Know-how for Horticulture™

Environmental research on the impact of bumblebees in Australia and facilitation of national communication for and against further introductions

Kaye Hergstrom
Tasmanian Museum & Art Gallery

Project Number: VG99033

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The Tasmanian Museum and Art Gallery, 2002

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Industry Summary

The bumblebee *Bombus terrestris* was first sighted in Tasmania in 1992 and has since become established in some areas. This is the bumblebee species used extensively throughout North America, Europe, Japan and New Zealand as an efficient pollinator.

There is considerable interest in Australia in the possible use of bumblebees to improve pollination of greenhouse vegetable and fruit crops, for market competitiveness. Serious concerns exist, however, about the possible deleterious effects that bumblebees may have on Australian flora and fauna.

In this three year project, we sought to answer the questions: what environmental impact has the bumblebee *Bombus terrestris* had on the native flora and fauna in Tasmania since its arrival in 1992, and what impact is this species likely to have on the native flora and fauna of mainland Australia and other current ecosystems, if it was introduced there to aid pollination of agricultural crops?

From scientific research, and a public survey, we recorded the following impacts and characteristics of bumblebees in Tasmania:

1. Evidence from the public survey, scientific survey and the data from the Royal Tasmanian Botanical Gardens consistently point to *B. terrestris* preferring introduced plants compared to native Australian plants.
2. A significant increase in the seed set of two minor weeds; Tree Lupin, *Lupinus arboreus* (29.7%) and Greater Trefoil, *Lotus uliginosus* (40.2%) in the presence of bumblebees, but a decrease in the seed set of the major weed Scotch Thistle, *Onopordum acanthium* (13.2%).
3. A significant increase (over three fold) in the number of pods produced per stem of common (native) heath *Epacris impressa* in the presence of bumblebees, but that bumblebees only visited 4% of the flowering periods observed at 30 sites.
4. A low visitation rate by bumblebees to *Eucalyptus globulus* (2% of pollinators observed at 18 locations), which is an important food source for the endangered swift parrot *Lathamus discolor.*
5. Bumblebees were not observed to forage on the native plant *Gompholobium huegelii* for two dry years when flower abundance was low, but in the 2001-02 flowering season, when flower abundance war relatively high, bumblebees comprised 7% of potential pollinator visitors at Huon Road, and 14% of visitors at Snug Falls Track.
6. Significantly higher populations of bumblebees in urban areas on introduced plants compared with rural or bush areas, with the mean count of bumblebees per hour in remote bush areas on native plants being only 2.5% of the mean count of bumblebees in urban areas on introduced plants.
7. In comparison with native pollinators, bumblebees occurred at higher mean densities only at urban locations on introduced plants.
8. A distinct preference of bumblebees for introduced plants, with only 11.1% of plants observed being visited at the Royal Tas. Botanical Gardens over 2.5 years being native Australian plants, and only 10.9% of the 1028 sightings of bumblebees on plants across Tasmania being native Australian plants. By far the most popular plant taxon was lavender *Lavandula* spp. (with 120 sightings, compared to 112 sightings on all native plants).

9 A check for internal and external pests and pathogens on bumblebees from across Tasmania revealed only one species present; a small mite *Kuzinia laevis* (a pollen feeder only ever recorded on *Bombus* species).
10 Observations of bumblebees across the State indicated that they are more likely to establish in wetter areas, around townships, and places with suitable overwintering sites.
11 A distinct cyclical pattern for bumblebee populations, commensurate with winter hibernation. For example, 60.4% of the 1022 sightings by the public occurred in summer, 27.5% in autumn, 1.5% in winter, and 10.6% in spring.
12 1% of bumblebee sightings by the public were offshore, including two bumblebees hitching a ride on a Parks and Wildlife boat to an outer island, and one bumblebee seen 28 km offshore, heading from the Tasman Peninsula to Bruny Island in a direct line. This suggests that *B. terrestris* could island hop or hitchhike to the mainland of its own accord.
13 Proof that a colony of bumblebees reared in artificial nests can be transferred to two remote bush sites and survive and produce queens there. Similarly, we monitored the survival of a naturally occurring small population of bumblebees at a remote site in the South West national park over two summers, until it died out in January 2002.
14 Many quirky changes to seed set of various plants were recorded by the public, eg an increase in the seed set of orange nasturtiums over yellow nasturtiums, cross-pollination of snapdragons by bumblebees producing a new coloured variety, efficient pollination of rhododendrons by bumblebees resulting in early flower droop, and an increase in seed set of some bean crops and blueberries, but a dramatic reduction in yield of one broad bean crop due to nectar robbing.

In conclusion, the research examined for the following impacts: competition with native pollinators, introduced pathogens that could switch to honeybees or native pollinators; changes to the seed set of native plants, and changes to the seed set of introduced weed species. What we established was closely related to the bumblebees biology: that because bumblebees only store two to three days food supply, they are reliant on a constant supply of nectar and pollen. To survive, a colony needs to have an abundance of nectiferous flowering plants within flight range. In Tasmania, constant flower abundance occurs mainly in urban and rural areas, and this was where bumblebees (and their impact) are concentrated. It is not surprising therefore, that the only significant impacts observed were changes to seed set of preferred plant species, usually near urban areas.

Photo: Mike Tobias

Technical Summary

At the beginning of this project a National Workshop on bumblebees was held, so that experts and stakeholders for and against the introduction of bumblebees could discuss the issues, and advise on the focus for this research project, and what methodology should be used. The National workshop decided on the following key questions for a bumblebee EIS to address:

1. Distribution
2. Pests and Pathogens
3. Impact on Native Plants
4. Sleeper Weeds
5. Effect on other Species of Pollinators

1. Distribution

The public survey and scientific monitoring indicated that *B. terrestris* preferred the wetter parts of the State, and urban areas. Both the public and scientific surveys indicated a distinct preference for introduced, rather than native, plants. Although *B. terrestris* was shown to be highly polylectic, and bumblebees were recorded on 198 plant species in the public survey, the scientific survey indicated that they exhibited distinct preferences, upon which they concentrated most of their foraging effort.

Trials to study nesting survival in remote bush areas proved that implanted *B. terrestris* colonies could survive there and produce queens. This result was confirmed in field observations at MacPartlan Pass over two years: a population of *B. terrestris* was monitored in the area until it died out in January 2002, presumably after a long period of inclement weather exhausted food reserves in nests, or because of nest flooding.

2. Pests and pathogens

The dissection of bumblebees collected from across the State indicates that Tasmanian bumblebees are largely free of parasites. Despite the long list of parasitic organisms that are recorded to associate with them, only one species of mite, *Kuzinia laevis,* considered a benign pollen-thief that is specific to the genus *Bombus* (Chmielewski, 1971, 1991) has co-invaded with *B. terrestris*. Therefore, the success of Tasmanian bumblebees could partially be attributed to their relatively parasite-free status.

3. Impact on native plants

The seed set of *Epacris impressa* was studied at 30 sites across South-East Tasmania, and it was found that *B. terrestris* was only present at 4% of flowering periods observed. On those occasions when they did forage on this plant, seed set was significantly higher compared with the mean seed set of flowerings when bumblebees were absent.

The visitation rates of *B. terrestris* to *Eucalyptus globulus* around Hobart and on the East Coast were also studied and it was found that bumblebees were only 2% of the total number of potential pollinators observed at the 18 locations checked. Honeybees were, by far, the most dominant visitor of *E. globulus* (56%), with birds being the second most prevalent visitor (25%). Bumblebees were present at two out of the 24 random monitorings, and were present on an average approximately half that of native bees (2% vs 4%).

Bumblebees were studied on *Gompholobium huegelii,* and it was found that they were only present when flowers were abundant, and plant population densities high. The level of competition with local pollinators then was variable, ranging from absent in December 2001, to 10% of visitors at Huon Rd in January 2002, to being the major bee visitor in mid-January 2002 at Snug Falls. The number of healthy seeds per pod was slightly higher at Snug Falls.

4. Impact on weed species

The three weed species most often associated with bumblebees were studied in the scientific survey. A significant increase was found in the seed set of two weed species with pea-type flowers: Greater Trefoil, *Lotus uliginosus* (40.2%), and Tree Lupin, *Lupinus arboreus* (29.7%). Also studied was a major weed from the Asteraceae family Scotch thistle, *Onopordum acanthium*. In this case, we found that the presence of *B.terrestris,* at locations where this weed occurred, was associated with a significant (13.2%) reduction in seed set. This was presumably due to nectar robbing of florets, but the florets are so tightly packed on the head of a stalk, that it is not possible to observe how a pollinator is collecting nectar. Introduced plants observed being nectar robbed during the project were: garden plants *Abelia* sp., *Aquilegia* sp. and *Salvia microphylla*; and a vegetable with a large pea flower; Broad Bean, *Vicia faba.*

5. Effect on other species of pollinators

The effect on other species of pollinators was studied by monitoring population densities of all potential pollinators observed throughout the project. This was on the assumption that the level of competition is directly related to the amount of foraging activity observed. Data indicated that honeybees are the dominant visitor, particularly at urban sites on introduced plants. Bumblebees are predicted to be more populous than native pollinators on introduced plants at urban sites, but significantly less on native plants at remote bush, rural, and urban bush locations. Bumblebee population densities are predicted to be not significantly different to native pollinator populations at bush locations on introduced plants, such as weeds.

6. Recommendations to industry

As there were significant changes recorded to the seed set of different plant species, industry must now compare and contrast the financial gains of the introduction of this new pollinator, to costs associated with the potential shifts in seed production of non-targeted plant species. Industry should then present their case to government, on the introduction of bumblebees, using this report as evidence of the environmental impact of *B. terrestris* in Tasmania.

Further research

To confirm predictions made regarding the impact of *Bombus terrestris* in Tasmania, it is recommended that:

- Laboratory tests be undertaken to confirm that the body mite, *Kuzinia laevis* found on Tasmanian bumblebees is specific to the genus *Bombus*.
- The survey/distribution data, and knowledge of preferred plant species and overwintering site requirements could be analysed, using an environmental modeling program such as Climex, to predict the habitat range of *B. terrestris* on mainland Australia.
- The flowering period of *Gompholobium huegelii* could be studied at more sites to confirm an increase in seed set in the presence of bumblebees.
- Broad bean crops could be surveyed to estimate the mean change in yield in the presence of bumblebees.

1. Introduction

1.1 Historical background to the project

There have been some attempts to introduce bumblebees into Australia in the past. In New South Wales, in 1891, bumblebee queens were released in the Sydney Botanic Gardens, Centennial Park, Merrylands, Penrith, Valley Heights, Maitland, Kiama, Bodalla, Bathurst, Tenterfield and at the Hawkesbury Agricultural College, Richmond (*Agricultural Gazette of NSW*, 1891). In 1909, consignments of bumblebees from New Zealand were released in the Botanical Gardens, Hobart, Falmouth (North-East Tasmania) and Gunns Plains (North-West Tasmania) (*Tas. J. Council of Agric*., 1909). The absence of specimens or sightings, before 1992, would indicate that these earlier introductions failed.

In 1992, a specimen of the bumblebee *Bombus terrestris audax* (L.) was collected in an inner city park in Hobart, Tasmania (Semmens *et al*., 1993). It is not known whether the recent introduction was accidental or deliberate. The source of the introduction is believed to be New Zealand, where four bumblebee species were successfully introduced from England in 1885 and 1906, for pollination of red clover (Donovan, 1980).

By 1993 it became apparent that this exotic bee species had become established in Tasmania, and would be impossible to eradicate. Its steady spread was recorded (Buttermore, 1997). People began to investigate whether this population could be used for agricultural purposes (Pomeroy *et al*., 1997 HRDC Project No: HG 631). Other people began to claim that this exotic bee species was a threat to Australian ecosystems and native pollinators (Hingston, 1997: Hingston & McQuillan, 1998).

In Australia, studies such as those reported by New (1997) and Paton (1993) found that introduced species of social Hymenoptera, such as the honeybee, *A. mellifera,* often reach high densities which threaten the long-term viability of the native biota. By contrast, a survey by Ettershank & Ettershank (1992), which examined the interactions between honeybees and native insects on Tasmanian leatherwood trees (before the advent of bumblebees to the State), found that at that time the leatherwood resource was sufficient for both native and introduced foragers.

Five research projects have studied different ecological aspects of Tasmanian bumblebees. Semmens (1996) looked at flower visitation; Buttermore (1997) measured population counts and production of reproductives of some successful colonies; Buttermore *et al*. (1998) found that the population was sufficiently inbred for diploid male production to be a factor in commercial rearing; and Hingston (1997) found evidence that *B. terrestris* may interfere with the foraging of two species of native leaf-cutter bees, and a species of colletid bee. The latter study was restricted to southern Tasmania during the summer of 1996. This may not have been sufficient time to gauge long-term effects. In the same study, Hingston also observed *B. terrestris* foraging on a wide range of native plants in several vegetative types (Hingston & McQuillan, 1998).

1.2 Impact of the introduction of bumblebee species in other countries

As with the importation of biological control agents, the movement of bees for agricultural purposes is currently a controversial issue. Bumblebees have been recently introduced into new habitats overseas: for example: *B. ruderatus* to Chile as part of an Organization of American States aid project to pollinate red clover (Arretz & Macfarlane, 1986); *B. terrestris* glasshouse colony escapees invading new regions of Israel (Dafni & Shmida, 1996); *B. terrestris* introduced to Japan in 1991 to pollinate glasshouse crops (*Japanese SCE*, 2000), *B. terrestris* to Tasmania (Semmens *et al.*, 1993); *B. impatiens* (native to eastern USA) moved to western states as a commercial replacement for *B. occidentalis*, due to outbreaks of the protozoan *Nosema bombi* in the *B. occidentalis* rearing facilities (van Doorn, Koppert Biological Systems, pers. comm.).

The effects of these movements have not been extensively studied, except for the Israeli experience, where Dafni & Shmida (1996) made observations over several years and concluded that the bumblebee threatened the biodiversity of the local bee fauna, including the honeybee (See also Dafni, 1998). *Bombus terrestris* has since disappeared from this study site (Dafni, pers. comm.). In Japan there have been 22 sightings from six areas over the nine years since *B. terrestris* was introduced.

In New Zealand, where bumblebees were introduced over 100 years ago, Donovan (1980) reviewed the interaction between native and introduced bees. He concluded that bumblebees forage primarily on introduced plant species. Since the peak period for native bee foraging occurs during the "honey flow" when pollen and nectar are abundant in both introduced and native plant species, competition between species for food is reduced.

1.3 Why the project was undertaken: its significance for industry

In 1995, Tasmanian Greenhouse Tomato and Vegetable Growers Association (TGTGA) twice applied to AQIS to import new *B. terrestris* genetic material into Tasmania. AQIS advised that in order to do this, major concerns about disease and environmental risks would need to be assessed. Discussions between interested parties stalled because of the lack of hard evidence and divergence of opinion. Criticism has centred on the lack of scientific evidence concerning the potential impact of this species on the Australian environment.

It has become apparent that approval to use this exotic bee species to pollinate crops commercially on mainland Australia, would not be given by Environment Australia and state quarantine authorities until an environmental impact assessment in Tasmania had indicated that the introduction of this species would not dramatically alter the current status of native and agricultural ecosystems.

Using bumblebees to pollinate greenhouse crops is expected to result in a significant increase in yield and fruit quality, as it has done in Europe, USA, Japan and Israel etc. It has also resulted in improved Integrated Pest Management (IPM) practices, and a reduction in chemical sprays applied to crops. Bumblebee pollination technology (using principally *Bombus terrestris)* was introduced in 1989 to assist greenhouse growers in Europe to improve marketable quality yields, and reduce costs and pesticide usage. Success was immediate and spectacular: now bumblebees are artificially reared and their hives are sold to growers for use with more than 25 crops in more than 30 countries (see Photo 2 page 8). Australia is one of the few developed countries that does not have access to this technology. The process was initially developed for greenhouse crops, but field crop pollination has also benefited (Barron *et al*., 2000).

Within Australia *B. terrestris* is found only in Tasmania which, for purposes of quarantine, is regarded as isolated from the mainland. Although horticulturalists and other agricultural producers are anxious to use them to pollinate commercial crops, the possible deleterious effects of bumblebees on Tasmanian flora and fauna must be minimal or absent to allow their use on the mainland. As a result, HRDC agreed to fund a three-year, $239,266 EIS by the Tasmanian Museum and Art Gallery (TMAG) beginning September, 1999.

1.4 Aims of the project

This project aimed to investigate what impact bumblebees are having in Tasmania, in an attempt to answer the question: does *Bombus terrestris* represent a significant environmental threat to Australian ecosystems?

The first part of the project was to conduct a National Workshop, in late November 1999, with the aim of identifying key environmental issues related to the possible import of bumblebees (or their genetic material) into Australia. A steering committee of experts then decided upon a strategy to investigate the five areas of importance: distribution; pests and diseases; the affect on native pollinators; the affect on native plants; and the affect on weed species.

Photo: Roger Buttermore

Photo 2. Commercial bumblebee domiciles in use in Europe

2. National Workshop to facilitate communication for/against further introduction of *Bombus terrestris* for pollination of horticulture crops in Australia

2.1 Introduction

Thirty-six industry, government, and conservation stakeholders participated in the National Bumblebee Workshop which was facilitated by Dr Peter Box (Integra Ltd), hosted by the Tasmanian Museum & Art Gallery (TMAG) and made financially possible by Horticulture Australia (Project No. VG99033). The aims of the workshop were to identify the key environmental questions relating to the possible introduction of bumblebees into Australia, and to discuss the research methodology necessary to address the key environmental issues of the project.

Before arrival, participants were provided with all the available background information, including the submission to AQIS and Environment Australia regarding the introduction of bumblebees to Australia. On day one of the workshop, participants were told:

1. that they were *not* charged with deciding whether or not bumblebees should be allowed into mainland Australia (this is the role of Environment Australia/EA), but rather to make sure the right questions were addressed in the project;
2. that there were obviously many associated issues (commercial issues, use of native bees, etc.) but these were not the focus of the workshop (although there was time on day two to discuss these concerns);
3. that there was a steering committee to finalise the methodology for the project.

On day one, eight key representatives from government, conservation, beekeeping, horticulture and environment sectors gave a series of short talks, presenting their views on the possible introduction of bumblebees into Australia. Presentations covered a variety of points from quarantine procedures to bumblebee colony development.

In general, speakers were asked to:

- take the perspective of the stakeholder group, not just a personal stance;
- provide the reasons/evidence to support their view;
- identify the environmental issues/questions (from their point of view) that need to be researched as a basis for EA to make a decision.

In the afternoon, based on all the presentations, seven table groups (each led by a member of the Steering Committee) discussed and identified five to six key/specific environmental issues that needed to be researched. These points were then reviewed by the whole group and descriptions of the main issues (and the reasons for them) were listed in order of importance. Day one finished with a summary of relevant references and parallel research projects and the proposed methodology and work to date (to be refined by the Workshop) for this project.

Day two was a half-day session. First, working in table groups, further detail/refinements/improvements to the issues/methodology and the project outline so far were presented to the whole group. Then, table groups identified some of the five or six most critical ‘other’ issues or questions (outside the brief of the present project) that require investigation. A secondary aim here was to identify who should deal with these issues. The workshop concluded with the steering committee meeting to evaluate the practicalities of the research methods suggested.

2.2 Program Outline- National Workshop on Bumblebees, November 1999

Day 1

9.00 am	**Welcome:** Ms Patricia Sabine, Director, Tasmanian Museum and Art Gallery **Overview:** Dr Les Baxter, Project Manager, HRDC **Workshop structure and process:** Dr Peter Box, Integra Ltd, Victoria	
9.20 am	Background to a submission to import bumblebees from New Zealand Dr Stephen Goodwin, Applicant Questions and discussion	
10.00 am	Perspectives on possible importation of bumblebees from the different stakeholder groups:	
	Environment Australia	Mr Rob Moore
	Australian Quarantine Inspection Service	Dr Glynn Maynard
	Hydroponic Farmers Federation	Ms Anne Wilson
10.50 am	Morning Tea	
11.20 am	Presentations/questions continued:	
	Conservationists	Dr Katja Hogendoorn, Flinders University
	Australian Beekeepers	Mr Bob McDonald
	Tasmanian Beekeepers Association	Mr Col Parker
	Bumblebee production companies	Dr Nelson Pomeroy, Zonda Ltd, NZ
12.30 pm	Lunch	
1.30 pm	Discussion to clarify the key environmental issues or questions relating to possible bumblebee introduction into Australia that need to be researched	
3.00 pm	Afternoon tea	
3.30 pm	Overview of current research relating to bumblebees Mr Roger Buttermore, Senior Curator (Invertebrate Zoology), Tasmanian Museum and Art Gallery Literature review and discussion to identify other relevant work	
4.15 pm	Overview of HRDC project: Proposed research methods Ms Kaye Hergstrom, Research Officer, Tasmanian Museum and Art Gallery Discussion and initial reaction	
5.00 pm	Close	

Day 2

8.30 am	Workshop to identify refinements/improvements to the methodology of the HRDC project
10.00 am	Morning Tea
10.30 am	Workshop to identify other critical aspects relating to bumblebees/pollination of horticulture crops that require research (beyond the environmental issues relating to possible introduction of bumblebees). Research options/alternative approaches to be considered. Who/how should these be pursued.
11.45 am	Next Steps and Final Address to the Workshop Dr Les Baxter
2.00 pm	Steering Committee met to plan Research Procedure

2.3 Outcome

The Workshop identified four possible ways in which bumblebees might impact on the Australian environment. They were:

- altered seed set of native plants;
- altered seed set of weed species;
- the possible introduction of diseases which may impact on honeybees and local bee species;
- a possible adverse effect on the local pollinators through competition for nectar and pollen resources.

A detailed subset of questions and methodologies for investigating each key question is provided in *Proceedings of the Workshop*, which is displayed on the TMAG web site: http://www.tmag.tas.gov.au/workshop/proceedings.html

After representatives of stakeholders had given their presentations, working groups were formed, and key environmental issues and relevant methodologies were discussed. The workshop decided on the following key questions for a bumblebee EIS to address:

1. Distribution
2. Pests and Pathogens
3. Impact on Native Plants
4. Sleeper Weeds
5. Effect on other Species of Pollinators

Ecologists at the national workshop felt that research on weeds would be the most likely area to observe/record a significant impact, and that emphasis should be placed on this aspect of the research. The Project Steering Committee approved the recommendations for the research method, subject to statistical and legal requirements. Each researcher of the five areas had an external referee for advice. Research methods used are outlined in the following chapters.

3. Distribution and plant preferences

Surveys consisted of three distinct sections:
A: a broad survey conducted by members of the community;
B: a scientific research survey;
C: a survey of the survival of nests at different locations.

3A. Public survey of *B. terrestris* distribution and feeding activities within Tasmania

A public survey has been conducted to obtain information on the current distribution of *B. terrestris* within Tasmania, and information on the species of plants they visit. This base data will help predict the potential of *B. terrestris* to be a competitor with other pollinators for pollination resources.

3A.1 Materials and methods

Members of the Tasmanian community were recruited to conduct a State-wide bee census and floral preference survey. In January, 2000, the Tasmanian Museum printed 20,000 copies of an information sheet/survey form. The bumblebee survey form is displayed at http://www.tmag.tas.gov.au/bumblebees/bee_survey.htm. Titled " Have you seen any bumblebees in Tasmania?" it included color images of bumblebee castes, honeybee *(Apis mellifera)* workers, native bees, a hoverfly and a European wasp. It included information about bumblebees in Tasmania, and a simple, fool-proof survey form, asking the date, time, location, weather conditions, habitat type, description of bumblebee activity, description of any plant species visited, and pollen load presence or absence. Participants were asked to estimate the numbers of bumblebees present, and whether they had seen any in national parks. A return address, phone and email details were included.

Three hundred copies of the public survey were hand delivered to each of 11 National Parks, in January 2000. Further copies were sent out as required in 2001 and 2002. We decided to target enquiries at wilderness and other bush areas to discover the extent of bumblebee populations in these areas. Rangers at all National Parks were requested to hand out regularly small numbers of surveys to bushwalkers, tourists, and parks and wildlife employees. Copies were also sent to all Landcare groups, Weed Alert Network, 240 Volunteer Fire Brigades, visitors to the Tasmanian Museum, and members of the public upon request.

In January 2000 and 2001, local newspapers in Launceston and Hobart ran articles on bumblebees, and many people 'phoned to report sightings of bumblebees, mainly in the South-East and the North-West of the State. Four ABC radio programs encouraged other people to report further sightings. In 2001 and 2002, a check was made on the presence of bumblebees in areas where bumblebees had been reported by: contacting previous information senders; sending out another 5,000 forms per year; speaking to National Parks officers; and through newspaper articles, which were very successful in contacting observers. When people who sent in information were contacted by phone, they were asked when they first saw bumblebees at the location mentioned (= first time sighting).

3A.2 Results and discussion

From January 2000 to May 2002, there was a constant flow of surveys sent back by local and interstate visitors to National Parks, and by other members of the general public. The first year of the survey alerted researchers to the recent incidence of bumblebees in the following areas for the first time: Tasman Peninsula, South Arm, some East Coast towns, the Lake St Clair area, Smithton and the Sheffield area. Since then, *B. terrestris* has become established around Port Arthur and Nubeena on the Tasman Peninsula, around Strahan, Rosebery and Queenstown on the West Coast, and has been seen at forty-seven locations around the North-West (particularly in 2002). Sightings along the East coast towns are still few, with no sightings in the North-East since 2000, and only four sightings in the Launceston area.

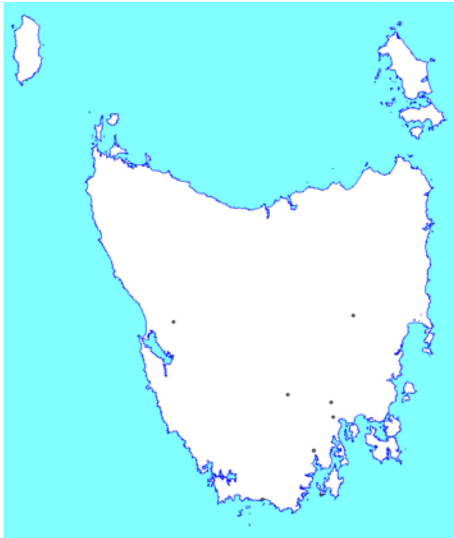
Bumblebees appear to struggle for survival in Tasmania's second largest city Launceston, where presumably there are useful resources for *B. terrestris* (floral resources and nesting sites of abandoned rodent nests). An untested theory is that *B. terrestris* has failed to thrive in Launceston because it has difficulty finding good overwintering sites there. This theory is based on the fact that places where a high concentration of emerging queens in spring (South Hobart, Cockle Creek) have been observed, have sloping, well drained soils with an insulating cover of moss where queens can dig in about 20 cm, and be protected from the elements (rain, cold) while they hibernate.

One thousand and twenty-two sightings were reported by a total of 613 people. Of these sightings, 60.4% occurred in summer, 27.5% in autumn, 1.5% in winter, and 10.6% in spring. The chances of sighting a bumblebee in an area are related to population density, but these data still suggest that bumblebees are common in summer, less common in autumn, rare in winter, and starting to increase in spring.

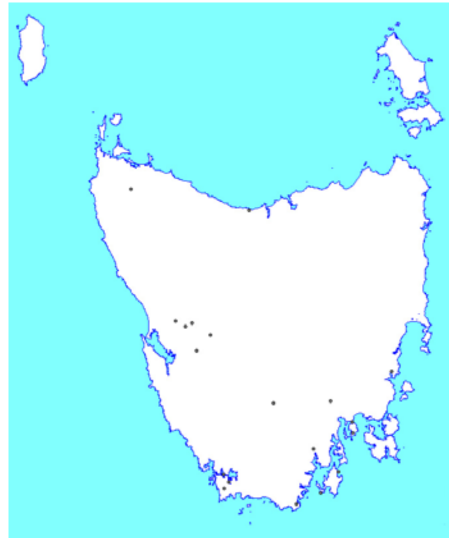
As shown in Figure 3.1, (observations in the summers of 1997-98 to 2001-02) in the summer of 1997-98 there were only six sighting locations, occurring in the lower half of the State. By the summer of 1999-2000, there were many reported sighting locations in the South of the State, spread out over a wide area, and several sightings in the North and West of the state. By last summer (2001-02), bumblebees were becoming a common sight in the South, North-West and West of the State, but still struggling to establish themselves in the Launceston area, the North-East, and on the East Coast.

Migration flights of *B. terrestris* have been reported in Europe: in spring, in Finland (Mikkola, 1978, Vepsalainen & Savolainen, 2000) and in autumn on the French coast (Danreuther, 1946). Migration was attributed, by one author, to bumblebees escaping predators (Mikkola, 1978). Other authors suggested spring flights could rid bumblebees of strong nest-site competition among colony-founding queens, and of severe predation by voles (small European rodents) in high vole-density regions. They could also take advantage of abundant, empty vole burrows as nest sites in low-predation, relatively vole-free areas (Vepsalainen & Savolainen, 2000). The only predators observed here in Tasmania have been European wasps, *Vespula germanica* (sighting by L.J. Carter, Queenstown, January 2001) and trout on Lake Burbury (sighting by Brian Naylor, Parks & Wildlife, January 2000). The sighting of more than 20 dead queens found on the mossy ground at Cockle Creek, in early spring 2001, may indicate that birds also predate on this newly introduced species, but no actual predation was seen (Hergstrom, personal observation).

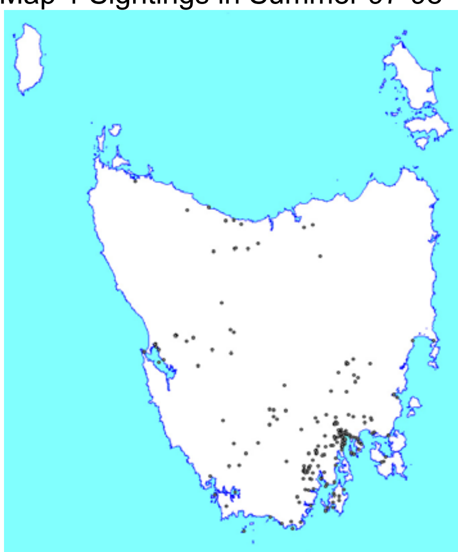
It was reported in Scotland that *B. terrestris* extended its range 98 km northwards between 1976 and 2000 (Macdonald, 2001). Aspects of that migration noted were: that it coincided with a 15% increase in precipitation; migrations were concentrated in areas with large towns (sightings at Aberdeen, Inverness); and that there were new records of queens in both spring and autumn (Macdonald, 2001).



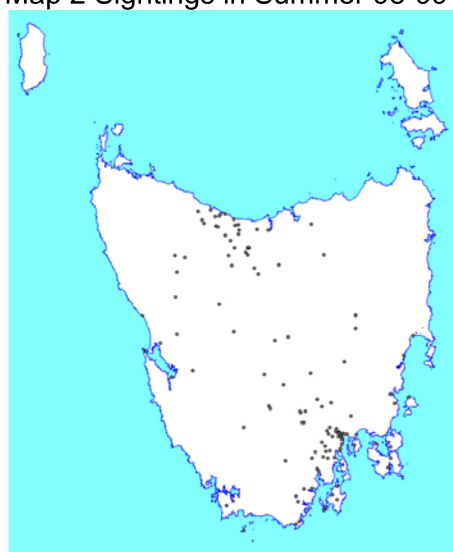
Map 1 Sightings in Summer 97-98



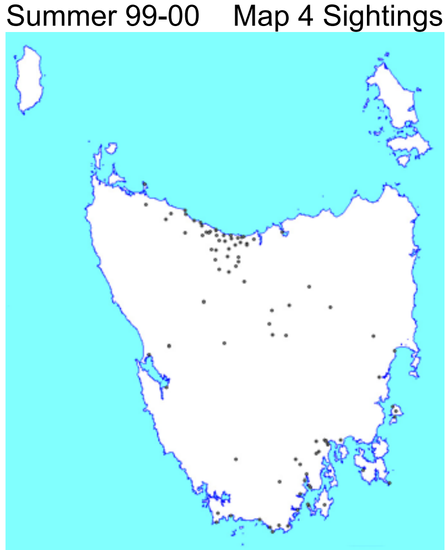
Map 2 Sightings in Summer 98-99



Map 3 Sightings in Summer 99-00



Map 4 Sightings in Summer 00-01



Map 5 sightings in Summer 01-02

Figure 3.1 Public Survey of bumblebee sightings recorded across Tasmania in five consecutive summers

Figure 3.2 shows the percentage of all observations recorded in each month of the year in Tasmania, compared to the percentage of first time sightings recorded in each month. Figure 3.2 shows a higher than average % observations of first time sightings, in April, September and October, indicating migration flights may occur in Tasmania in mid autumn and early spring.

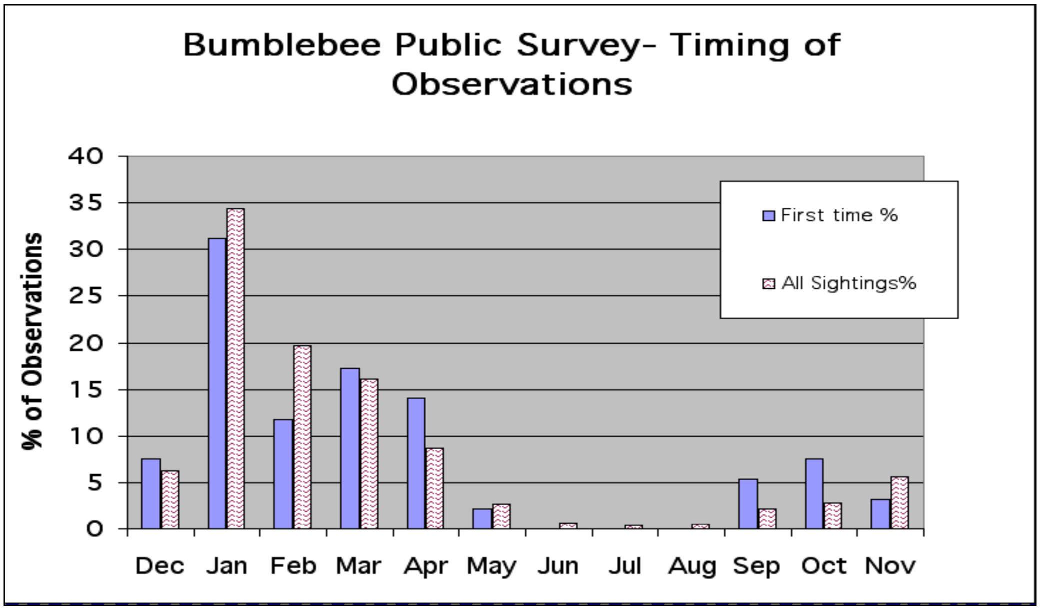
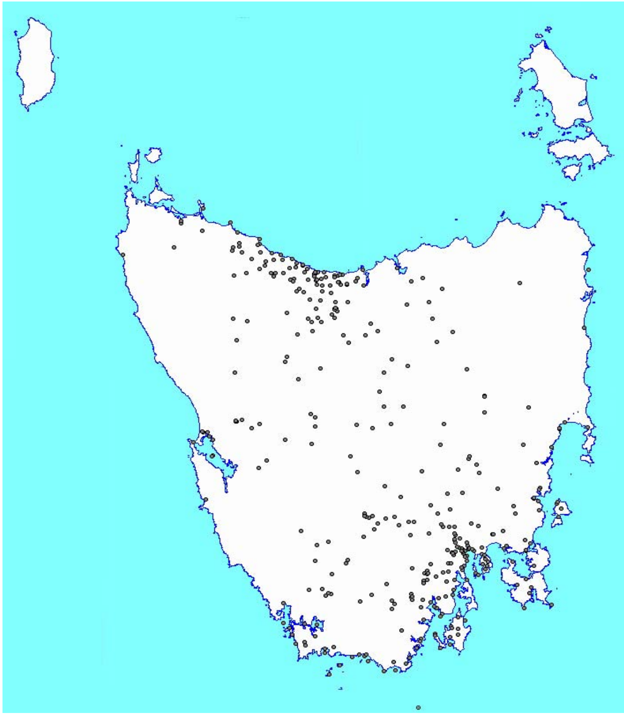


Figure 3.2 The timing of a first sighting of bumblebees at a location, compared with the timing of all sightings.

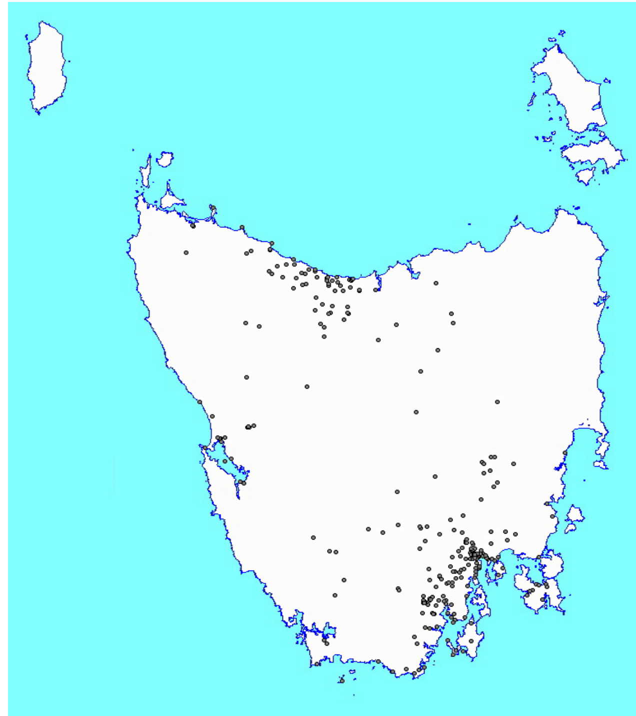
Figure 3.3 (Maps 6, 7 and 8) shows a comparison between records where only one bumblebee was observed (this would include recently arrived migrant queens); records where more than one bumblebee was observed (mostly sites where bumblebees had become established); and average annual rainfall across the state (Bureau of Meteorology). The comparison between maps suggests that one observation of a bumblebee in an area does not necessarily mean that bumblebees will become established there. Comparison between the rainfall map and the places where more than one bee was observed indicate that *B.terrestris* is more prevalent in wetter areas, and in urban areas around Hobart, where people have made artificially wet habitats with a high concentration of introduced plants in their gardens.

Sightings where more than one bumblebee was seen are a good indication that a nest may be established in an area. The proportion of these sightings in different area types were: Urban 46%, Rural 39%, Remote Bush 8%, and Urban bush 3%. The 31 sightings of more than one bumblebee at remote locations were from 25 different locations. Eighteen of these locations were from the South West National Park, three from Bruny Island National Park, two from Tahune National Park, one from Mt Field National Park, and one from the Central Highlands (Arthurs Lake) area. All these locations are in the high rainfall belt shown on Map 8, Figure 3.3.

Numbers of nests observed in different area types were: 19 urban nests, 7 in rural areas, 1 in remote bush (at Melaleuca, under sphagnum moss) and one in urban bush (Zig-zag trail, Mt Wellington).



Map 6 Sightings of 1 bumblebee



Map 7 Sightings of more than one bumblebee

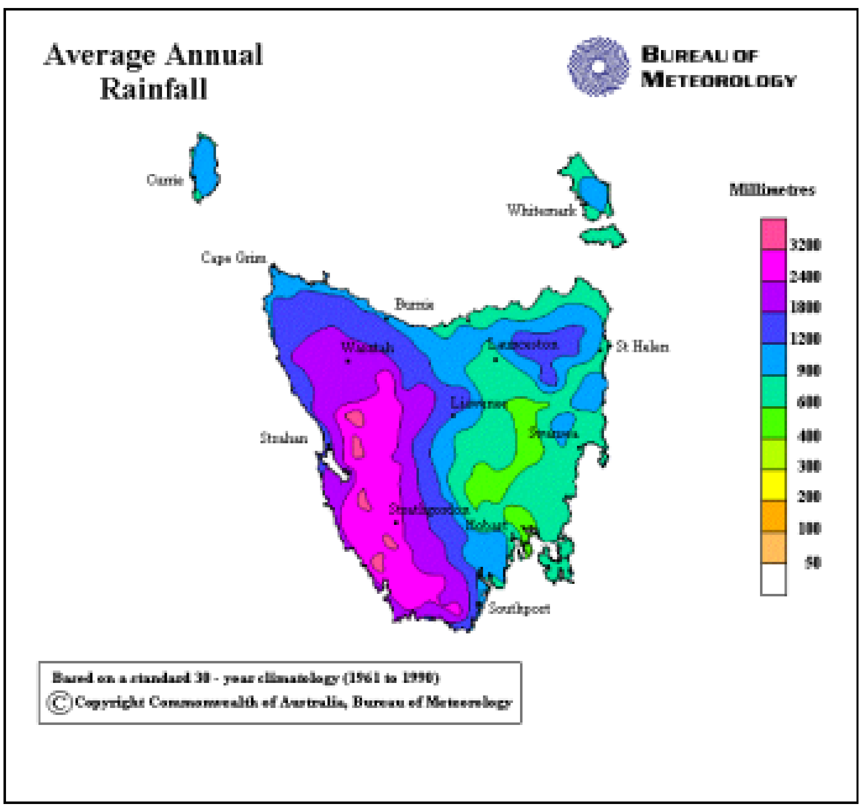


Figure 3.3. Bumblebee sightings as compared with annual rainfall across Tasmania

Map 8 Average Annual Rainfall for Tasmania

Appendix 1 gives a list of 200 plant species on which the public observed bumblebees foraging. Of the 1028 sightings of bumblebees on plants across Tasmania, 89.1% were on exotic plants, and 10.9% were on native plants. By far the most popular plant taxon was the lavender, *Lavandula* spp. (with 120 sightings, compared with 112 sightings on all native plants). The most popular plant with bumblebees was the Lamiaceae family, with 16.8% of all sightings coming from this family. Of the 72 plant families recorded as attracting bumblebees, twelve were families endemic to Australia.

3B Scientific research survey

In conjunction with the public survey, a scientific survey was conducted to compare the population densities of bumblebees to native pollinators in Tasmania: in remote bush; urban bush; and urban gardens; and also to study the relative attractiveness of introduced and native plants.

3B.1 Materials and methods

From September 1999 to June 2002, the following sites were regularly monitored (every two to six weeks, depending on the time of year):

- Royal Tasmanian Botanical Gardens (RTBG), Hobart;
- a 1 km route through North Hobart urban gardens;
- 3-5 km along Mt Wellington walking tracks: Big Bend trail; Icehouse walking track or Pinnacle track;
- 0.5km Urban route at Ferntree: base of Mt Wellington;
- native bush and urban gardens at Huon Road, South Hobart;
- Coffee Creek native reserve;
- 3-10 km along walking track at Cockle Creek.

The differences in distance and time taken on the walks were accounted for by presenting data as numbers of potential pollinators observed per hour.

The technique for monitoring was to walk slowly, so as to minimise disturbance of pollinators, and maximise the chance of seeing any pollinators. When trees or plants further than 3 m away from the track were seen to be in flower, (x8) binoculars were used to determine the identity of any pollinators. When insects moved too quickly to determine whether they were a native bee or a dipteran, or moth etc, their size and characteristic speed of movement were used to decide what type of insect taxon was observed.

All insects observed on the walk were recorded, together with numbers seen, time seen, plant they were observed on, whether they were feeding or just resting on the plant, or whether they were flying by. Ants were only recorded when they were associated with flowering plants. Samples of pollinators, for identification purposes, were occasionally taken, but this was kept to a minimum so as not to disturb the insect pollinators at sites. Birds were recorded as either calling, flying by, or feeding on flowering plants. All the data was then processed, according to numbers observed per hour.

In addition to the regularly monitored sites, observations were also made in National Parks across Tasmania each summer, and by sporadically monitoring townships and sites across the State. Some of this monitoring was at bush sites where bumblebees had been observed in the previous summer, and they were checked to ascertain whether bumblebees had become established within that area.

3B.2 Data analysis

Data from the Royal Tasmanian Botanical Gardens (RTBG), were analysed separately, as they provided a unique site to test the null hypothesis: that bumblebees were observed on exotic plants as often as on native plants. Before using analysis of variance, the data were log transformed to restore normality and correct for non-uniform variance. The means were separated using least significant difference (pr. = 0.05)

To account for the difference in distances covered and time taken on walks, observation effort was expressed as counts of pollinators observed per hour. Observation counts of all native pollinators were compared with observation counts of introduced pollinators. The null hypothesis to be tested was: that observations of honeybees, bumblebees, European wasps and native pollinators do not differ significantly between urban, rural, urban bush and remote bush sites, or between introduced and native plants. A logarithmic transformation of the data set was used before analysis. These data were analysed using REsidual Maximum Likelihood (REML), which analyses mixed model data, like ANOVA, but which can cope with the imbalance caused by the different numbers of observations obtained from each site, and plant type (*ie*. introduced or native). The means were separated using least significant difference (pr. = 0.05).

3B.3 Results and discussion

Analysis of the data from the RTBG indicated that honeybees *Apis mellifera* populations were significantly higher than all other pollinators on both native and introduced plants (See Table 3.1). On introduced plants, bumblebees were the second most prevalent pollinators. On native plants, native bees were the second most prevalent pollinators (see Photo 3 page19).

Pollinators at the Royal Tasmanian Botanical Gardens (RTBG)

Table A

Plant	mean	
Introduced	1.306	a
Native	0.893	b

Table B

Species	mean	
Honeybees	3.487	a
Bumblebees	1.457	b
Native bees	0.53	c
Hoverflies	0.172	cd
Eur. Wasp	-0.095	d

Table C

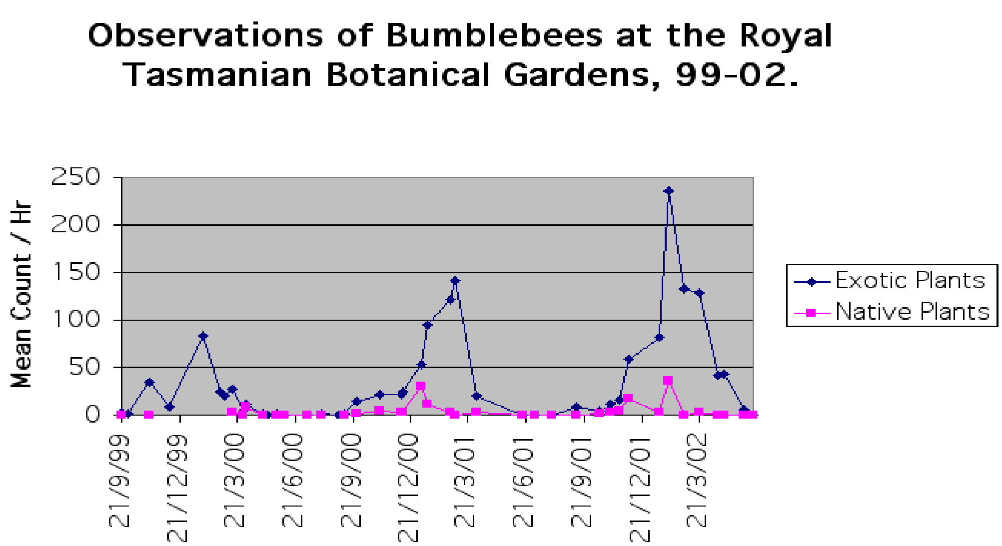
Species	Plant	Mean Count / hr	
Honeybees	Introduced	76.76	a
Honeybees	Native	54.41	b
Bumblebees	Introduced	36.34	c
Native bees	Native	10.27	d
Bumblebees	Native	4.14	de
Native bees	Introduced	3.512	def
Hoverflies	Introduced	3.415	def
Hoverflies	Native	2.405	ef
Eur. Wasp	Native	1.757	ef
Eur. Wasp	Introduced	0.854	f

Table 3.1 Pollinators at the RTBG, expressed as mean numbers observed per hour. Means followed by the same letter are not significantly different (pr. > 0.05) Tables A and B compare plant types and pollinator means and contain the converted means $=\log_e(\text{count} + 0.5)$. Table C shows a comparison of the unconverted means (mean counts per hr).

Feeding activities within Tasmania
At the RTBG, bumblebee population densities were significantly higher on introduced plants than on native plants. The rise and fall of bumblebee populations over 2.5 years at the RTBG on native and exotic plants is illustrated in Figure 3.4. Of the 955 sightings of bumblebees foraging at the site over two and a half years, 11.1% were on native plants, and 59.3% were on plants from the family Lamiacae. They were observed foraging on 80 plant species.

Photo: Mike Tobias

Photo 3. Native bee (*Megachile* sp.) on Rosemary



Pollinators at all sites

Pollinator	Site – plant type	Mean Count / Hr	No. observations
Honeybees	Urban-Introduced	5.990a	210
Honeybees	Rural	5.033a	44
Honeybees	Bush-Introduced	3.876ab	34
Bumblebees	Urban-Introduced	1.075b	210
Native pollinators	Urban-Introduced	1.038c	210
Native pollinators	Remote Bush - Native	0.626cd	119
Native pollinators	Urban Bush - Native	0.581d	346
Native pollinators	Rural	0.389de	44
Native pollinators	Bush-Introduced	0.271de	34
Bumblebees	Bush-Introduced	0.242e	34
Bumblebees	Rural	0.077fg	44
Honeybees	Urban Bush - Native	0.075f	346
Bumblebees	Urban Bush - Native	0.039gh	346
Honeybees	Remote Bush - Native	0.383ghi	119
Bumblebees	Remote Bush - Native	.027hi	119
European Wasp	Urban-Introduced	.021ij	210
European Wasp	Remote Bush - Native	.012jk	119
European Wasp	Urban Bush - Native	0.007kl	346
European Wasp	Bush-Introduced	.003kl	34
European Wasp	Rural	.002l	44

Table 3.3 Pollinators Observed at All Sites Surveyed, expressed as mean number observed per hour. Means followed by the same letter are not significantly different (pr. > 0.05)

Table 3.3 shows the predicted means after analysis of the Monitoring Data from all sites. It shows that honeybees are the dominant pollinator, particularly at urban sites on introduced plants. Bumblebees were predicted to be more populous than native pollinators on introduced plants at urban sites. But at remote bush, rural and urban bush locations, native pollinators are significantly more prevalent than bumblebees.

3B.4 Monitoring of remote sites where the public had reported sightings

Junee Caves and the Prince Charles Hut area are two sites with Leatherwood, *Eucryphia lucida* trees where more than one bumblebee was observed in summer 1999-00, when the second flowering of leatherwood occurred. These areas were checked during both a morning and an afternoon in September 2000 for over 2 hrs, during the first flowering of the leatherwood, but bumblebees were not seen. A quick check of tree lucerne plants in nearby rural areas confirmed that bumblebees had become established in the area, and could be located at nearby Maydena, within 10 minutes drive of the monitoring site.

Dr Michael Driessen noticed more than one bumblebee at McPartlan Pass (South-West National Park) in March 2000, when he was studying native mammals. He noticed four queens there again in September 2000. During a search on 20 September, 3 queens were found after monitoring for two hours. Ten similar sites along the Strathgordon Highway and Scotts Peak Dam area (where *Epacris impressa* was also in flower), produced only one other sighting: one queen foraging on *E. impressa,* 3.2 km away from the McPartlin Pass site. This area was monitored carefully to study the survival of bumblebee colonies in a remote area. The population continued to exist in the area at similarly low population densities until the end of spring the following year, when a long period of continuous rain appeared to cause the disappearance of bumblebees from the area from December 2001.

Cockle Creek was the site where the greatest number of recorded sightings of bumblebees occurred in a remote bush area. It is a camping area at the start of the South-West coast track, with approximately 50 holiday shacks with both native and introduced plants present. The site was checked on 18 and 19 September 2000, and bumblebees were found foraging on Tree Lucerne, *Cytisus palmensis*; a native coastal plant, *Leucopogon parviflorus*; Montpellier Broom, *Genista monspessulana*; and Blue Butterfly Bush, *Psoralea pinnata.* While monitoring this site during the spring of 2000 and 2001, it became evident that an inordinately high survival rate of bumblebees over winter was a strong factor in the survival of bumblebees in the area. This is attributed to the well-drained sandy soil, and the insulation characteristics of the moss present in some of the local glades.

3C Survival of nests at different locations

3C.1 Introduction

This subsection addresses the question posed by Workshop members concerning bumblebee distribution: can *B. terrestris* maintain successful colonies in Tasmanian native vegetation? (Individual bumblebees, possibly in transit, had been observed in such areas, but not a nest *in situ*.) To answer this, the Workshop members suggested transferring colonies at a young stage to bushland (out of flight range from urban gardens) to test their survival and longevity. (N.B. there is some uncertainty about the foraging range of bumblebee workers. For many years the maximum distance was considered to be 3 km, but a recent study by Goulson and Stout (2001) on *B. terrestris* suggests that the figure should be more than doubled.)

Wild bumblebee nests are normally underground, which makes them notoriously hard to find, even in suburbia. They are usually spotted by accident only after the colony becomes sufficiently populous enough to attract attention. To track a statistically valid number of bumblebee colonies from their beginning stages, it is necessary to either:

- artificially begin their development in the laboratory, using the methods of Plowright & Jay (1966); or
- allow young queens to freely nest in underground, surface, or aerial outside hives (this is called trap nesting or hive acceptance); or
- queens can be netted and briefly (i.e. a few days) imprisoned in boxes that are provided with food *ad libitum*. After this time, some queens will accept the hives and start building a nest, at which point they can be allowed their freedom. Using queens netted on sites where authorities had proscribed the importation of new stock, fifteen incipient colonies were produced in this way and then monitored in 2000-01 (Buttermore unpublished data).

Colonies obtained by any of these methods can then be transplanted to distant locations for further monitoring.

Worldwide, hive acceptance rates range from 0% (Delaplane & Mayer, 2000) to 93% (Pomeroy, 1981). The highest acceptance levels are in New Zealand, where the availability of natural nesting sites is thought to be very low (N.B., there are four species of bumblebees present in New Zealand, compared with only one in Tasmania). This might increase competition for natural nesting sites between queens, because invading queens will sometimes try to usurp the rightful owner, who will fight to the death for her nest site, but other factors such as hive attractiveness, design, placement, local bumblebee populations and habitat characteristics may also have some impact. See Barron, Wratten & Donovan (2000) for a discussion on lack of nesting habitat in New Zealand. Before the present study, nothing was known about any of these factors in Tasmania.

A secondary aim, therefore, was to determine if the level of queen competition for nesting sites in suburban and bushland sites in Southern Tasmania is a limiting factor in bumblebee distribution. This could be checked (imprecisely - there is debate about the method) by placing empty domiciles in areas where queens had been seen nest-searching. A high incidence of trap nest success might correspond to a high level of competition, and vice-versa. Obviously, if the rate of success was moderate to high, occupied boxes could then be either left *in situ* or relocated to other sites for further monitoring and comparison of survival, colony growth and success (i.e. production of reproductives) in suburban and bushland nests. (Strictly speaking, the two are not strictly comparable because the transplanted hives have been artificially manipulated.)

In earlier trials, conducted during 2000-01, only a few trap nested or briefly-imprisoned queens formed outdoor hives that eventually produced gynes (unmated queens) or males; none of the laboratory-reared colonies did (Buttermore, unpublished results). The short survival period of very young, laboratory-reared colonies transplanted outdoors in 2000-01 may have been due to their vulnerability and lack of vigour at a critical stage. Obtaining, imprisoning and later releasing queens at remote sites also presented major difficulties. It was decided to abandon indoor culture and concentrate on trap nesting in 2001-02, adding underground domiciles to augment the 200 or so surface boxes already deployed. Installation of underground nest boxes is more labour intensive but was considered worth the effort since Pomeroy (1981) reported a greater domicile acceptance rate for them.

3C.2 Materials and methods

More than 200 specially prepared surface nest boxes (see Photo 5 page 24) constructed and outfitted to the specifications of Donovan and Weir, (1978) were deployed around selected habitats in southern Tasmania for the 2001-02 season. Twenty-five domiciles were located at Wellesley Park, South Hobart, and 25 at Cascade Gardens, South Hobart (together considered as one suburban site); 50 at Warra Long-Term Ecological Research Site (south of Geeveston), and 50 on the Big Bend Trail on Mt Wellington. Another 50 boxes were scattered around various Hobart backyards. Depending on the terrain, groups of boxes were placed relatively close together, on fairly level ground and not more than six metres apart. They were concealed as well as possible to minimise interference from the general public.

Beginning in August, 2001, 75 underground domiciles (see Photo 6 page 24) were constructed, fitted with nesting material and dug into the ground at Sandy Bay (3), Wellesley Park, South Hobart (16), Cascade Gardens, South Hobart (17), Mt Nelson (15), Fern Tree (4), The Springs (5), and Warra (15), where queen nest searching had been observed. In some cases, underground boxes were sited directly below existing surface types. Suburban locations were checked at least weekly. Others were checked every month, weather permitting. All time spans recorded were rounded up to whole weeks. At various times, and when available, 25 hives collected (see Photo 4 page 24) in either South Hobart or Mt Nelson were then transplanted to bush locations as soon as possible after their discovery. Eight controls were left *in situ* (their foundation dates spaced roughly one month apart) at Wellington Park, Cascade Gardens and a Bellerive backyard. Collection of the queen and unemerged brood took place at night. If the original nest had been started in an underground box, it was put in a small cardboard box and installed in a surface box at a bush location the next day. (Underground boxes were prone to flooding; surface boxes were not.)

Transplanting to environmentally sensitive locations was avoided. There is some inherent risk that artificially placing hives in the bush could inadvertently extend bumblebee distribution. Therefore, sites were selected that were known to already have a resident bumblebee population nearby. It was hoped that in those areas, hives would have less impact than in bumblebee-free areas. Although bumblebees were already in evidence at Warra and Mt Wellington, authorities nevertheless ruled against bringing in new colonies or queens to those areas. Available queens for colony foundation in those areas were in short supply during the 2001-02 season and so no hives were founded there as in 2000-01. Except for one hive, attempts at founding suburban colonies by transplantation were likewise unsuccessful in 2001-02. That one hive was left *in situ* in a backyard garden and was not considered part of this experiment.

Photo: Mike Tobias

Photo 4. A naturally occurring bumblebee nest

Photo: Roger Buttermore

Photo 5. An above ground domicile

Photo: Mike Tobias

Photo 6. Roger Buttermore and an underground domicile

Hives were distributed to nine different sites as follows:

< 3 km from permanent human habitation

Two at Marion Bay (East Coast beachside habitat) - 42°49' 39.1" S 147°51' 62.8" E, 9.1 m.

Two at Orford bush block (East Coast dry sclerophyll habitat) - 42°32' 41.0" S, 147°51' 49.4" E, 212 m.

Four at Shag Bay Reserve, (dry sclerophyll habitat) -42°50′ S 147°20′ E.

> 3 km from permanent human habitation

Four at Wielangta State Forest (temperate rainforest habitat at low altitude) - 42°43' 80.9" S 147°50' 46.5" E, 365 m.

Two at Buckland Road, N of Buckland (dry sclerophyll habitat at low altitude) - 42°33' 19.0" S 147°40'42. 5" E, 305 m.

Seven to the summit of Mt Tim Shea (>900 m altitude habitat) - 42°42' 96.8" S 146°27' 96.3"E, 935m.

Four to the summit of Mt Hobbes (>800 m altitude habitat) - 42°30' 23.8"S 147°35' 46.2"E, 847 m.

If possible, two colonies were initially delivered to each site. If both nests died, they were replaced at a later date, except at Orford, which obviously lacked flowers throughout the whole period when hives were available for relocation. Mt Tim Shea received the greatest number because nest failure occurred very rapidly during several attempts.

Following the convention established by Donovan & Weir (1978) and later researchers, hives were considered to be occupied if any attempt at nest founding was made, even if no workers were produced. Nest termination and reproductive/non-reproductive definitions were also used. Nests at remote locations were checked every two weeks to the end of March, weather permitting.

3C.3 Results

Occupancy of nest boxes and hives

In 2000-01, only two surface domiciles (both at Wellesley Park) were naturally accepted by queens. In 2001-02, that figure increased to four (Table 3.4): one at Wellesley Park (but in a different box to those of the previous year), two at Cascade Gardens, and one in a Bellerive backyard. Forty suburban underground boxes in Sandy Bay, Wellesley Park, Cascade Gardens and Mt Nelson (55 boxes in total, of this type, at the four sites) were occupied during the season. Queens accepted no boxes of either type at any other site. Only two cases of usurpation were observed (one in each type of domicile) during the whole experimental period, but 11 underground boxes were reoccupied at least twice. In fact, two domiciles (u/g 38 Cascade Gardens and u/g XIX Mt Nelson) were accepted by four and five queens respectively over the season, sometimes only a few days after the occupying queen and her brood were taken away.

Time of nest foundation

Nest founding occurred at intervals from late-August to mid-January. Of the 44, 2 were founded in August, 15 in September, 12 in October, five in November, three in December and seven in January.

Table 3.4 Nest Survival and Production of Queens (Gyne)

Original Site	First Occupied	Survival Weeks	In situ	Transferred to	Gyne	Workers +Males
Wellington u/g	16-Oct-01	19	yes		257	589
Wellington u/g	20-Aug-01	20	yes		147	437
Cascade u/g	24-Sep-01	26		Buckland Rd, 4 Oct	120	518
Wellington u/g	21-Oct-01	23		Wielangta, 16 Nov	83	873
Cascade Surface	16-Oct-01	18	yes		45	438
Cascade u/g	27-Oct-01	18	yes		32	618
Cascade u/g	28-Sep-01	22		Marion Bay, 4 Oct	11	353
Wellington u/g	29-Sep-01	19		Buckland Rd, 4 Oct	0	162
Bellerive	28-Dec-01	16	yes		0	52
Cascade u/g	12-Dec-01	14		Mt Hobbes, 14 Dec	0	11
Cascade Surface	14-Sep-01	6	yes		0	8
Cascade u/g	14-Sep-01	9		Wielangta, 20 Sep	0	8
Mt Nelson u/g	28-Sep-01	3		Orford, 4 Oct	0	8
Wellington u/g	31-Aug-01	7		Mt Hobbes, 20 Sep	0	4
Cascade u/g	3-Jan-02	8	yes		0	4
Mt Nelson u/g	30-Nov-01	11		Mt Hobbes, 5 Dec	0	2
Cascade u/g	14-Sep-01	3		Orford, 20 Sep	0	0
Cascade u/g	14-Sep-01	3		Wielangta, 20 Sep	0	0
Mt Nelson u/g	14-Sep-01	3		Marion Bay, 20 Sep	0	0
Wellington u/g	18-Sep-01	4		Mt Hobbes, 20 Sep	0	0
Mt Nelson u/g	22-Sep-01	4		Shag Bay, 3 Oct	0	0
Mt Nelson u/g	22-Sep-01	4		Mt Tim Shea, 3 Oct	0	0
Cascade u/g	27-Sep-01	1	yes		0	0
Mt Nelson u/g	28-Sep-01	3		Shag Bay, 3 Oct	0	0
Wellington u/g	29-Sep-01	2	yes		0	0
Mt Nelson u/g	2-Oct-01	3		Mt Tim Shea. 3 Oct	0	0
Mt Nelson u/g	6-Oct-01	1	yes		0	0
Wellington u/g	6-Oct-01	1	yes		0	0
Sandy Bay u/g	6-Oct-01	1	yes		0	0
Cascade u/g	9-Oct-01	0			0	0
Cascade u/g	9-Oct-01	1			0	0
Mt Nelson u/g	27-Oct-01	3			0	0
Cascade u/g	8-Nov-01	4		Wielangta,16 Nov	0	0
Mt Nelson u/g	8-Nov-01	1	yes		0	0
Mt Nelson u/g	20-Nov-01	6		Mt Tim Shea, 29 Nov	0	0
Cascade u/g	20-Nov-01	4		Mt Tim Shea, 29 Nov	0	0
Cascade u/g	24-Dec-01	2		Shag Bay, 26 Dec	0	0
Mt Nelson u/g	2-Jan-02	5		Mt Tim Shea, 5 Jan	0	0
Mt Nelson u/g	2-Jan-02	3		Mt Tim Shea, 5 Jan	0	0
Mt Nelson u/g	2-Jan-02	2		Shag Bay, 7 Jan	0	0
Cascade u/g	3-Jan-02	6		Mt Tim Shea, 24 Jan	0	0
Wellington S	14-Jan-02	2	yes		0	0
Wellington u/g	16-Oct-01	2			vandalized	

Occupancy of abandoned nests

Thirty-six nests did not produce gynes. Of those, 28 queens did not even produce workers or males. Of these 28 nests nine were founded in September, eight in October, four in November, one in December and six in January. Colony life span ranged from 0-6 weeks before the queen died or abandoned her nest. The cause of abandonment in most cases could not be determined, although five were the result of heavy rain.

Wasps (*Vespula germanica* L.) and various species of ants may also have contributed to bumblebee abandonment in some cases. *Vespula germanica* queens and comb were found in 22 boxes (10 surface, 12 underground) located in Wellesley Park, Mt Nelson, Cascade Gardens, Sandy Bay, and one at The Springs, Mt Wellington. Nest foundation dates ranged from mid-September to February, though none ever stayed alive for long. Four of these boxes (two of each type) had both *B. terrestris* and *V. germanica* as simultaneous occupants.

Ants were a problem at times but could also be found co-existing with bumblebees at all stages of the bees' colony development. Mice were found, mostly in several empty surface boxes; a grid on the underground tube entrances was designed to thwart their entry, though one or two got in. A mouse was observed in a surface box with a small bumblebee colony at Mt Hobbes. It appeared to be nesting there. A swarm of *Apis mellifera* (L.) temporarily occupied a surface box at Wellesley Park in late November, but left after about a fortnight.

Nine nests produced workers but no queens. All but two of these had 11 or fewer worker/male cocoons and survival time ranged from 6-14 weeks. One colony that was transferred to a dry sclerophyll habitat at Buckland (where it survived for 19 weeks) had 162 worker/male cocoons at cycle completion. In April, a dog overturned the nest box of the final colony of the season (founded in Bellerive in December) and the nest was abandoned, so its cycle completion could not be calculated. The box contained 52 worker/male cocoons at last count.

In 2000-01, 27 laboratory-reared nests that were transplanted to the bush (or, in the case of Warra and Mt Wellington, colonies begun from queens netted on site and imprisoned in boxes for a few days that were provided with food *ad libitum*), produced only six queen cocoons in four colonies, of which two were in high altitude sites. The longest surviving bush colony lasted 14 weeks and contained cocoons of 29 worker/male and three queens. The other two survived seven and eight weeks respectively. Out of 29 suburban nests, one had 66 gyne cocoons in a queen-accepted domicile. Another suburban colony founded by imprisoning a queen produced 26 gyne cocoons. These nests existed for 23 and 19 weeks respectively. The ratio of reproductive hives to all hives that season was 7%.

In 2001-02 there were seven reproductive nests: 16% of all hives artificially founded that season. Four of these were left *in situ*, one was transplanted to an East Coast beachside environment, and two more were relocated to remote areas - one in dry sclerophyll habitat and the other in temperate rainforest. Total cocoon counts ranged from 364 to 949. The smallest colony also had the lowest number of queens: 11. This was raised at the East Coast beachside habitat. The largest nest produced 83 queen cocoons, compared with 257 by the second largest hive. There appears to be no correlation between weeks of colony existence (18-26) and number of queens or total cocoons.

The colony situated in dry sclerophyll woodland lasted 26 weeks, and had cocoons of 120 gyne and 518 worker/males. It was founded in late September and transferred in early October. The temperate rainforest nest was founded about a month later, and produced cocoons of 83 gyne and 873 worker/males. Of all the reproductive nests, 50% were founded in October.

3C.4 Discussion

This experiment shows that very young bumblebee colonies can survive and thrive in remote Tasmanian locations, but their number and size fluctuate widely from year to year and/or in different habitats. The numbers of gynes produced in both bush and suburban hives in 2001-02 increased dramatically from those in 2000-01. Gyne production at high altitude sites is relatively low, which lessens the chances of nest foundation by them in the following season. Temperatures at the high altitude sites were also noticeably low for most of the season, and may have retarded colony development. The other two habitat types tested produced robust colonies at cycle completion. Their numbers are comparable with those of the control colonies *in situ* and also with those of natural colonies in Southern Tasmania recorded by Buttermore (1997). Obviously, if more sites could be monitored and tested over several years, it might be possible to derive a more detailed analysis of the complex spatio-temporal variation of *B. terrestris* populations in Tasmania.

There also appears to be some competition for suburban Tasmanian nesting sites. Although usurpation was relatively low (e.g. in New Zealand a domicile with nine dead queens but no nest inside was observed, although there were several other unoccupied boxes nearby), the number of underground boxes that were reoccupied suggests that there are more queens than nesting spots in certain neighbourhoods.

Alternatively, it may simply indicate that the boxes, especially the underground type, were more attractive or easily found than natural sites. Only 4% of suburban surface boxes were occupied. Ignoring the reoccupation factor, the suburban underground acceptance ratio was 22%. This last is quite high for *B. terrestris*, compared with rates reported in New Zealand and the U.K. Obviously, to have 40 underground boxes out of 55 occupied and reoccupied over a season is a good result.

4. Parasites associated with Tasmanian *Bombus terrestris* (L.)

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4.1 Introduction

The large earth bumblebee, *Bombus terrestris* (L.), was first detected in Hobart in 1992 (Semmens *et al.,* 1993) and has since spread throughout Southern Tasmania. If the introduction was accidental, the number of founding queens for this population is likely to be one; if illegal, a few queens may have founded the population. Either way, Tasmanian bumblebees probably represent a highly inbred – yet successful – population.

Given a low number of establishing queens and, therefore, low genetic diversity, bumblebees in Tasmania have been extremely invasive. After 10 years, high densities of bees can be found along the South-Eastern coast, and in the West Coast towns of Queenstown and Strahan, about 200 km from Hobart. Why have these bees been so prolific when genetic diversity is a key factor affecting the establishment of many species, such as biocontrol agents, in foreign habitats (e.g., Simberloff, 1989; Hopper & Roush, 1993)? One hypothesis is that Tasmanian bumblebees may be relatively free of parasites and, without this constraint, their low genetic diversity has not been a disadvantage.

Bombus terrestris are host to an impressive diversity of parasitic organisms. Several species of mite (e.g., *Garmaniella* spp., *Hypoaspis* spp., *Kuzinia laevis*, *Parasitellus* spp., and *Scutacarus acarorum*) live in the nests of bumblebees, where they feed on pollen stores, debris, and nest microfauna (Chmielewski, 1971; Schmid-Hempel, 1998). These mites have a phoretic life stage that can be found on the exterior of the bees, for example, *K. laevis* disperses as a non-feeding deutonymph. *Locustacarus buckneri* is an extraordinary mite that lives within the tracheae of adult bees (Husband & Sinha, 1970). The parasitic wasp *Melittobia acasta* can quickly overcome bumblebee nests (de Wael *et al.,* 1995); parasitic conopid flies attack bees as they forage (Schmid-Hempel & Schmid-Hempel, 1988); nematodes live within and eventually kill queens soon after emerging from diapause; wax moths invade and destroy colonies and the protozoan *Nosema bombi* can kill numerous bees (Fantham & Porter, 1914), as can the trypanosome *Crithidia bombi* (Brown *et al.,* 2000).

Some of these parasites, such as the external mites, appear benign, but insect parasitoids, nematodes, and internal microparasites can kill individuals and, in some cases, significantly damage or even kill colonies (Schmid-Hempel & Durrer, 1991; Schmid-Hempel & Loosli 1998). In *Bombus terrestris*, the number of parasites in a colony is closely linked to the genetic diversity of the colony (Skyhoff & Schmid-Hempel, 1991; Liersch & Schmid-Hempel, 1998; Schmid-Hempel & Loosli, 1998; Baer & Schmid-Hempel, 1999). One would expect that parasites would cause considerable damage to a genetically homogenous population, such as that in Tasmania. Should Tasmanian bumblebee colonies be free of parasites, however, they could be further used to understand the interplay between parasites and genetic diversity.

4.2 Materials and Methods

Capturing bees

Bumblebees were captured between January and April, 2000. Tasmania was divided into five *regions*: Southern, West Coast, Derwent Valley, Northern, and Eastern (Figure 4.1). In each of these regions, five *locations* were sampled, but bumblebees were absent or in insufficient numbers in some locations. Locations with sufficient bumblebees were: Huonville, Pelverata, Geeveston, Southport, Cockle Creek (Southern); Strahan, Queenstown (West Coast); Hobart, New Norfolk, Ouse, Blue Gum Knob, Maydena (Derwent Valley); Oatlands (Northern); Sorell, Orford (Eastern). Within each of these locations, bumblebees captured were at five *sites* that were at least 1 km apart. Worker bumblebees are believed not to forage further than 1 km from their nests (Dramstad, 1996). At each site at least five bees were captured. Because the primary aim of the study was genetic diversity, at least three workers were captured from each site. Drones and queens were also captured. Bumblebees were placed in labelled tubes, which were then placed into a cooled container. Bees were returned to the laboratory and placed in a fridge at about 7 °C; after cooling, the bees were examined (see below) and then placed into labelled cryotubes and frozen in liquid nitrogen.

In September and October 2000, 50 queens were also captured from numerous locations within Hobart. These queens were returned to the laboratory, killed, and dissected for the purpose of detecting parasitic nematodes. Whether these queen bees were foraging or nest-searching was also recorded because the nematode alters its host's behaviour by causing it to search continually for nests. Samples were not taken outside Hobart because the highest chance of detecting parasites would be closest to the point of entry of *B. terrestris* into Tasmania.

Examination for parasites

The length of each bee was measured by pressing it down against a hard object, and measuring the bee from the front of the clypeus to the tip of the abdomen with a digital calliper. As an indication of its age, whether or not the wings showed signs of wear (tattering) was recorded. The exterior was then examined for mites, and the number of mites estimated; exact counts were impossible as mites were extremely abundant and the amount of time bees were allowed to defrost had to be minimised. These estimates ranged from –16% to +7% of actual counts (n = 20).

For queens and workers, the head and thorax was removed and placed in liquid nitrogen storage; drones were treated similarly, but not all were bisected. The bee abdomens were initially sterilised by placing molten wax on the anterior and posterior orifices (to protect the haemocoel from the sterilising solutions), dipping in 95% ethanol for 2 sec., soaking in 5.25% sodium hypochlorite for 3.5 min., soaking the 10% sodium thiosulfate for 3.5 min., then washing three times in sterile distilled water. The bee was then dissected, and a sample of haemolymph, midgut tissue, and hindgut tissue removed. Samples of haemolymph were smeared on glass slides and stained with a standard Gram-stain method; samples of midgut and hindgut were treated similarly, but treated with a Giemsa-stain method. Full details of the methods used are available as a Microsoft Word® document from Owen Seeman, courtesy of Christene Reber and Regula Schmid-Hempel. During the preparation of the slides, the remainder of the abdomen was examined for tracheal mites (Husband, 1967), nematodes and parasitoid larvae. Prepared slides were examined at x1000 under phase contrast.

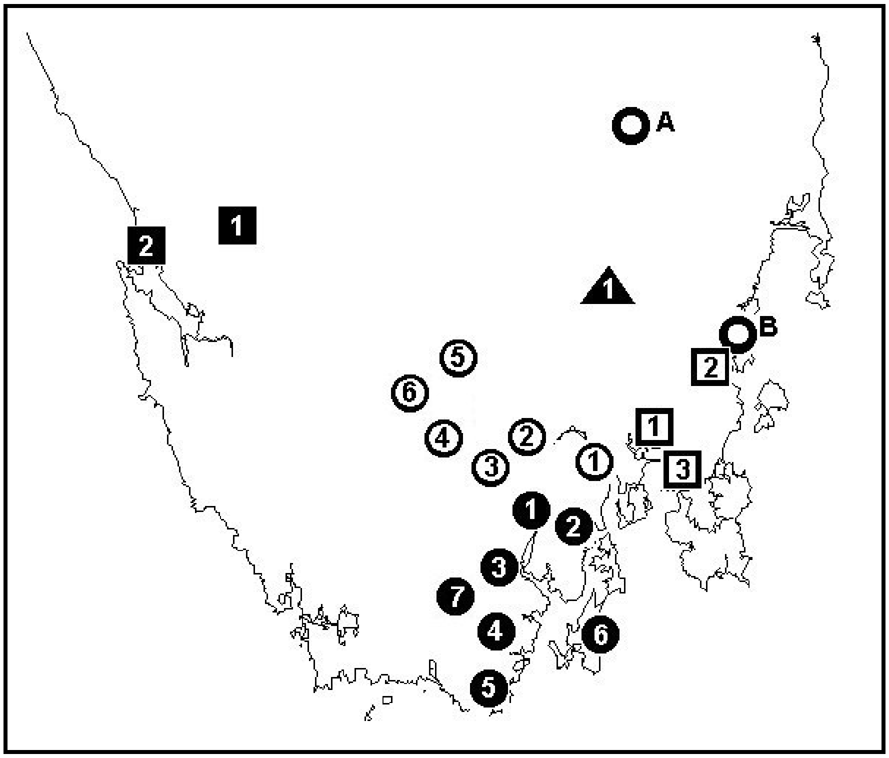

Figure 4.1 Collection locations of bumblebees in Tasmania. Open circles (Derwent Valley region): 1 = Hobart; 2 = New Norfolk; 3 = Blue Gum Knob; 4 = Maydena; 5 = Ouse; 6 = Mt Field National Park. Filled circles (southern region): 1 = Huonville; 2 = Pelverata; 3 = Geeveston; 4 = Southport; 5 = Cockle Ck; 6 = South Bruny Island; 7 = Arve Valley. Filled squares (western region): 1 = Queenstown; 2 = Strahan. Open squares (eastern region): 1 = Sorell; 2 = Orford; 3 = Dodges Ferry. Triangle (northern region): 1 = Oatlands. Locations A and B represent well-searched places where bumblebees were not found.

Bumblebee nest survey

The contents of bumblebee nests were examined from colonies in natural and artificial nests. When a colony began to die or a dead colony was retrieved from the field, the contents of the nest were thoroughly examined and brood dissected or reared at room temperature. Dead and live arthropods were collected into 80% ethanol, and identified with the aid of dissecting and slide microscopes, where appropriate.

Photo: Mike Tobias

Photos 7 and 8. *Kuzinia laevis* on bumblebee

Photo: Mike Tobias

4.3 Results

A total of 511 bees (47 queens, 181 drones, 283 workers) were captured from 19 sites scattered across 5 regions. Four of these sites (Mt Field National Park, South Bruny Island, Dodges Ferry and the Arve Valley) had small numbers of bumblebees, but they were included in the analysis because of their isolation from other sampled populations. Bumblebees were absent at Campbell Town and Triabunna (Figure 4.1).

External parasites were represented by only one species, the phoretic deutonymphs of the mite *Kuzinia laevis* (see photos 7 and 8, page 32). There were significant differences between castes in the number of mites present on bees (F = 124.82, df= 2,508, P < 0.0001). Mites were extraordinarily abundant on drones (355 ± 31 mites, range: 0 - 2000; 87% with mites) and queens (411 ± 84, range 0 - 2400; 81% with mites), but were relatively uncommon on workers (38 ± 9, range 0-1400; 51% with mites).

Drones without wing damage had on average 3 times more mites upon them (513 ± 49) than those with wing damage (171 ± 21) (Fig. 2; F = 37.04, df = 1,179, P < 0.0001). Neither drone size (F= 0.05, df = 1,130, P = 0.81) nor geographic region (F= 0.48, df = 4,130, P = 0.75) significantly influenced mite numbers. At the Hobart site, where collections of drones were made over 39 days, time since the first collection day had no significant influence on mite numbers (F= 0.84, df = 1,33, P = 0.37).

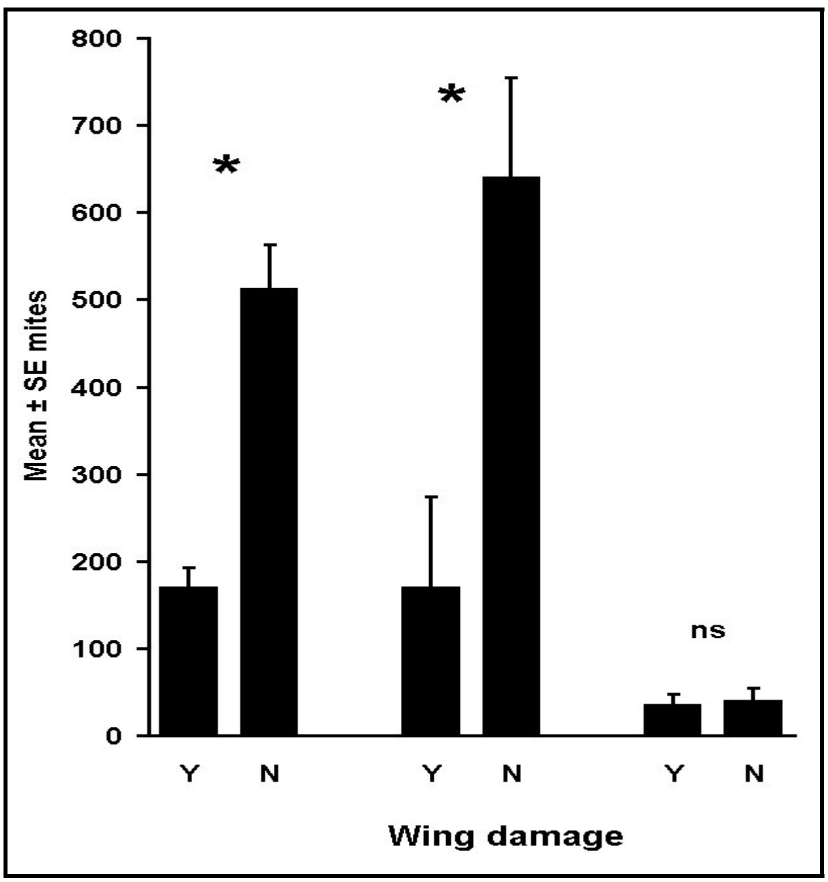

Figure 4.2 Mean ± s.e. *Kuzinia laevis* on, from left to right, bumblebee drones, queens, and workers with (Y) and without (N) wing damage.

Summer-autumn collected queens without wing damage had on average nearly 4 times more mites on them (641 ± 113) than those with wing damage (171 ± 104) (Fig. 4.2; $F = 22.39$, df = 1, 45, $P < 0.0001$). Neither queen size ($F= 2.72$, df = 1, 39, $P = 0.11$) nor whether a queen was carrying a pollen load (Fig. 4.3; $F= 0.57$, df = 1, 39, $P = 0.46$) significantly influenced mite numbers.

Unlike drones and queens, it was found that among worker bees there was no significant difference between workers without wing damage (41 ± 14) and those with wing damage (36 ± 11) (Fig. 4.2; $F = 0.96$, df = 1, 241, $P = 0.33$). Workers carrying a pollen load (13 ± 3) had, however, significantly fewer mites upon them than those without a pollen load (73 ± 21) (Fig. 4.3; $F = 9.66$, df = 1, 242, $P = 0.002$). Worker size was a significant co-variate with mite numbers ($F= 5.15$, df = 1, 242, $P = 0.02$) with mite numbers increasing with increasing worker size ($r^2 = 0.14$ $P = 0.03$). There was no significant difference in mite numbers found on workers across the five geographic regions ($F= 0.73$, df = 4, 238, $P = 0.57$).

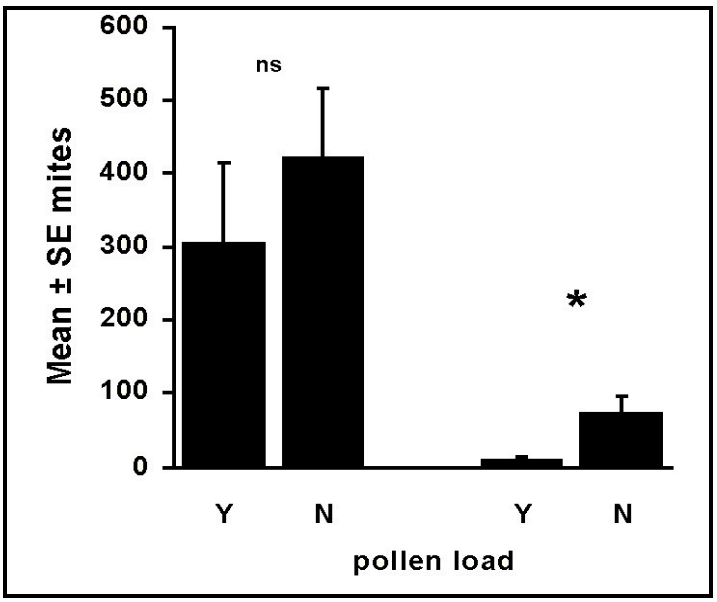

Figure 4.3 Mean ± s.e. *Kuzinia laevis* on bumblebee queens (left) and workers (right) with (Y) and without (N) pollen loads. * = significant difference, P = 0.002.

Queens that had overwintered as adults and were collected in spring had high mite loads similar to those of summer-autumn collected queens without wing damage. There was no significant difference in mite loads between queens that were collected when searching for a nest (664 ± 65) and those that were collected foraging on flowers (626 ± 58) (Fig. 4; $F= 0.08$, df = 1, 43, $P = 0.78$). Unlike summer-autumn queens, but like summer-autumn workers, the spring queen bees that were carrying pollen had significantly lower mite loads (13 ± 7) than those without pollen loads (624 ± 45) ($F= 14.38$, df = 1, 43, $P <0.001$). Queen size had no significant effect on mite load (F= 0.07, df = 1, 43, P = 0.80). Although spring queen collections were made over 46 days the number of days that had elapsed since the first collection day had no significant influence on mite numbers (F= 0.64, df = 1, 43, P = 0.43).

A total of 200 bees (30 queens, 20 drones, 150 workers) were examined for internal parasites but only gut bacteria associated with > 90% of bees was found. Similarly, nematodes were not detected in foraging or nest-searching bees in spring.

Seventeen nests were searched but no evidence of brood parasitism, wax moths, or any other bumblebee parasite with the exception of the free-living life stages of *K. laevis* was found. These mites were always present in active nests, and in some cases were infesting the pollen stores in uncountable thousands (up to a conservative estimate of 1 million in 3 nests). Other common invertebrates were booklice (*Leptoscelus bicolor*), ants of several genera (especially *Technomyrmex albipes* (pale-footed house ant), *Linepithema humile* (Argentine ant), and an *Anonychomyrma* sp.), tenebrionid larvae, and European earwigs.

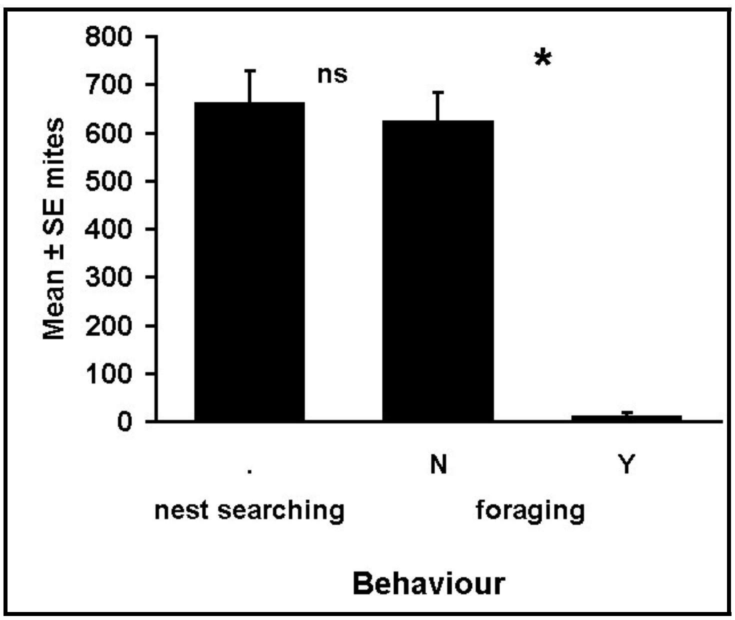

Figure 4.4 Mean ± s.e. *Kuzinia laevis* on bumblebee queens captured in Hobart during spring. Queens were classified as nest searching (no pollen load), foraging (no pollen load), or foraging (but with pollen load). * = significant difference, P < 0.001.

4.4 Discussion

Tasmanian bumblebees are largely free of parasites. Despite the long list of parasitic organisms that associate with them, only one species of mite has co-invaded with Tasmanian *B. terrestris*. Therefore, the success of Tasmanian bumblebees could be partially attributed to their relatively parasite-free status.

Kuzinia laevis is a common associate of bumblebees. Overseas populations usually infest the majority of the bumblebee population, in contrast with many other parasite species that usually are found on, or in, the minority of individuals (e.g., Schmid-Hempel & Loosli, 1998; Corbet & Morris, 1999). Thus, it is not surprising that *K. laevis* and no other parasite species were introduced, given the probably low number of founding queens.

Kuzinia laevis is considered a benign pollen-thief, having little or no measurable impact upon their hosts (Chmielewski 1971, 1991). Average mite numbers overseas appear far fewer than those in Tasmania (Corbet & Morris, 1999). For example, the average number of *K. laevis* on Tasmanian queen bees is over 600 individuals, whereas queen bees from England have, on average, just 13 *K. laevis* (Corbet & Morris, 1999). This difference could have a significant impact on the success of nests, especially nest establishment.

As an example of the potential impact of *K. laevis*, consider two queen bees: one with 10 mites, the other with 1000 mites. For a conservative and easy-to-follow estimate, assume that *K. laevis* lay 5 eggs a day for 30 days before dying. This means that a nest established on October 1 by the queen carrying 1000 mites will contain about 150,000 mites by 1 November, and by 1 December, the population of living females will be producing an astonishing 300,000 eggs per day. This compares to 3,000 mites per day on 1 December with the queen carrying just 10 mites. Clearly, initial mite populations could have a significant impact on their rate of increase. Furthermore, without known predators in Tasmania, only abiotic factors and unknown parasites and predators of *Kuzinia* could keep their populations in check.

Kuzinia laevis actually lays more eggs and lives longer than the values given in the above example. The pre-oviposition period of *K. laevis* is about 2.7 days, their egg-reproductive adult duration is about 20.3 days, and their longevity is 65 days. Female *K. laevis* will lay an average of 7.3 eggs per day (Chmielewski 1991, 1994). Any attempt to rear bumblebees commercially in Tasmania should be aware of the potential impact of this mite.

The patterns of *K. laevis* abundance on different castes of bees shows that drones and queens are far more attractive than workers (Figure 4.2). The reason for the high number on queens seems obvious: by catching a ride on queens, the mites will ensure they colonise a new nest. Their equal abundance on males, however, is more puzzling. Perhaps some mites transfer during bumblebee copulation, or move off males at a later time; otherwise, these mites will die.

The prevalence of mites on young bees (i.e., those with intact wings; Figure 4.2) indicates that mites move onto bees soon after bees emerge from pupae. The gradual loss of mites may be caused by natural mortality, shedding during flight, or their transfer to new nests or younger bees in the same nest. During spring, queens with pollen loads probably had few mites (Figure 4. 4) because they had established a nest with a pollen store, and the mites had disembarked.

The smaller number of mites on workers without pollen loads, compared with those carrying pollen, is difficult to explain (Figure 4.3). The absence of differences in age classes, as indicated by wing tattering (Figure 4.2), means that the explanation does not involve the age of the bee. Beyond this, one may not speculate further without greater understanding of the behaviour and ecology of mites and bumblebees.

4.5 Recommendations – scientific and industrial

The Tasmanian populations of *B. terrestris* are almost free of parasites. Only the kleptoparasitic pollen-thieving mite, *K. laevis*, has been introduced with the bumblebee. This mite is known only from species of *Bombus*. Therefore, honeybees and native fauna are under no threat from the co-invasion of *K. laevis*.

Populations of *K. laevis* are far greater in Tasmania than overseas. This may be due to their freedom from predators and parasites in Tasmania, or because of the low genetic diversity of their hosts. Although this mite is usually considered benign, it is speculated that their especially high populations may impact on the success of nests. Therefore, it is recommended that attempts to rear *B. terrestris* should consider control of mites to improve rearing methods.

5. Impact on native plants

This section discusses research to ascertain the level of impact that *B. terrestris* is currently having on native plants in Tasmania. Two of the plants chosen are plants that have been cited in literature (Hingston, 1997; Hingston & McQuillan, 1998) as being at risk from the presence of *B. terrestris: Epacris impressa* and *Gompholobium huegelii.* The third plant, *Eucalyptus globulus,* was selected because it is an important food source of the endangered swift parrot.

Photo: Lyn Cave Photo 9 *Epacris impressa*

5A *Epacris impressa* (common heath)

5A.1 Materials and methods

In order to study the level of impact and incidence of *B. terrestris* on the native plant *Epacris impressa* (see Photo 9) a total of 30 sites where *E. impressa* grows were located in the South-East of the State, in five districts: Hobart area, Huon area, South area (near Cockle creek), Bruny Island, and the Tasman Peninsula. At each site, a 2 m x 2 m quadrat containing at least three *E. impressa* plants was marked out at each site. Four stems on each of the four plants per quadrat were each tagged with fine wire, 20 cm from the apex.

Epacris impressa is able to flower several times a year, so floral records for each 20 cm stem at each site were recorded every four to eight weeks. This usually took between 20 and 40 minutes, during which time any potential pollinators visiting the plants were also noted.
When seed capsules occurred on stems, a sample of up to 5 near-mature, closed capsules per stem were collected in separate zip-lock bags, and taken back to the laboratory, where numbers of seeds per capsule were counted under the microscope.

In November 2001, capsule numbers were also recorded, and samples collected from four sites where *B. terrestris* had recently been visiting *E. impressa* flowers, at remote bush locations along the Strathgordon Road. Capsules were also taken from a new site, on Mt Nelson, in March 2002, where *B. terrestris* was observed nectar robbing *E. impressa.* Nectar robbing (see Photo 10) occurs when the insect cuts a hole in the side of the corolla of a flower, so that it can access nectar in the flower without contacting the style and stigma (positioned near the top of the corolla). When insect nectar robs, it is unlikely to pollinate the flower, yet it has taken away the nectar attractant that other pollinators seek.

Photo: Roger Buttermore

Photo 10. Nectar robbing on borage

5A.2 Results and discussion

There were 216 periods of flowering recorded, over 2.5 years, at the 30 sites. Of these flowering periods, nine were aborted at the bud, flower or developing pod stage, due to an extended dry period or cold snap. On four occasions flowers were mown down by council workers, preventing pods developing. On one occasion near the end of the experiment, plants were destroyed at one site when people dumped a trailer load of garbage on the site! There was only one flowering, at Mt Nelson, when nectar robbing by bumblebees (or other nectar robbers observed such as ants) was extremely common.

Bombus terrestris was present at only 8 of the 203 flowering periods (4%) that produced seed capsules from the 30 sites.

Capsule counts *Epacris impressa*

Bumblebees	Mean Count Per Stem	n
Y	25.67a	203
N	8.07b	2574

Table 5.1 Predicted means for capsule counts per 20 cm Stem of *Epacris impressa* in the presence (Y) and absence (N) of *B. terrestris.* Means followed by a different letter are significantly different ($P < 0.05$). "n" is the number of observations.

As presented in Table 5.1, capsule counts of *Epacris impressa* were significantly higher in the presence of bumblebees (Y), compared with when they were absent from a site (N).
This could, however, be because bumblebees chose sites with a greater concentration of flowers /stem. (This has not yet been tested).

The significant increase (45.1%) in mean number of seeds per capsule observed (shown in Table 5.2) is a good indication that bumblebees have increased the seed set of this plant when they chose to visit.

Bumblebees	Mean No. Seeds per Capsule	N
Y	23.67a	695
N	16.31b	2372

Table 5.2 Predicted means for the number of *E. impressa* seeds per capsule in the presence (Y) of Bumblebees, compared to in their absence (N). Means followed by a different letter are significantly different ($P < 0.05$).

5B *Gompholobium huegelii*

5B.1 Introduction

Gompholobium huegelii is a native plant from the pea family Fabaceae. It was present at three sites (Huon Rd, Coffee Creek and Snug Falls) monitored from January 2000 to June 2002. It flowers once per year in mid summer. I monitored pollinator visitors to the plant during its flowering periods to ascertain whether *B. terrestris* was competing with native pollinators at comparatively high population densities.

Monitoring at the sites indicated that flower abundance of *G. huegelii* was extremely low in the first two summers of the project at Huon Road and Coffee Creek and *B. terrestris* was not observed visiting this species at any site when conditions were dry. Along Snug Falls track in

December 2001, flower abundance was moderate, but no bumblebees were present. After a high rainfall in December 2001, plant numbers at Huon Road and along Snug Falls track were quite high, as were numbers of open flowers per plant.

5B.2 Materials and methods

A monitoring session was conducted over a full morning on 10 January 2002, to simultaneously record numbers of pollinators visiting two adjacent quadrats, each measuring 2 m x 2 m, at each of five positions on the Huon Road site. To do this, five people with good observational skills, (but variable knowledge about insect identification) were asked to sit quietly next to their two quadrats, and record the time each pollinator observed entered a quadrat, how many flowers were visited, and when they left that quadrat. Observers were asked to describe the pollinator in their own language, (eg brown butterfly, tiny native bee (5 mm), fly, larger black native bee, bumblebee etc). Later on, an insect collection from the site would be used to identify the visiting pollinators. To aid identification, observers were given photographs (numbered, with a scale) of native bees collected previously from Huon Rd.

If another potential pollinator entered while an observer was tracking a pollinator, observers were directed to record the time of entry of the new pollinator, but keep tracking the original pollinator, and estimate the number of flowers visited by the second pollinator later. Fortunately, numbers of pollinators were generally low enough to make this tracking technique feasible, and reasonably accurate. If visits to quadrats by bumblebees were frequent, observers were directed to 'shoo' bumblebees away from one of the quadrats, but allow them to enter the other quadrat. In reality, bumblebee visits were few, so the 'shoo' treatment was abandoned by all observers.

The Huon Road site was again monitored by entomologist Kaye Hergstom at one, four, five, six and thirteen days after the long monitoring session, to ascertain the variability of pollinators visiting the site over time. Floral records of all quadrats were kept.

The Snug Falls site was also monitored three times over the same flowering season to compare sites. The Coffee Creek site produced few flowers of *G. huegelii* and there were no sightings of bumblebees on them, and so this site was not included in the results.

A sample of 20 pods produced was collected from each of the quadrats monitored at Huon Road, and a sample of 20 pods was taken from plants at Snug Falls track. Each of these pods was opened, the number of healthy, late aborted, and unfertilised seeds per pod recorded (and whether the seeds had been eaten by a moth larvae). After counting, seeds and pods were then returned to either Huon Road or Snug Falls, and scattered over the respective quadrats that they came from.

5B.3 Results and discussion

The morning monitoring session was an attempt to revisit an experiment performed by Andrew Hingston, (as part of his Honors Degree project) in January 1997, at the same Huon Road site (Hingston & McQuillan, 1999). The method in that experiment, was for one observer to monitor two adjacent quadrats with *G. huegelii* flowers over an entire day, and allow bumblebees access to one quadrat, but 'shoo' them away from the other. This process was repeated once, on the following day, but this time bumblebees were kept away from the alternate quadrat (Hingston & McQuillan, 1999). Our method was to increase the number of quadrats checked by a factor of five, to get a larger view of visitation rates. Checking the block again, on five more days during the flowering period, was undertaken to look at the variability of pollinators across the flowering period, rather than on just one occasion. Checking the only other site known where *G. huegelii* was flowering in abundance (Snug Falls track), enabled a comparison of the variability in pollinators between sites.

During Hingston's experiment at Huon Road on 2 and 3 January, 1997 two native bee species of the genus *Chalicidoma* (*Hackeriapis)* were the only regular visitors to the *G. huegelii* flowers monitored (Hingston & McQuillan, 1999). During our experiment at Huon Road on 10 January 2002, a total of 16 potential pollinator species were recorded from the 10 quadrats monitored. This was not the intimate relationship between a highly specialised native bee genus and a native plant species that was expected.

Members of the pollination guild which visited and collected nectar and pollen on *G. huegelii*, included four different species of native bees, *B. terrestris,* five species of butterflies, three moth species, a fly species, two beetle species and a wasp species. Bumblebees represented 10% of visitors, and represented 17% of the *G. huegelii* flower visits recorded on that day.

If one compares all the records of pollinators to *G. huegelii* at Huon Road in that flowering season (from 19 Dec 2001 to 26 Feb 2002, a total of 25.8 hours of monitoring), *B. terrestris* comprised 7% of observed visitors to *G.huegelii*. Taking into account that *B. terrestris* was not observed visiting *G. huegelii* at Huon Road in the two previous flowering seasons, these data would indicate that *B. terrestris* has not displaced the native megachilid bees at Huon Road, as previously predicted (Hingston & McQuillan, 1999).

At Snug Falls track, the situation was completely different. In the two previous years, another megachilid species (*Megachile chrysopyga* Smith) and an *Exoneura* species were observed to be the main pollinators of *G. huegelii* , and bumblebees were absent. On 19 December 2001, bumblebees were absent, and the pollen guild on this plant species was broad (3 hoverflies, 4 native bees, 2 butterflies, 1 beetle , 3 thrips, and 1 ant). But on 16 January 2002, bumblebees were present, and pollinators observed on *G. huegelii* were: 8 *B. terrestris*, 1 native bee, and 35 thrips during 151 minutes. In the past, bumblebees had been rarely seen at this site (about one sighting per 8 one-hour monitoring sessions in 2000 and 2001), even though it is less than 3 km from bumblebee populations in Snug. The relative abundance of *G. huegelii* in January 2002, however, clearly caught their attention, as they represented 14% of potential pollinators observed in that flowering season.

A comparison of mean numbers of healthy seeds set per pod at Snug Falls, where bumblebees averaged 2.12 visits to *G. huegelii* per hour, to seed set at Huon Road, where visits of *B. terrestris* averaged 1.12 visits per hour, were similar 8.9 vs 8.2 respectively. Further analysis from individual plots (and in the future, from many sites where this plant occurs) monitored may shed more light on the matter.

In conclusion, *B. terrestris* was not observed on *G. huegelii* flowers at Coffee Creek during any of the three years it was monitored. At Huon Road, bumblebees were not seen on *G. huegelii* during the two years when flower abundance was low, but in 2001-2, when flower abundance was much greater, bumblebees represented 7% of the pollinators observed on this plant species. The pollination guild observed was broad and the level of competition variable, ranging from absent, in December, to 10% of visitors at Huon Road, to being the major bee pollinator in mid-January at Snug Falls. Number of healthy seeds per pod did not appear to differ between locations in 2002. As at Huon Road, at Snug Falls bumblebees were absent from *G. huegelii* when flower abundance was low in 1999-00, absent when flower abundance was moderate in 2000-01, but in 2001-02, bumblebees represented 14% of visitors to *G. huegelii* observed in that flowering season.

5C *Eucalyptus globulus*

Photo: Roger Buttermore

Photo 11. *Eucalyptus globulus* in flower

5C.1 Materials and methods

Eucalyptus globulus Labill. (see Photo 11) is a gum tree that used to be abundant along the East coast of Tasmania, but clearing for timber and agricultural purposes has greatly diminished the stand available to pollinators, including the Swift Parrot *Lathamus discolor* (MacNally & Horrocks, 2000).

From September to December 2001, any *E. globulus* tree passed on the way to visiting monitoring sites was checked to record any pollinators visiting the tree over a short 3-5 minute period. Using the same technique, any *E. globulus* trees observed on a one-day drive up the East coast from Hobart to Swansea was monitored on 14 December 2002. A long period of wet weather after this date seemed to shorten the flowering period of *E. globulus*, and random monitoring ceased after 19 Dec 2001. Using this technique, data from a total of 24 monitoring periods, at 18 locations, were collected.

To compare this with population densities on other *Eucalyptus* species (including the non-Tasmanian red-flowering gum *E. ficifolia* found at many urban locations), data from *E. globulus* was compared with 48 brief monitoring periods at 23 different locations, on 48 occasions when a lone eucalypt was observed to be flowering during scientific surveys. This data is a sub-set of the total monitoring data.

5C.2 Results and discussion

Bumblebees represented only 2% of the total number of potential pollinators observed at the 18 locations checked. Honeybees were by far the dominant pollinator visiting *E. globulus* (56%), with birds being the second most prevalent pollinator (25%). Bumblebees were present at two out of the 24 random monitorings, approximately half the recorded presence of native bees (2% vs 4%).

When these data are compared with observations on other *Eucalyptus* species, the distinguishing difference is that birds are less common (1% of total number of pollinators visiting) than honeybees (87%), which tend to dominate. This would suggest that birds find *E. globulus* particularly attractive at this time of year, compared with other occasions throughout the year, on other *Eucalyptus* species. Bumblebees were again present only as a minor pollinator, at approximately half the population density of native bees (3% vs 5%).

6. Impact on weed species

6.1 Introduction

Workshop delegates concluded that the most easily detected impact of introducing a new genus of pollinator, was likely to be an increase in the seed set of weed species, in particular, the seed set of 'sleeper' weeds (weeds that could become a significant problem if they suddenly had an active 'buzz' pollinator at hand).

After hours of monitoring population densities in urban, rural and bush areas, it became clear that *B. terrestris* exhibited a distinct preference for certain plant species, and it was on those plant species frequently visited (rather than those rarely visited by inexperienced new recruits) that the most significant impacts would occur. Therefore, we researched the seed set of three weed species most often associated with bumblebees in our scientific survey and general monitoring across the State. Two weed species had pea-type flowers: Greater Trefoil, *Lotus uliginosus* Schkuhr, which often grows in high rainfall areas, often by the side of the road where run-off makes soil moisture high, and Tree Lupin, *Lupinus arboreus* Sims, which was once planted as a sand-dune stabiliser in Tasmania, but has since become a minor weed in some areas. The other weed studied was a major weed from the Asteraceae family: Scotch Thistle, *Onopordum acanthium* L.

6.2 Materials and methods

I collected as much information from as many different sites across the State as was practicable. Samples of seed pods/heads were collected from many sites where the weed species were observed on trips across the State for two or three years. This amounted to 34, 36 and 39 site visits respectively for Tree Lupin, Greater Trefoil, and Scotch Thistle These particular weed species were chosen for the study, because they were all species on which bumblebees were often seen at several sites, and were the most likely species to have their pattern of seed set disturbed by a different pollinator entering the "pollinator guild".

At each site where seeds were collected, five plants were chosen at random. From each of these five plants, four stems were chosen at random from the North, South and East and West directions of the plant. Each stem was then placed in a paper bag, which was labelled with the plant type, location, date, plant number (1-5) and stem number (1-4).
Collection at each site took about 20 minutes, and any observations of pollinators on the weeds were recorded, particularly the presence or absence of bumblebees.

All stem samples were later examined, and numbers of healthy and aborted pods (shown by scars on stems) were recorded, as was number of seeds per pod recorded, by randomly sampling 5 pods per stem.

6.3 Statistical Analysis

For each of the three weed species, data sets were sufficiently large to invoke the central limit theorem (ie. the sample distribution for a sample drawn from any population approaches normality as the sample size approaches infinite). Data were collected from different sites in different years, and were unbalanced, so the analysis technique used was REsidual Maximum Likelihood (REML), which analyses mixed model data, like ANOVA. Pair wise comparisons of the means were conducted using least significant difference (pr. = 0.05), adjusted for the varying numbers of observations contributing to each mean.

6A Tree Lupin, *Lupinus arboreus*

Results and discussion

As shown in Table 6.1, the seed set of healthy seeds within pods was significantly higher, when bumblebees were present at a site, than at sites where bumblebees were not observed. Thus, it is predicted that total seed set by *L.arboreus* in areas where bumblebees occur will be significantly increased.

Tree Lupin (Seeds)

Bumblebees	Seed type	Mean	
Y	Healthy	4.622	a
Y	Malformed	4.377	b
N	Malformed	4.332	bc
N	Healthy	4.295	c

Table 6.1. The Predicted Means for the Number of Healthy and Malformed seeds per Tree lupin pods in the Presence (Y) and Absence (N) of Bumblebees. Means followed by the same letter are not significantly different ($P > 0.05$).

Table 6.2 shows that there were significantly more healthy pods at sites where bumblebees were present.

Tree Lupin (Pods)

Bumblebees	Pod type	Mean	
N	Aborted	30.23	a
Y	Aborted	21.76	b
Y	Healthy	13.33	c
N	Healthy	11.06	d

Table 6.2. The Predicted Means for the Number of Healthy and Aborted pods per Tree lupin stalk in the Presence (Y) and Absence (N) of Bumblebees. Means followed by a different letter are significantly different ($P < 0.05$).

The overall predicted percentage increase in seed set due to the presence of bumblebees was (mean no. seeds/pod x mean no. healthy pods/stalk at sites where bumblebees were present) ÷ (mean no. seeds/pod x mean no. healthy pods/stalk at sites where bumblebees were absent)x 100= (4.622 x13.33)÷ (4.295 x 11.06) x 100 = 129.7%, or a 29.7% increase in seed set.

6B Scotch Thistle, *Onopordum acanthium*

Results and discussion

Year	Bumblebees	Mean	
2001	N	258.2	a
2002	N	245.3	a
2001	Y	237.1	a
2002	Y	199.8	b

Table 6.3. The Predicted Means for the Number of Healthy Seeds found in Scotch Thistle heads in Different Years, and in the Presence (Y) and Absence (N) of Bumblebees. Means followed by the same letter are not significantly different ($P > 0.05$).

As indicated in Table 6.3, mean numbers of seeds per head were significantly lower in the presence of bumblebees in 2002 ($P < 0.05$), and lower also for 2001, but not significantly so. When data from all years are combined, the predicted number of healthy seeds per head at sites where bumblebees are absent is significantly higher (251.7a seeds per stem) than at sites where bumblebees are present (218.4b seeds per stem) ($P < 0.05$). This represents a predicted reduction in seed set of 13.2%.

How can bumblebees be helping to significantly reduce the seed set of the Scotch thistle? An untested theory is that, due to the long thin, tightly packed florets in the head of a Scotch thistle, bumblebees are nectar robbing some of the time, and this nectar robbing is somehow reducing the seed set of the plant. It could also be that seed set of Scotch thistle is significantly less in wet locations, but nectar production is higher, so bumblebees choose these sites in preference to dry locations.

Photo: Mike Tobias

Photo 12. Bumblebee on Scotch thistle

6C Greater Trefoil, *Lotus uliginosus*

Results and discussion

Table 6.4 gives the predictions of the mean number of pods produced per stalk in the presence and absence of bumblebees, based on the combined data from 2001 and 2002. REML predicts that there will be a significant (7.236 ÷ 5.662 = 28%) increase in numbers of healthy pods produced per stalk in the presence of bumblebees.

Bumblebees	Mean No. Pods/Stalk	
Yes	7.236	a
No	5.662	b

Table 6.4 Predicted Mean Number of Pods per Stalk for *L. uliginosus* in the Presence and Absence of Bumblebees. Means followed by a different letter are significantly different ($P < 0.05$).

As indicated in Table 6.5, although the mean number of healthy seeds per pod for *L. uliginosus* was higher when bumblebees were present (Y) than when bumblebees were absent in 2001 and 2002, the difference was only significant in 2001.

Bumblebees	Year	Mean Healthy Seeds/Pod	
Y	2001	15.50	a
Y	2002	13.86	b
N	2002	13.41	bc
N	2001	12.50	c

Table 6.5 Predicted Mean Number of Healthy Seeds per Pod for *L. uliginosus* In the Presence (Y) and Absence (N) of Bumblebees for each Year. Means followed by the same letter are not significantly different ($P > 0.05$).

When all data is combined, (see Table 6.6) REMLpredicts that there will be a significant but small increase (14.46 ÷ 13.18 = 9.7%) in the numbers of healthy seeds per pod.

Bumblebees	Mean no. Healthy Seeds/Pod	
Yes	14.46	a
No	13.18	b

Table 6.6 Predicted Mean Number of Healthy Seeds per Pod for *L. uliginosus* In the Presence (Y) and Absence (N) of Bumblebees.

The overall predicted percentage increase in seed set due to the presence of bumblebees was (mean no. healthy seeds/pod x mean no. healthy pods/stalk at sites where bumblebees were present) ÷ (mean no. healthy seeds/pod x mean no. healthy pods/stalk at sites where bumblebees were absent) x 100 = (7.236 x 14.46) ÷ (5.662 x 13.18) x 100 = 140.2%, or a 40.2% increase in seed set.

7. Recommendations

Recommendations to Industry

As there were significant changes to the seed set of different plant species recorded, it is up to industry to compare and contrast the financial gains of the introduction of this new pollinator with costs associated with the potential shifts in seed production of non-targeted plant species. Then industry should present their case to decision makers on the introduction of bumblebees, using this report as evidence of the environmental impact of *B. terrestris* in Tasmania.

Further Research

As a follow up to confirm predictions made regarding the impact of *Bombus terrestris* in Tasmania, it is recommended that:

- Laboratory tests be done to confirm that the mite *Kuzinia laevis* found on Tasmanian bumblebees is specific to the *Bombus* genus. For example, honey bee and native bee individuals could be closely confined with a mite-laden *B. terrestris* for twenty-four hours, and the transfer and survival of *K. laevis* studied.
- The survey/distribution data, and knowledge of preferred plant species and overwintering site requirements could be analysed, using an environmental modeling program such as Climex, to predict the habitat range of *B. terrestris* on mainland Australia.
- The flowering period of *G. huegelii* could be studied at more sites to confirm an increase in seed set in the presence of bumblebees.
- Broad bean crops could be surveyed to estimate the mean change in yield in the presence of bumblebees.

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Appendix 1: Observations of Bumblebees on Different Plant Species in Tasmania, (Tasmanian Museum Public Survey on Bumblebees)

Plant Name	No. Sightings	Common Name	Family	Native plant (NP)
Lavandula spp.	120	Lavender	Lamiaceae	
Rosa spp.	42	Rose	Rosaceae	
Fuchsia spp.	40	Fuchsia	Onagraceae	
Agapanthus sp.	30	African lily	Liliaceae	
Dahlia variabilis	25	Dahlia	Asteraceae	
Penstemon sp.	21	Penstemon	Scrophulariaceae	
Rhododendron spp.	20	Rhododendrons	Ericaceae	
Antirrhinum majus	19	Snapdragons	Scophulariaceae	
Tropaeolum majus	16	Nasturtium	Tropaeolaceae	
Rubus fruticosus	15	Blackberries	Rosaceae	
Geranium gracile	13	Geranium	Geraniaceae	
Eucalyptus spp.	13	Gum trees	Myrtaceae	NP
Banksia spp.	13	Banksia	Proteaceae	NP
Trifolium spp.	12	Clover	Fabaceae	
Salvia uliginosa	12	Bog sage	Lamiaceae	
Salvia officinalis	12	Sage	Lamiaceae	
Lotus uliginosus	11	Greater Trefoil	Fabaceae	
Geranium maculatum	11	Chinese lantern	Geraniaceae	
Aquilegia vulgaris	11	Granny's bonnet	Ranunculaceae	
Hebe sp.	11	Hebe	Scophulariaceae	
Onopordon acanthum	10	Scotch thistles	Asteraceae	
Lonicera spp.	10	Honeysuckle	Caprifoliaceae	
Eucryphia lucida	10	Leatherwood	Eucryphiaceae	NP
Phaseolus multiflorus	10	Scarlet runner beans	Leguminoseae	
Callistemon spp.	10	Bottlebrush	Myrtaceae	NP
Digitalis purpurea	10	Foxgloves	Scophulariaceae	
Abelia spp.	9	Abelia	Caprifoliaceae	
Plantago media	9	Lambs ear	Plantaginaceae	
Grevillea spp.	9	Grevillea	Proteaceae	NP
Bellis perennis	8	Daisies	Asteraceae	
Buddleia alternifolia	8	Buddleia	Buddleiaceae	
Lupinus spp.	8	Lupins	Fabaceae	
Althea rosea	8	Hollyhocks	Malvaceae	
Papaver spp.	8	Poppies	Papaveraceae	
Hydrangea arborescens	8	Hydrangea	Saxifragaceae	
Alstroemeria spp.	7	Alstroemeria	Amaryllidaceae	
Cosmos atrosanguineus	7	Cosmos	Asteraceae	
Taraxacum officinale	6	Dandelion	Asteraceae	
Cheiranthus mutabilis	6	Wallflowers	Brassicaceae	
Lathyrus odoratus	6	Sweet peas	Fabaceae	
Cytisus palmensis	6	Tree lucerne	Fabaceae	
Abutilon globosum	6	Golden dollar plant	Malvaceae	
Borago officinalis	5	Borage	Boraginaceae	
Brassica oleracea	5	Cabbages	Brassicaceae	
Campanula medium	5	Canterbury Bells	Campanulaceae	
Vicia faba	5	Broad beans	Fabaceae	
Nepeta faassenii	5	Catmint	Lamiaceae	
Delphinium spp.	5	Delphinium	Ranunculaceae	
Lycopersicon esculentum	5	Tomato	Solonaceae	
Calendula officinalis	4	Marigold	Asteraceae	
Helianthus spp.	4	Sunflowers	Asteraceae	
	4	Thistles	Asteraceae	
Scabiosa graminifolia	4	Scabiosa	Dipsacaceae	

Montbretia sp.	4	Montbretia	Iridaceae	
Phaseolus vulgaris	4	Climbing beans	Leguminoseae	
Lilium spp.	4	Lily	Liliaceae	
Leptospermum spp.	4	Tea tree	Myrtaceae	NP
Cotoneaster spp.	4	Cotoneaster	Rosaceae	
Citrus limon	4	Lemon tree	Rutaceae	
Lycium ferocissimum	4	African Boxthorn	Solonaceae	
Disphyma australe	3	Pigface	Aizoaceae	NP
Allium cepa	3	Onions	Alliaceae	
Centaurea cyanis	3	Cornflower	Asteraceae	
Chrysanthemum leucanthenum	3	Sun daisies	Asteraceae	
Cucurbita maxima	3	Pumpkin	Cucurbitaceae	
Epacris impressa	3	Common Heath	Epacridaceae	NP
Erica spp.	3	Heath	Ericaceae	
Rhododendron spp.	3	Azalea spp.	Ericaceae	
Cytisus scoparius	3	Broome	Fabaceae	
Pisum sativum	3	Peas	Fabaceae	
Pelargonium spp.	3	Pelargonium	Geraniaceae	
Gladiolus communis	3	Gladioli	Iridaceae	
Marjorana hortensis	3	Marjoram	Lamiaceae	
Monardo didyma	*3*	*Bergamot*	*Lamiaceae*	
Salvia microphylla	3	Salvia	Lamiaceae	
Thymus vulgaris	3	Thyme	Lamiaceae	
Salvia elegans	3	Pineapple sage	Lamiaceae	
Lobelia erinus	3	Lobelia	Lobeliaceae	
Rubus sp.	3	Boysenberry	Rosaceae	
Petunia spp.	3	Petunia	Solonaceae	
Viola spp.	3	Pansies	Violaceae	
Parthenocissus quinquefolia	3	Creeper	Vitaceae	
Acanthus mollis	2	Bears Breech	Acanthaceae	
Eranthemum puthellum	2	Blue sage	Acanthaceae	
Zephyranthes candida	2	Peruvian lily	Amaryllidaceae	
Eryngium maritimum	2	Sea holly	Apiaceae	
Hedera helix	2	Ivy	Araliaceae	
Senecio glomeratus	2	Fireweed	Asteraceae	NP
Bellis sp.	2	Easter daisy	Asteraceae	
Chrysanthemum parthenium	2	Feverfew	Asteraceae	
Raphanus raphanistrum	2	Wild radish	Brassicaceae	
Dianthus spp.	2	Carnations	Caryophyllaceae	
Sedum spathulifolium	2	Sedum	Crassulaceae	
Cucurbita pepo	2	Zucchini	Cucurbitaceae	
Hibbertia scandens	2	Climbing guinea-flower	Dilleniaceae	NP
Schizolobium parhyba	2	Jacaranda	Fabaceae	
Trifolium fragiferum	2	Strawberry clover	Fabaceae	
Hypericum spp.	2	Hypericum	Guttiferae	
Westringia brevifolia	2	Westringia	Lamiaceae	NP
Agastache foeniculum	2	Anise	Lamiaceae	
Fritillaria meleagris	2	Daffodil	Liliaceae	
Kunzea ambigua	2	Kunzea	Myrtaceae	NP
Passiflora sp.	2	Passionfruit vine	Passifloraceae	
Bursaria spinosa	2	Native box	Pittosporaceae	NP
Limonium macrophyllum	2	Statice	Plumbaginaceae	
Cymbopogon nardus	2	Lemon balm	Poaceae	
*Hakea laurin*a	2	Pincushion Hakea	Proteaceae	NP
Anemone nemorosa	2	Windflowers	Ranunculaceae	
Ranunculus plebius	2	Buttercup	Ranunculaceae	
Malus pumila	2	Apples	Rosaceae	
Rubus spp.	2	Raspberries	Rosaceae	
Escallonia spp.	2	Escallonia	Escalloniaceae (Saxifragaceae)	
Sphagnum sp.	2	Sphagnum moss	Spagnaceae	NP

Pimelea nivea	2	Riceflower	Thymelaeaceae	NP
Tropaeolum tuberosum	2	Peruvian nasturtium	Tropaeolaceae	
Allium ascalonicum	1	Shallots	Alliaceae	
Galanthus byzantinus	1	Death's flower	Amaryllidaceae	
Carum petroselinium	1	Parsley	Apiaceae	
*Beaumontia terdon*iana	1	Trumpet creeper	Apocynaceae	
Mandevilla splendens	1	Trumpet flower	Apocynaceae	
Ammobium sp.	1	Ammobium	Asteraceae	NP
Olearia phlogopappa	1	Dust daisy bush	Asteraceae	NP
Brachyscome augustifolia	1	Native daisies	Asteraceae	NP
Echinacea augustifolia	1	Purple cone flower	Asteraceae	
Lactuca sativa	1	Lettuce	Asteraceae	
Senecio jacoboea	1	Ragwort	Asteraceae	
Venidium fastuosum	1	Venidium	Asteraceae	
Begonia spp.	1	Begonia	Begoniaceae	
Cerinthe spp.	1	Honey wort	Boraginaceae	
Echium candicans	1	Pride of Madiera	Boraginaceae	
Myosotis palustris	1	Forgetme nots	Boraginaceae	
Brassica oleracea	1	Broccoli	Brassicaceae	
Cardamine pratensis	1	Naked ladies	Brassicaceae	
Matthiola incana	1	Stock	Brassicaceae	
Wahlenbergia stricta	1	Bluebell	Campanulaceae	NP
Humulus lupulus	1	Hops	Cannabaceae	
Helianthemum sp.	1	Sun bush	Cistaceae	
Ipomoea pandusata	1	Potato vine	Convolvaceae	
Cupressus macrocarpa	1	Monterey cypress	Cupressaceae	
Kennedia prostrata	1	Native creeper	Fabaceae	NP
Laburnum anagyroides	1	Golden chain	Fabaceae	
Lotus majus	1	Birdsfoot trefoil	Fabaceae	
Lupinus sp.	1	Dwarf lupin	Fabaceae	
Medicago sativa	1	Lucerne	Fabaceae	
Vicia sativa	1	Bean	Fabaceae	
Vicia cracca	1	Vetch	Fabaceae	
Goodenia ovata	1	Goodenia	Goodeniaceae	NP
Paspalum sp.	1	Paspalum	Graminae	
Hypericum perforatum	1	St John's wort	Guttiferae	
Nigella sativa	1	Love in a mist	Helleboraceae /Ranunculaceae	
Leonotis leonurus	1	Lion's Ear	Lamiaceae	
Mentha sp.	1	Mint	Lamiaceae	
Nepeta cataria	1	Catnip	Lamiaceae	
Ocimum basilicum	1	Basil	Lamiaceae	
Salvia patens	1	Cambridge blue	Lamiaceae	
Atherosperma moschatum	1	Sassafras tree	Lauraceae	NP
Acacia longifolia	1	Boobyalla	Leguminosae /Mimosaceae	NP
Acacia sp.	1	Native wattle	Leguminosae /Mimosaceae	NP
Wistaria spp.	1	Wisteria	Leguminoseae	
Blandfordia spp.	1	Blandfordia	Liliaceae	NP
Kniphofia uvaria	1	Red-hot Pokers	Liliaceae	
Magnolia spp.	1	Magnolia	Magnoliaceae	
Lavatera plebeia	1	Australian hollyhocks	Malvaceae	NP
Gravesia sp.	1	Gravesia	Melastomataceae	
Tibouchina urvilleana	1	Lasiandra	Melastomataceae	
Melaleuca gibbosa	1	Paperbark	Myrtaceae	NP
Syzygium coolminianum	1	Blue Lilly Pilly	Myrtaceae	NP
Acmena hemilampra	1	Lilly Pilly	Myrtaceae	
Jasminum officinale	1	Jasmine	Oleaceae	
Oxalis incarnata	1	Oxalis	Oxalidaceae	

Paeonia spp.	1	Peony	Paeoniaceae	
Plantago lanceolata	1	Plantain	Plantaginaceae	
	1	Native grasses	Poaceae	NP
Portulaca grandiflora	1	Portulaca	Portulacaceae	
Anenome blanda	1	Anenome	Ranunculaceae	
Reseda lutea	1	Mignonette weed	Resedaceae	
Ceanothus cyaneus	1	Californian lilac	Rhamnaceae	
Chaenomeles speciosus	1	Japonica creeper	Rosaceae	
Fragaria vesca	1	Strawberries	Rosaceae	
Pyrus communus	1	Pears	Rosaceae	
Manettia biocolor	1	Manettia	Rubiaceae	
Correa alba	1	White correa	Rutaceae	NP
Citrus aurantifolia	1	Lime tree	Rutaceae	
Populus tacamahaca	1	Tacamahac tree	Salicaceae	
Bauera rubioides	1	Horizontal Bauera	Saxifragaceae	NP
Ribes americanum	1	Black currant	Saxifragaceae	
Ribes rubrum	1	Currants	Saxifragaceae	
Alonsoa spp.	1	Alonsoa	Scophulariaceae	
Verbascum sp.	1	Verbascum	Scrophulariaceae	
Camellia japonica	1	Camellia	Theaceae	
Typha latifolia	1	Bulrushes	Typhaceae	NP
Lantana salviifolia	1	Lantana	Verbenaceae	
Viola spp.	1	Violas	Violaceae	
Vitis vinifera	1	Grapevine	Vitaceae	
Hedychium gardnerianum	1	Wild ginger	Zingiberaceae	
	76	Unidentified exotic plants		
	14	Unidentified native plants		NP
Total, Exotic Plants	916	89.10%		
Total, Native Plants	112	10.90%		
Grand Total	1028			

Appendix 2. National Workshop on Bumblebees- Attendees

1. Dr Peter Box, Vic, Facilitator of Workshop
2. Mr Anthony Brandsema, Tas. Veg. Growers Association, Chair of Workshop
3. Dr Les Baxter, HRDC
4. Mr Roger Buttermore, TMAG
5. Ms Kaye Hergstrom, TMAG
6. Dr Michael Schwarz, Flinders University
7. Dr Glynn Maynard, AQIS
8. Mr Robert Moore, Invasive Species Unit, Environment Australia
9. Ms Ann Wilson, HFF, Vic
10. Dr Barry Donovan, NZ
11. Dr Don Griffiths, UK
12. Dr Michael Driessen, DELM,Tas
13. Dr Frances Fitzgibbon, CSIRO Canberra
14. Ms Marilyn Steiner, NSW Agric
15. Dr Stephen Goodwin, NSW Agric
16. Mr Trevor Semmens, DPIWE, Tas
17. Mr Alex Buchanan, TMAG Herbarium, Tas
18. Ms Jane Stout, U Southhampton, UK
19. Dr Dave Goulson, U Southhampton, UK
20. Ms Cindy Hanson, Weed unit, DPIWE, Tas
21. Mr Andrew Youngberry, Grower, QLD
22. Mr Graeme Smith, VHFF, Vic
23. Dr Andrew Hingston, UTAS
24. Dr Katja Hogendoorn, Flinders University
25. Dr Geoff Allen, UTAS
26. Mr Colin Parker, Tas Beekeepers Assoc.
27. Dr Margaret Williams, Quarantine Entom, DPIWE, Tas
28. Mr Ray Hart, DPIWE, Tas
29. Mr Steven Mallick, UTAS
30. Prof Andrew Beattie, Macquarie University
31. Mr Bob McDonald, Australian Beekeepers Assoc., Vic
32. Ms Andrea Kells, U Southhampton, UK
33. Mr Mike Tobias, TMAG
34. Mr Nelson Pomeroy, Zonda Ltd, NZ
35. Mr Owen Seeman, UQ
36. Mr Lionel Hill, Entomologist, DPIWE