Preliminary study of the effects of honey bees (*Apis mellifera*) in Tongariro National Park

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ABSTRACT

A study of the effects of honey bees (*Apis mellifera*) in Tongariro National Park was conducted during the summers of 1993/1994 and 1994/1995. Three possible effects of the introduced honey bee were examined. Firstly, honey bee impact on the reproductive success of heather, an important weed species in Tongariro National Park, was examined. Insect visitation rates on heather flowers were low at each of four study sites within the park. Bagging plants to exclude insect flower visitors had little effect on the level of seed set. The potential of other pollen vectors, wind and thrips, as pollinators of heather was also examined. The studies indicate that none of these vectors significantly effect the amount of viable seed produced so it is concluded that heather is capable of autonomous self-pollination. The second part of the study examined the impact of honey bees on the pollination systems of a native plant species. Flax is thought to be predominantly bird pollinated, but the floral resources are also utilised by a variety of native and introduced insect species including honey bees. Fruit and seed set was found to be significantly higher at sites with bird visitation. The results also suggest, however, that flax has a flexible pollination system that enables it to maintain a range of fruit and seed set levels under different pollinator regimes. In the third study, competition between native flower visitors and honey bees was examined for two common alpine shrubs—manuka and *Hebe stricta*. The abundance and diversity of insect visitors varied considerably between sites, and between observational periods. Some of this variation may be ascribed to differences in the weather or to altitude. However, the abundance and diversity of diptera appeared to also be strongly negatively influenced by levels of honey bee activity. This indicates that honey bees do play a role in determining the structure of pollinator communities and may be a threat to local native biodiversity.

Keywords: honey bees, *Apis mellifera*, Tongariro National Park, New Zealand, pollination, native plants, heather, *Calluna vulgaris*, displacement

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1. Introduction

The honey bee (*Apis mellifera*) was introduced to New Zealand as early as 1839 (Donovan 1980). The New Zealand beekeeping industry that has subsequently developed fulfils two important functions—firstly, the production of honey and related products, with world-wide sales worth over $8 million; and, secondly, the industry provides pollination services for many plant species, particularly for commercial crops. The central North Island is an important area for the production of manuka and heather or ling honey. Until 1991, apiarists were allowed to place their hives within the boundaries of Tongariro National Park. Changes to the Department of Conservation's (DOC) Tongariro/Taupo Conservancy management policies were made in accord with the regulations set down in the National Parks Act (1980). These changes prevent hives being placed within Tongariro National Park. The hives are currently situated on either private or DOC-administered lands just outside the park boundary. The change in management policies has not prevented honey bees from utilising park resources, yet the impact of these introduced honey bees on native insect species has yet to be determined.

Honey bees may affect native communities in several different ways:
1. Facilitation of weed dispersal by providing pollination services
2. Inefficient pollination of native flora
3. Competition with native fauna for resources

Introduced weeds are important sources of both nectar and pollen for honey bees and the potential therefore exists for beekeeping to aggravate the problems already caused by weeds in protected natural areas. The impact of honey bees on the pollination of heather (*Calluna vulgaris)* is examined here by comparing the levels of pollen deposition and seed set in open flowers, and flowers bagged to exclude insect visitation.

A review of current literature by Butz Huryn (1995) on the use of New Zealand's native plants by honey bees indicates that introduced honey bees use only a small proportion of the plant species available in a given area. Butz Huryn (1995) suggests that honey bees, and other introduced species, are unlikely to have a negative impact on the pollination of native plant species due to their relatively unspecialised pollination systems. She also suggests that honey bees may actually be more effective than native pollinators due to their high floral constancy whilst foraging. In our study, the impact of honey bees on the pollination of New Zealand flax (*Phormium tenax*) is examined.

Honey bees have been shown to compete with native floral visitors in French Guiana (Roubik 1978), North America (Schaffer et al. 1979, 1983) and Australia (Paton 1993). Their impact on New Zealand's native pollination systems has not been previously examined. We examined the effect of honey bees on the abundance and diversity of native floral visitors on flax, manuka (*Leptospermum scoparium*) and *Hebe stricta*.

2. Methods

2.1 STUDY AREAS

Tongariro National Park can be broadly classified into several vegetation types. In the South at low altitudes podocarp broadleaf forest dominates. This gives way to mountain beech forest at higher altitudes and alpine vegetation above that. The eastern margin bounded by the desert road is a mosaic of kanuka (*Kunzea ericoides*) shrubland, small pockets of mountain beech (*Nothofagus solandri* var. *cliffortioides*) and degraded tussock grasslands. Along the northern boundary there is a broad band of manuka (*Leptospermum scoparium*) shrubland below mountain beech forest. The western edge previously contained the largest areas of red tussock grassland with patches of mountain beech forest. These tussocklands are now heavily invaded by heather. Commercial hives of honeybees are placed around the northern and western boundaries of Tongariro National Park, primarily to exploit heather and manuka.

A survey of honey bee distribution was conducted during the summers of 1993/94 and 1994/95 using feeding stations (Danka et al. 1990). The most highly utilised feeding stations were located around the western boundary, corresponding to the placement of commercial hives around the National Park (Fig. 1). Small numbers of honey bees were observed at feeding at some stations. These bees were thought to be 'scouts' as there was no evidence of further recruitment to the feeding stations. At several sites, particularly those some distance into the park, we found no evidence of honey bee activity. The survey was used as a guide for selection of sites to use in the study (Fig. 2).

There was no evidence for feral bee hives at any of the sites examined using feeding stations. The lack of evidence for feral hives within Tongariro National Park is consistent with low survival rates of overwintering bees in alpine areas in Australia (Pyke 1990).

2.2 FLOWER VISITOR SURVEYS

Preliminary observations of visitors on heather, flax, manuka and *Hebe stricta* flowers were conducted. For subsequent identification in the field, insects were collected from flowers and pinned and used as a reference collection. A video camera was set up at each of the flax, manuka and *Hebe stricta* study sites to determine the rate of floral visitation by different species, including birds. For each species, several periods of filming were used scattered over several days, at different times during the day, and through different kinds of weather (provided there was no heavy rain). When filming for birds, the cameras were set back to include a wide field of view and included several plants, while the insect-filming used a much shorter focal distance and included flowers on single plants. The video tapes were later viewed to determine the number of flowers visited by groups of species (guilds). The number of flowers available for foraging was counted and the length of the observation period recorded. In addition, a

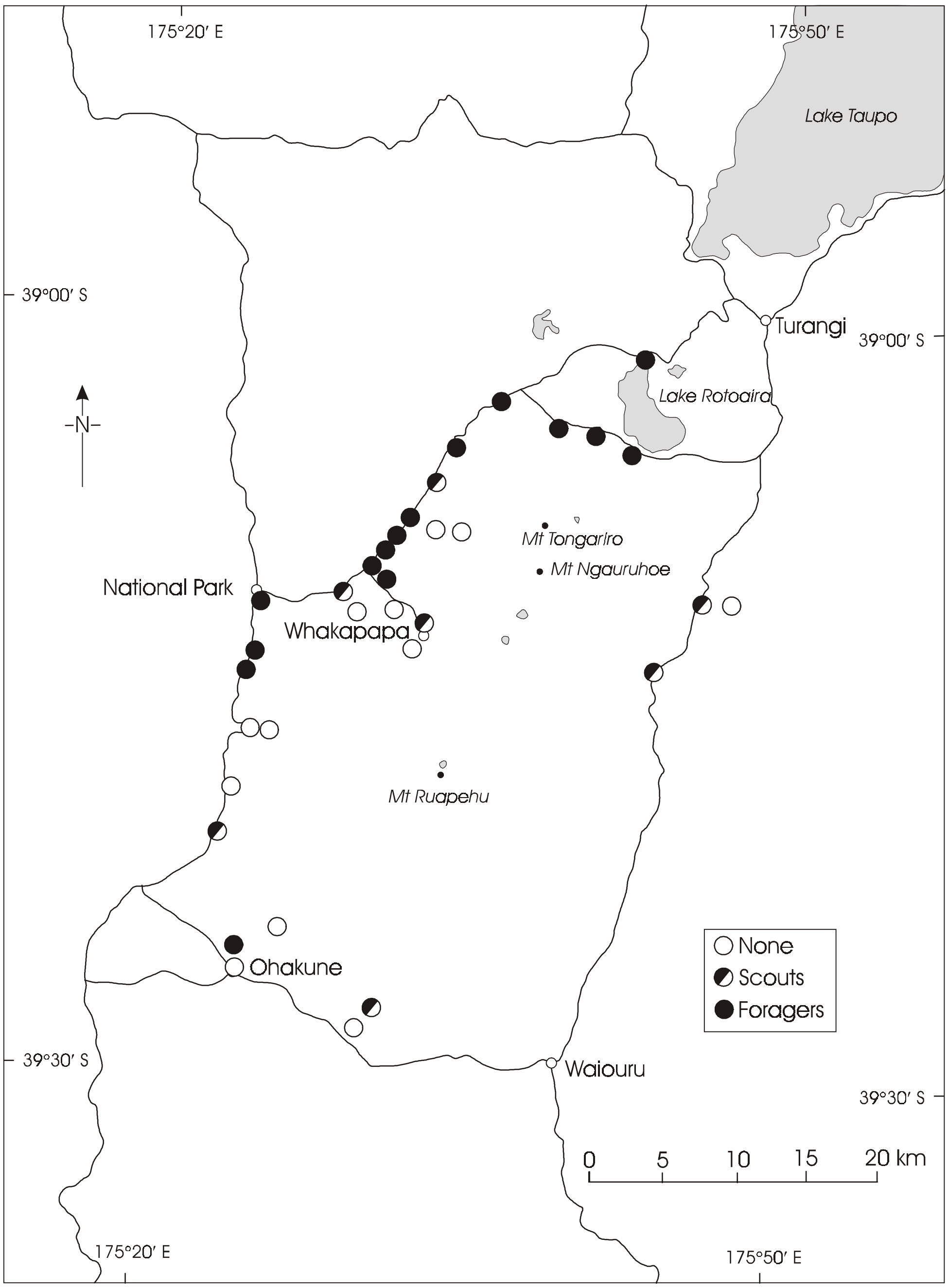


Figure 1. Location of honeybees on the volcanic plateau during the summers of 1993/94 and 1994/95. The major towns and state highways are shown along with the density of honey bee workers observed at feeding stations. None—no workers observed and feeding stations not emptied, Scouts—only a few bees observed and feeding stations emptied slowly, Foragers—many bees observed and feeding stations emptied quickly.

census of insect abundance and diversity at each site was conducted by recording the number and type of insect observed on flowers over a 10–15 minute random walk through the site. The observation period for heather was extended to 30 minutes due to initial low visitation rates.

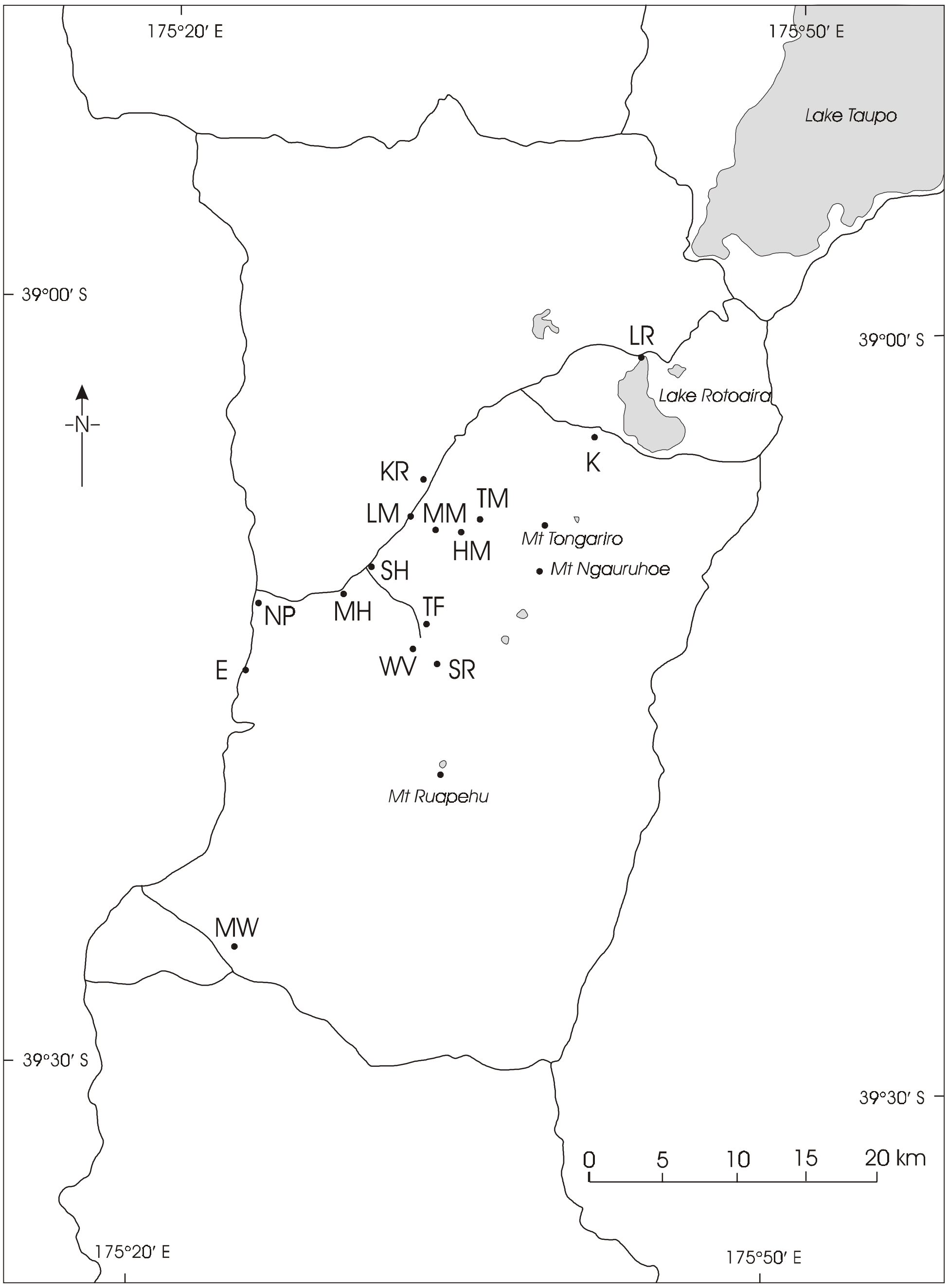


Figure 2. Map showing study sites used in the pollination studies. Abbreviations for study sites are as follows: LR—Lake Rotoaira, K—Ketatahi track, KR—Kapoor's Rd, LM—Lower Mangatepopo Rd, MM—Mid Mangatepopo Rd, HM—High Mangatepopo Rd, TM—Top Mangatepopo Rd, SH—SH48 turnoff, TF—Taranaki Falls, WV—Whakapapa Village, SR—Silica rapids, MH—Mangahuia campsite, NP—National Park corner, E—Erua, MW—Mangawhero campsite.

2.3 FRUIT AND SEED SET (FLAX AND HEATHER)

Fruit set for flax was determined by counting the number of pods formed on twelve randomly selected plants at each site. Two stalks were selected from each plant. The number of pods formed and flowers aborted were recorded. Evidence of aborted pods was provided by the retention of petioles. Two pods were collected off each inflorescence and counted to determine seed set. Heather seed set was examined by dissecting seed capsules under a microscope and recording the number of seeds counted. Seeds were categorised as being:

1. unpollinated ovules—pale cream, small
2. aborted seed—brown or dark cream, medium to large, shrivelled
3. set seed—brown, large, plump

2.4 POLLEN VECTOR EXCLUSION (HEATHER)

In order to investigate the importance of honey bees and other large insects for seed set in heather, in the 1994 season plants were placed into one of two treatments:

- bagged plants (n=5)
- open plants (n=5)

Ten plants were selected at three sites along Mangatepopo Road. An open wire cage was placed around each plant and bagged plants were enclosed in mesh bags placed over the frame. The mesh was considered fine enough to prevent flying insects from visiting the heather flowers. All plants were of similar size and phenological stage. In the 1995 season, the role of wind and thrips as pollen vectors for heather was considered. Twenty field plants whose flowers were uniformly infested with thrips, were selected at the lower Mangatepopo Road site and placed into one of two treatments:

- thrips, wind (n=10)
- thrips, no wind (n=10)

Twenty plants from the same area were grown for several months at Massey University and were, at time of flowering, free of thrips. These plants were placed back into the field at Mangatepopo Road in one of two treatments:

- no thrips, wind (n=10)
- no thrips, no wind (n=10)

Plants in the ‘no wind’ treatments were placed in large paper bags to prevent the transfer of air-borne pollen. All plants were placed inside fine mesh bags to prevent flying insects visiting heather flowers and to prevent thrip infestation of plants in the ‘no thrip’ treatments.

2.5 NECTAR STANDING CROPS (FLAX)

Flax flowers present their pollen before the stigma is receptive (Craig & Stewart 1988). The nectar standing crop of flax nectar was determined by collecting a flower that had finished presenting pollen and whose stigma was becoming receptive (Craig & Stewart’s [1988] ‘stage 2’ flower) from twenty randomly selected plants at each of the seven study sites. The volume and concentration of nectar was recorded to determine an average standing crop for each site. Nectar samples were collected using capillary tubes. The amount of nectar collected was measured and the sugar concentration determined using a refractometer (Bellingham & Stanley close-set 0–50% sugar refractometer). These measurements were then converted to milligrams of sugar per flower (Kearns & Inouye 1993).

3. Results and Discussion

3.1 HEATHER POLLINATION

Flower visitation rates

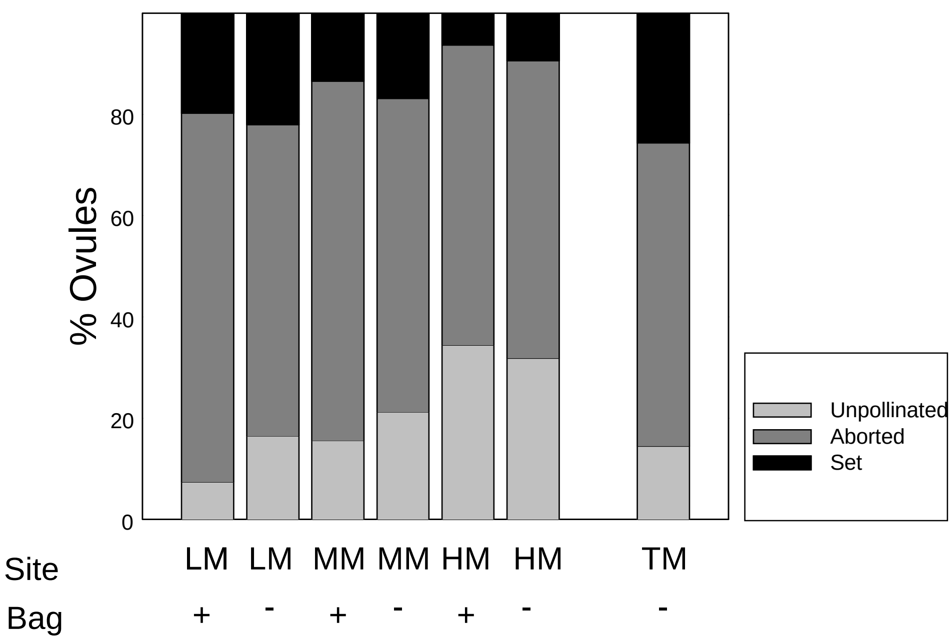
In general, visitation rates to heather flowers were low. Flies were the most common insect on plants, but may have been using heather as a resting site rather than as a source of food, although some flies were seen feeding. Honey bees were the only other insects observed on heather in this study.

Seed production

Although honey bees are thought to be important pollinators of heather in Europe, our study provides no evidence that they influence the pollination or seed set levels of heather in Tongariro National Park. Plants that were bagged to exclude honey bees and other pollinators, did not differ significantly from open plants in terms of the number of pollen grains deposited per stigma, the number of ovules pollinated, or seed set levels. Bagged plants did, however, have slightly lower levels of pollen tubes than unbagged plants at each study site. This difference did not alter seed production, however, as both treatments had similar seed set levels (Fig. 3).

In 1995, the presence of both wind and thrips were found to have negative effects on at least one measure of seed production. Wind had a significant effect on the amount of pollen received by flowers, with plants in the no wind treatments having higher levels of pollen deposition. This may be a side effect of the bagging treatment. The paper bags not only reduced air flow around the plant, but also protected flowers from any rain effects. Wind did not significantly affect any of the other measures of seed production (Fig. 4). Thrips had significant effects on three measures of pollination rate, but only

Figure 3. Proportion of ovules that were apparently unfertilised (Unpollinated), aborted after fertilisation (Aborted), or set (Set) in bagged (+) and unbagged (-) heather plants at four sites on the Mangatepopo Road (see Fig. 2 for locations).



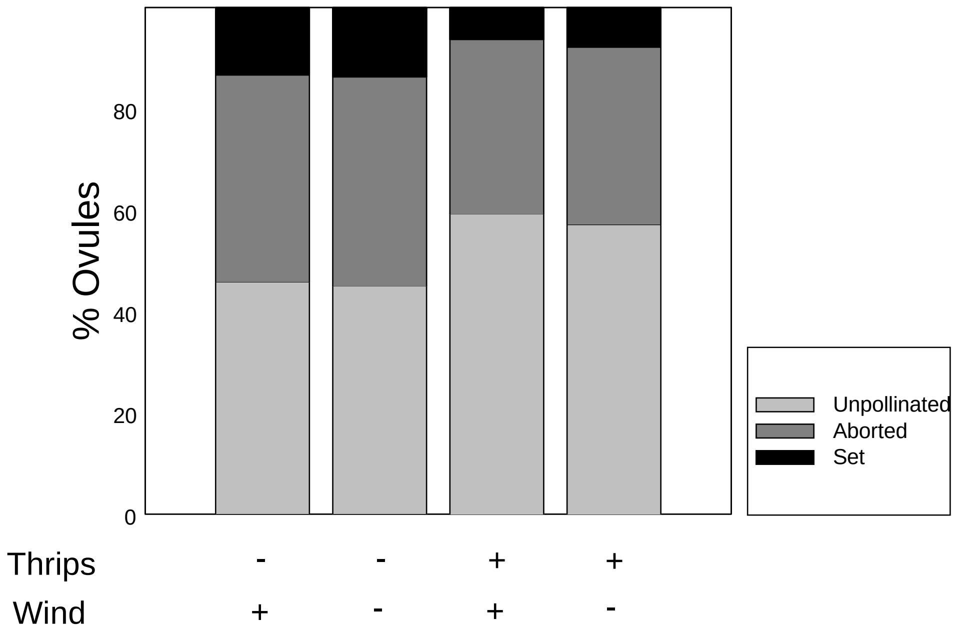


Figure 4. Fate of ovules in heather plants at the lower Mangatepopo site when they were enclosed in either mesh (+ wind) or paper bags (- wind), and with (+) or without (-) thrip infestations.

insignificant effects on seed set. Plants that were not infested with thrips had higher numbers of pollen grains per stigma, pollen tubes, and a higher proportion of fertilised ovules. These results may have been influenced by the quality of plants used for each treatment. Plants in the no thrip treatments were grown at Massey University in fertilised plant mix for several months before being placed in the field. The high level of nutrients available to these plants may increase their overall fitness, enabling them to produce more pollen and increase reproductive success. Another explanation for the observed thrip effect is the feeding behaviour of thrips. Thrips are pollen feeders, so high infestation levels may reduce the number of pollen grains available to plants for fertilisation. Certainly, no positive role in pollination of heather for thrips can be suggested.

These results of heather pollination over two flowering seasons indicate that none of the potential pollen vectors (honey bees, wind or thrips) have a significant effect on the overall fitness of heather in terms of seed set. Our interpretation of these results is that heather has a flexible pollination system that enables it to maintain a constant level of seed set under a variety of pollination regimes. A propensity for self-pollination combined with an over-abundance of ovules allows heather to compensate for poor pollination rates. The two seasons differed in the rate of pollen receipt (as shown by the higher proportion of unfertilised ovules), but there was little or no subsequent effect on seed production.

3.2 FLAX POLLINATION

Flower visitation rates

Observations of flax visitation rates indicate that flax flowers are visited by a variety of bird and insects. The abundance of these visitors, particularly birds, varies between the sites monitored (Table 1). The honeyeaters (tui and bellbirds) were only ever observed foraging on flax flowers at sites where the

TABLE 1. FLAX FLOWER VISITATION RATES, EXPRESSED AS THE NUMBER OF VISITS/FLOWER/HOUR, FOR (A) INSECTS ARRANGED BY GUILD AND (B) BIRDS AT SIX SITES AROUND TONGARIRO NATIONAL PARK. (SITE ABBREVIATIONS AS GIVEN IN FIG. 2, THE NUMBER SUFFIX REPRESENTING SEPARATE SAMPLING OCCASIONS).

(A) INSECT VISITATION RATES

Site	MW1	MW2	LR	MH1	MH2	SH1	SH2	E	NP1	NP2
Date	11/2	12/2	25/1	29/1	10/2	31/1	31/1	10/2	29/1	10/2
Time (min)	32	31	29	66	31	27	29	32	34	35
Flower No.	17	23	27	25	31	19	16	21	21	11
Honey Bees	0.11	0.75	0.23	0	0.43	0	1.30	0.18	0.08	1.89
Native Bees	0	0	1.47	0	0.50	0	0.26	0.53	0	0
Native Flies	0.89	0	1.08	0.29	0.56	0	0.91	0.09	0.92	1.72
Syrphids	0	0	0.46	0.07	0	0	1.20	0	0.25	0
Other	0	0	0.08	0	0.25	0	0	0.45	0	0
Total	1	0.75	3.32	0.36	1.74	0	3.67	1.25	1.25	3.61

(B) BIRD VISITATION RATES

Site	LR1	LR2	LR3	LR4	MW1	MW2	E1
Date	20/1	21/1	25/1	25/1	9/2	9/2	21/1
Time (min)	118	140	119	96	121	115	34
No. Flowers Observed	1635	1292	479	646	455	883	365
No. Flowers Visited	0	0	120	0	113	452	0
Visitation Rate	0	0	0.13	0	0.46	0.26	0

plants were close to forest habitats. These sites included Lake Rotoaira (LR), Erua (E), Mangawhero (MW) and Whakapapa Village (WV). This suggests that the forest provides other resources, such as shelter and nesting sites.

The sites where birds were not seen may have been too far away for foraging on flax to be profitable. For example, the tui that were observed at Erua restricted their foraging to plants closest to the bush edge, even though there were other flowers available at the site. The higher rate of visitation recorded by video at Mangawhero may reflect the timing of observations. The site was not discovered until late in the flowering season when most of the plants were past peak flowering. This meant that there were fewer flowers available for foraging and these were concentrated on a small number of plants. One effect of this timing was that tui were observed defending patches of flax. This territorial behaviour was not observed at Lake Rotoaira, where flowering was abundant. A second explanation may be that the dense bush surrounding the Mangawhero study site can support a higher resident tui population.

Nectar standing crops

The standing crop of nectar of Stage 2 flowers for each study site is shown in Fig. 5. The lowest values occurred at the two sites were honeyeaters were regularly observed (Lake Rotoaira—LR and Matawhero campsite—MW). The mean nectar concentration for flax flowers was determined to be 18.09% and the average volume per flower was 179.85 ml, so the mean amount of sugar per flower was calculated at 35.18mg. This figure is very high compared with other published values from New Zealand and worldwide and suggests that flax is potentially a major source of nectar for birds. Sites that were regularly visited by honeybees but not birds (Erua—E and National Park—NP) had the highest standing crops of nectar. This suggests that birds were the major consumer of flax nectar and that honeybees played little part in depleting nectar and therefore don't appear to be major competitors with birds for access to flax nectar around Tongariro National Park.

Fruit set and seed set

Craig & Stewart (1988) suggest that open infloresences of flax typically set about 20% of their flowers, which is consistent with the data obtained from our sites, with an average of 16.5% fruit set (Fig. 6). Low flower to fruit ratios are common in outcrossing hermaphroditic species and may be caused by selective abortion of inferior developing seed, resource limitation (water or nutrients) or by the plant adopting a strategy of using additional flowers only as pollen donors (Lloyd 1980, Sutherland & Delph 1984). Resource limitation is likely to be the explanation here but can only be confirmed by supplementary hand pollination experiments.

Seed set (seeds per ovule), was more variable among sites than fruit set (pods per flower) (Fig. 7). There was some evidence that high seed set depends in part on birds. Mangawhero (MW) and Lake Rotoaira (LR), the only sites with observed bird visitation, also had the highest seed set levels. However, pollination success in flax, measured as either fruit set or seed set, was not significantly related to any of the variables examined, including visitation rates by birds or insects, or nectar standing crops. There was no evidence that the presence of honeybees at a site affected either measure of seed production. Flax, like heather, appears able to produce abundant seed under all the pollination regimes we observed.

3.3 COMPETITIVE INTERACTIONS OF HONEY BEES AND NATIVE INSECTS

Comparisons of sites with different honey bee densities

The abundance and diversity of insect floral visitors for manuka and *Hebe stricta* was examined under different honey bee densities. Overall, manuka had the widest range of flower visitors, with 32 insect species observed (Table 2). A total of 23 insect species were observed foraging on *Hebe stricta*. The insects were classified into five guilds—honey bees, native bees, nectar feeding flies, pollen feeding syrphids and others including bumble bees (*Bombus*), wasps

Figure 5. Nectar standing crops in flax (mean ± standard error) expressed as milligrams sugar equivalents at seven study sites in Tongariro National Park (see Fig. 2 for site details).

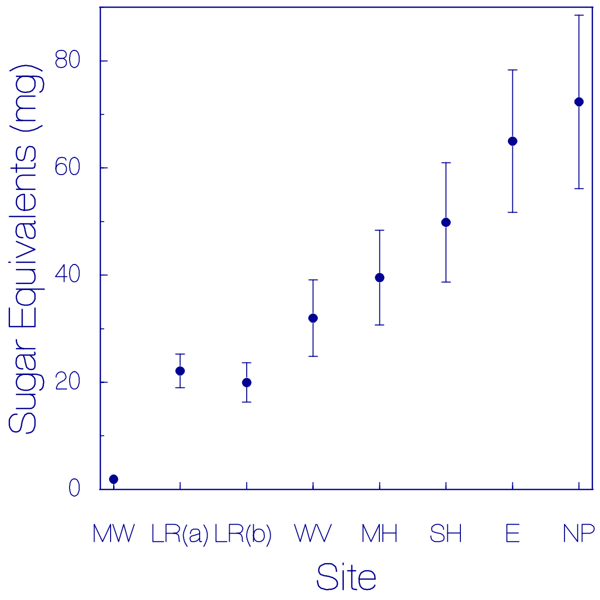


Figure 6. Fruit set (pods per flower) in flax (mean ± standard error) at six study sites in Tongariro National Park (see Fig. 2 for site details).

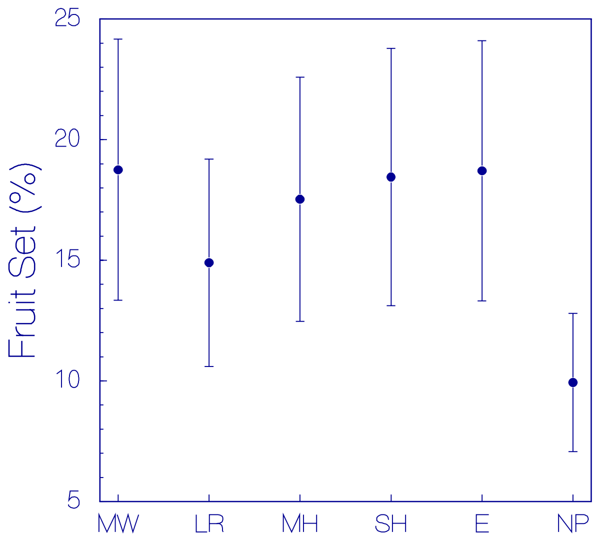


Figure 7. Seed set (seeds per ovule) in flax (mean ± standard error) at six study sites in Tongariro National Park (see Fig. 2 for site details).

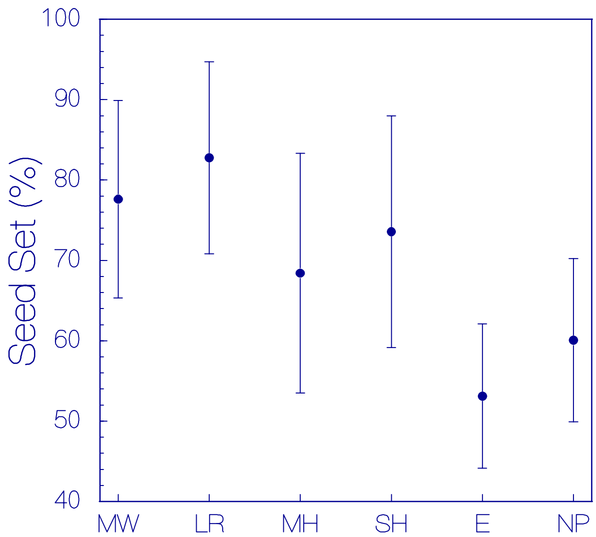


TABLE 2. FLOWER VISITOR DIVERSITY FOR TWO PLANT SPECIES (A) MANUKA AND (B) *Hebe stricta*.

(A) MANUKA

SITE	HONEY BEES (NO./MIN)	NATIVE BEES	NATIVE FLIES	SYRPHIDS	TOTAL
Lake Rotoaira	1.26	2	3	3	11
Mangahuia	0.05	2	11	5	20
Taranaki Falls	0.02	2	5	3	12
Silica Rapids	0	2	14	2	19
Total	-	2	22	5	32

(B) *Hebe stricta*

SITE	HONEY BEES (NO./MIN)	NATIVE BEES	NATIVE FLIES	SYRPHIDS	TOTAL
Lake Rotoaira	2.14	1	4	1	8
Mangahuia	2.20	2	4	0	9
Ketetahi	1.00	1	7	1	12
Mangawhero	1.34	1	9	2	15
Total	-	2	15	2	23

(*Vespula*) and for *Hebe stricta,* the copper butterfly (Lycaenidae). The number of species observed in the three main native guilds are shown in relation to honey bee densities at each site (Table 2). In general, there was an inverse relationship between honey bee abundance and native insect diversity, particularly of native flies.

Changes within sites when honey bees are brought in

During the initial sampling period at Mangawhero, honey bees were not present in high numbers. However, when the site was surveyed three weeks later, large numbers of honey bees were seen foraging at the site. As the number of honey bees increased (Table 3), there was a decrease in the number of native insect pollinators observed. In other studies, the number and diversity of insect pollinators has been shown to vary dramatically between sites, day and the time of observation (Primack 1983). These differences may be related to temperature (Primack 1983, Arroyo et al. 1985), wind (Kevan & Baker 1983) or altitude (Arroyo et al. 1982).

Butz Huryn (1995) suggests that New Zealand native flower visitors are limited more by weather conditions than the presence of honey bees on flowers, and that honey bees merely represent an addition to pollinator assemblages. However, analysis of the pollinator assemblages of manuka and *Hebe stricta* in our study suggests that some of the observed differences may be associated with honey bee densities and that the abundance and diversity of diptera may be influenced by increased honey bee activity. This trend is most apparent for *Hebe stricta* at Mangawhero, where honey bee numbers increased considerably over a three week interval. When honey bee activity in the area was high

TABLE 3. TEMPORAL CHANGES IN FLOWER VISITOR DIVERSITY FOR *Hebe stricta* AT MANGAWHERO.

DATE	HONEY BEES (NO./MIN)	NATIVE BEES	NATIVE FLIES	SYRPHIDS	TOTAL
11 February	0.18	1	9	1	14
14 February	0.87	1	7	2	13
8 March	5.50	1	0	0	3
Total	-	1	9	2	15

(encounter rate 5.5 bees per minute), no diptera, in either the native fly or syrphid guilds, were observed foraging on *Hebe stricta.* If it is confirmed that honey bees may have a marked effect on dipteran pollinators, it has implications for the pollination of many New Zealand native plant species (Thompson 1927, Heine 1938, Primack 1978, 1983).

Honey bees' apparent ability to alter pollinator assemblages on different plant species may be due to their using up limited resources, which may make foraging inefficient for other insect species. On the other hand, it could reflect agonistic behaviours directed towards other potential competitors. Competition between the honey bees and native insects is likely as both groups are generalist feeders, visiting a wide variety of plant species and are active during the same periods of the day. Manipulation of honey bee densities within Tongariro National Park would be useful in determining what aspects of honey bee activity are important in determining the structure of the native pollinator communities.

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