio (1949) in her survey of pollen in mixed source Swiss honeys.

Honeydew honey (Table 13)

Of the 19 samples examined, only one (H96) was collected outside Canterbury. This sample, from Lady Lake, near Lake Brunner, contained high relative frequencies of pollen from kamahi, quintinia, and rata — trees absent from Canterbury beech forests. Every sample contained the spores and hyphae of a sooty mould (Hughes 1972) together with dandelion, gorse-type, and white clover-type pollen. Beech (*Nothofagus fusca*-type), grass, manuka, and willow pollen were recorded in most samples. The honeydew elements were included in the sum although their counts were variable, a result which may be influenced by the acetolysis technique used to process the samples. There are pollen grains of 9 wind-pollinated plants represented in the pollen spectra, more than in any other honey studied so far, but of these, beech and grass are the only regularly occurring types.

DISCUSSION

The results demonstrate that pollen analysis can be applied successfully to the study of New Zealand honey. The acetolysis procedure adopted is as useful a technique in melissopalynology (see Lieux 1980) as it is in other pollen analytical investigations. Materials are simple and easy to obtain, and identification of pollen with cleared exines is relatively easy. Acetolysis procedures result in the destruction of algal cells which sometimes characterise a honeydew honey, and the technique is limited in this respect. However, the honeydew honey samples examined all contained relatively high numbers of fungal spores and fragments of hyphae, most contained beech pollen, and the overall number of pollen types derived from wind-pollinated plants is greater than in floral source honey. This combination of characters is unique for New Zealand honey derived from beech honeydew, and identification is assured.

Quantitative pollen analysis is used to determine the characteristics of a unifloral honey. This is achieved by spiking with *Lycopodium* spores as already described, but some workers prefer to use their own prepared suspensions of pollen grains. Once the characteristics of a unifloral honey are satisfactorily established, spiking is not strictly necessary, but since the procedure is so simple, its routine use provides the opportunity for quantitative counts if the need arises.

Assessment of a honey does not always confirm judgements based on organoleptic criteria which lack the quantitative control of pollen analysis. The advantages of a pollen analysis is that all, or most, nectar sources involved are recognised, and if quantitative data are available, their relationship to each component, or to the dominant source, can be determined. Pollen analysis therefore offers a useful objective method of classifying honey, and certainly complements traditional methods of doing so.

In this work a judgement is more soundly based if floral structure, nectar secretion, pollen production, and pollination of the plants involved have been determined. However, this information is not always available. White clover flowers are well adapted to cross pollination by bees. When the bee alights on the lateral petals (the alae) they are depressed by the bees weight, which forces the stigma and the stamens to protrude from their enclosing petals. The stigma and the stamens then come into contact with the bees body and pollen transfer is effected as the bee reaches down the short calyx for nectar.

Willow pollen occurs in many honey samples, but it is never recorded as more than a minor component. The simplest explanation may be that since willows flower early in the season a honey surplus is never, or rarely, produced. However, recent experiments with willows (*Salix caprea*) suggest that honey bees exhibit a degree of faithfulness to either the male or female plants of dioecious species (van

Table 11 Pollen analysis of rewarewa (*Knightia*) honey and related samples. Samples 41, 207a, 207b, and 134 are considered to be unifloral rewarewa honey; Samples 40, 67, 28, and 26 are clover honeys; Sample 44 is a kamahi honey; and the remainder are mixed source honeys.

	Locality												
	N7	N8	N9	N9	N9	N10	N10	N12	N13	N13	N15	N16	N19
	Honey sample												
Pollen source	H41	H40	H47	H207a	H207b	H28	H126	H188	H26	H206	H117	H134	H44
Knightia	31	5	1	14	12	3	4	2	1	4	8	19	2
Lotus	11	22	10	4	3	6	24	1	32	14	1	7	3
Salix	1	2	2	5	6	1	3	25	1	2	13	2	< 1
Trifolium repens-type	34	47	67	35	41	66	35	34	47	15	33	28	5
Cirsium-type		< 1	< 1	+	< 1	< 1	1	< 1	1	1	3	< 1	< 1
Rosaceae		1	< 1	1	4	6	7	1	< 1	1	20	2	1
Taraxacum-type	< 1	1	1	< 1	1	1	< 1	< 1	< 1	1		1	< 1
Weinmannia	1	5	1	17	14	2	2	5	2	6		5	65
Leptospermum	2	1		< 1		10	20	20	1	46	11	10	1
Ranunculus		1	< 1	2	2	< 1	< 1	2		< 1	3	1	1
Metrosideros	2	2	< 1	< 1	1	2			< 1		1		1
Aristotelia	1	1		1	1		< 1	< 1			< 1		1
Cordyline			< 1	< 1	< 1	< 1		2		< 1		< 1	
Cruciferae	< 1			< 1	< 1	< 1	1	< 1	< 1				
Geniostoma	4			6	4			2		2		< 1	
Ixerba		4	10	3	2								4
Citrus				< 1	< 1			1			1	< 1	
Compositae		< 1			< 1		< 1			< 1		+	
Elaeocarpus			< 1				< 1			1		4	21
Eucalyptus			1		< 1				< 1		< 1	1	
Hedycarya	1				< 1					1		< 1	< 1
Mentha			< 1				1	1			< 1	< 1	
Pseudopanax	1								7	2	< 1	< 1	
Trifolium pratense		2	< 1				< 1		2	< 1			
Ericaceae							< 1	1		< 1		7	
Laurelia	< 1		< 1			< 1							+
Papilionaceae				< 1	1	< 1			3				
Rhamnaceae			< 1	< 1	< 1							< 1	
Acacia	< 1	1						< 1					
Griselinia	< 1					< 1						< 1	
Lonicera		< 1	< 1					< 1					
Macropiper	< 1		< 1					< 1					
Muehlenbeckia			1			< 1	< 1						
Ulex-type				8	8							3	

Table 11 (continued).

	Locality												
	N7	N8	N9	N9	N9	N10	N10	N12	N13	N13	N15	N16	N19
	Honey sample												
Pollen source	H41	H40	H47	H207a	H207b	H28	H126	H188	H26	H206	H117	H134	H44
Acaena							< 1			< 1			
Calluna									< 1	1			
Freycinetia		< 1					< 1						
Fuchsia									< 1	+			
Labiatae				< 1		< 1							
Phormium						< 1	< 1						
Quintinia				< 1						< 1			
Solanum					1					< 1			
Caryophyllaceae												+	
Corynocarpus								< 1					
Hoheria										< 1			
Ligustrum								1					
Myosotis										< 1			
Pennantia												< 1	
Pomaderris		1											
Ripogonum												< 1	
Scrophulariaceae										< 1			
Tretrapathaea													< 1
Umbelliferae			< 1										
Gramineae (W)	< 1	1	1	1	1	< 1	< 1	< 1	< 1	1	< 1	1	< 1
Plantago (W)	3	1	< 1	1	< 1	< 1	< 1	< 1		+	1	< 1	< 1
Coprosma (W)	< 1		< 1			< 1	< 1	< 1		< 1		< 1	
Coriaria (W)	< 1								< 1	1		1	
Rumex (W)				< 1			< 1			< 1		< 1	
Cyperaceae (W)												< 1	
Podocarpus (W)								< 1					
Cyathea colensoi-type (W)		< 1		< 1	< 1					+			
Dicksonia (W)				< 1						+			
Unidentified		2				< 1		2		1	5	1	1
Pollen sum	464	555	682	564	763	1210	1119	709	1423	1244	721	1353	958
APF	107 000	89 000	24 000	16 024	15 679	96 000	42 000	71 000	1 000 000	102 000	76 000	257 000	95 000

Table 12 *(and opposite)* Pollen analysis of mixed source honeys.

	Locality									
	N1	N6	N6	N8	N10	N10	N12	N13	N15	N15
	Honey sample									
Pollen source	H191	H27	H125	H67	H54	H126	H188	H135	H113	H117
Lotus	8	38	47	1	13	24	1	45	3	1
Trifolium repens-type	9	31	44	40	37	35	34	37	27	33
Leptospermum	55	22	1		2	20	20	8	61	11
Rosaceae	2		1	3	4	7	1	1		20
Ranunculus	5	< 1	< 1	1	2	< 1	2	< 1	< 1	3
Salix	10	1	2	1	6	3	25	< 1		13
Taraxacum-type	1		2	< 1	< 1	< 1	< 1	7	< 1	
Cirsium-type	< 1			+	< 1	1	< 1		3	3
Cruciferae		1		< 1		1	< 1	+	< 1	
Mentha	< 1		2			1	1		3	< 1
Trifolium pratense		< 1		1	3	< 1		+		
Weinmannia	< 1			48	5	2	5			
Cordyline	< 1				< 1		2			
Ulex-type	1			1		< 1	< 1		1	
Aristotelia					2	< 1	< 1			< 1
Eucalyptus		< 1		< 1				< 1	< 1	< 1
Knightia					< 1	4	2			8
Muehlenbeckia	< 1					< 1		< 1	1	
Papilionaceae				< 1			1			
Echium					2					< 1
Metrosideros				1					1	1
Compositae										< 1
Corynocarpus	< 1						< 1			
Ericaceae					1	< 1	1			
Hedycarya				< 1						
Ligustrum			< 1	+			1			
Acacia	1						< 1			
Acaena						< 1				
Citrus							1			< 1
Geniostoma							2			
Ixerba				< 1	2					
Labiatae					2	1				
Lonicera				+			< 1			
Medicago				1	1					
Myrtaceae		< 1			< 1					
Phormium						< 1				
Pseudopanax			< 1							< 1
Umbelliferae									< 1	
Alectryon									1	
Caryophyllaceae		6								
Cotula										
Cyathodes fasciculatus										
Elaeocarpus						< 1				
Freycinetia						< 1				
Galega										
Griselinia										
cf. Hakea	< 1									
Heracleum	2									
Macropiper										
Pennantia									< 1	
Polygonum			< 1							

	Locality					
	N16	N16	N16	N20	S119	S158
	Honey sample					
Pollen source	H130	H131	H132	H115	H5	H14
Lotus	10	23	20	7	6	
Trifolium repens-type	28	37	24	13	1	36
Leptospermum	59	29	31	15	4	
Rosaceae	2	4	11	< 1	< 1	4
Ranunculus	< 1		2	< 1		
Salix	< 1	1	1			15
Taraxacum-type	1	1	1	< 1		< 1
Cirsium-type	< 1	2	1			< 1
Cruciferae		< 1	1	< 1		
Mentha		1	5			
Trifolium pratense	< 1	< 1				< 1
Weinmannia	< 1			< 1	36	
Cordyline	< 1	1		< 1	1	
Ulex-type				34		< 1
Aristotelia	< 1	< 1				
Eucalyptus			1			
Knightia			< 1	< 1		
Muehlenbeckia			< 1		< 1	
Papilionaceae	< 1		2	4		2
Echium		< 1				39
Metrosideros					24	
Compositae			< 1			2
Corynocarpus			+			
Ericaceae						
Hedycarya		< 1		8		
Ligustrum						
Acacia						
Acaena			< 1			
Geniostoma		< 1				
Ixerba						
Labiatae						
Lonicera						
Medicago						
Myrtaceae						
Phormium			< 1			
Pseudopanax						
Umbelliferae						
Alectryon						
Caryophyllaceae						
Cotula			< 1			
Cyathodes fasciculatus				2		
Elaeocarpus						
Freycinetia						
Galega				14		
Griselinia	< 1					
cf. Hakea						
Heracleum						
Macropiper	< 1					
Pennantia					1	
Polygonum						

Table 12 *(and opposite)* continued.

	Locality									
	N1	N6	N6	N8	N10	N10	N12	N13	N15	N15
					Honey sample					
Pollen source	H191	H27	H125	H67	H54	H126	H188	H135	H113	H117
Quintinia	13									
Sapindaceae	< 1									
Gramineae (W)	1	1	1	1	< 1	< 1	< 1	< 1	1	< 1
Plantago (W)	1		< 1	+	< 1	< 1	< 1	< 1		1
Rumex (W)	< 1				< 1	< 1			< 1	
Coprosma (W)	< 1					< 1	< 1			
Coriaria (W)	< 1						< 1		< 1	
Podocarpus (W)	< 1				< 1		< 1			
Unidentified		5	< 1						< 1	
Pollen sum	602	1087	1017	693	513	1119	709	500	805	721
APF	151 225	143 803	38 851	66 444	20 106	42 406	70 900	28 579	71 579	76 250

Table 13 *(and opposite)* Pollen analysis of honeydew honey.

	Locality								
	S6	S7	S9	S9	S9	S9	S9	S9	S9
					Honey sample				
Pollen source	H96	H34	H37	H38	H39	H150	H153	H154	H159
Honeydew elements	67	43	44	24	30	76	94	41	68
Taraxacum-type	< 1	1	2	3	2	< 1	< 1	1	< 1
Trifolium repens-type	1	36	26	14	37	5	3	8	12
Ulex-type	< 1	3	1	13	6	8	1	30	13
Salix		1	3	10	5	5	< 1	10	3
Leptospermum		4	1	17	5	2	< 1	2	1
Rosaceae	< 1	1	< 1	< 1		1	1	1	< 1
Trifolium pratense		1	< 1	+	< 1	< 1	< 1	1	< 1
Discaria		2	7	6	6	< 1		< 1	
Cirsium-type		< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Muehlenbeckia		< 1	< 1	1	1	< 1		< 1	
Pseudopanax		+	< 1			< 1		1	
Aristotelia		< 1	1	2	1	< 1	< 1	< 1	
Ranunculus	< 1	< 1	< 1	+	+			< 1	< 1
Cruciferae		< 1			+		< 1	< 1	
Griselinia			3	1	< 1	< 1			
Cyathodes						< 1		< 1	< 1
Echium		1	< 1	< 1			< 1		
Bulbinella		+	< 1	+	< 1				
Eucalyptus		< 1			< 1				
Papilionaceae			2	< 1	< 1				< 1
Phormium	< 1	1		< 1	< 1				
Compositae		< 1			< 1		< 1		
Fuchsia		+		< 1					< 1
Lotus	1	< 1	1		< 1			< 1	
Ericaceae		+							

	Locality					
	N16	N16	N16	N20	S119	S158
	Honey sample					
Pollen source	H130	H131	H132	H115	H5	H14
Quintinia			< 1			
Sapindaceae						
Gramineae (W)	1	1	1	1	< 1	< 1
Plantago (W)			< 1			< 1
Rumex (W)	< 1	1	< 1			
Coprosma (W)				< 1		
Coriaria (W)			< 1			
Podocarpus (W)						
Unidentified	1		< 1	1	1	< 1
Pollen sum	967	533	1050	822	525	551
APF	88 628	21 537	126 444	47 758	119 318	44 310

	Locality									
	S9	S9	S9	S9	S9	S9	S11	S11	S11	S11
	Honey sample									
Pollen source	H160	H161	H168	H175	H176	H183	H35	H36	H151	H152
Honeydew elements	58	54	9	19	32	79	59	31	55	51
Taraxacum-type	1	< 1	2	1	1	< 1	2	1	1	1
Trifolium repens-type	9	5	37	26	23	22	17	46	3	20
Ulex-type	23	30	19	12	13	< 1	2	2	1	7
Salix	6	4	12	9	3		11	6	< 1	12
Leptospermum	1	1	13	23	23	18		< 1		
Rosaceae		< 1	1	< 1	1		1	1		3
Trifolium pratense		< 1	< 1			< 1	3	2	< 1	3
Discaria	< 1		4	8	3		< 1	2		
Cirsium-type		< 1			< 1			< 1	< 1	
Muehlenbeckia		< 1	< 1	< 1						
Pseudopanax			1		1		< 1	+	< 1	< 1
Aristotelia								< 1		2
Ranunculus			< 1					+		
Cruciferae							< 1	+	< 1	1
Griselinia		< 1		< 1				< 1		< 1
Cyathodes	< 1	< 1				< 1				
Echium		< 1					< 1	< 1		
Bulbinella						< 1		2		
Eucalyptus		< 1		< 1				+	< 1	
Papilionaceae		< 1								
Phormium		< 1						< 1	1	< 1
Compositae			< 1			< 1				
Fuchsia			< 1							
Lotus										
Ericaceae			< 1	< 1	< 1					

Table 13 *(and opposite)* continued.

	Locality								
	S6	S7	S9	S9	S9	S9	S9	S9	S9
	Honey sample								
Pollen source	H96	H34	H37	H38	H39	H150	H153	H154	H159
Lupinus								1	2
Vicia					< 1				< 1
Carpodetus	< 1					< 1		< 1	
Cordyline				< 1	< 1				
Cotula-type			< 1						
Escholtzia							< 1		
Metrosideros	14		< 1						
Rubus									
Quintinia	4		< 1						
Weinmannia	9		1						
Astelia						< 1			
Caryophyllaceae					+				
Dracophyllum									< 1
Elaeocarpus	< 1								
Gaultheria					+				
Leucopogon fraseri				+					
Lonicera		1							
Malvaceae	< 1								
Pennantia	< 1								
Pittosporum									
Gramineae (W)	< 1	1	< 1	1	< 1		< 1	< 1	< 1
Plantago (W)	< 1	< 1			< 1	< 1	< 1	< 1	
Coprosma (W)		< 1		+					
Chenopodiaceae (W)							< 1		
Coriaria (W)				+			< 1	< 1	
Pinus (W)		+		+					
Rumex (W)		+							< 1
Cupressus (W)									
Cyperaceae (W)									
Myrsine (W)									
Nothofagus fusca-type (W)	+	3	4	5	2	+	< 1	< 1	< 1
Unidentified						< 1		< 1	
Sum (pollen + honeydew)	920	651	624	584	923	378	1907	1164	1789
APF	72 116	83 635	138 090	178 490	247 075	308 000	22 205	218 269	63 851
Honeydew elements	147 355	63 517	108 105	55 014	104 312	1 183 000	261 646	154 808	137 049

der Werf 1983), and the 2 commonest willow species in New Zealand, the crack willow (*Salix fragilis*) and the weeping willow (*S. babylonica*) are dioecious. The situation is probably complicated by the fact that in New Zealand, crack willows are derived from a male clone and weeping willows are derived from a female clone. This apparent preference of bees for either male or female plants of dioecious willow species may be relevant for other species as well.

Thyme pollen is clearly under-represented in thyme honey, and floral structure is a major factor in determining this. Thyme is a gynodioecious plant (i.e., hermaphrodite flowers are produced by some plants, female flowers by other plants) and there is evidence that environmental factors play an important and complex role in determining sexual expression in thyme (Dommee et al. 1978). Both types of flower produce abundant nectar and are equally available to bees, although pollen is available in only a proportion of flowers. On the other hand, manuka bears male and hermaphrodite flowers on the same plant (andromonoecious), and nectar is produced in small quantities by both types of flower (Primack & Lloyd 1980). The small pollen grains are therefore available whenever bees work the flowers, and on present evidence they are clearly over-represented. Demianowicz (1964)

	Locality									
	S9	S9	S9	S9	S9	S9	S11	S11	S11	S11
	Honey sample									
Pollen source	H160	H161	H168	H175	H176	H183	H35	H36	H151	H152
Lupinus		1								
Vicia							< 1			
Carpodetus										
Cordyline										
Cotula-type							< 1			
Escholtzia					< 1					
Metrosideros		< 1								
Rubus				< 1	< 1		+			
Quintinia										
Weinmannia										
Astelia										
Caryophyllaceae										
Dracophyllum										
Elaeocarpus								< 1		
Gaultheria										
Leucopogon fraseri										
Lonicera										
Malvaceae										
Pennantia										
Pittosporum			< 1			1	< 1			
Gramineae (W)	1	< 1	< 1				1	< 1	< 1	< 1
Plantago (W)			< 1				+			< 1
Coprosma (W)				< 1	< 1					
Chenopodiaceae (W)		< 1								
Coriaria (W)										
Pinus (W)										
Rumex (W)										
Cupressus									< 1	
Cyperaceae (W)		< 1					< 1			
Myrsine (W)								< 1		
Nothofagus fusca-type (W)	< 1	< 1	< 1	+	+		< 1	< 1		
Unidentified		< 1					2	1		
Sum (pollen + honeydew)	459	1656	818	619	493	571	601	549	2273	652
APF	71 323	123 684	249 390	415 833	231 250	28 538	51 405	125 114	15 520	128 629
Honeydew elements	97 246	147 039	23 476	1 000 000	111 111	106 132	75 212	60 692	195 725	134 274

found that highest absolute pollen counts were often recorded for plants with the smallest pollen grains.

Rewarewa flowers are pollinated by birds (Cheeseman 1890) although an abundant nectar flow attracts bees which produce from it a honey of characteristic flavour (Walsh 1967). The floral structure is such that bees are able to take nectar without disturbing the anthers (Moore & Irwin 1978) so that pollen is unlikely to be included in the honey in great numbers. The results of pollen analysis confirm this, but the pollen counts (Table 11) are variable enough to suggest that rewarewa honey requires further investigation.

The survey has identified characteristic pollen spectra of honey from a particular period. With current changes in agricultural and horticultural practice (e.g., the rapid destruction of gorse hedges in Canterbury, and the increased interest in various new horticultural and tree crop plants) it is clear that nectar and pollen sources may also change. The need to monitor the characteristics of any particular honey is obvious, especially when new and different combinations of nectar may alter its character. It is equally important to examine the honey flora on a regional basis, to identify regional differences in pollen spectra. The unexpectedly high

values for *Aciphylla* pollen in thyme honey from Central Otago, and the occasions when a pollen type eludes identification further emphasise this need. Unless the flora of a district is well documented it is sometimes difficult to identify the unknown.

Less than 30 years ago, honeydew honey was regarded as an unacceptable product (Seal 1957) and attitudes in this respect have only recently changed (Cook 1978, 1981). Honeydew honey is now a prized export product (Crozier 1981) which should be "produced wholly or mainly from secretions of, or found on, living parts of plants other than blossoms" (Honey export certification regulations 1980). The analyses suggest that most samples fit the above definition although some contain relatively high values of gorse and other pollen. Whether these qualify as pure honeydew honey is uncertain, but there is no doubt that every sample contains honeydew. The regular occurrence of hyphae and spores of sooty mould, and pollen grains of beech, clover, willow, and gorse, provide spectra which identify this product.

The fluctuating values for honeydew elements may result from the preparation technique used or they may reflect differences in infestation of the beech trees by the sooty mould. This clearly needs further investigation, but the relatively high values for gorse, willow, and white clover-type pollen in some samples suggests that care is necessary in selecting sites for hives which may be located at the forest edge close to both honeydew and floral sources of honey.

CONCLUSIONS

This pollen analytical survey has provided insights into our knowledge of New Zealand honeys, and extends the early observations made by Harris & Filmer (1948). On the basis of the data obtained from the present study the following points can be made.

(1) The number of pollen types recorded during the survey is well over 100 but the number in any particular sample rarely exceeds 22. In this respect New Zealand honey is not especially rich in pollen types and compares with many honeys characteristic of north-west Europe.

(2) Wind-blown pollen grains are regularly found in New Zealand honey, as elsewhere, although their numbers in any one sample are insignificant. There are generally more pollen-types derived from wind-pollinated plants in honeydew honey than in floral honey, which probably reflects the manner in which the honeydew is collected by the bees moving over the sticky mass of sooty mould on the beech trunks. The presence of these pollen types is considered accidental, especially as numbers are always low. However, some wind-pollinated plants, e.g., grass, plantain (Maurizio & Grafl 1982), and *Coprosma*, are worked by bees for pollen.

(3) White clover is the most important nectar source available to bees in New Zealand, and its pollen occurs in honeys as a dominant, secondary, or minor type. This frequency reflects the role white clover plays in New Zealand's pastoral economy, and consequently its value in honey production (Godley 1979).

(4) The district from which a honey originates can be determined within limits by pollen analysis. Such deductions depend upon careful pollen identifications together with a sound knowledge of the flora and vegetation in New Zealand. In some instances it is possible to recognise a relatively small area as the source (e.g., goats rue in the Manawatu) whereas in others a much larger area may be involved, up to and including the North or the South Islands.

(5) It is clear that an analytical characterisation of pollen content may be at variance with traditional methods of assessing the origin of a honey. This is especially true for mixed source honeys where personal judgement is often critical. Pollen analysis thus provides an objective means of assessing a honey, and further, can be used to monitor standards and practices on a consistent basis. Routine examination can be conducted rapidly by means of orienting or complete analyses provided that details based on absolute pollen counts and percentage frequencies for the various honey types are available.

(6) Determination of absolute pollen content is necessary when establishing the floral source of a honey. Spiking with *Lycopodium* tablets provides a relatively simple method producing comaparable results to those based on methods used in Europe. Thus clover and mixed source honey, as in Europe and elsewhere, is a normal honey whereas thyme and manuka are included in the under-represented and over-represented categories respectively. However, more samples should be examined before minimum frequencies are finally accepted as characteristic of a unifloral honey. This is especially true for those under-represented honeys (citrus and rewarewa) and over-represented honeys (kamahi and manuka) of which only a few samples were available for study.

(7) The samples must be processed in a uniform manner, but the samples themselves need to be collected in the field in as uniform a way

as possible. Comparison of results from samples extracted by different methods (e.g., centrifugation and pressing) is impossible, for absolute pollen content may vary greatly. Similarly when attempting to establish details of unifloral honeys commercial packs, which may have been blended, should not be used, and have been discarded for this purpose during the present survey.

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APPENDIX 1

In any analytical survey of pollen in honey it is necessary to use samples obtained in a standard manner (e.g., standard extraction techniques) so that results may be compared. This is especially important when determining standards for particular honey types.

Pollen analyses are based upon the extraction of pollen grains from a 10 g sample of honey. A duplicated sample is stored as a precaution against accident during processing or for an unforseen later requirement.

Samples are processed as follows:

(1) Ten g of honey are dissolved in distilled water in a water bath at a temperature not exeeding 45°C.

(2) The sediment is concentrated by repeated centrifuging in a bench centrifuge at 3000 revolutions per min. If centrifuge tubes are of a limited capacity (15 ml) the sample is kept at an even temperature, and the centrifugation process is continued until all the sediment is included in one tube.

(3) Two Stockmarr's tablets (*Lycopodium* tablets) are added to the precipitate and dissolved in about 10 ml 10% HCl. HCl is added slowly and stirred until the tablets are completely dispersed through the solution. The sample is then centrifuged for about 3 min at 3000 revolutions per min, and the supernatant is decanted.

(4) Acetolysis follows in the usual manner.

(a) About 10 ml glacial acetic acid is added to the precipitate, mixed thoroughly, centrifuged and decanted.

(b) About 10 ml acetolysis mixture is added ,consisting of 9 parts acetic anhydride to 1 part concentrated sulphuric acid. This mixture generates heat and is explosive if it comes into contact with water, so it is essential that the preceding step using glacial acetic acid is carefully applied. A face mask is a useful precaution against possible mishap.

The tubes with the acetolysis mixture are placed in a water bath at 100°C for 3–4 min and stirred vigorously taking care not to splash water into them. They are then centrifuged and decanted into a clean beaker or into a sink with fast running water (some reaction may occur).

(c) About 12 ml glacial acetic acid is added, stirred thoroughly, centrifuged, and decanted. The precipitate is washed in about 12 ml distilled water, centrifuged, and decanted.

(d) About 12 ml 7% KOH is added, stirred thoroughly, centrifuged, and decanted. Then a lightly coloured solution of Basic Fuchsin is added, which stains pollen grains red.

(e) One drop of well mixed precipitate is placed onto a microscope slide, mixed thoroughly with melted glycerine jelly, and covered with a 22 × 22 mm cover glass. Only enough jelly to reach the edges of the cover glass should be used — this is a matter for practice and experience — but 1–2 ml of jelly may be enough. When the jelly is set the slide is ready for counting.

Although counting procedures are simple, a mechanical stage fitted with a vernier scale is essential to traverse the width of the cover glass. Slides are always placed in the same relative position on the mechanical stage which is moved vertically after each traverse by one division of the vernier to avoid overlap of the field of view. For easiest counting, a 40× objective is used in combination with a ×10 or ×12 ocular, and the number of grains counted depends upon the purpose of the analysis. An orienteering analysis involves no more than identification of the most numerous or characteristic pollen grains. To determine the distribution among frequency classes 300 pollen grains should be counted (up to 500 for greater precision). *Lycopodium* spores need only be counted if absolute pollen content is to be calculated.